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Managing N Fertilizers to Reduce Nitrous Oxides Emissions: Just Hot Air?

Soil Ecology

University of Manitoba

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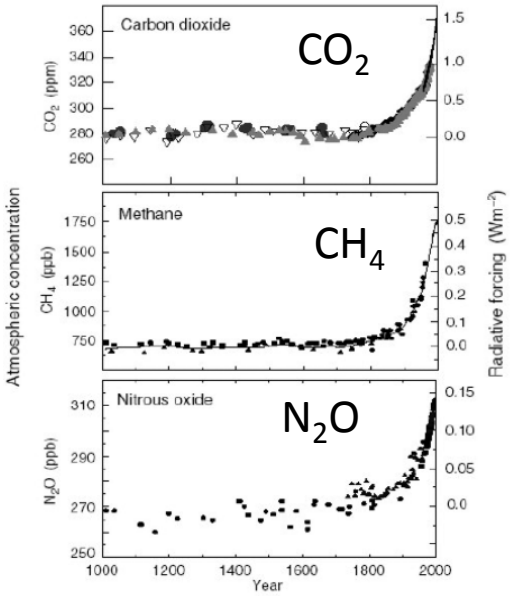
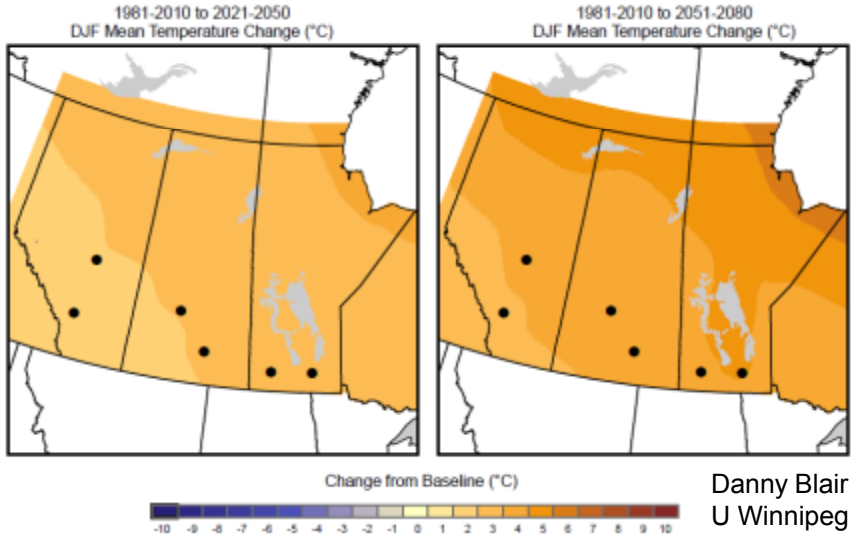
Presentation to Agvise Soil Fertility Seminar
March 14, 2017

UNIVERSITY OF MANITOBA

Background

Why Care About GHG?



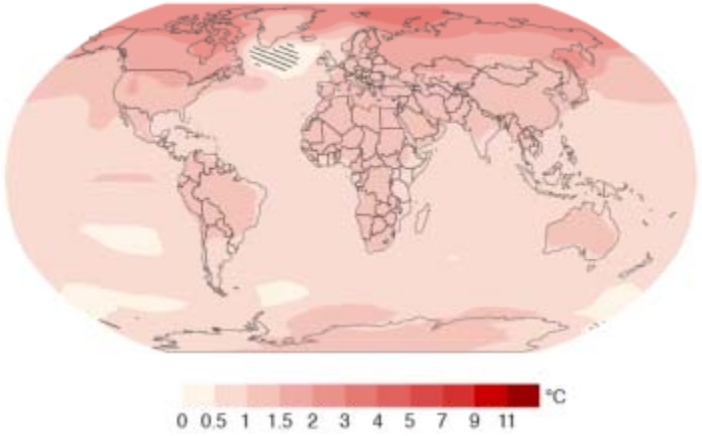


Increase in Mean Winter Temperature For Manitoba

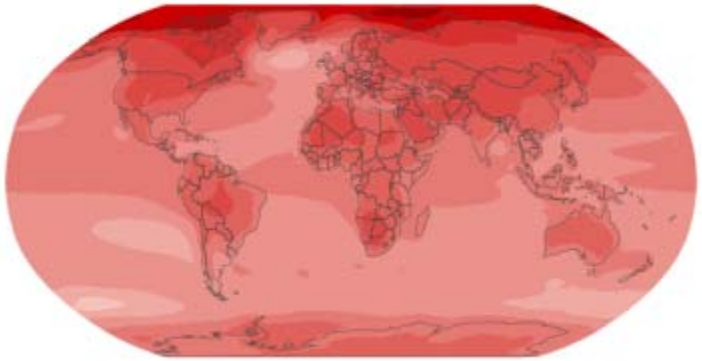
Danny Blair
U Winnipeg

Projected temperature change (1986–2005 to 2081-2100)

If greenhouse gas emissions peak between 2010 to 2020 and then decline substantially (RCP2.6).

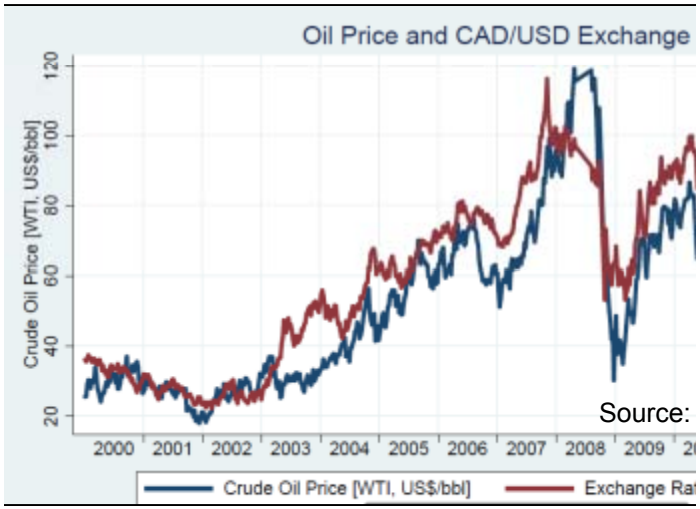


If greenhouse gas emissions continue to rise throughout the 21st century (RCP8.5)



Source: International Panel on Climate Change - Fifth Assessment Report (AR5)

Tide Has Turned



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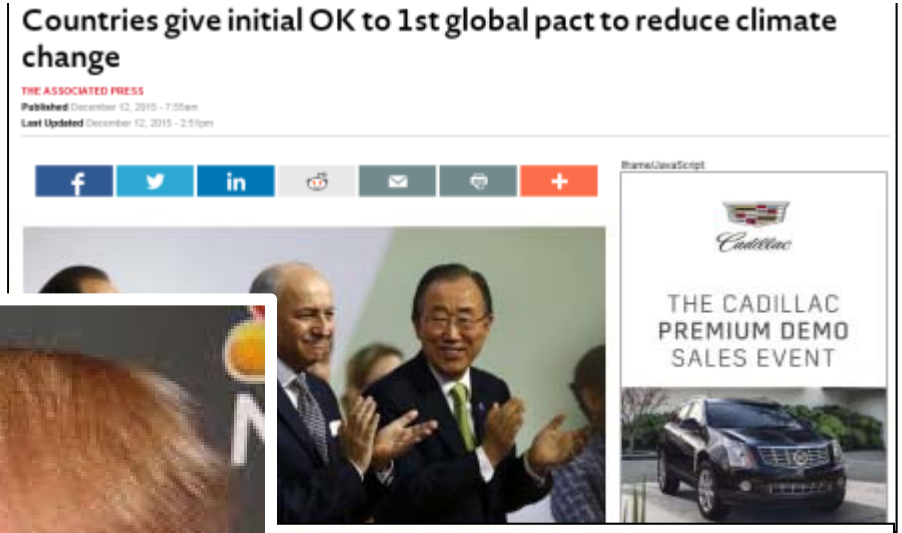
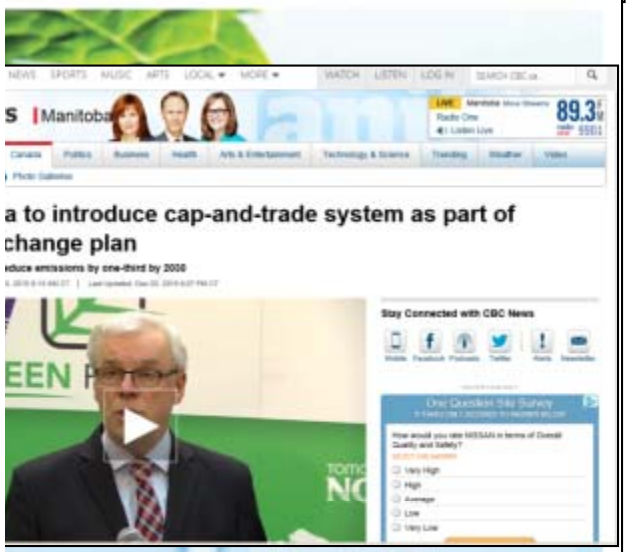
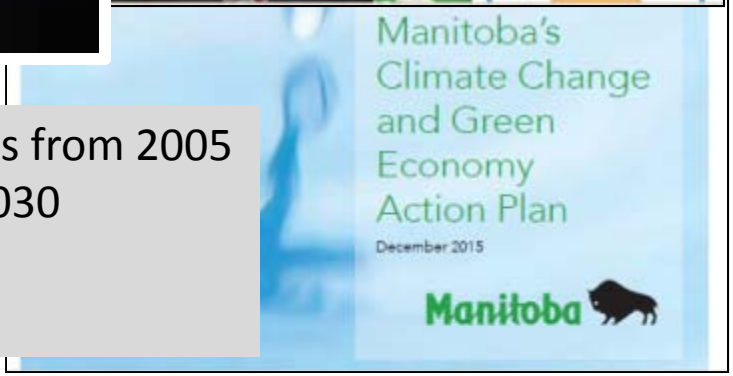


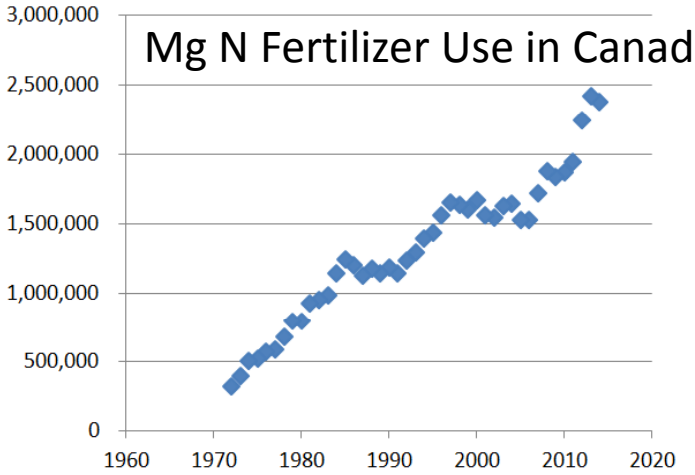


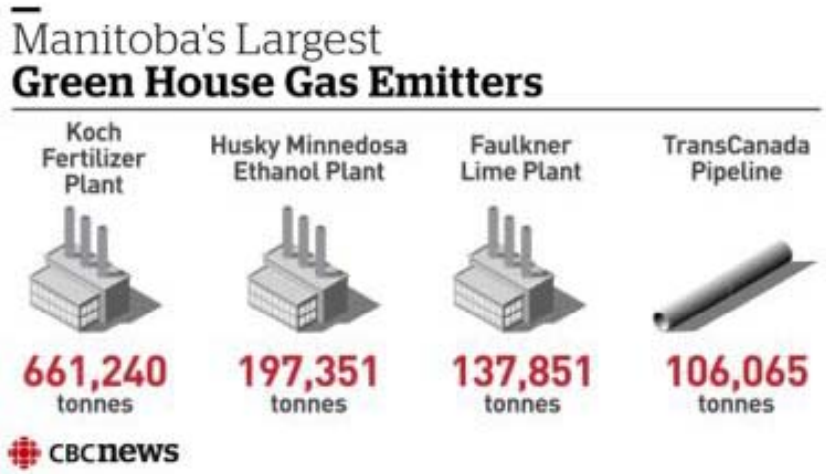


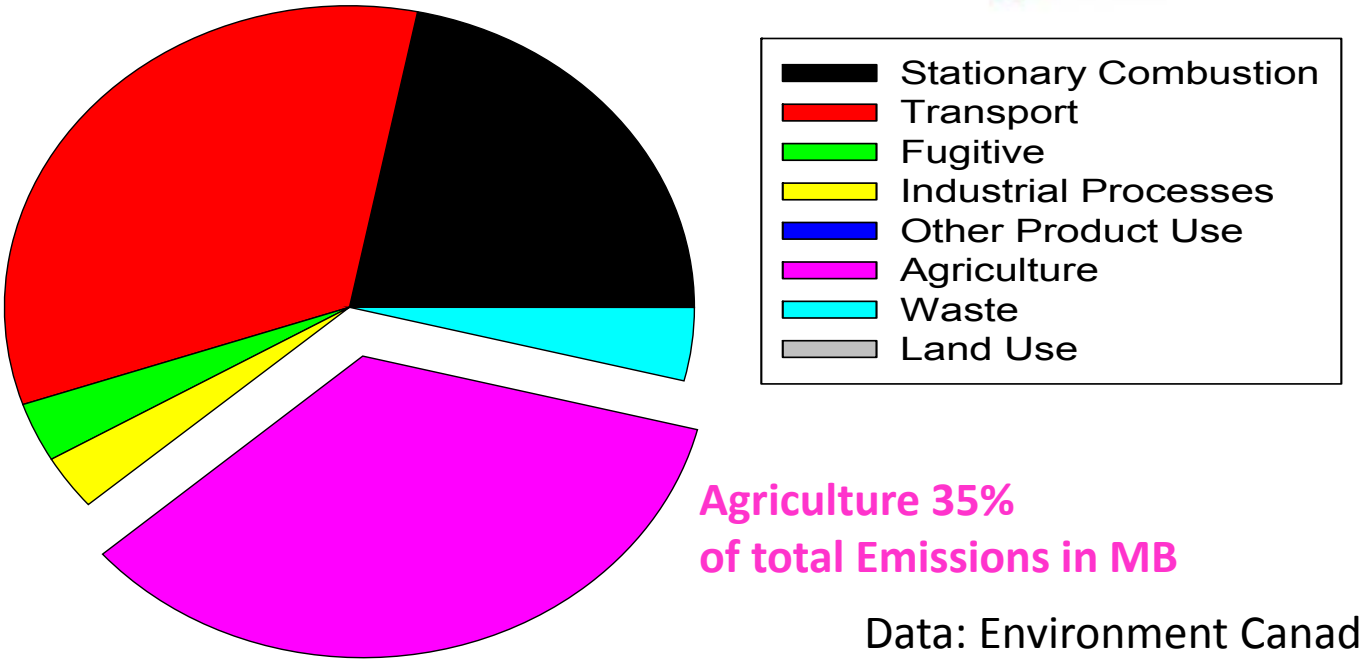
MB will reduce emissions from 2005

- o 1/3 from 2005 by 2030
- o ½ by 2050
- o Neutral by 2080

Nitrous Oxide is Our Concern?





