Emissions of N_2O from Canadian Agricultural Sources: An IPCC Tier II approach.

Agriculture and Agri-Food Canada

Philippe Rochette[1], Devon Worth[2], Reynald Lemke[2], Brian McConkey[2], Raymond Desjardins[2], Edward Huffman[2], Dan Pennock[3], Anthony Brierley[2], Jingyi Yang[2], Samuel Gameda[2] and Julian Hutchinson[2],
(1) Agriculture and Agri-Food Canada, 2560, Boul. Hochelaga, Québec City, QC G1V 2J3, Canada, (2) Agriculture and Agri-Food Canada, Ottawa, (3) University of Saskatchewan
rochettep@agr.gc.ca

Introduction

- International initiatives (UNFCCC and Kyoto) require that countries conduct national inventories of their greenhouse gas emissions.
- Intergovernmental Panel on Climate Change (IPCC) recommends that country-specific (Tier II) inventory methodology be used when local information on emissions is available.

Objective

- Develop and use a country-specific (Tier II) methodology to estimate N_2O emissions from agricultural sources in Canada for the period 1990-2005.

Material and Methods

1) N_2O from agricultural sources (N_2O_{agr})

- Country-specific methodology
- Based on summary of Canadian field research data
- Activity data, emission factors and N_2O emissions were estimated annually at the ecodistrict scale (150 000 ha)
- Includes all IPCC sources but biological N fixation
- Accounts for additional N_2O sources/offsets

2) N_2O from agricultural sources (N_2O_{agr})

$$N_2O_{agr} = N_2O_{soils} + N_2O_{awms} + N_2O_{ind}$$

where N_2O_{soils} is the direct emissions from soils, N_2O_{awms} is the emissions from animal waste management systems, and N_2O_{ind} is the emissions from indirect sources

N_2O_{awms}, N_2O_{ind} } Estimated using Tier I (IPCC 2006) methodology

N_2O_{soils} = Estimated using Tier II or country specific methodology

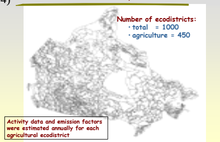
3) Direct N_2O Emissions from Agricultural Soils — N_2O soils "Tier II"

$$N_2O_{soils} = \sum N_2O_{sources}$$

IPCC sources:
- Organic soils (N_2O_{os}) +
- Grazing animals (N_2O_{prp}) +
- N inputs (N_2O_{inputs}) +

new sources/offsets:
- Soil Tillage (N_2O_{till}) +
- Irrigation (N_2O_{irrig}) +
- Summerfallow (N_2O_{fallow}) +
- Topography (N_2O_{topo}) +
- Soil texture (N_2O_{text}) +
- Spring thaw (N_2O_{thaw})

4) Emissions are estimated annually at the Ecodistrict level



Activity data and emission factors were estimated annually for each agricultural ecodistrict

5) Activity data

- **Activity data** = N inputs; acreage under no-till, irrigation and summerfallow; soil texture; crop type and yield; livestock populations; AWMS; climatic data; etc.)
- **Activity data** were estimated annually in each ecodistrict using information from provincial statistics, national censuses, models, remote sensing and expert opinion

6) " N_2O_{inputs} "

N_2O emissions are proportional to soil N inputs

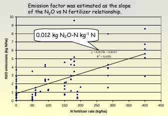
$$N_2O_{inputs} = (N_{min} + N_{man} + N_{res} + N_{som})\ (kg\ N) \times EF\ (kg\ N_2O\ kg^{-1}\ N)$$

Tier I — EF or Emission factor = 0.01 kg N_2O kg^{-1} N

Tier II — EF = f(climate)
- EF reflects local climatic conditions estimated at the Ecodistrict level

7) EF for the Québec-Ontario Region

Emission factor was estimated as the slope of the N_2O vs N fertilizer relationship.



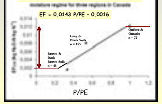
8) "EF was determined for 3 regions"

Region	EF (kg N_2O-N kg^{-1} N)
Québec-Ontario	0.012
Prairies (Black soil zone)	0.008
Prairies (Brown soil zone)	0.0016

9) EF as a function of local climate

P= precipitations
PE = potential evapotranspiration

EF = f (P/PE)



10) Spring Thaw "N_2O_{thaw}"

Low soil aeration and N availability during spring thaw often result in high N_2O emissions. These emissions are not included in N_2O_{inputs}.

$$N_2O_{thaw} = N_2O_{inputs} \times (RF_{thaw} - 1)$$

RF_{thaw} = Ratio Factor (annual/spring thaw emissions)

Emissions during snow-free season	Emissions during spring thaw	RF_{thaw}
2.82 kg N_2O/ha	1.19 kg N_2O/ha	1.4 (1 + 1.19/2.82)

11) Soil Texture "N_2O_{text}"

Soil texture is correlated with several factors influencing N_2O production and emissions.

$$N_2O_{text} = N_2O_{inputs} \times (RF_{text,fine} - 1) \times F_{text,fine} + N_2O_{inputs} \times (RF_{text,coarse} - 1) \times F_{text,coarse}$$

$RF_{text,i}$ = Ratio Factor (emissions for texture "i"/all textures)

Texture	RF_{text}
coarse	0.8
medium & fine	1.2

12) Soil Tillage "N_2O_{till}"

Tillage practices affect several factors influencing N_2O production and emissions.

