As the ice caps melt and the sea level rises

… and you cling to the last tree top still above water

… and you watch the sharks circling around you

… you might begin to wish we had tried harder

…to reduce greenhouse gas emissions

How do you estimate soil-emitted N_2O for all of the agricultural land in Canada?

(And who would be foolish enough to try???)

Dr. Philippe Rochette

Devon Worth, Brian McConkey, Dan Pennock, Claudia Wagner-Riddle,
Ray Desjardins…..many others…

Tier II Refinements/Additions

- A spatially- and temporally-variable emission factor determined as a function of the climatic moisture regime
- The contribution of emissions during winter and spring thaw is included
- The contribution of biological N fixation is omitted
- Emissions from summerfallow is added
- Modifiers included for:
  - soil tillage
  - Irrigation
  - landscape position
  - soil texture

Calculating N_2O Emissions:

$$Soil\_N_2O = Ninputs\_N_2O + fallow\_N_2O + irrigation\_N_2O + topography\_N_2O + tillage\_N_2O + texture\_N_2O$$

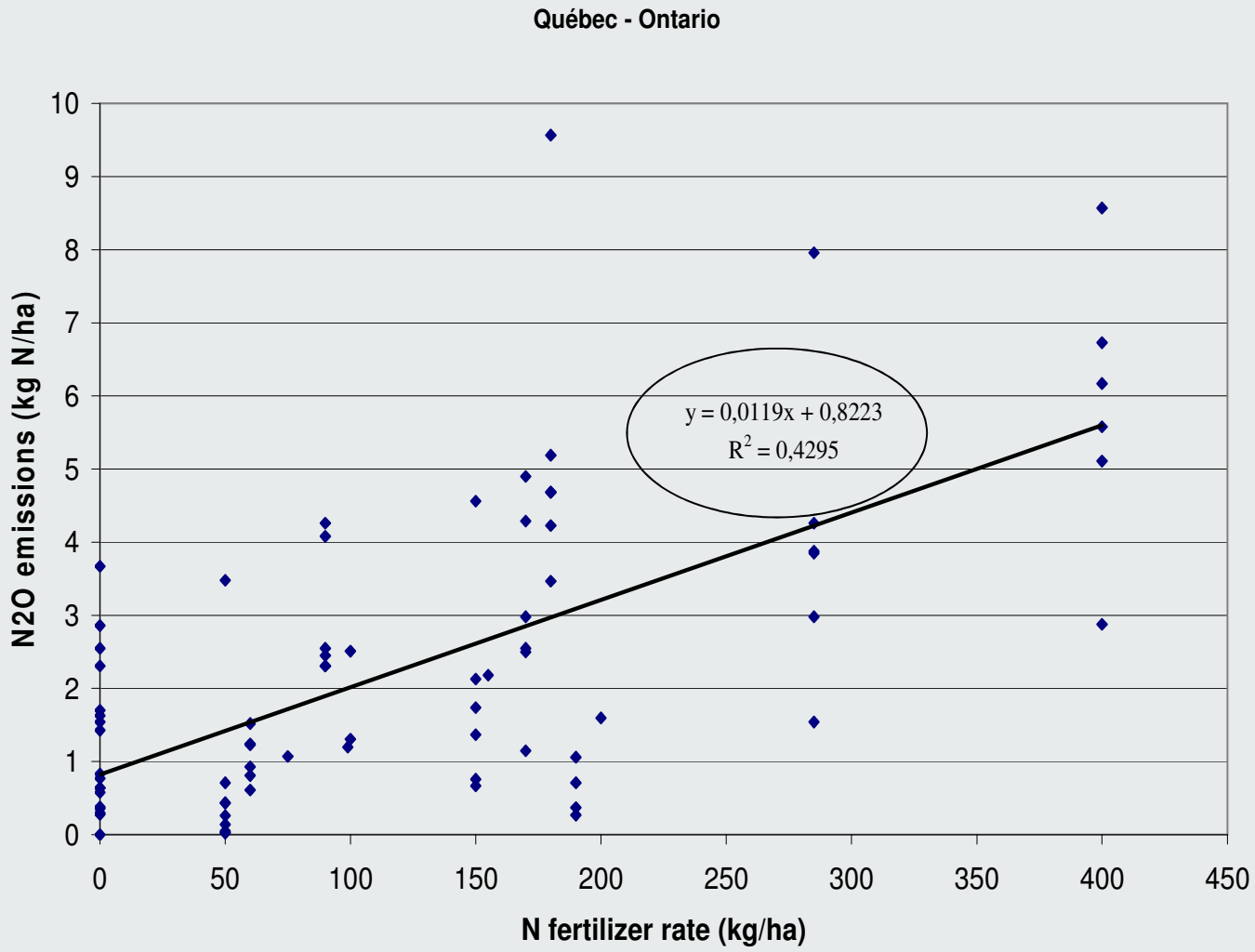
Source: Rochette et al. (2008)

Calculating N_2O Emissions:

$Soil\_N_2O = Ninputs\_N_2O$ + "modifiers"

$Ninputs\_N_2O$ = (Fertilizer N + residue N + manure N)*EF

EF for the Québec-Ontario Region



Original Derivation of IPCC coefficient

$$\text{Total } N_2O = 1.0 + 0.0125^*(\text{N inputs})$$

"Background emissions"

"Anthropogenic Emissions"