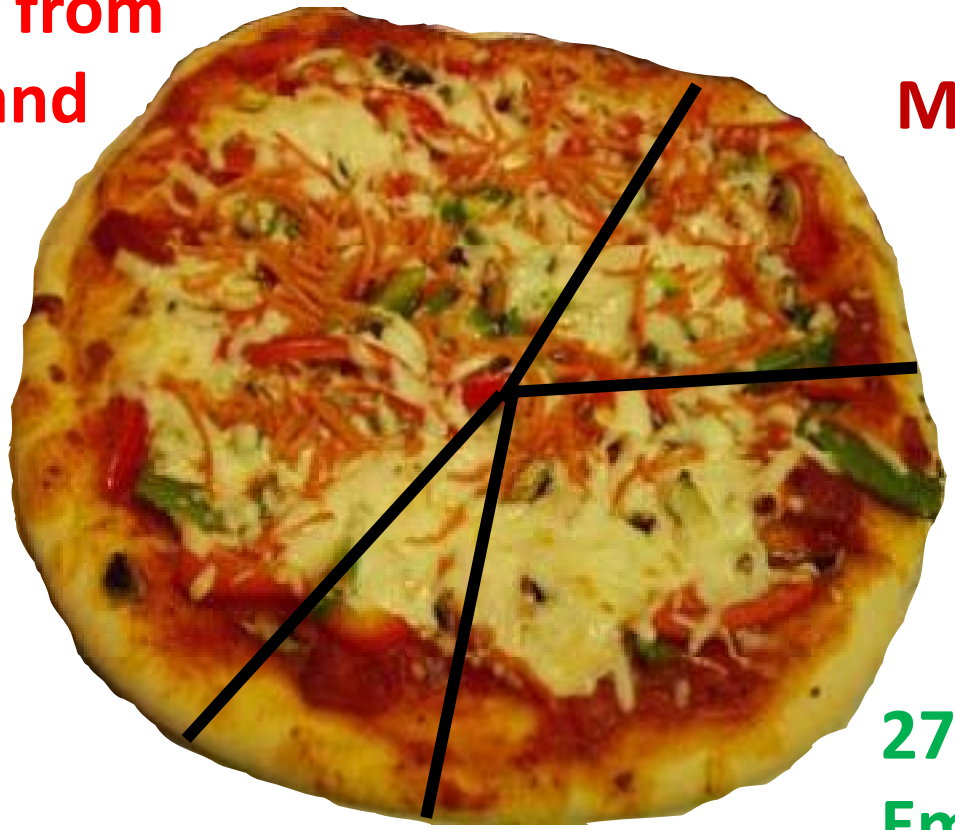


Agriculture 35%
of total Emissions in MB

Data: Environment Canada 2009

Sources of Nitrous Oxide from Ag

Emissions from fertilizer and residues



Manure to soil

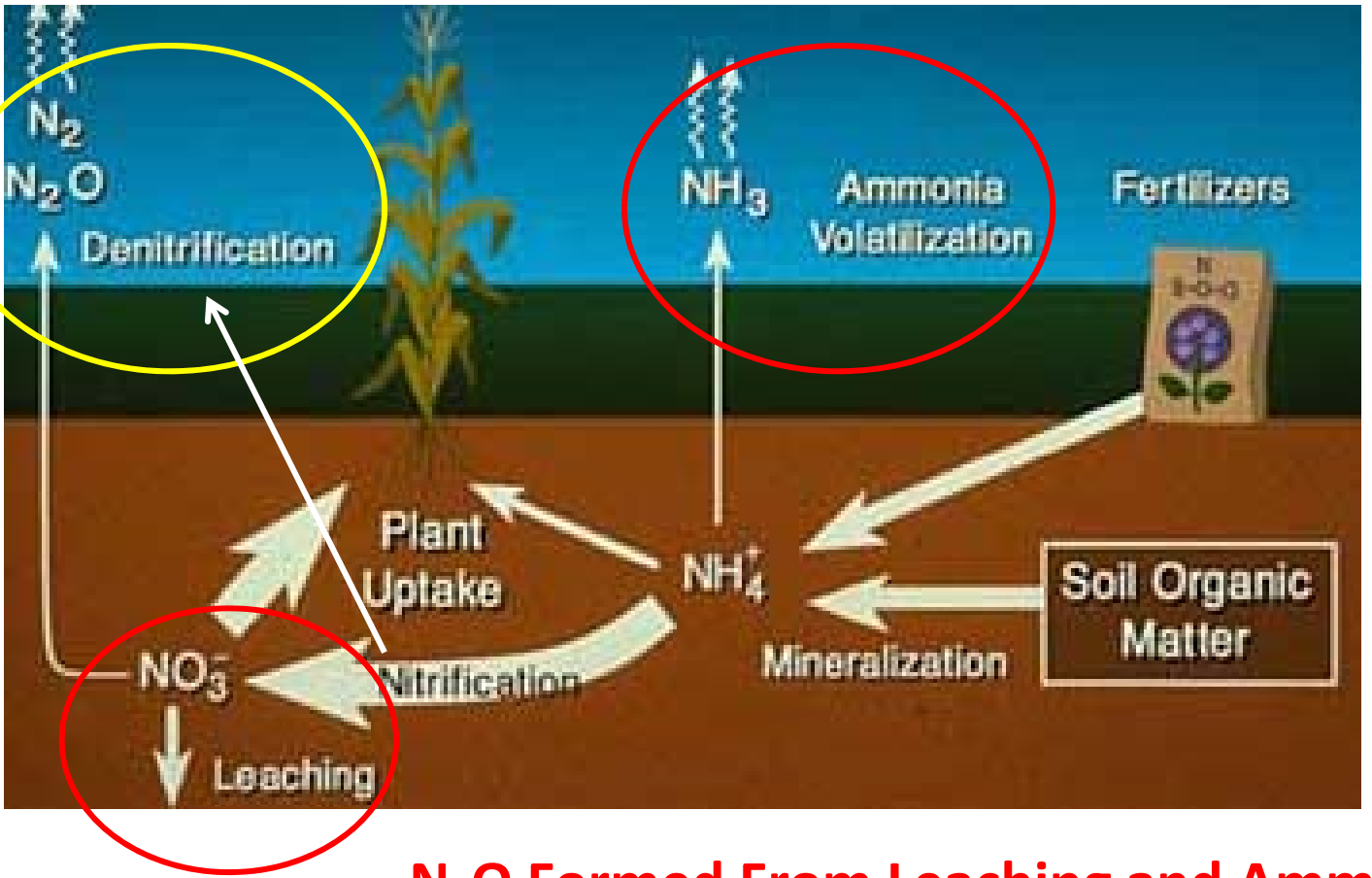
Excreta Paddocks and Pastures

27% N_2O Emissions Indirect From Soil

Data: Environment Canada 2009

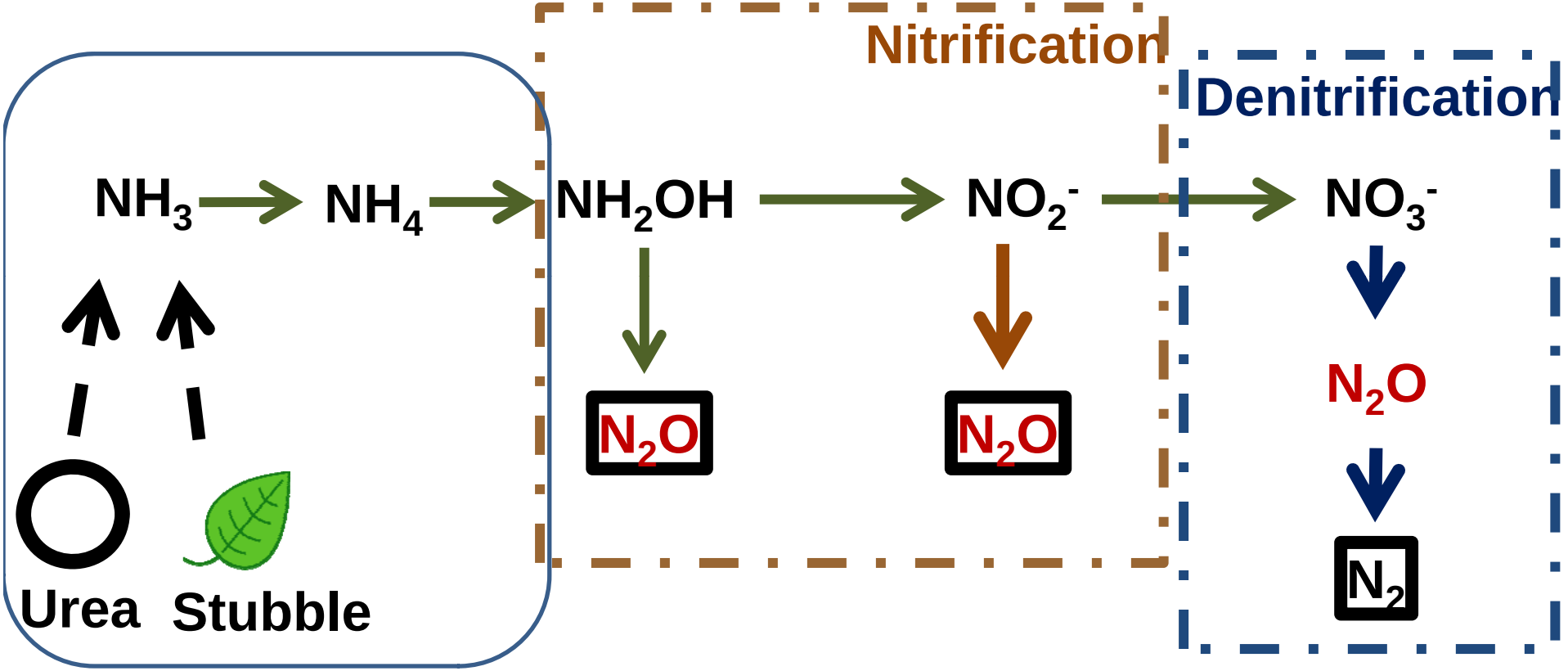
N_2O Direct and Indirect Emissions

N_2O Directly Emitted



N_2O Formed From Leaching and Ammonia (Indirect)

Direct Sources of N_2O From Soils



Production of Nitrate in Soil From N Additions Major Source of N_2O

But, but, but….denitrification is important from N fertilizer loss

Carbon Costing- Anhydrous Ammonia Use

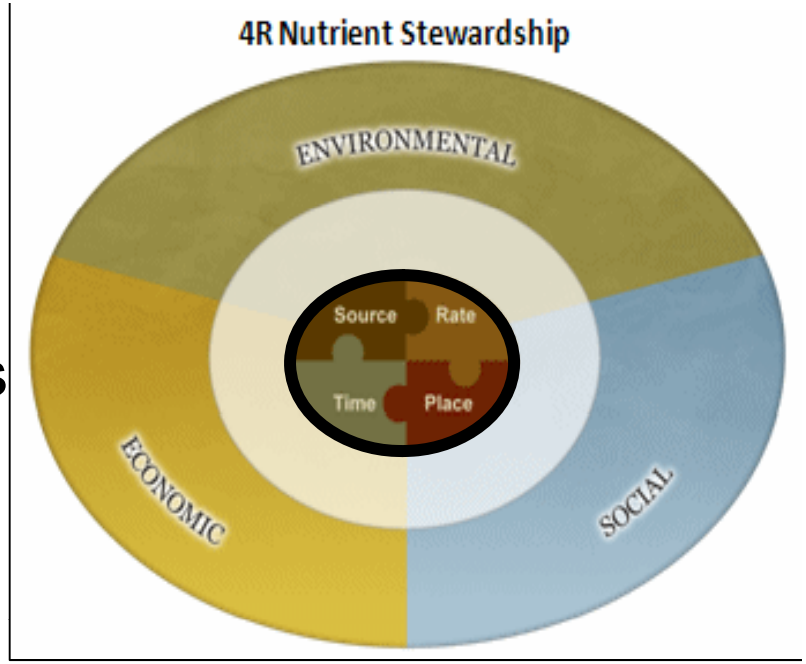
	$/t CO2 C cost	$ /t N NH3	$ /t NH3 NH3	kg N2O-N/kgN EF%	100 kg N/ha rate	User tax $ tax/ha	Manufacture Tax $ tax/100kgN/ha	Total C tax $/ha	Fert Cost no tax $/ha
Taxes ½ Fertilizer Cost	10	975.61	800	2	100	9.43	2.05	11.48	97.56
	20	975.61	800	2	100	18.86	4.10	22.95	97.56
	30	975.61	800	2	100	28.29	6.15	34.43	97.56
	40	975.61	800	2	100	37.71	8.20	45.91	97.56
	50	975.61	800	2	100	47.14	10.24	57.39	97.56
Taxes > Fertilizer Cost	60	975.61	800	2	100	56.57	12.29	68.86	97.56
	70	975.61	800	2	100	66.00	14.34	80.34	97.56
	80	975.61	800	2	100	75.43	16.39	91.82	97.56
	90	975.61	800	2	100	84.86	18.44	103.30	97.56
	100	975.61	800	2	100	94.29	20.49	114.77	97.56

Forget about Tax on Fertilizer Production – Be concerned about tax on adding N fertilizer to soil!

C tax needs to be over $150/t to have significant affect on total GHG emissions

Message: We need to avoid a N use tax by showing change in practices reduces emissions

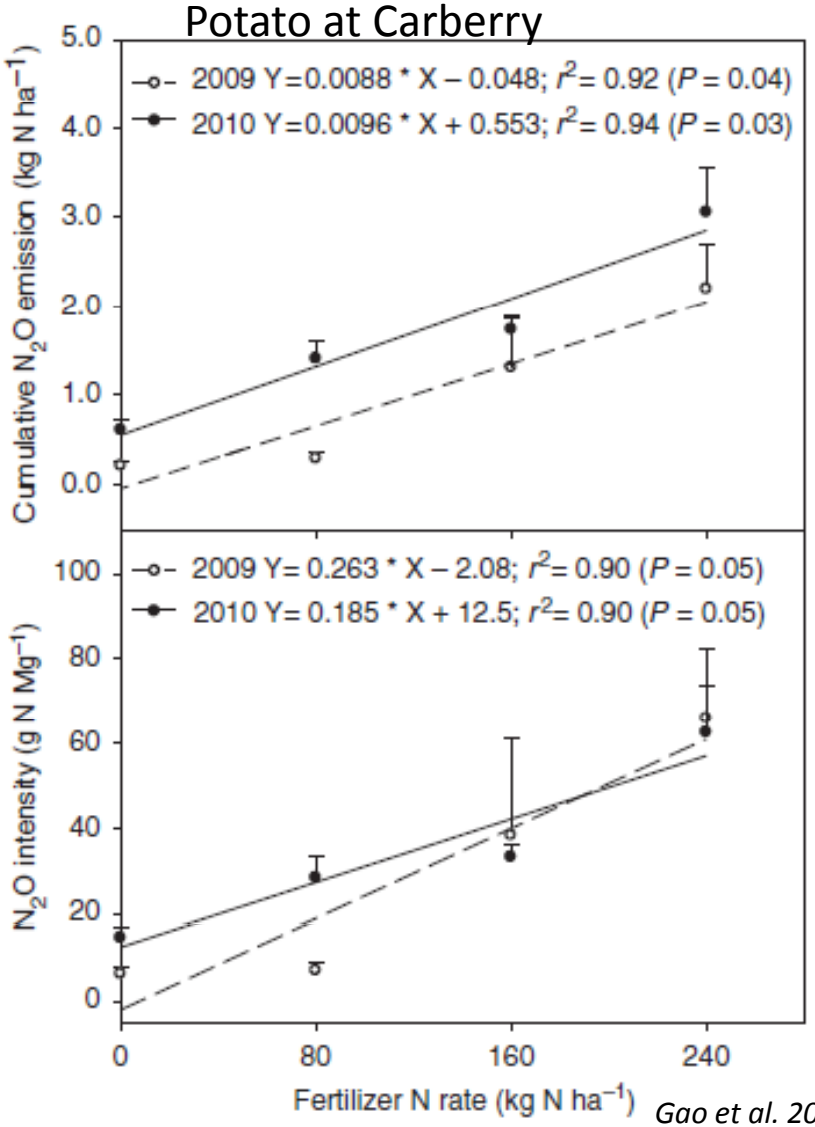
4R Nutrient Stewardship



- Best use of crop nutrient additions
- Improve/maintain yields
- Improve profitability
- Limit losses
- Have co-benefits (water and air quality, GHG)
- Understandable and easy to follow
- Auditable, provide credits, use $incentive programs
- Applies “agronomic sense” of past, present and future advances

