Evaluating the DNDC Model for Estimating Nitrous Oxide Emissions from a Poorly Drained Soil in the Canadian Prairies

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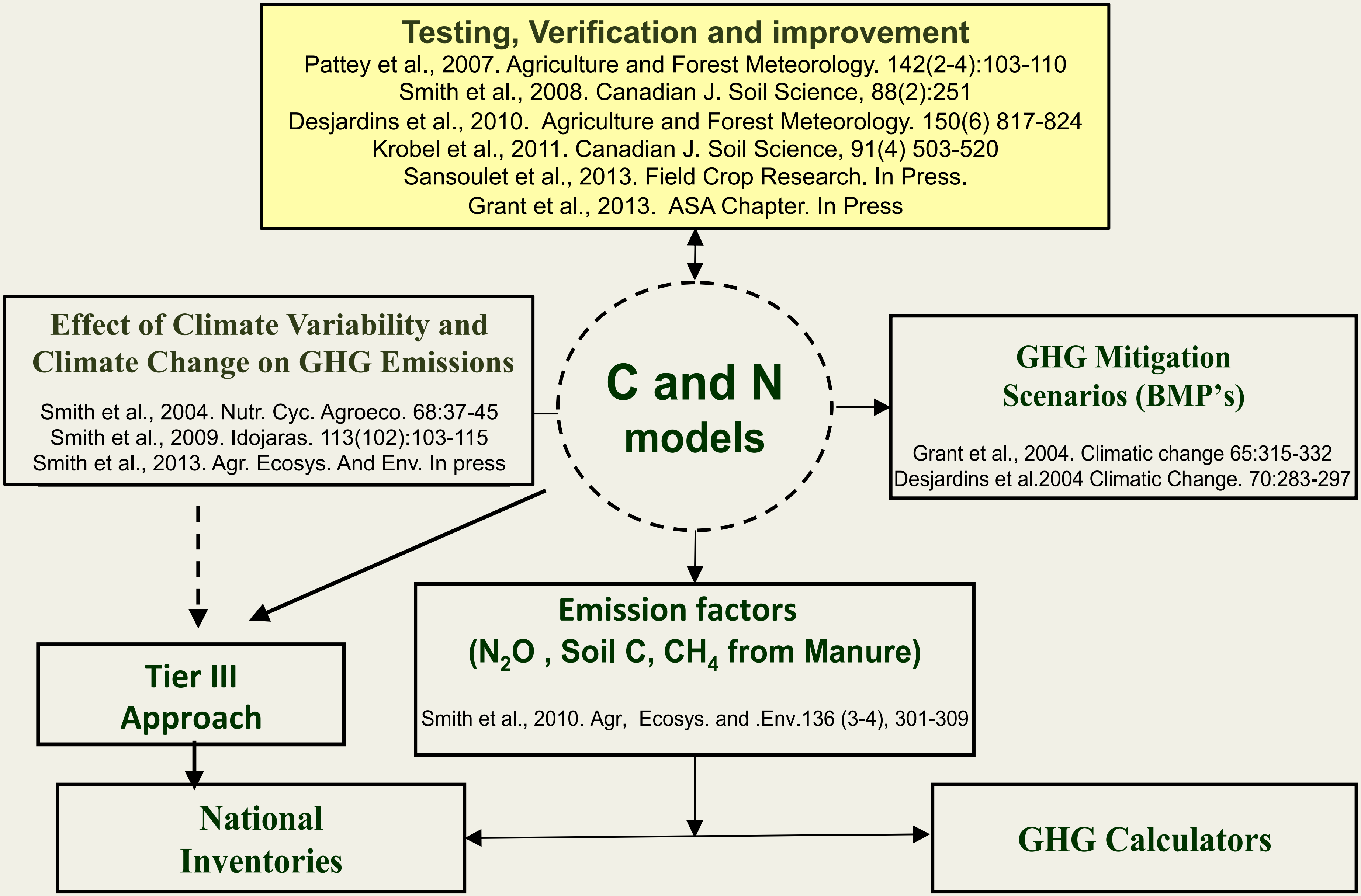
Development of the DNDC model to better estimate crop biomass production and GHG emission intensities from agroecosystems