Quebec–Ontario

$$\text{Total } N_2O = 0.8 + 0.0119^*(\text{N inputs})$$

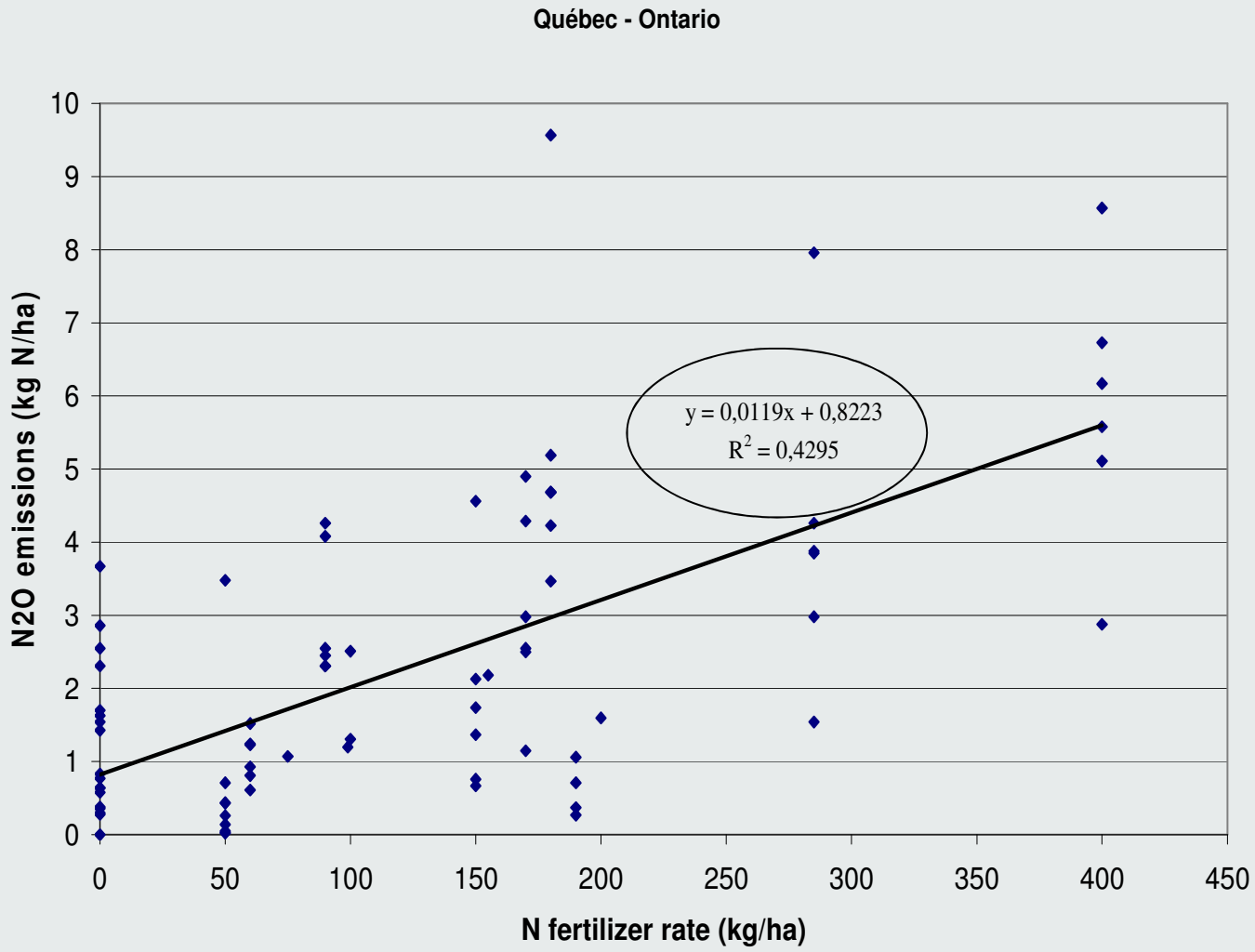
Source: Bouwman et al. 1996

Percentage of fertilizer N lost as N_2O averaged across soil zones in western Canada

Soil Zone (Great Group)	% N lost as N_2O			
	Minimum	Maximum	Mean	number of studies
Brown	0.0	0.4	0.2	3
Dark Brown	0.0	0.4	0.2	3
Black	0.2	1.9	0.9	4
Grey/Dark Grey	0.1	1.0	0.4	2

(sources: Burton et al. 2003; Farrell et al. 2003; Lemke et al. 1999 & 2003)