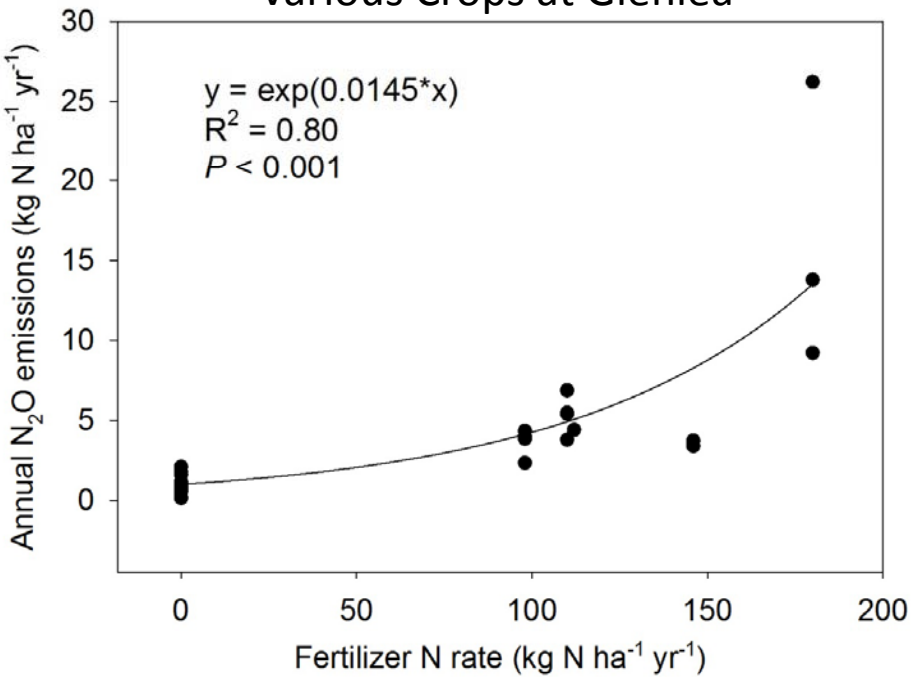
Greater the Rate, More N_2O Emitted

Potato at Carberry



Gao et al. 2013 Can J Soil Sci

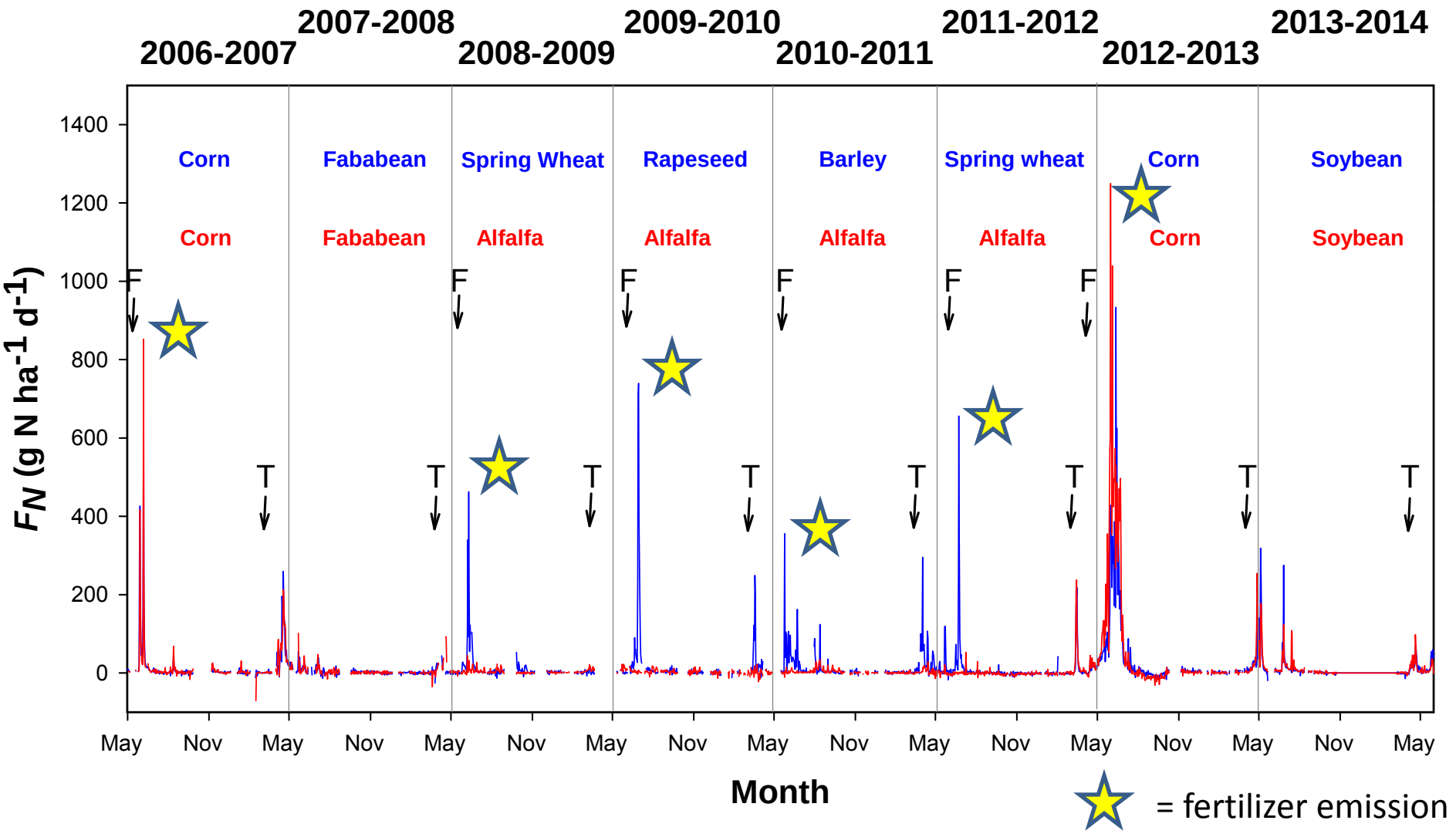
Various Crops at Glenlea



Tenuta et al., in prep.

Rate

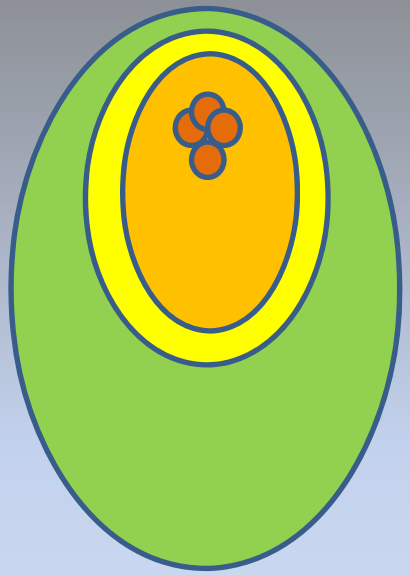
Good N fixing Legumes Emit Little N_2O



Right Rate Recommendations

- Apply N at most economically rate
- Consider good N fixing legumes
- Use experience if to apply variable rate N
  - Understand if moisture drives variable response
- Soil test for N every year
  - Wet warm falls and springs, perhaps spring tests are best
  - Coarse soils, perhaps spring tests are best
- Understand variety/hybrid N requirements
- Understand variety/hybrid grain quality response to N
- Understand impact of Placement, Timing and Source of N
- Question University, MAFRD, CCA, and sales staff

Banding Slows Formation of Nitrate



Urea

Lower soil contact delayed release of Ammonia

Ammonia/Ammonium

Delayed nitrification by high pH and NH_3

Nitrite

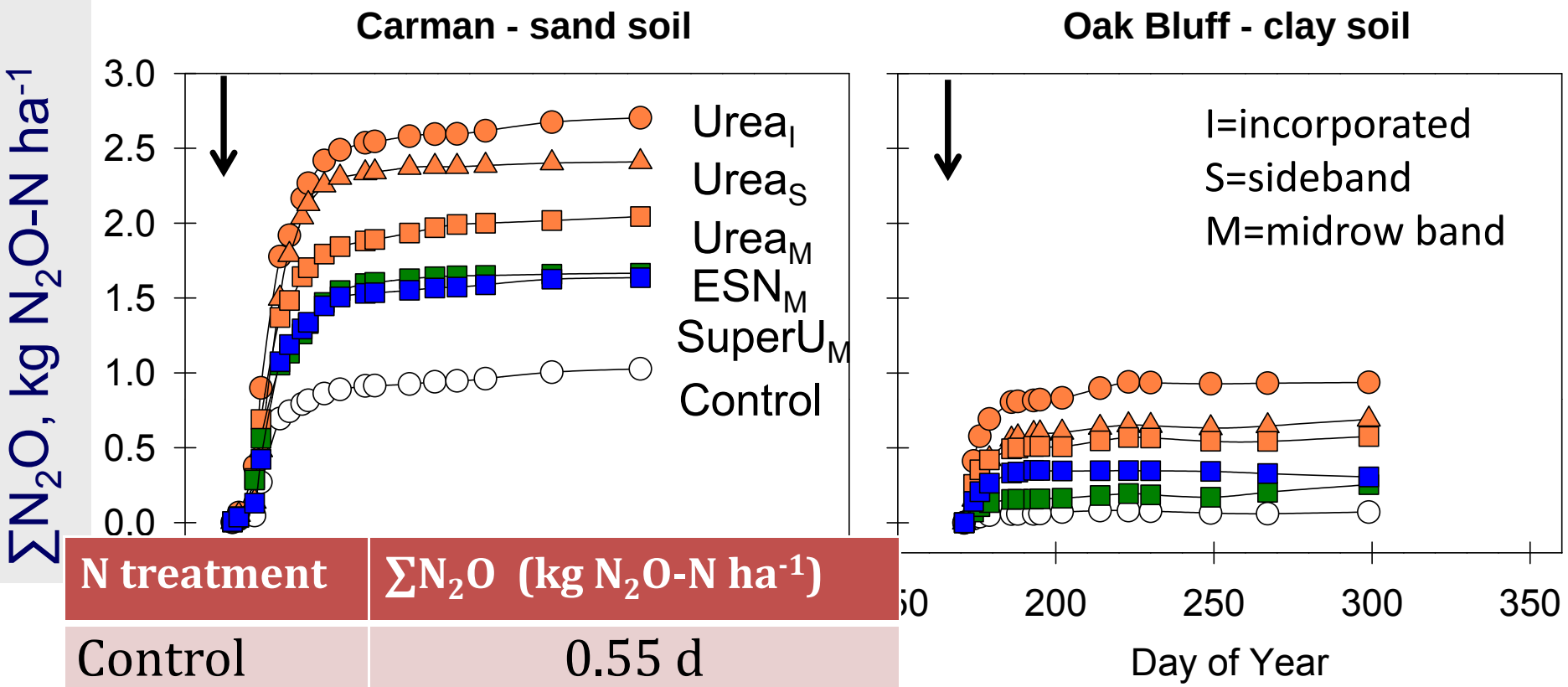
Nitrite slows 2nd step nitrification

Nitrate

Nitrate appears in concentrated zone
Appearance delayed than broadcast
N protected from early season leaching/denitrification losses

Placement

Placement N_2O emissions-2011



N treatment	$\sum N_2O$ (kg N_2O-N ha^{-1})
Control	0.55 d
$Urea_I$	1.82 a
$Urea_S$	1.55 a
$Urea_M$	1.31 ab
ESN_M	0.97 c
$SuperU_M$	0.98 c

→ Banding tends to reduce

→ EEF 26% less than urea when banded

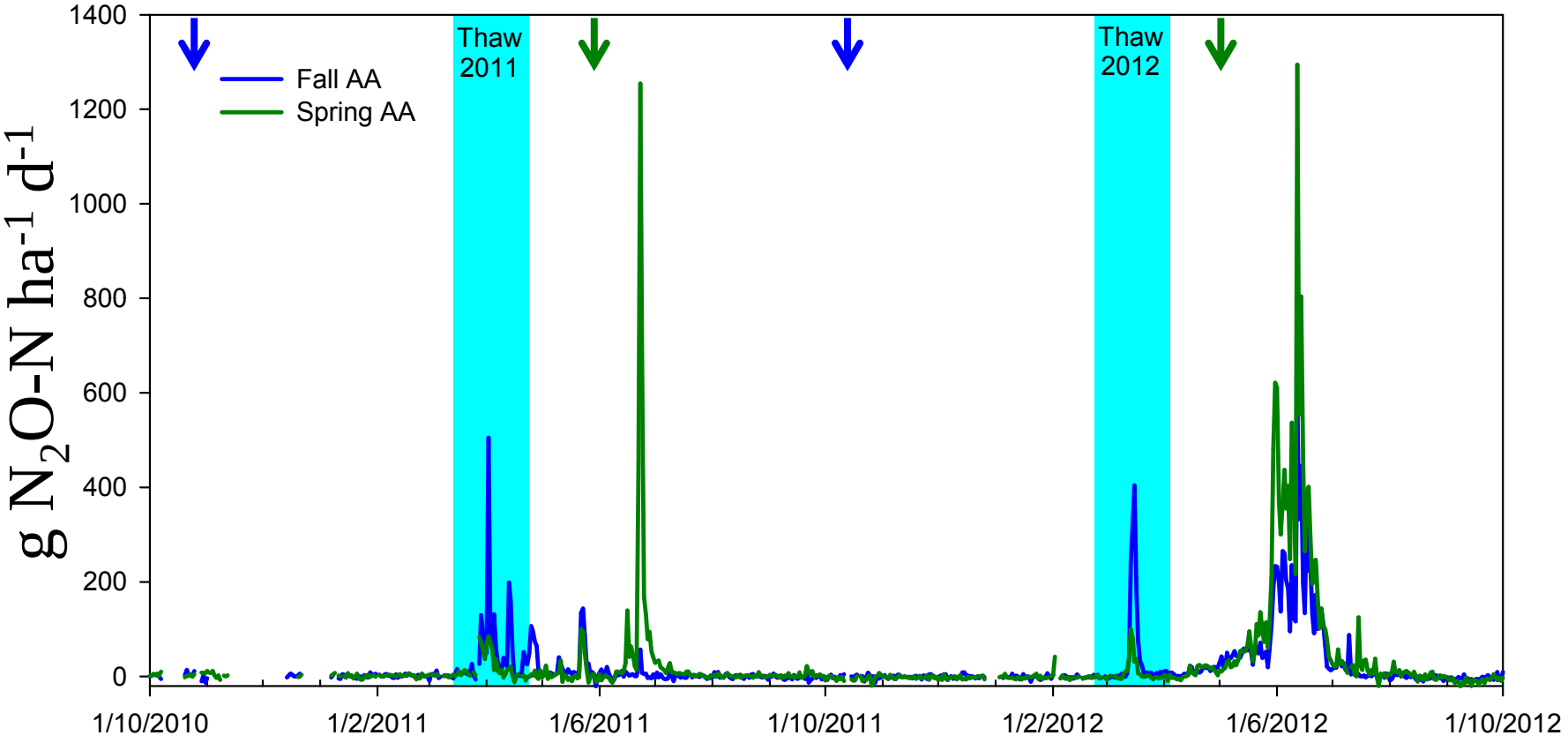
Gao et al. 2014. Agron J

Placement BMPs

- Banding fall and spring recommended
- Good band closure and coverage important
- Wet years N2O reduced with banding
- Looking into effect of band depth
- We found mid-row to tend to reduce N_2O more than side-row and both better than incorporation – at odds with findings of others

Timing

Fall Fertilizer Addition is Supposed to be Bad?