$$N_2O_{till} = N_2O_{inputs} \times (RF_{till} - 1) \times F_{till}$$

RF_{till} = Tillage Ratio Factor (no-till/conventional)
F_{till} = Fraction of agricultural land under no-till

Region	tilled	no-till	RF_{till}
East	1.71 kg N ha^{-1}	1.90 kg N ha^{-1}	1.1
Prairies	0.53 kg N ha^{-1}	0.44 kg N ha^{-1}	0.8

13) Irrigation "N_2O_{irri}"

$$N_2O_{irri} = N_2O_{inputs} \times (0.012 - EF)/EF \times F_{irri}$$

F_{irri} = Fraction of agricultural land that is irrigated

We assumed that N_2O emissions on irrigated land are equal to those where P/PE =1. Accordingly, an EF values of 0.012 kg N_2O kg^{-1} N was used for irrigated land

14) Topography "N_2O_{topo}"

We assumed that N_2O emissions in lower sections of the landscape are equal to those where P/PE =1. Accordingly, an EF value of 0.012 kg N_2O kg^{-1} N was used in those areas.

$$N_2O_{topo} = N_2O_{inputs} \times (0.012 - EF)/EF \times F_{topo}$$

F_{topo} = Fraction of the agricultural land where soil moisture is likely to remain high (lower portions)

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

15) Summerfallow "N_2O_{fallow}"

In the Prairie region, N_2O emissions during the fallow year are equal to those during the crop year

Accordingly, N_2O emissions on fallowed land were estimated as being equal to N_2O_{inputs}

$$N_2O_{fallow} = N_2O_{inputs} \times EF \times F_{ann} \times F_{fallow}$$

F_{ann} = Fraction of agricultural land that is cropped
F_{fallow} = Fraction of F_{ann} that is under fallow

16) Other sources

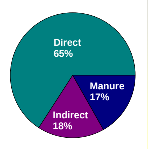
- N_2O emissions from drained organic soils (N_2O_{os}), grazing animals (N_2O_{prp}), indirect sources (N_2O_{ind}) and animal manure management systems (N_2O_{awms}) were estimated using the IPCC 2006 guidelines for national inventory of GHG (default Tier I)
- Emissions associated with biological N fixation (IPCC 1997) were not included in the inventory (Rochette and Janzen, 2005; IPCC 2006)

Results and Discussion

N_2O emissions from agricultural sources in Canada --1990 to 2005--

Mean N_2O emissions from agricultural sources in Canada (1990-2005) =

58.3 Gg N_2O-N yr^{-1}

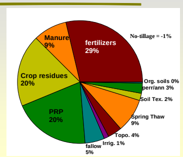


Two thirds of agricultural N_2O emissions are from direct soil sources

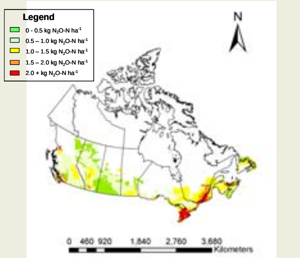
N_2O emissions from agricultural soils in Canada --1990 to 2005--

Direct N_2O emissions from agricultural soils in Canada (1990-2005) =

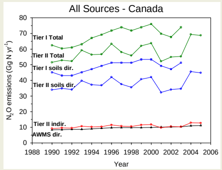
38 Gg N_2O-N yr^{-1}



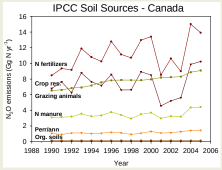
- 75% of direct emissions from soils result from N inputs
- Additional Tier II soil sources account for 25% of N_2O soil



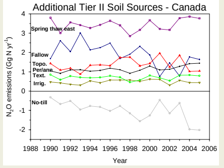
Most intense N_2O emissions are from southern Ontario and Québec where intensive agriculture occurs under humid climate



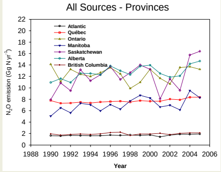
- Tier II estimates are lower than Tier I estimates.
- No net increase in direct emissions from soils between 1990 and 2005.



Large inter-annual variations due to variations in precipitations, livestock populations and crop yields



- .Emissions associated with the practice of summerfallow and no-till decreased from 1990-2005.
- Other sources were stable or slightly increased over the period.



Provinces can be grouped as fallows regarding soil N_2O emissions:
"Alberta = Saskatchewan = Ontario" >
"Québec = Manitoba" >
"Atlantic region = B. C."

Conclusions

- A function relating EF to climate (ratio of precipitation to potential evapotranspiration) was developed to estimate annual emission factors at the ecodistrict scale (avg. area of agricultural ecodistricts = 150, 000 ha).
- Regional coefficients were also developed to account for the effect of several additional factors on soil N_2O emissions (soil texture, topography, tillage, summerfallow, spring thaw and irrigation).
- Total direct annual N_2O emissions from agricultural soils averaged 37.9 Gg N yr^{-1} between 1990 and 2005 with variations from 32.3 to 45.4 Gg N yr^{-1}.
- Application of synthetic N fertilizers was the largest source of soil N_2O followed by crop residues, grazing animals and manure applied to soils.
- These estimates are approximately 22% lower than estimates obtained using the IPCC default (Tier I) methodology. Differences were mostly the result of lower emission factors in the dry central Prairies and the omission of emissions associated with the biological N fixation by legume crops.
- Because it is based on country-specific emission coefficients, the Tier II methodology likely improves national soil N_2O estimates compared to the Tier I approach.