EF for the Québec-Ontario Region



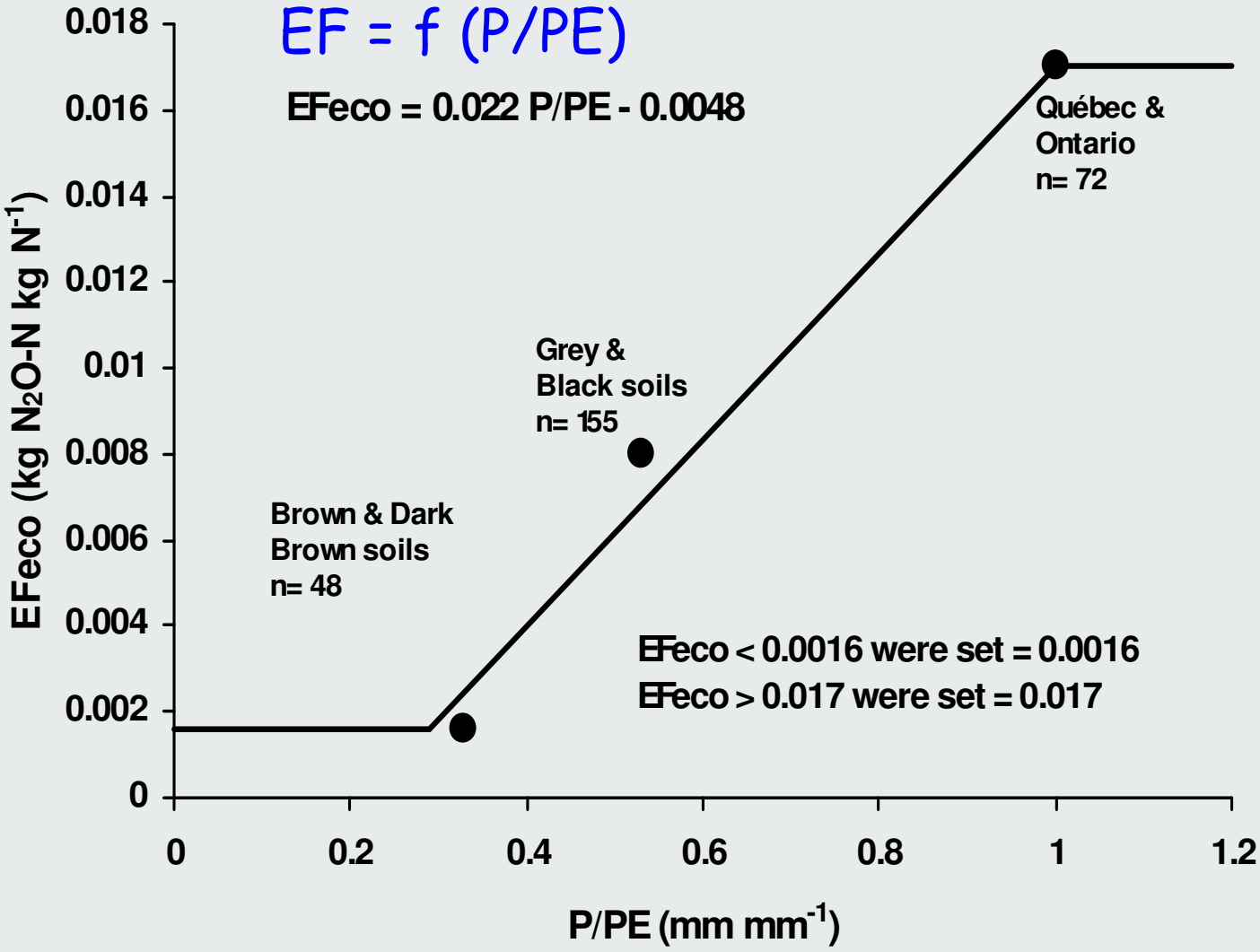
Soil N_2O Emissions
spring thaw

$$N_2Othaw = N_2Oinputs \times (RFthaw - 1)$$

Emissions during snow-free season	Emissions * during spring thaw	RFthaw
2.82 (kg N_2O/ha)	1.19 (kg N_2O/ha)	**1.4** (1 + 1.19/2.82)

*as measured with micromet flux systems

Emission factor as a function of local climate



(Rochette et al., 2008)

Calculating N_2O Emissions:

$Soil\_N_2O = Ninputs\_N_2O$ + "modifiers"

$Ninputs\_N_2O$ = (Fertilizer N + residue N + manure N)*EF

EFeco = EF calculated specifically for each ecodistrict

Ecodistrict

Ecodistricts are characterized by relatively homogeneous biophysical and climatic conditions including regional landform, local surface form, soil development, textural group, vegetation cover/land use classes, range of annual precipitation, and mean temperature.

Ecodistrict size ~150 000 ha

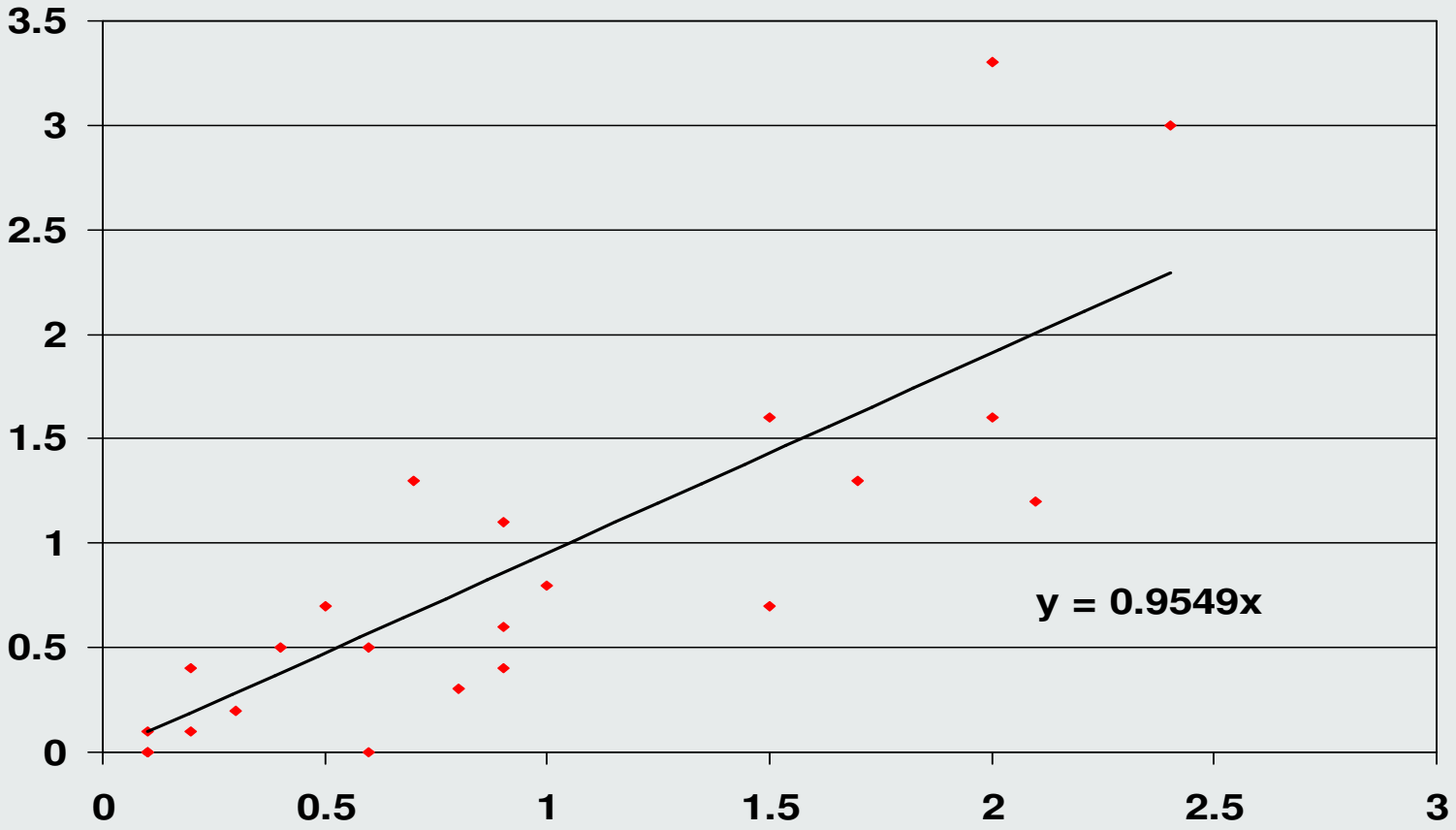
Calculating N_2O Emissions:

EFeco = EF calculated specifically for each ecodistrict

Reference situation = ‘‘a non-irrigated soil located in well- drained portions of the landscape under conventional tillage practices’’

Soil_N2O = Ninputs_N2O + “modifiers”

Annual N_2O loss from fertilized continuous wheat versus fallow at five sites in Alberta and Saskatchewan (n = 24; 12 site years x 2 tillage)



Lemke, published and unpublished data

N_2O loss from summerfallow

$$N_2Ocrop = N_2O\ back + N_2O\ N\ inputs$$

$$N_2Ofallow = N_2O\ back + N_2O\ fallow\_effect$$

$$N_2Ocrop = N_2O\ fallow$$

$$\cancel{N_2O\ back} + N_2O\ fallow\_effect = \cancel{N_2O\ back} + N_2O\ N\ inputs$$

$$N_2O\ fallow\_effect = N_2O\ N\ inputs$$

Soil N_2O emissions
Tillage

$$N_2Otill = N_2Oinputs \times (RFtill - 1) \times Ftill$$

RFtill = Tillage Ratio Factor
Ftill = Fraction of agricultural land under no-till

Region	tilled	no-till	RFtill
East	1.54 kg N ha^{-1}	1.55 kg N ha^{-1}	**1.1**
Prairies	0.53 kg N ha^{-1}	0.44 kg N ha^{-1}	**0.8**

Soil N_2O Emissions

Soil Texture

$$N_2Otext = N_2Oinputs \times (RFtext,fine -1) \times Ftext,fine + N_2Oinputs \times (RFtext,coarse,medim -1) \times Ftext,coarse,medium$$

Texture	RF_{text}
Coarse, medium	0.8
fine	1.2

Determination of RFtext was based on experimental data for the Québec-Ontario region summarised by Gregorich et al. (2005)

Soil N_2O Emissions
Topography

$$Topography\_N_2O = N_2O_{inputs} \times (0.017 - EF)/EF \times F_{topo}$$

F_{topo} = Fraction of agricultural land where soil moisture is likely to remain high

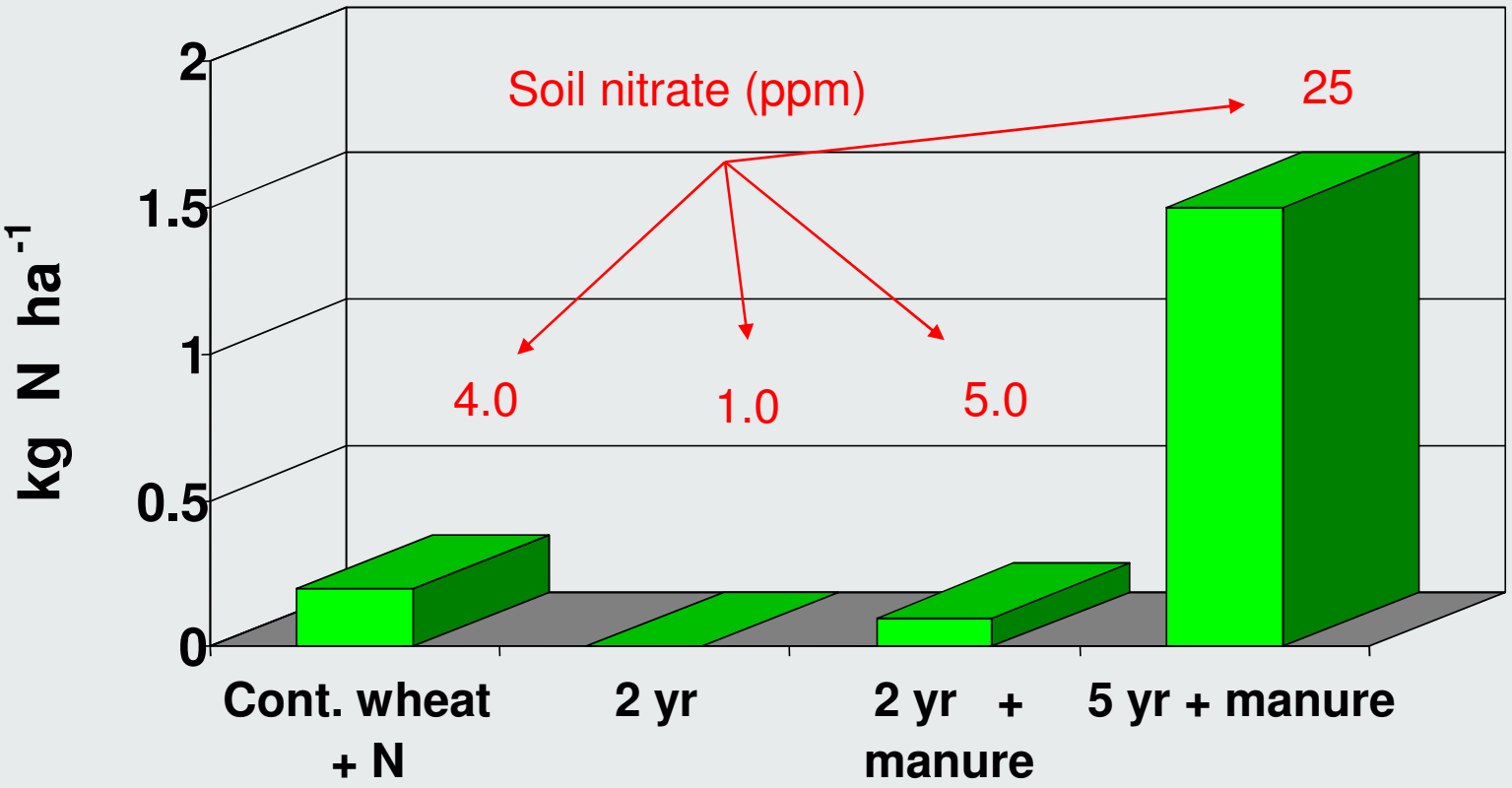
Lanscape type	Positions associated with F_{topo}	F_{topo}
Inclined +Dissected	none	0
Steep	none	0
Undulating	Depressions	0.08
Level	Depressions	0.06
Terraced	Depressions	0.10
Hummocky + Knoll + Kettle	Depressions + ½ lower slope	0.16
Rolling	Depressions + ½ lower slope	0.16
Ridged	Depressions + ½ lower slope	0.10
All cultivated land		0.10