Tenuta et al., J Environ Qual 2015

Crop	Spring AA		Fall AA	
Year	$\sum F_N$	$\sum F_{N\ winter}$	$\sum F_N$	$\sum F_{N\ winter}$
	kg N ha^{-1}			
2010/11	5.1	1.0	3.2	2.5
2011/12	14.1	0.4	9.4	1.6

Timing BMPs

Estimated Average Yield for Application of N Fertilizer in MB

Fall broadcast, incorporated	80%	of spring b'cast
Fall banded	100	"
Spring broadcast, incorporated	100	"
Spring banded	120	"

Banded N is 20% better than broadcast N

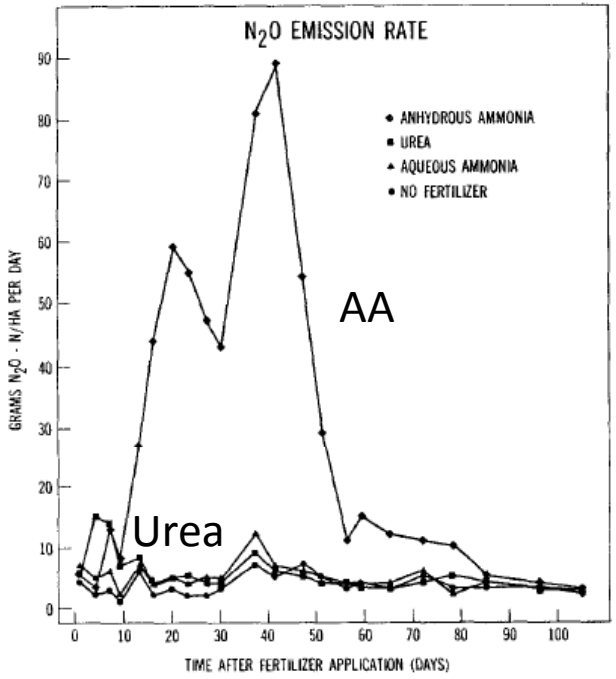
Spring applied N is 20% better than fall applied N

Very late fall application just before freeze up doesn't increase N_2O compared to spring

Source

Conventional Sources of N

- AA > Urea > Ammonium > Nitrate
- Nitrification reason for most emissions



Breitenbeck & Bremner 1986

Tenuta and Beauchamp 2003 Can J Soil Sci

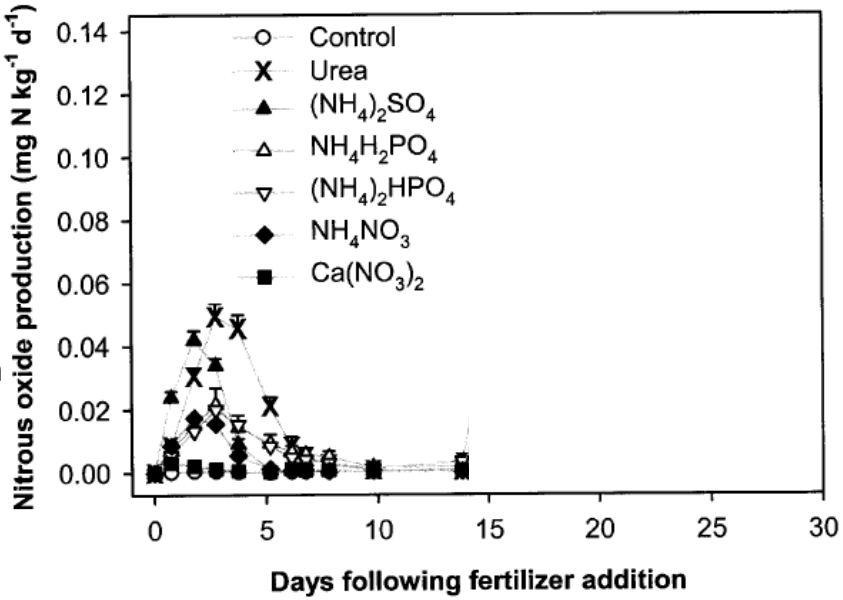
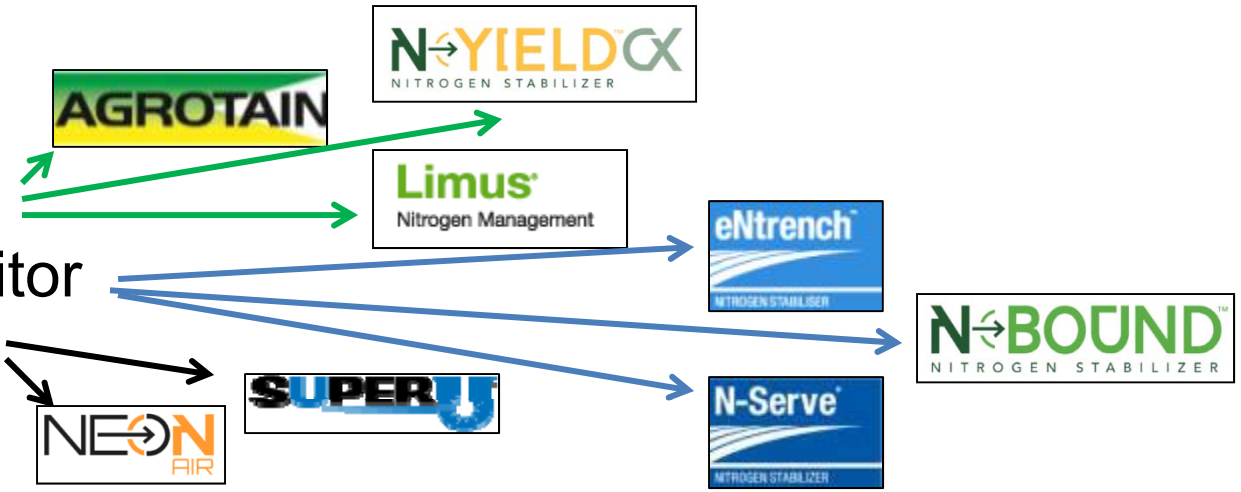


Fig. 7. Nitrous oxide production with various N fertilizers added to microcosms in laboratory experiment B. Mea
dard error) are shown.

Enhanced Efficiency N Fertilizers

- **Stabilized N**
  - Urease inhibitor
  - Nitrification inhibitor
  - Double inhibitor

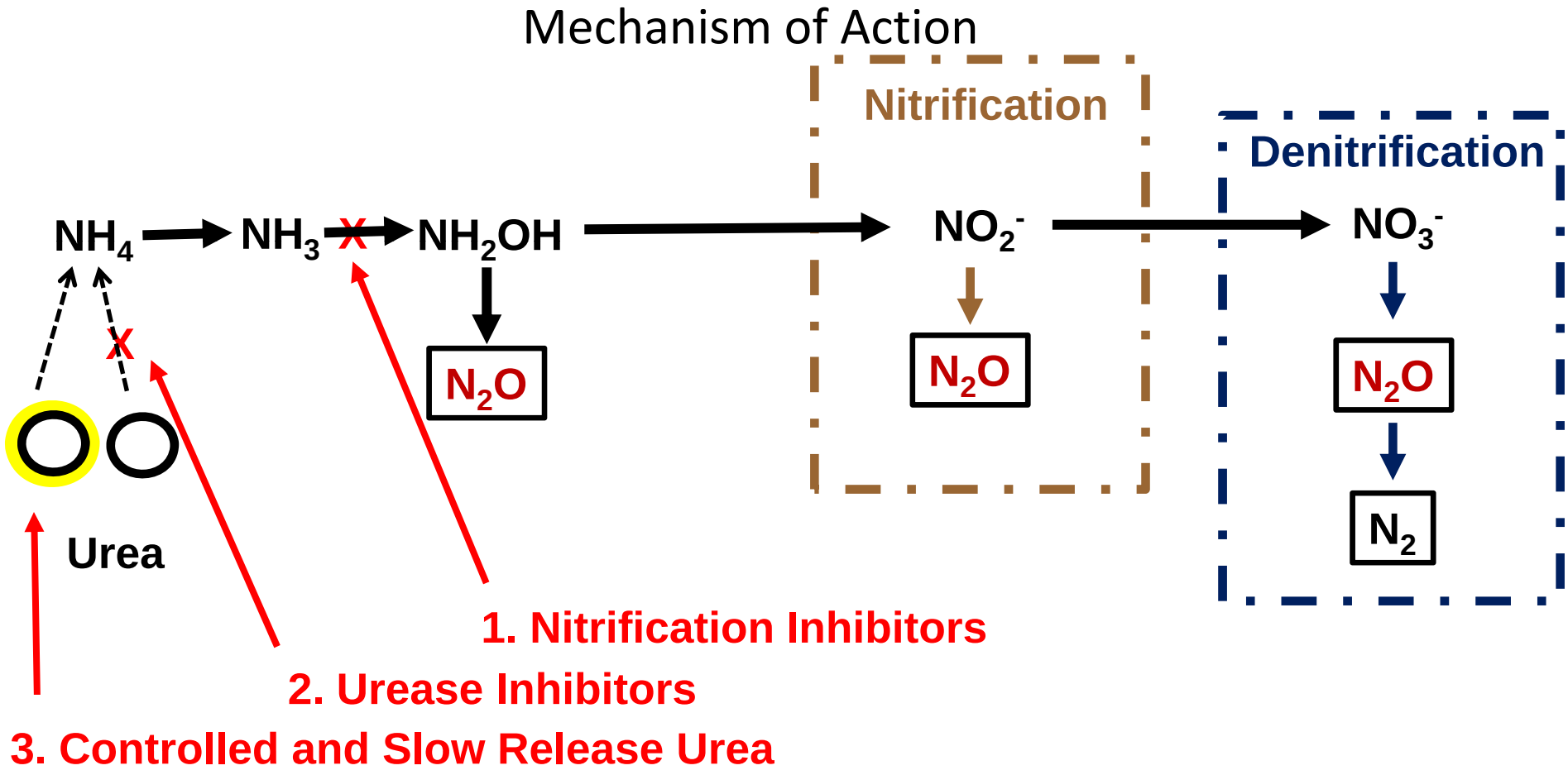


- **Controlled Release**
  - Polymer Coated Urea

- **Slow Release**
  - Sulfur-coated Urea, Methylene Urea, Isobuylidene Diurea, Urea Formaldehyde, Urea Triazone

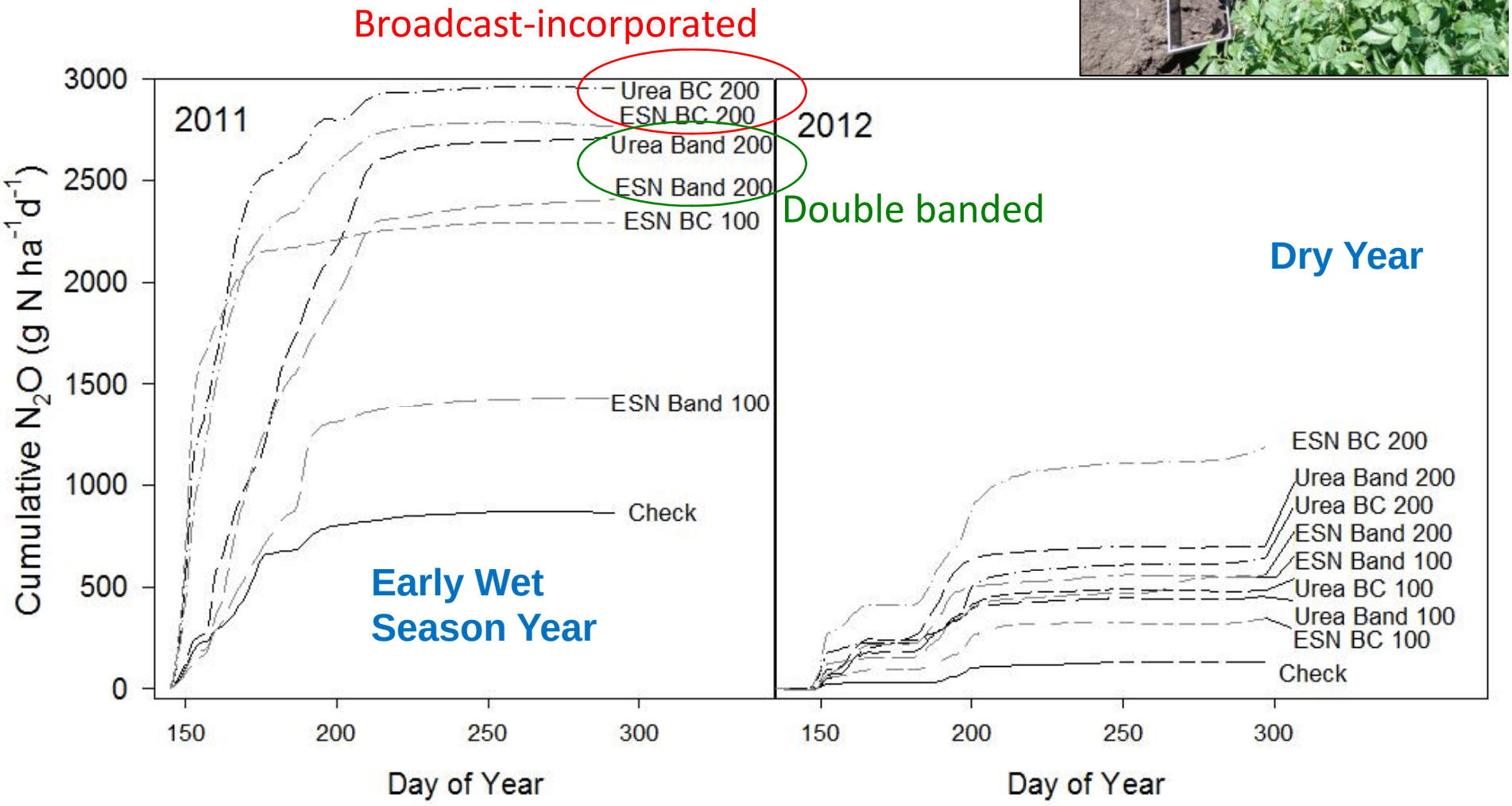
Source

Enhanced Efficiency Fertilizers



Source

Irrigated Potato Carberry



Baron et al., in prep

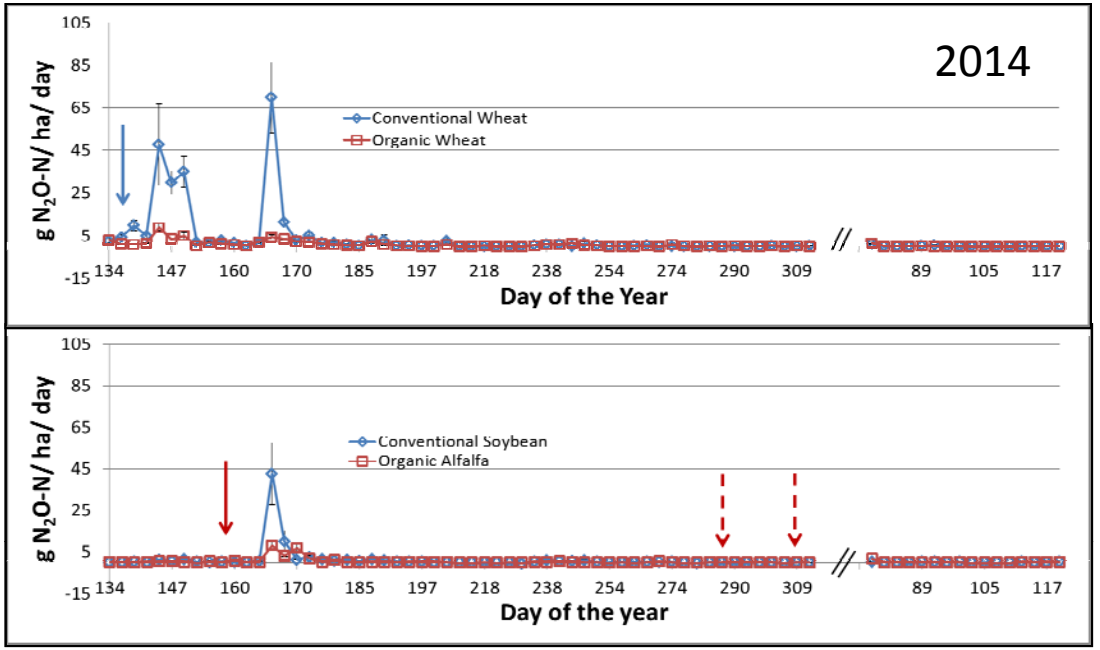
Source BMPs

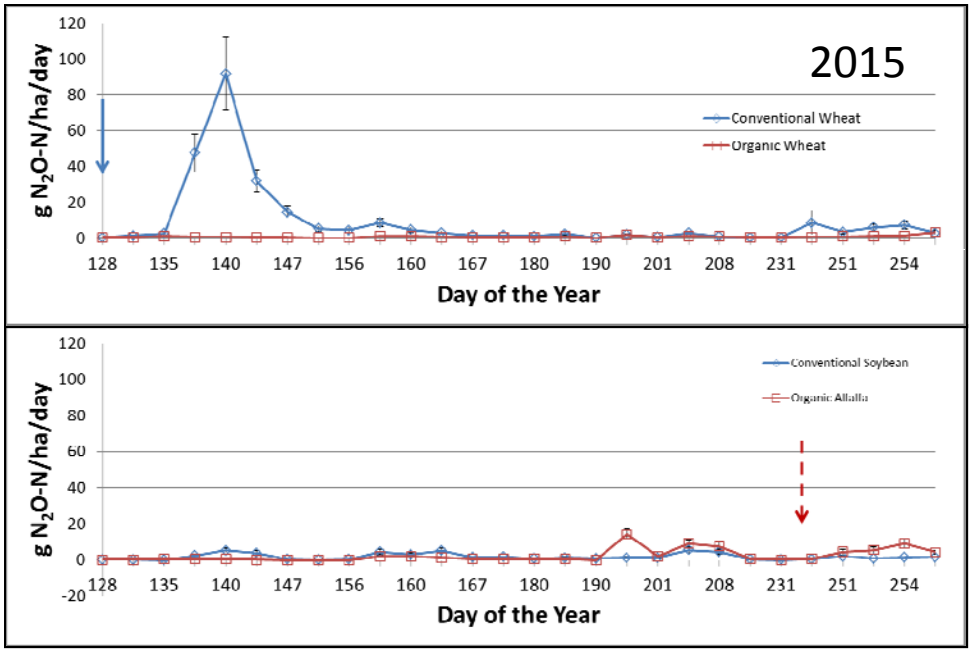
- From other research, UAN emits less N_2O than AA and urea
- SuperU reduced N_2O in wet years if subsurface banded
- ESN must be subsurface place
- Wet seasons, advantage for yield and N_2O reduction with ESN
- Cost a factor:
  - ex. Urea $0.63, UAN $0.65, SuperU $0.80, ESN $0.83 /lb N
- Urease inhibitors if need to surface place limit ammonia volatilization and therefore reduce indirectly N_2O emissions

Source

Organic Systems?

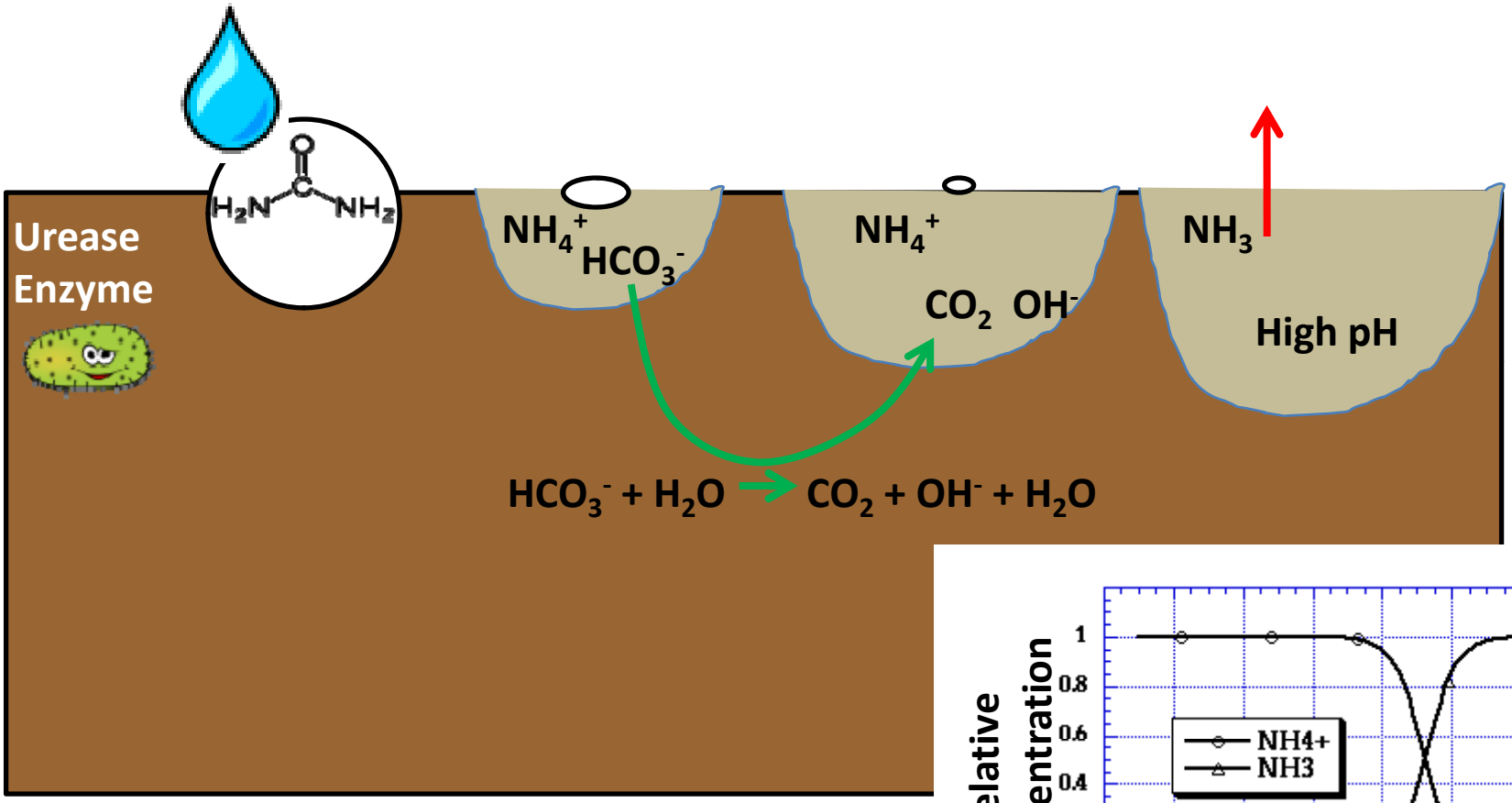
Legume ploughdown as an Enhanced Efficiency N Source?

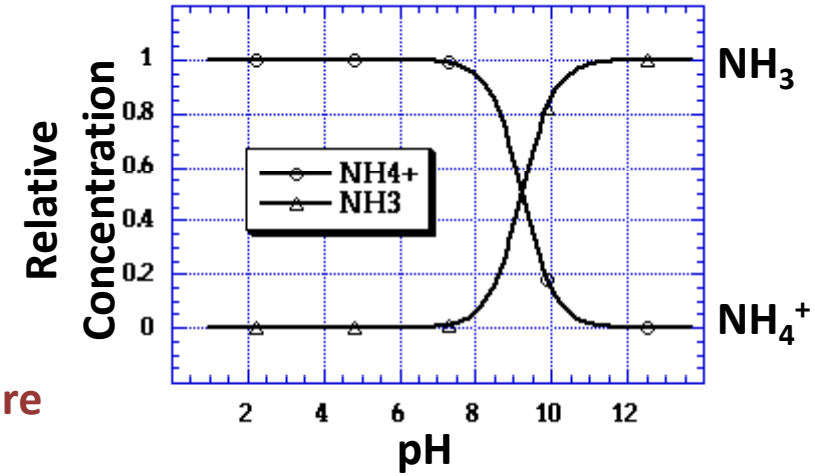




Megan Westphal, M.Sc. project

Ammonia Volatilization from Urea



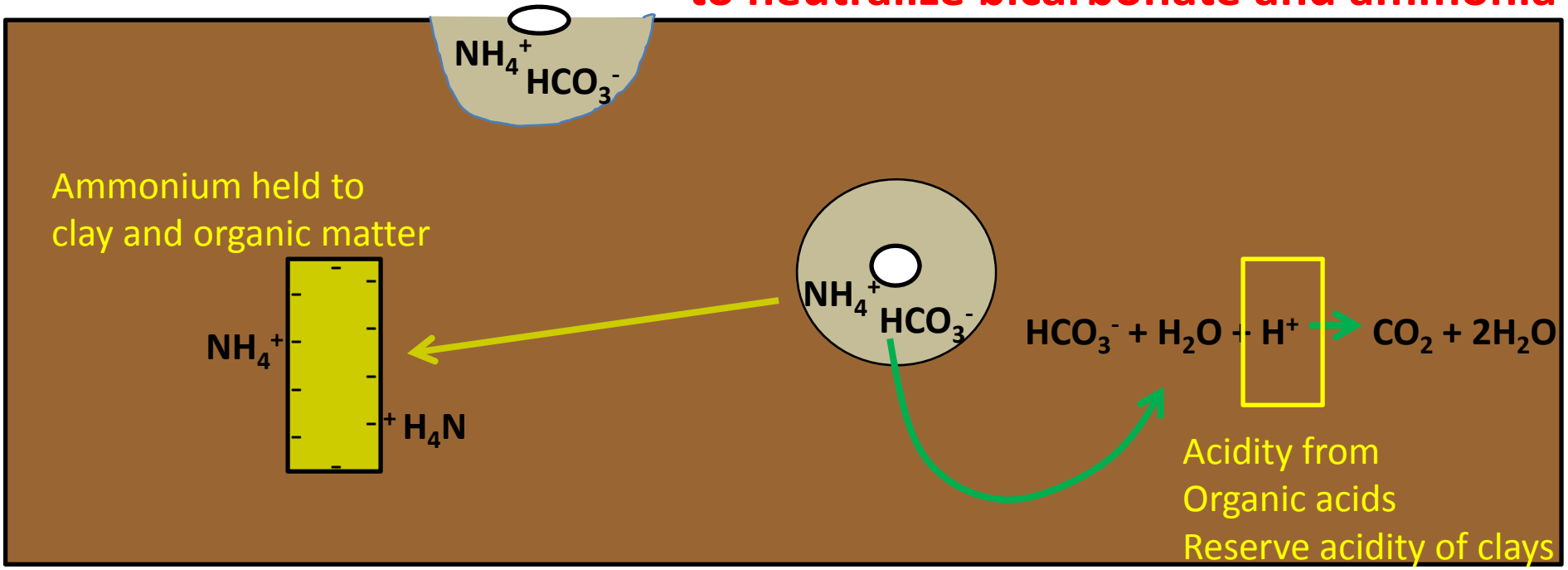


What Promotes Volatilization?

- Low organic matter
- Sand
- Low CEC
- High urea concentration
- Moisture
- Wind
- Temperature

How Deep Placement Reduces Ammonia Volatilization from Urea

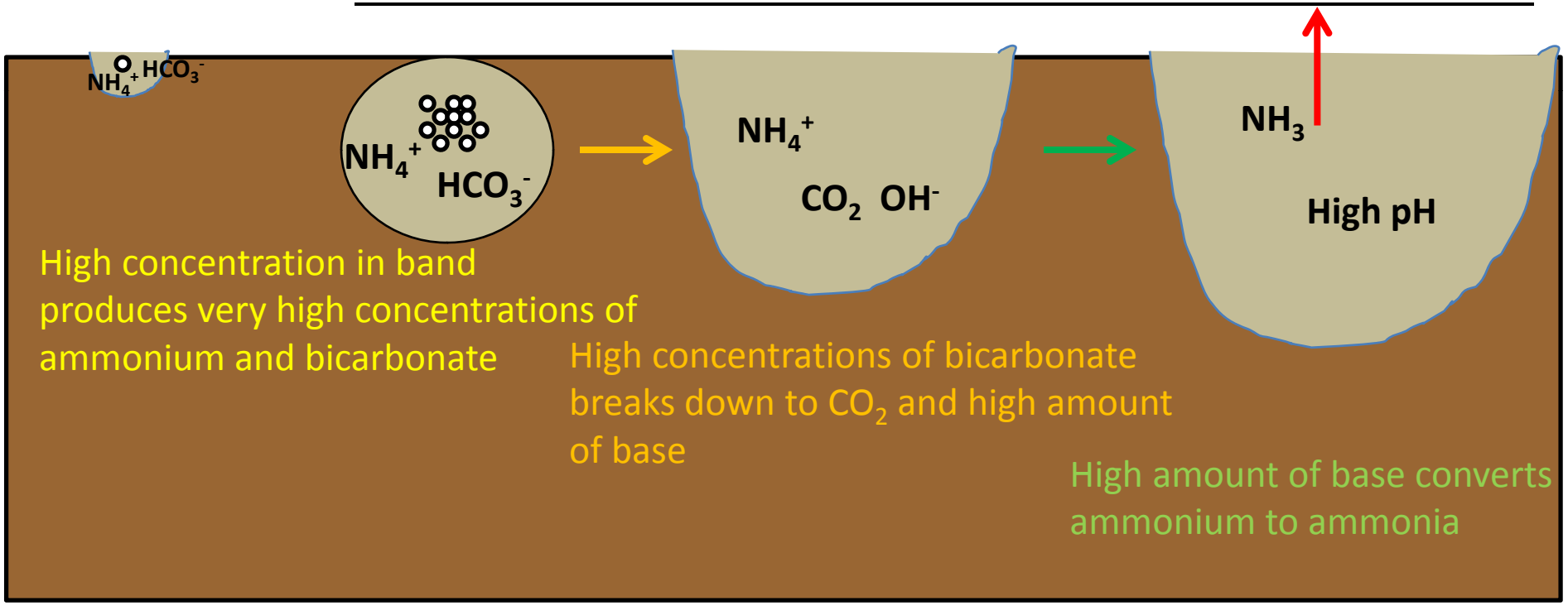
Deeper the incorporation
more opportunity for acidity from
organic acids and reserves on clay
to neutralize bicarbonate and ammonia



How Shallow Placement May Increase Ammonia Volatilization from Urea

Surface Broadcast

Shallow Banded

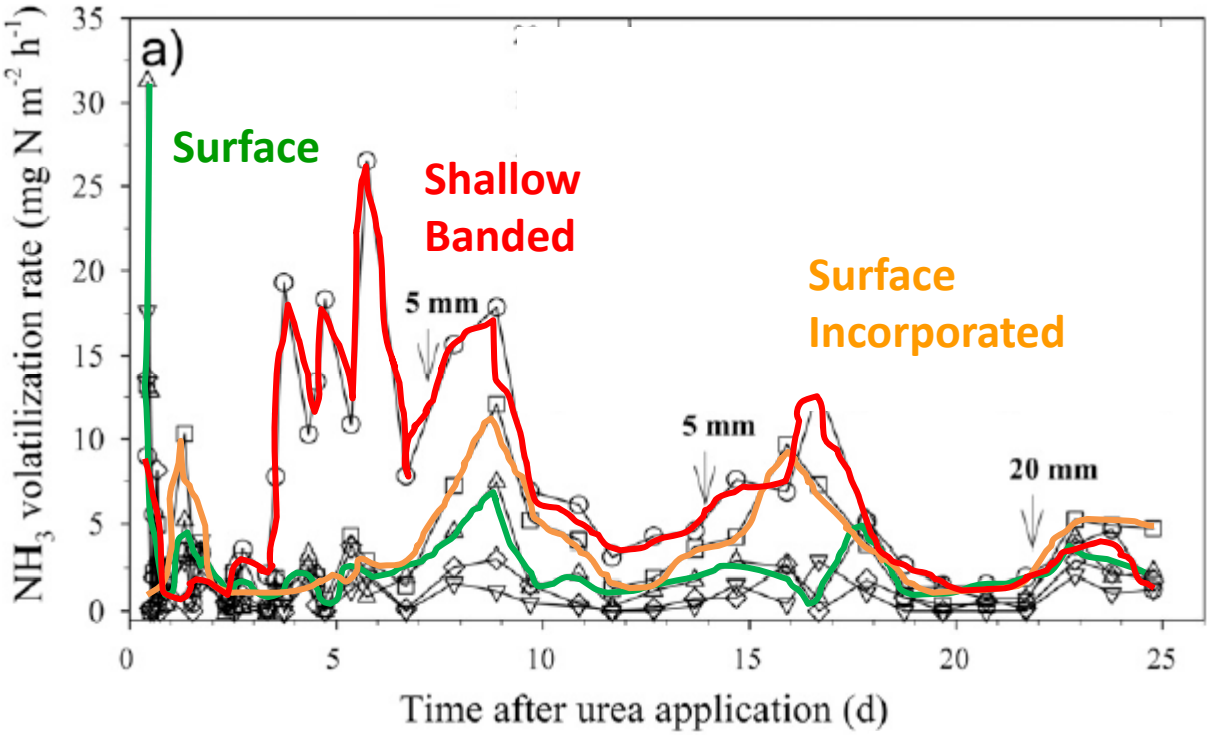


For shallow banded,

less volume of soil to buffer before ammonia gets to atmosphere

Shallow Banding Ammonia Loss Concern

- Standard recommendation is band to >3”
- Increasing use of shallow banding
  - Saves time
  - Saves fuel
- Some evidence ammonia losses may be higher for shallow banding than surface placement of granular urea



Ammonia Loss Study Near Quebec City

Silty clay loam (27% clay)
125 lbs N/acre
20” band spacing
5 cm depth hand trenched band

Table 3. Cumulative losses of NH_3–N following land application of urea at different moments during the experiment.