We assumed that N_2O emissions in lower sections of the landscape are equal to those where P/PE =1. Accordingly, an EF values of 0.017 kg N_2O kg^{-1} N was used in these areas.

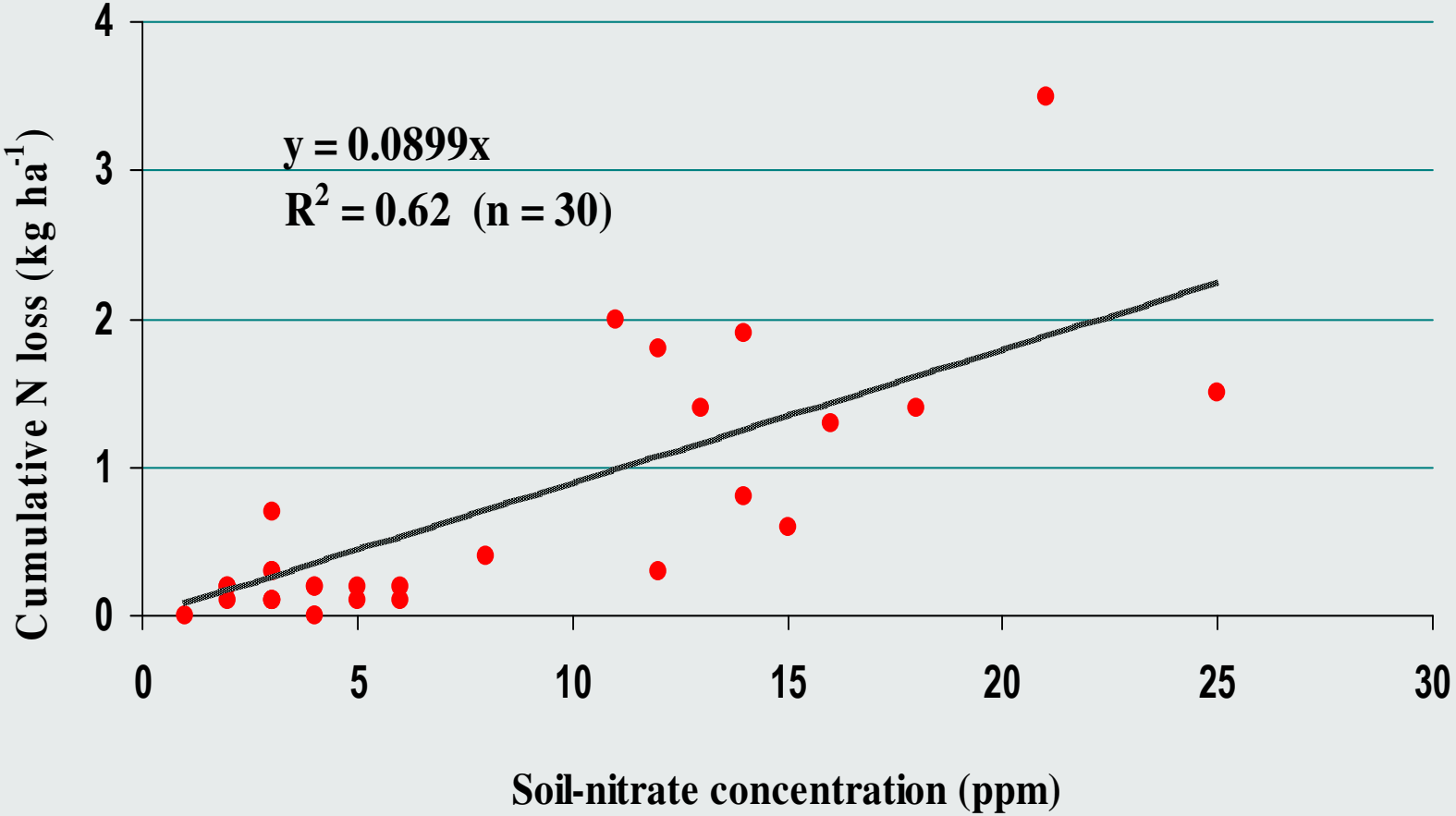
(Rochette et al., 2008)

Comments on Specific N management strategies

Breton 1995: estimated N_2O loss from selected treatments during spring thaw



Mean "pre-thaw" soil-nitrate concentration vs. estimated N_2O-N loss at six locations in Alberta