Urea application method or type	Cumulative NH_3 losses				
	Day 1	Day 2	Day 5	Day 10	Day 25
	mg NH_3–N m^{-2}				
Broadcast	54	120	194	563b‡	1331b
Broadcast/Incorporated	40	165	245	921b	2250b
Banded/Incorporated	23	68	553	2102a	3768a
NBPT†	40	45	88	290c	669c
Polymer-Coated	31	88	159	225c	508c
Treatment *P* value	NS	NS	NS	> 0.001	> 0.001

† Urea treated with urease inhibitor *N*-(*n*-butyl) thiophosphoric triamide.

‡ Values in the same column with same letter are not significantly different ($P < 0.05$).

Rochette et al. JEQ 2009

Ammonia Loss From Shallow Band Urea Increases with N Rate

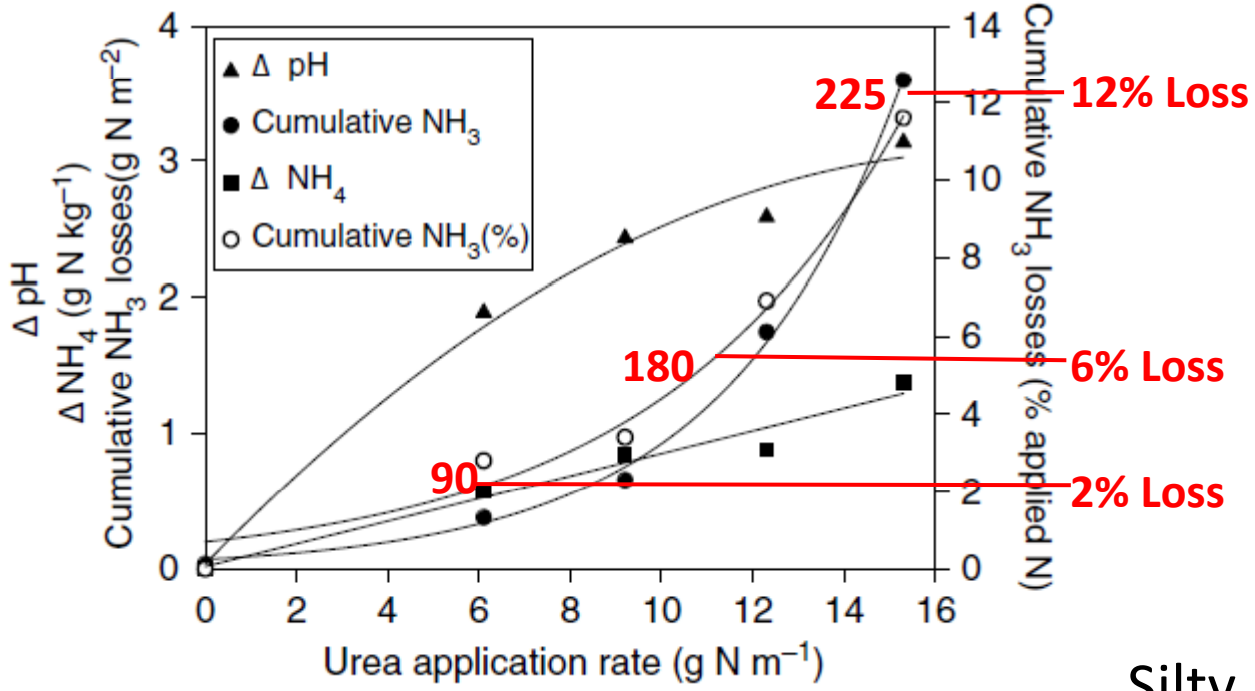


Fig. 3. Maximum change in soil NH_4-N (ΔNH_4) concentration and maximum change in soil pH (ΔpH) during the monitoring period, and cumulative volatilization NH_3 losses following subsurface (5 cm) banding of urea at increasing application rates.

lbs N/ac equivalent for 16" band spacing

Silty loam (19% clay)
146 lbs N/acre
20" band spacing
5 cm hand trenched band

Rochette et al. CJSS 2013

Deeper Band Placement Reduces Ammonia Loss

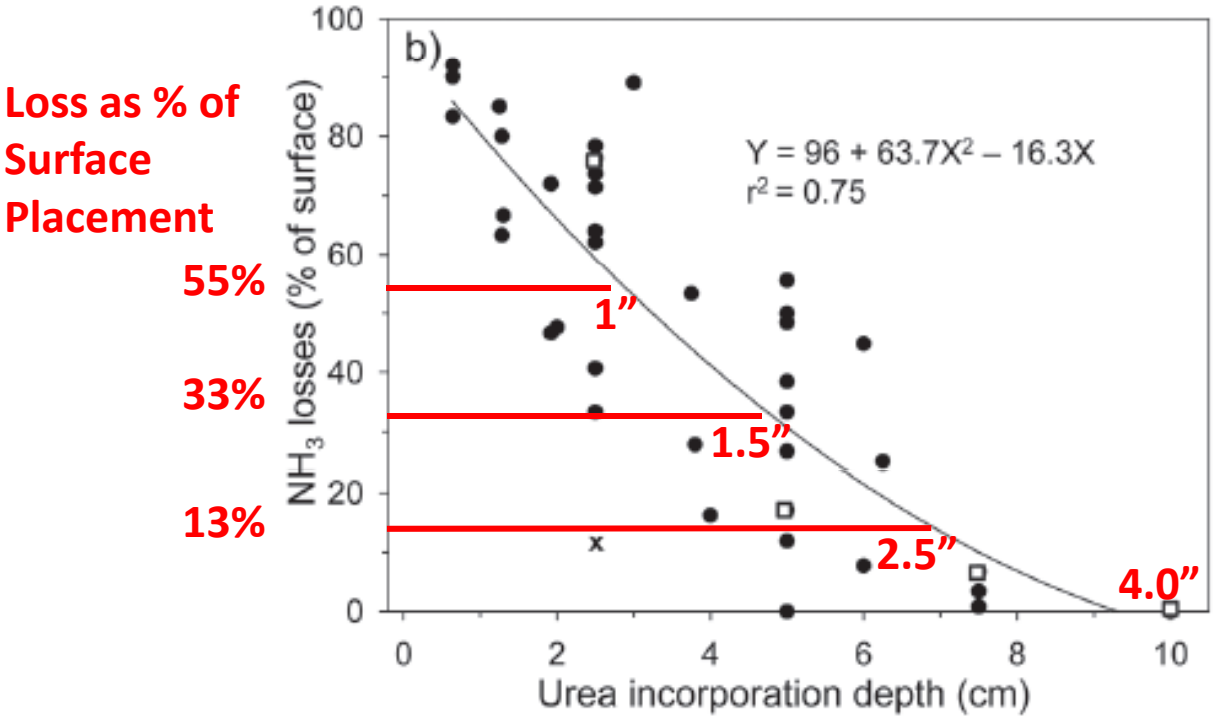
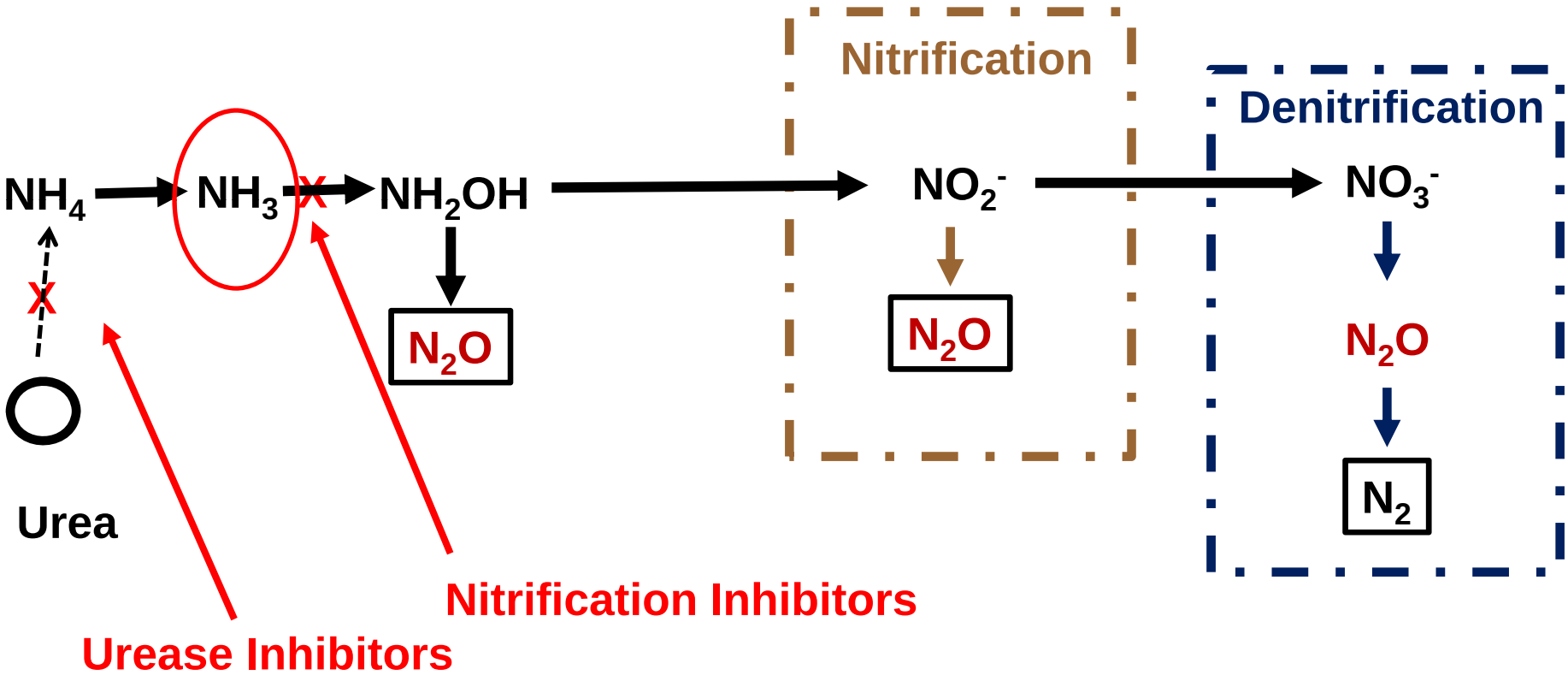


Fig. 4. Summary of literature data on ammonia volatilization response to urea incorporation depth. Volatilization losses were expressed as proportion (%) of applied N (a) and proportion (%) of losses for a surface-application (b). Open squares are observations from this study. One datapoint (“x”) from Bouwmeester et al. (1985), for which water accumulation over the band artificially reduced volatilization, was not included in the analysis.