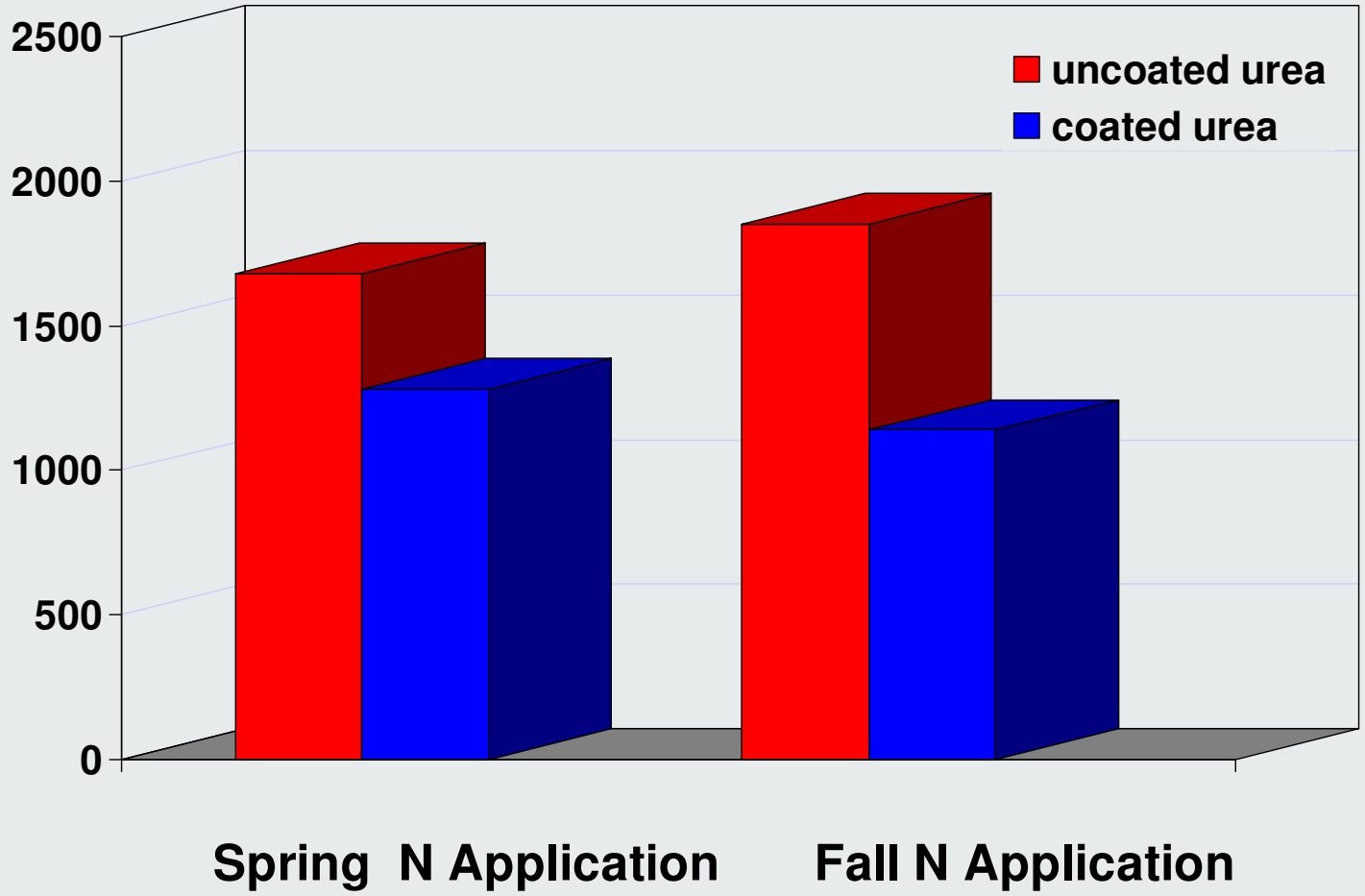


Fall versus Spring applied N (N=36)

	Mean	Geomean	ratio (fall/spring)
	—— g N ha^{-1}——		
Fall N	503	269	
Spring N	405	212	1.24 / 1.27

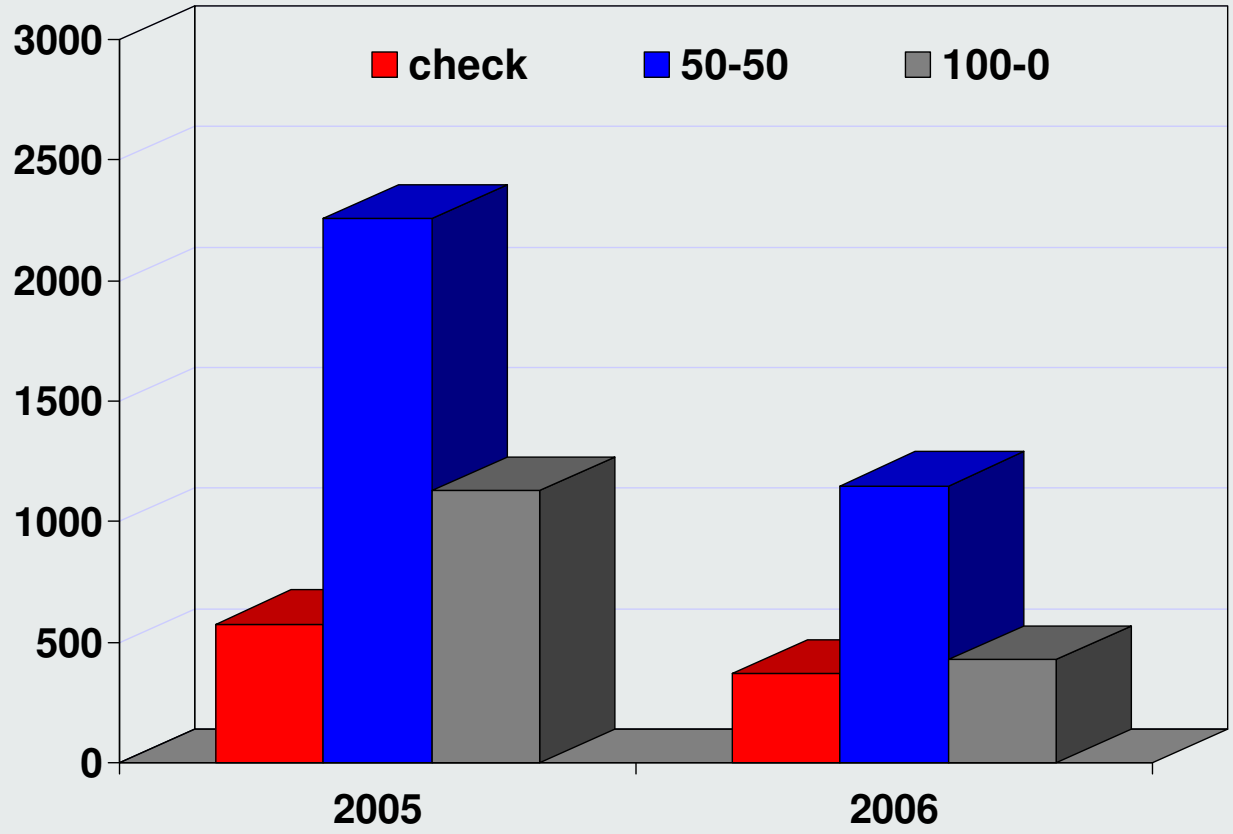
Ratio of fall/spring > 0 for 24 out of 36 comparisons

Estimated annual N_2O loss at Melfort, SK (2006)



Source: Malhi/Lemke/Grant, unpublished data

Split N applications: N_2O loss at Ottawa, ON (2006)



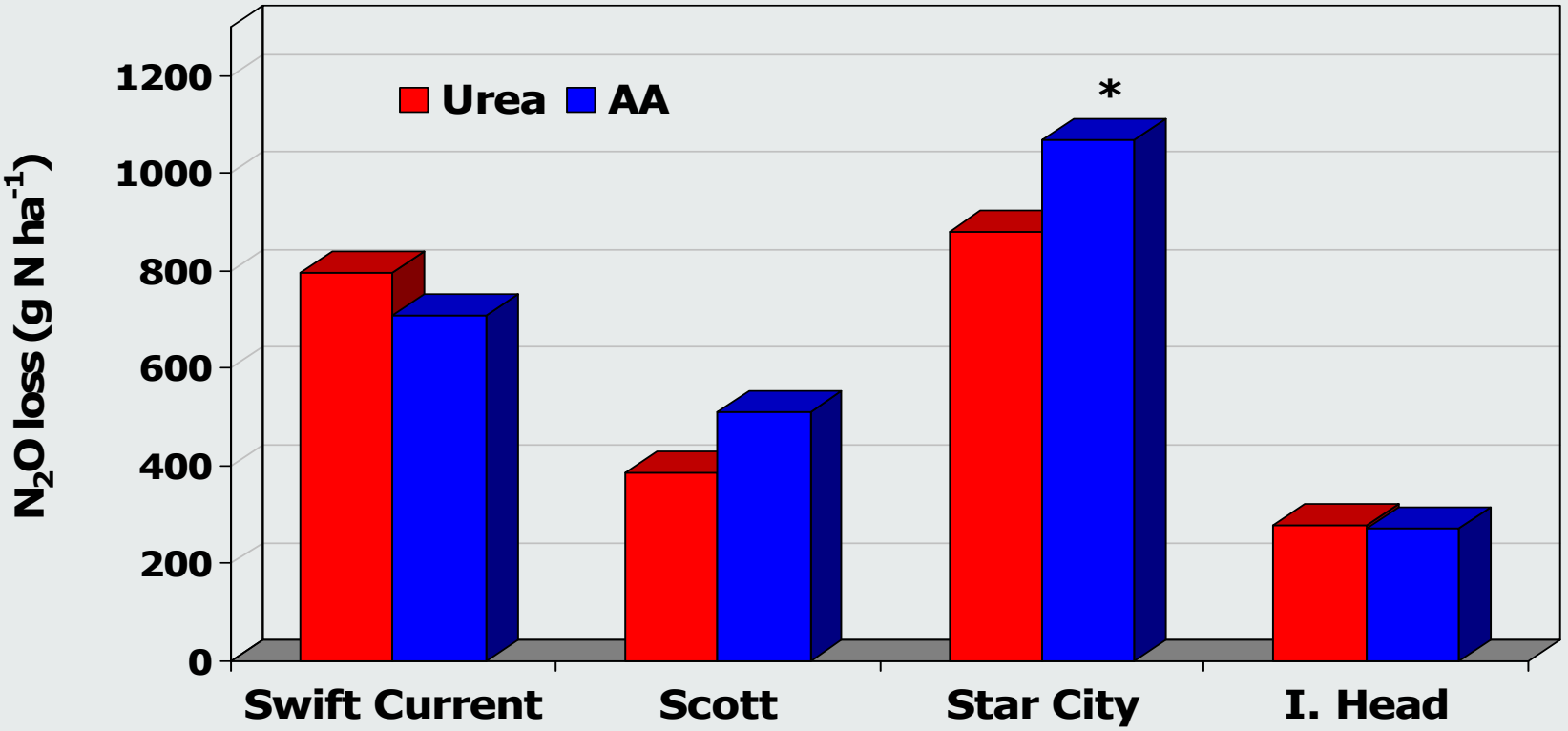
Source: Lafond/Morrison/Lemke unpublished data

Split N applications:

- Emissions for Split N > spring N
  - 1 of 9 site years prairies
    (Brandon, Indian Head, Swift Current)
  - 2 of 3 site yrs at Ottawa
  - Split N ~ spring N for all other site years

Source: Lafond/Lemke et al. unpublished data

Estimated N_2O loss (3-yr total) from N applied as urea or AA at four Saskatchewan sites



* = p<0.1

Source: R. Lemke, unpublished data

Energy inputs and CO_2 equivalents for urea and AA applied at the recommended rates on wheat at Star City in 2000

N-form	Energy Input (MJ ha^{-1})	N_2O (kg CO_2E) [Z]	EI + N_2O (kg CO_2E ha^{-1})	Grain/CO2E (kg kg^{-1})
AA	7730	290	496 [Y]	4.8
Urea	9628	156	484	4.9

[Z] CO_2E = CO_2 equivalents (Global warming potential of N_2O is about 300 times that of CO_2)

[Y] CO_2 emission coefficients for fertilizer-N presented in Nagy, C., 2000.