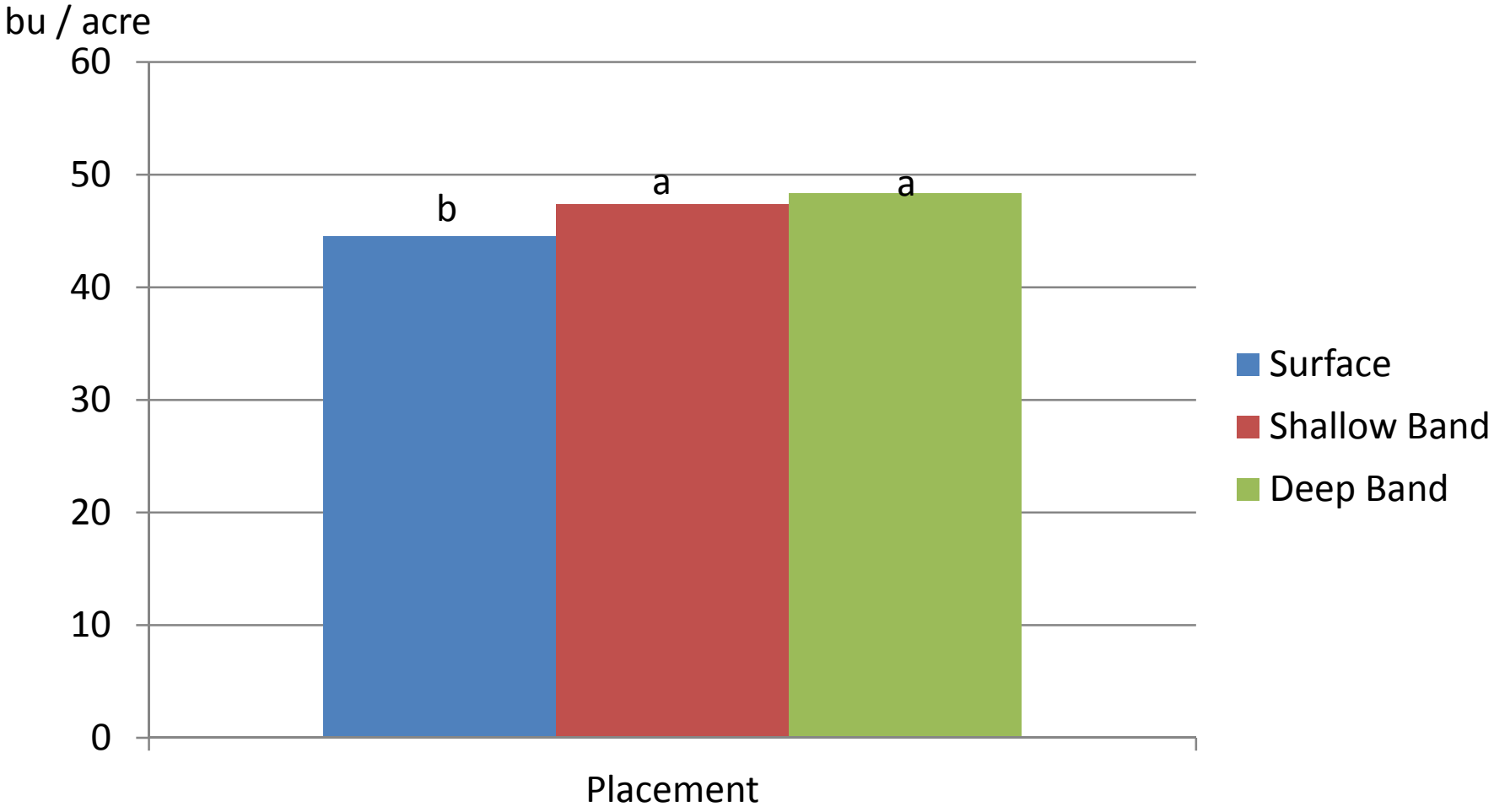
Data from 15 published studies

Rochette et al. JEQ 2014

Fertilizer Additives to Reduce N Losses

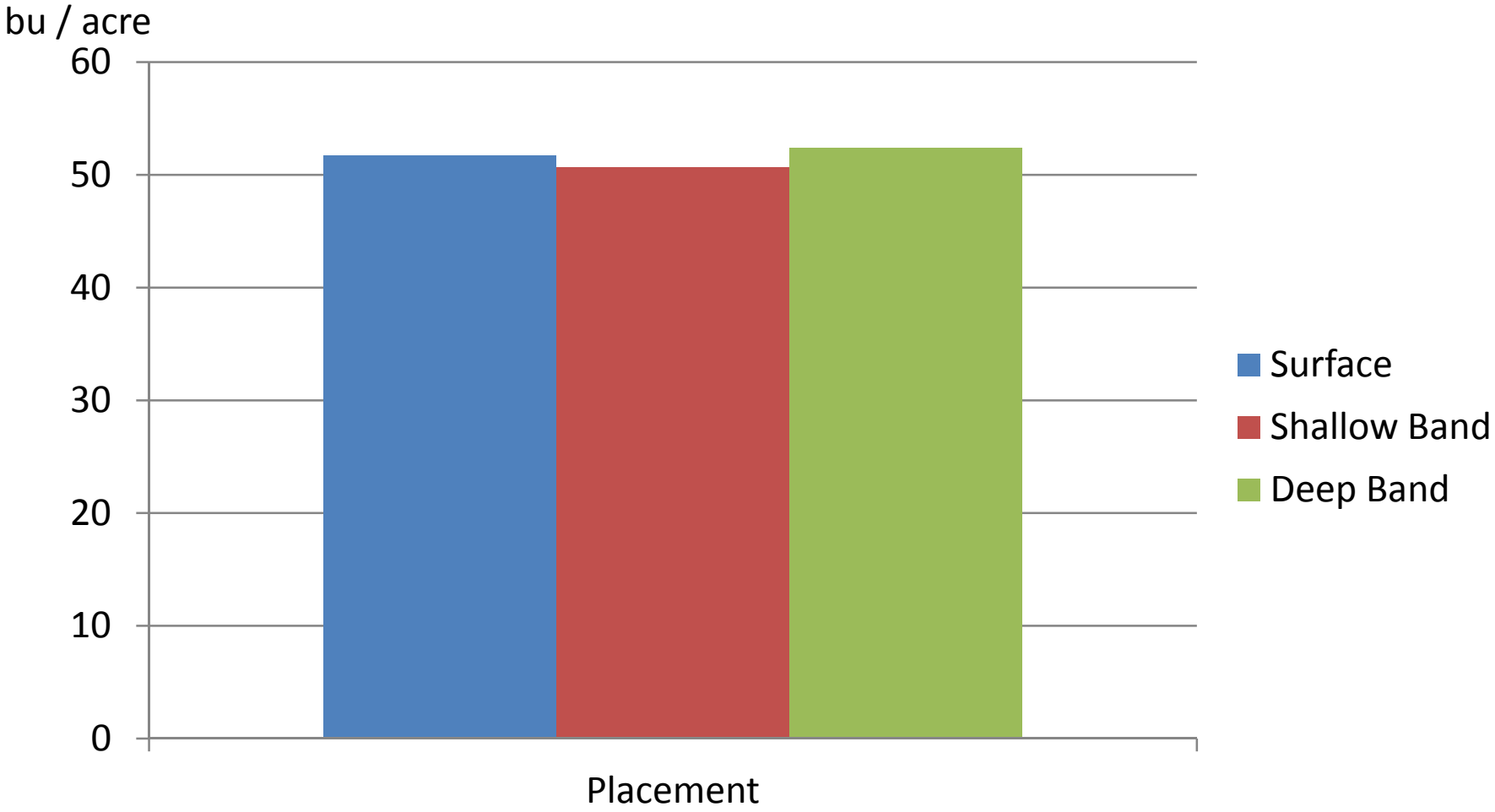


N Rate Not Optimum (70% of Recommended)



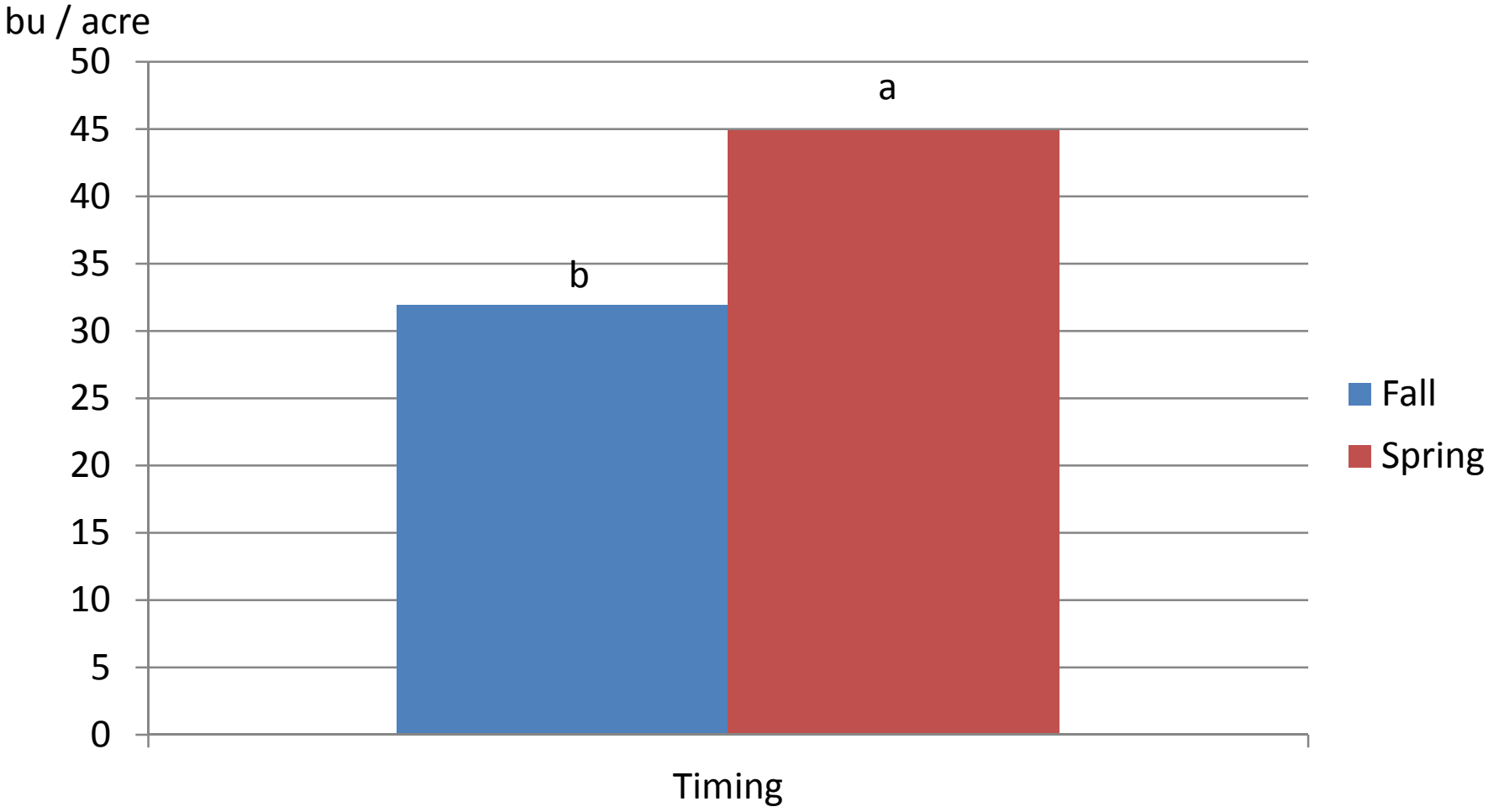
*no effect of N source or ‘placement x source’ interaction

N Rate Optimum
(100% of Recommended)



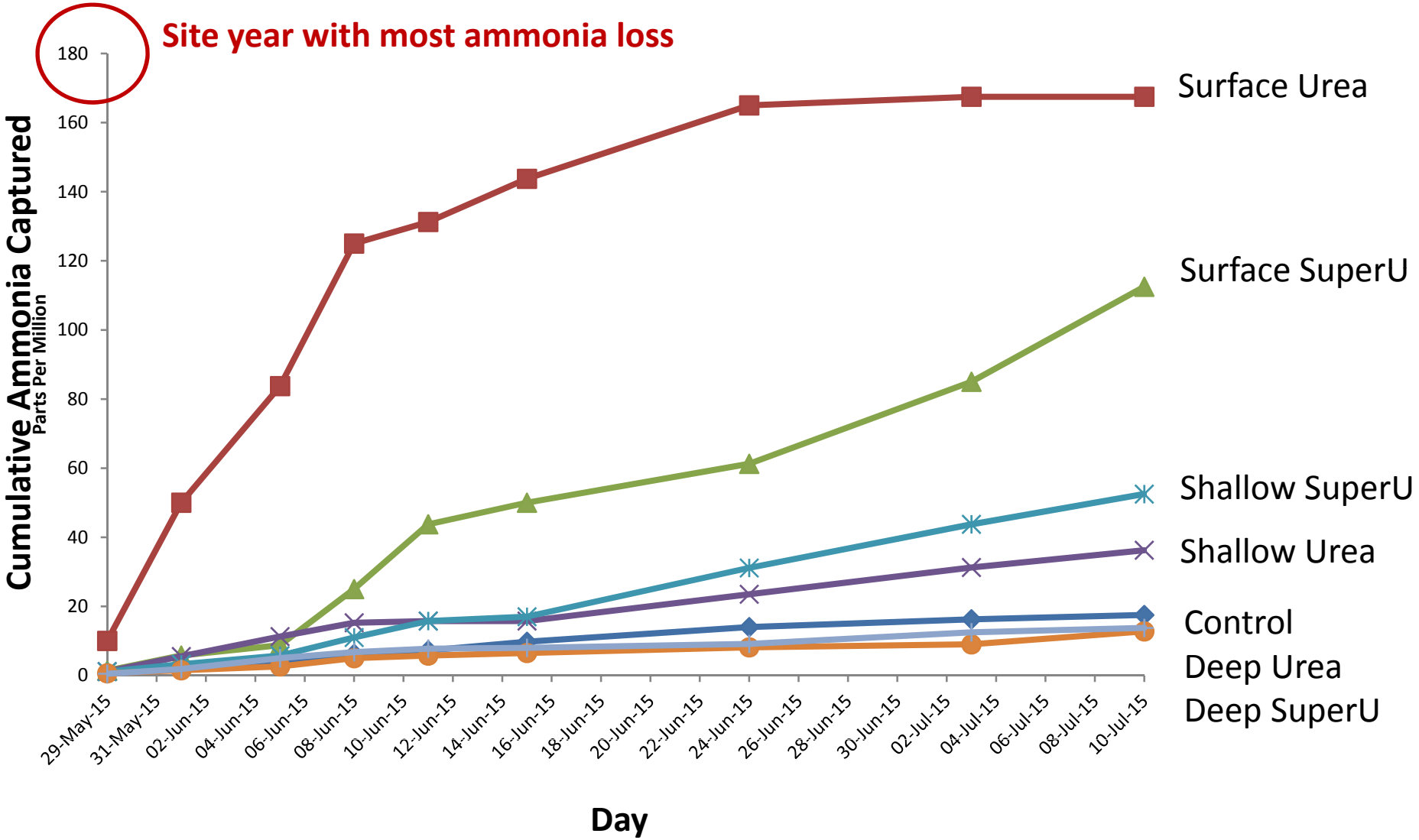
*when N rate optimum, no effect of placement
*no effect of product or ‘product x placement’ interaction

Fall vs. Spring Surface Application (2016 Two Sites Years)

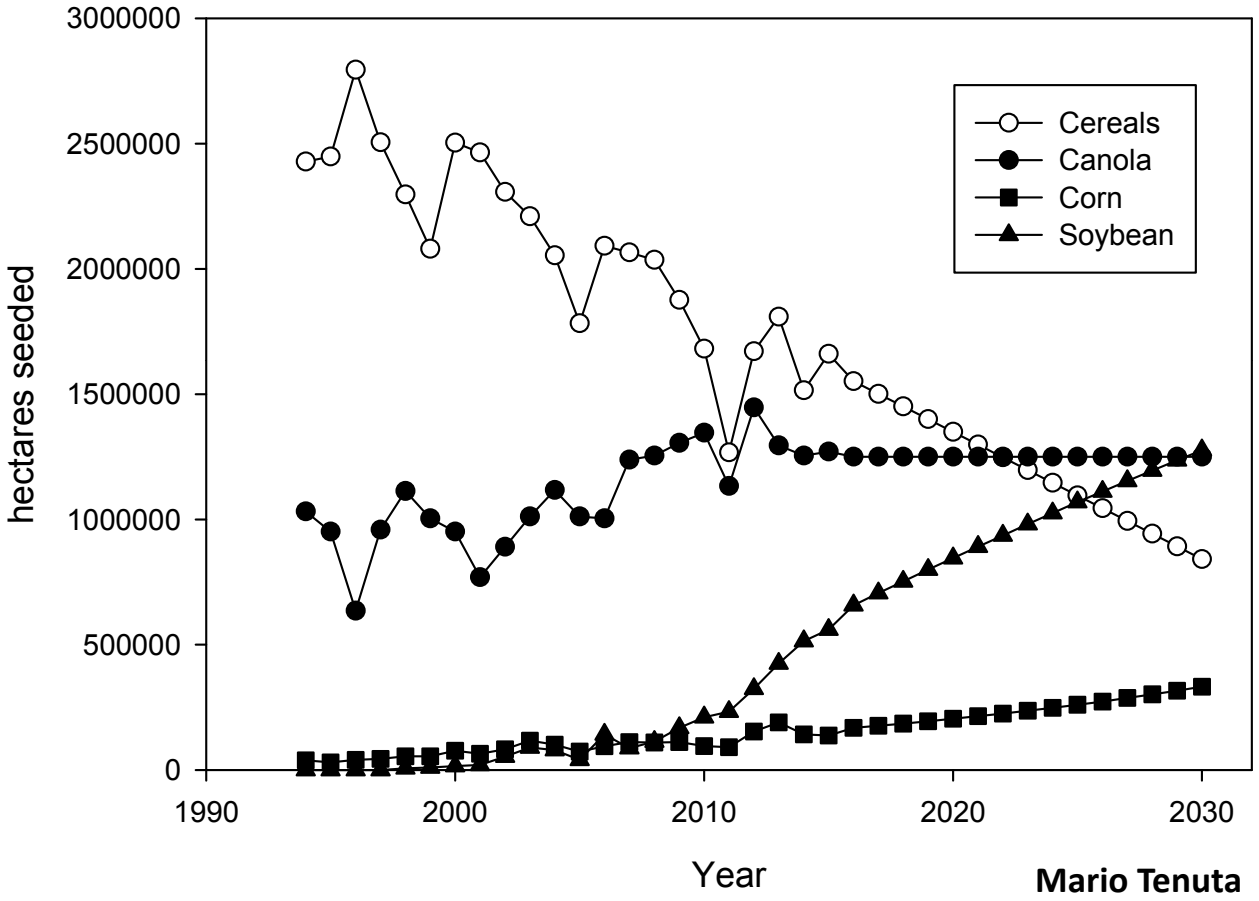


*no effect of product (Agrotain or SuperU) or ‘product x time’ interaction

Ammonia Loss Carman2 2015



Manitoba Major Field Crops



Historical data from Statistics Canada

Assumes continued cereal decline

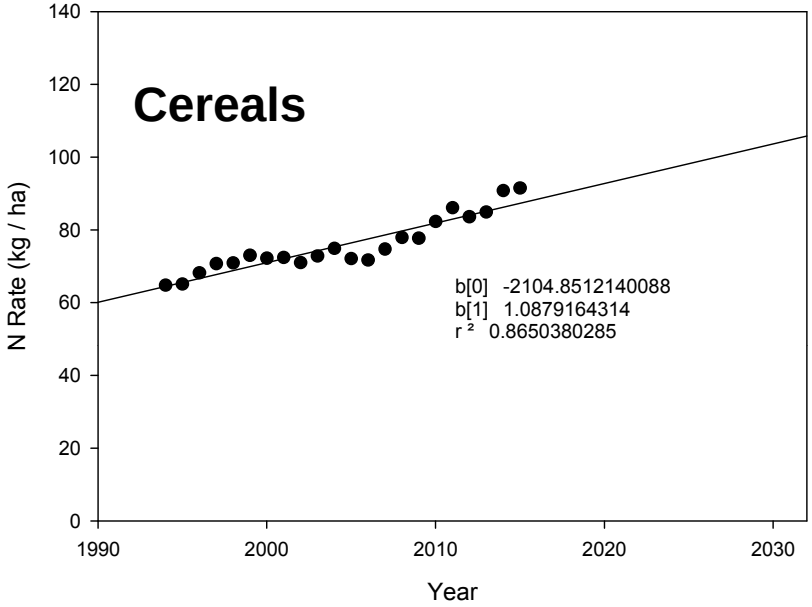
Canola stabilized

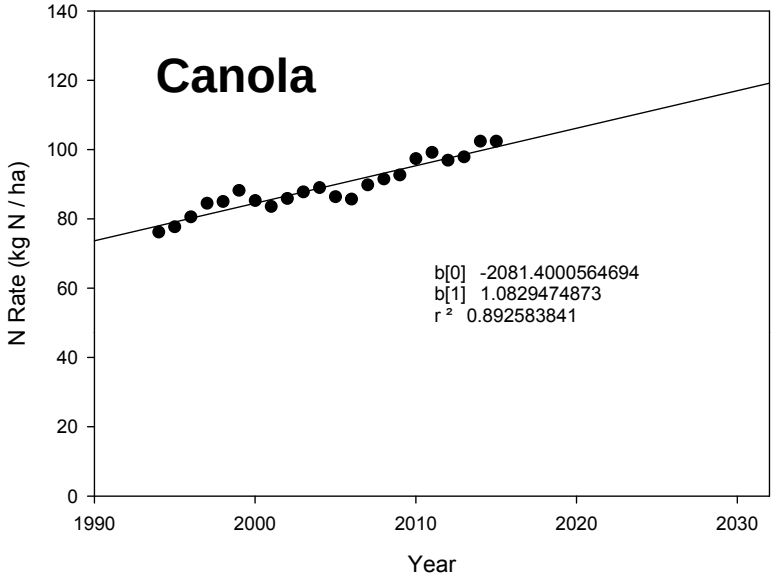
Corn increase a bit more than historical rate increase

Total cropped area very slight increase

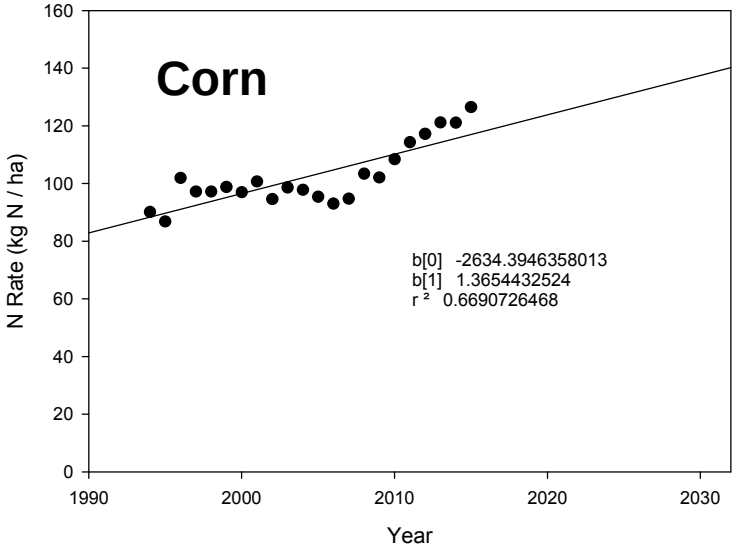
Soybean picks up remaining area of cereal decline

N Rates Keep Increasing

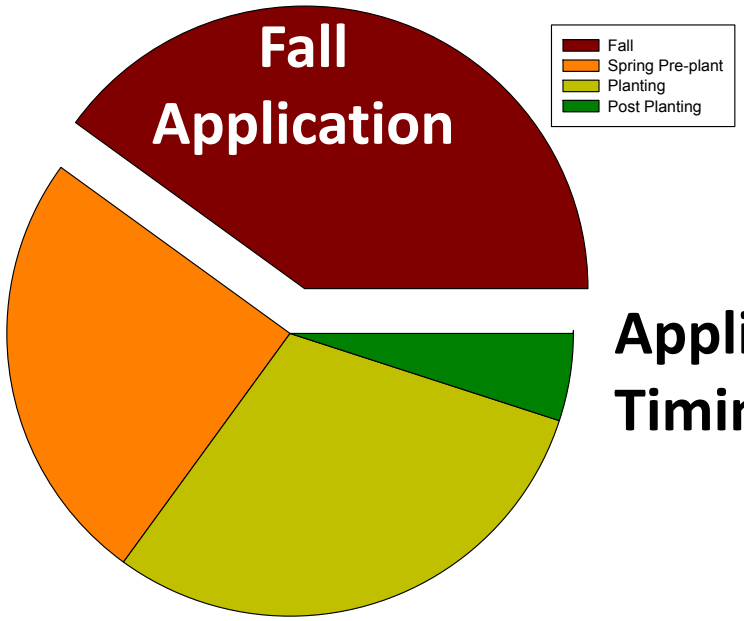




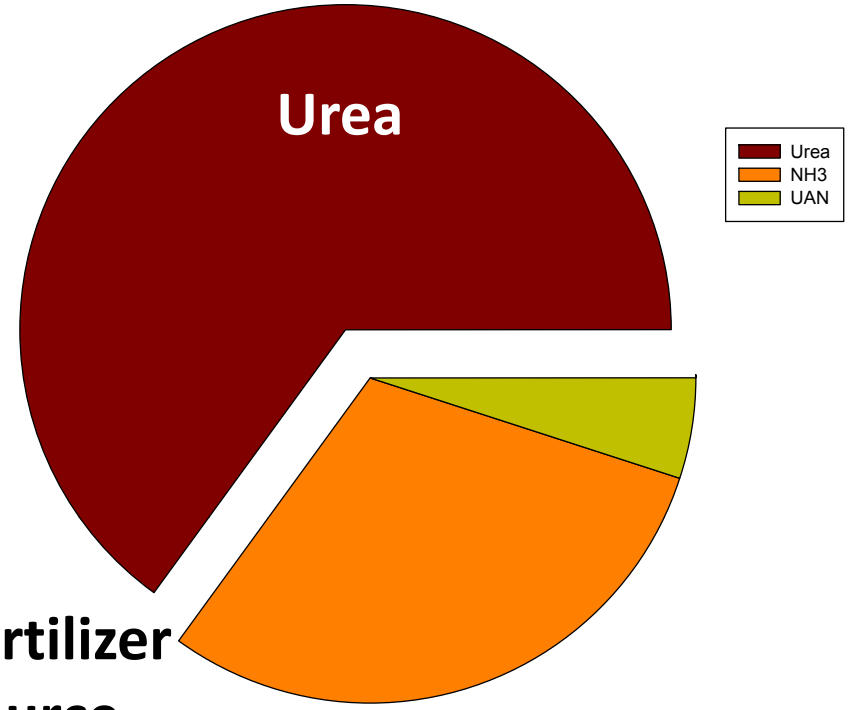
Data from MB
Crop Insurance



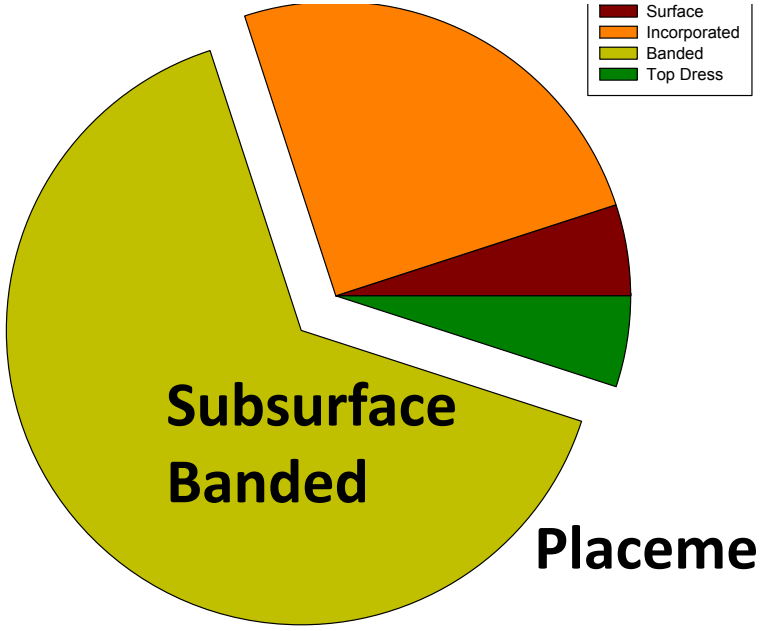
MB Fertilizer Use Survey 2015 (85 growers)



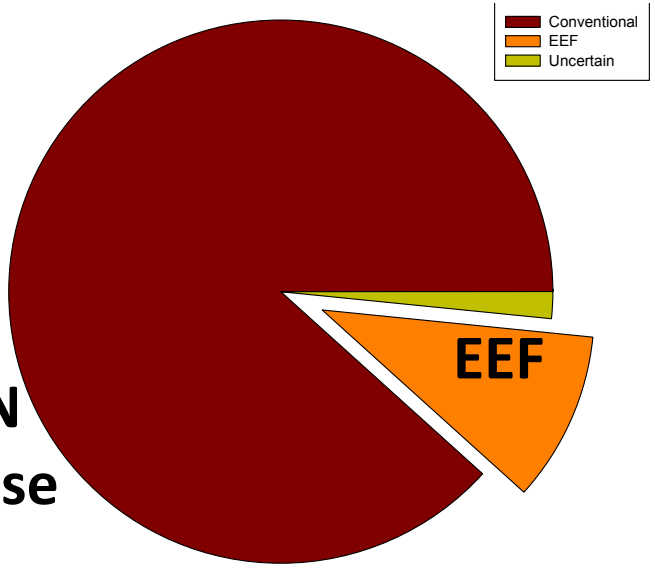
Application Timing



N Fertilizer Source

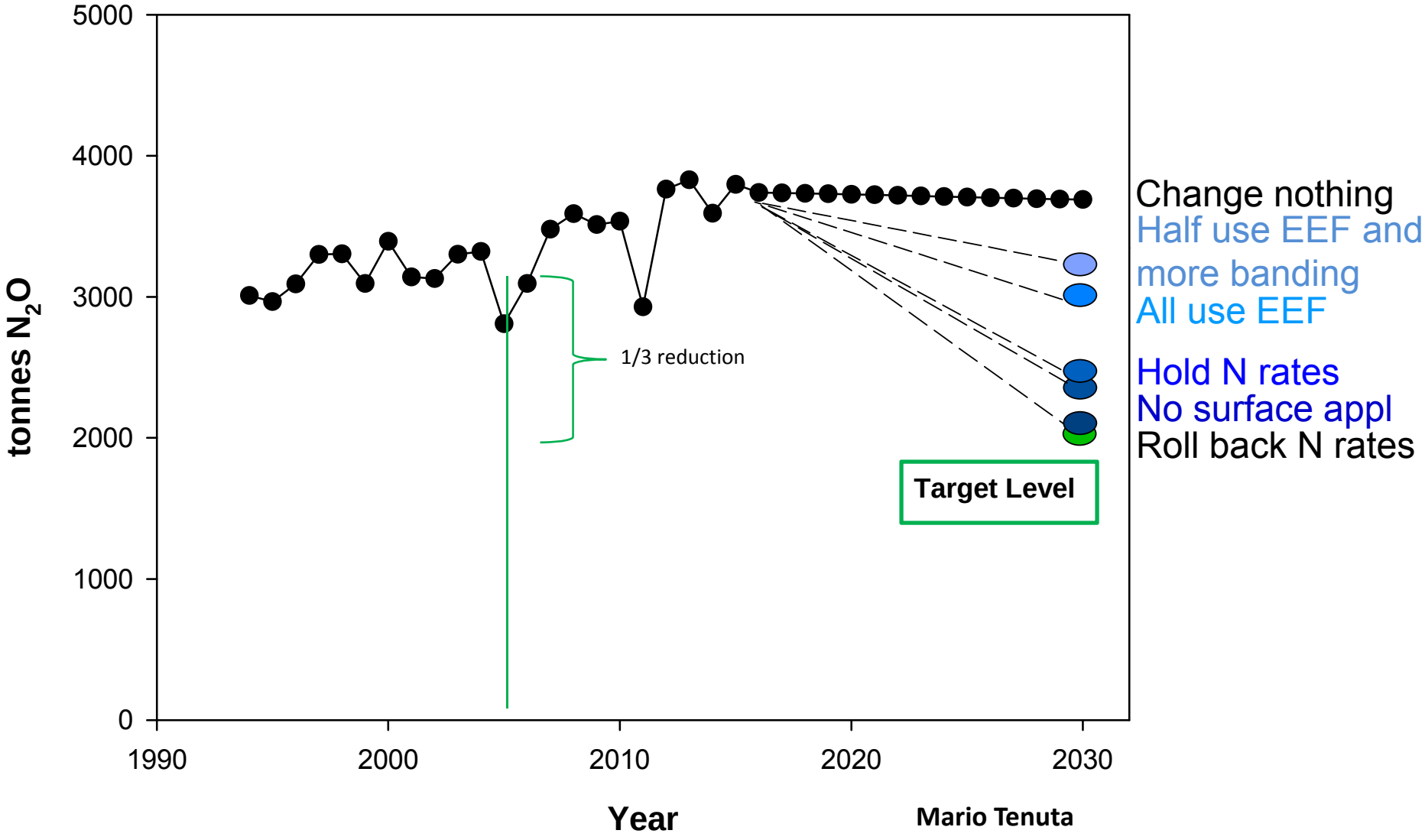


Subsurface Banded Placement



Enhanced Efficiency N Fertilizer Use

Changes in Practices to Reach Reduction Target in MB



What Can We Recommend?

- Use the 4Rs
- Optimize N addition Rates
  - Testing, requirements, interactions with 3Rs
- Good N fixing legumes emit little N_2O
- Adding N via green manures limits N_2O
- Let's Band Together
- Estimate if EEFs worth it for your system (ex. reduce fall application rate, need to broadcast)
- Spring application unless can apply shortly before fall freeze-up, but consider EEF for insurance of spring weather
- Question your University, MAFRD, CCA, and salesperson advice

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