Nitrous oxide emissions from pulse crops grown in soil boxes under controlled conditions

Treatment	N_2O emissions ($kg\ N_2O\text{-}N\ ha^{-1}$)	Treatment	N_2O emissions ($kg\ N_2O\text{-}N\ ha^{-1}$)
Lentil + Rh	0.60 ± 0.07c	Wheat	3.85 ± 0.78a
Lentil – Rh	1.29 ± 0.33bc	Control	0.52 ± 0.06c
Pea + Rh	0.76 ± 0.11c		
Pea – Rh	2.88 ± 0.36ab		

Source: Zhong, 2006. M.Sc. Thesis, U of S

Summary

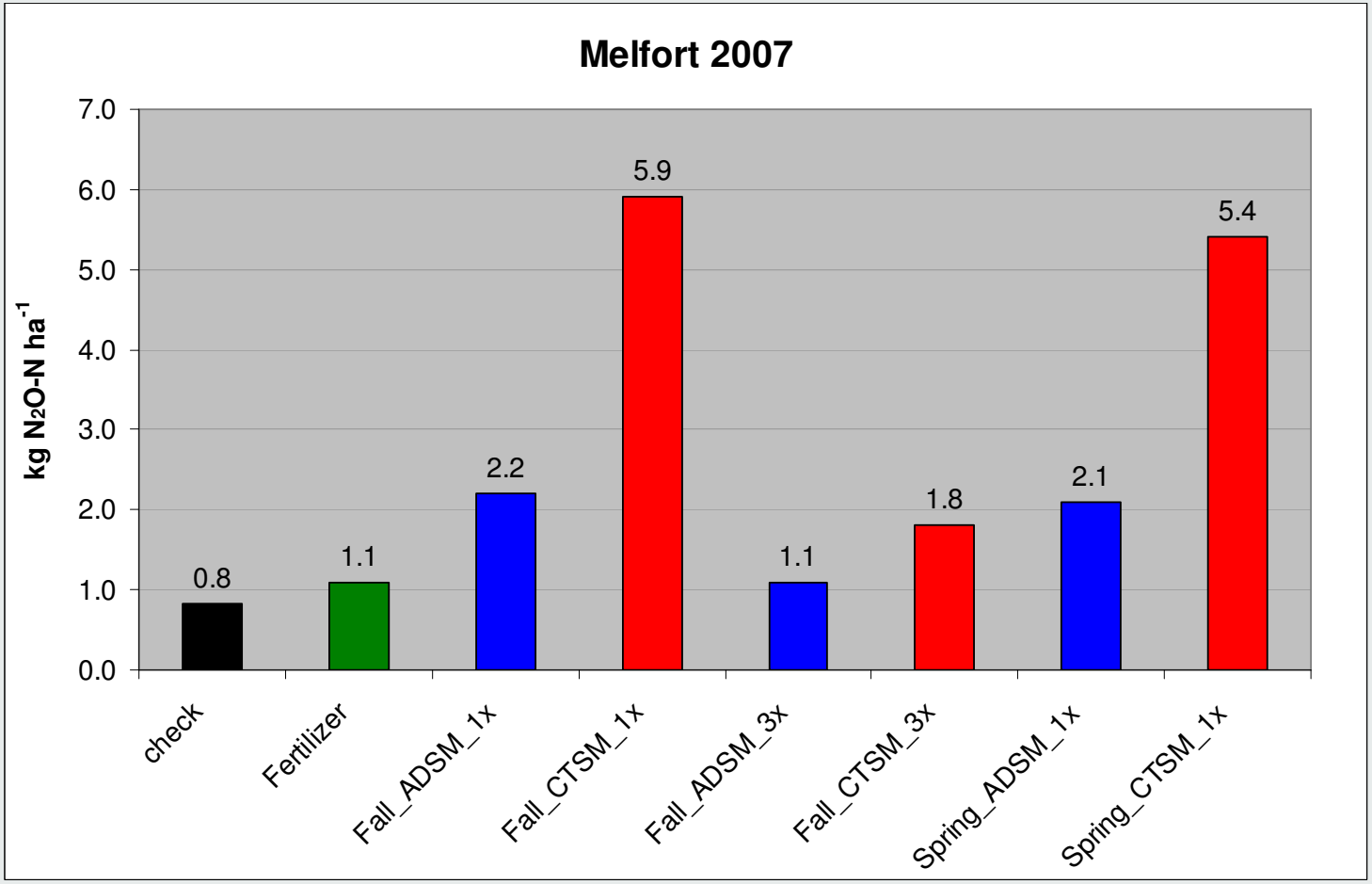
- Evidence indicating the fall applied N increases the risk of N_2O emissions
- Coated-urea may lower N_2O emissions (compared to uncoated) under specific conditions
- No evidence of consistently higher emissions from anhydrous ammonia compared to urea for prairie region
- Equivalent amounts of N applied in spring or in “split” applications does not reduce emissions on the prairies (split sometimes increased emissions for eastern Canada)
- Emissions during pulse phase similar to background
- Care must be taken to consider all aspects of a proposed reduction protocol (e.g. energy from manufacture & transport)

Research Needs

- Refinement for virtually all “factors”
- Indirect emissions are highly uncertain
- Variable rate technology verified
- Reliable Models required

Thank you for your kind attention!

Estimated N_2O loss at Melfort during the 2007 field season.



Lemke/Malhi unpublished