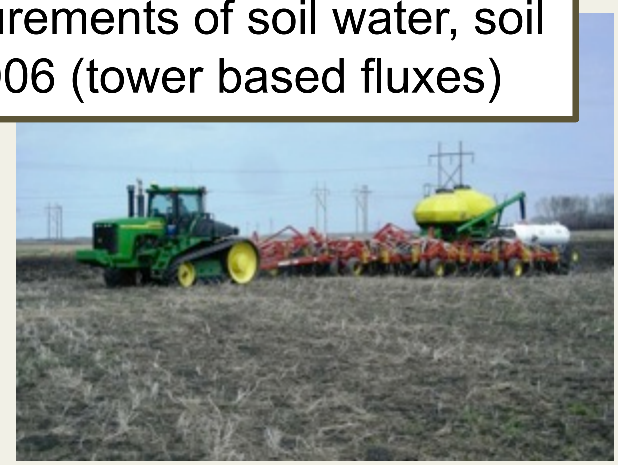


Recent modifications to the CDN-DNDC model

- New formulation for temperature stress on crops: $\frac{r}{Rmax} = \left(\frac{Tmax - T}{Tmax - Topt}\right)\left(\frac{\mathrm{T}}{Topt}\right)^{\frac{Topt}{Tmax - Topt}}$
- Included the effect of exposure to high temperature during anthesis on crop growth
- Empirical growth curves were modified for Canadian cultivars of corn, soybeans and wheat
- Partitioning of N in the soil profile was improved by conceptualizing a deep N pool that parallels the existing deep water pool
- “Proof of concept” mechanism to emulate the increased preferential flow in the soil due to soil cracking
- Incorporated new research regarding the effects of CO_2 fertilization on crop growth
- Deep water pool size regulated by soil properties at depth

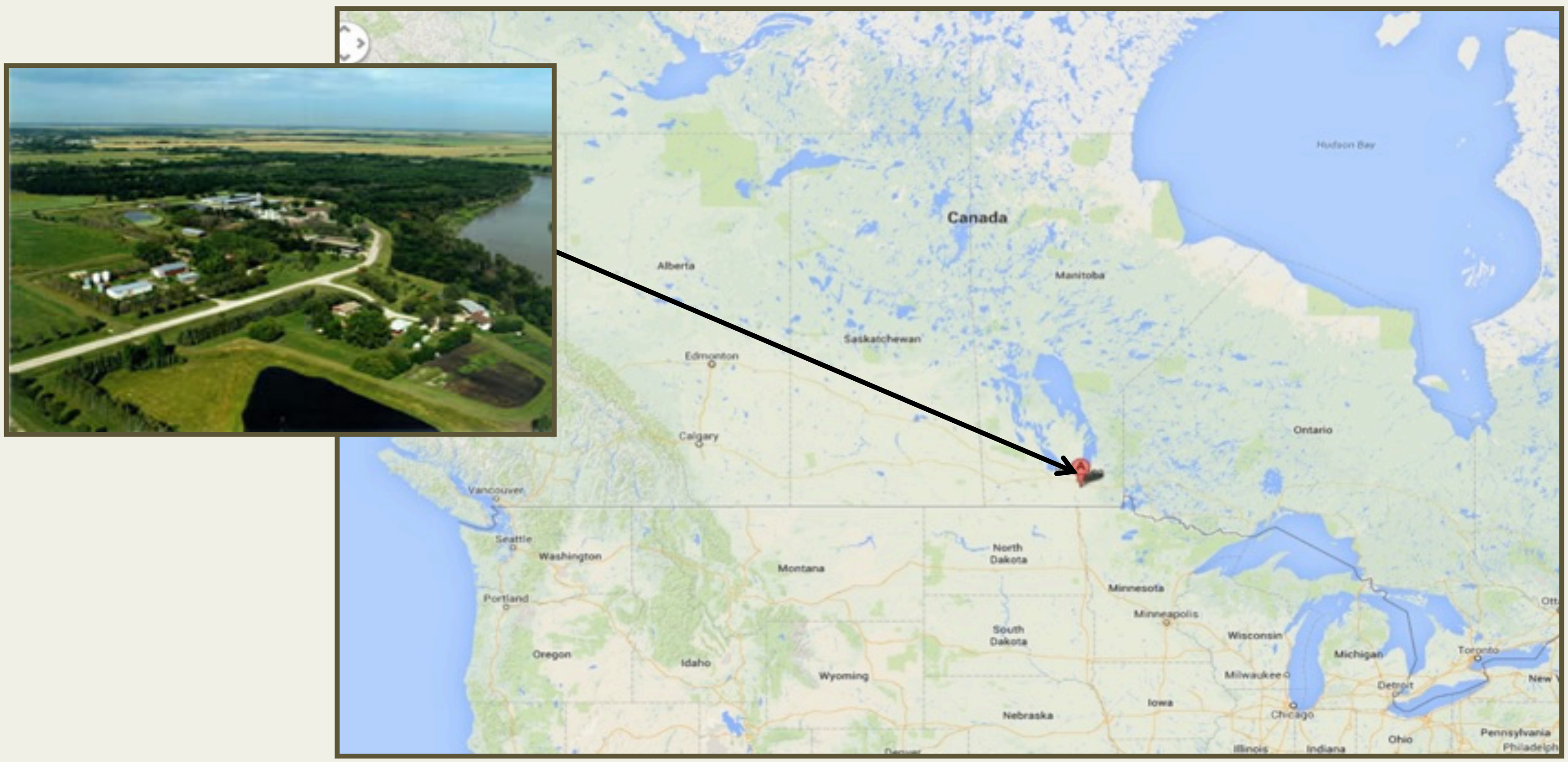
Objectives

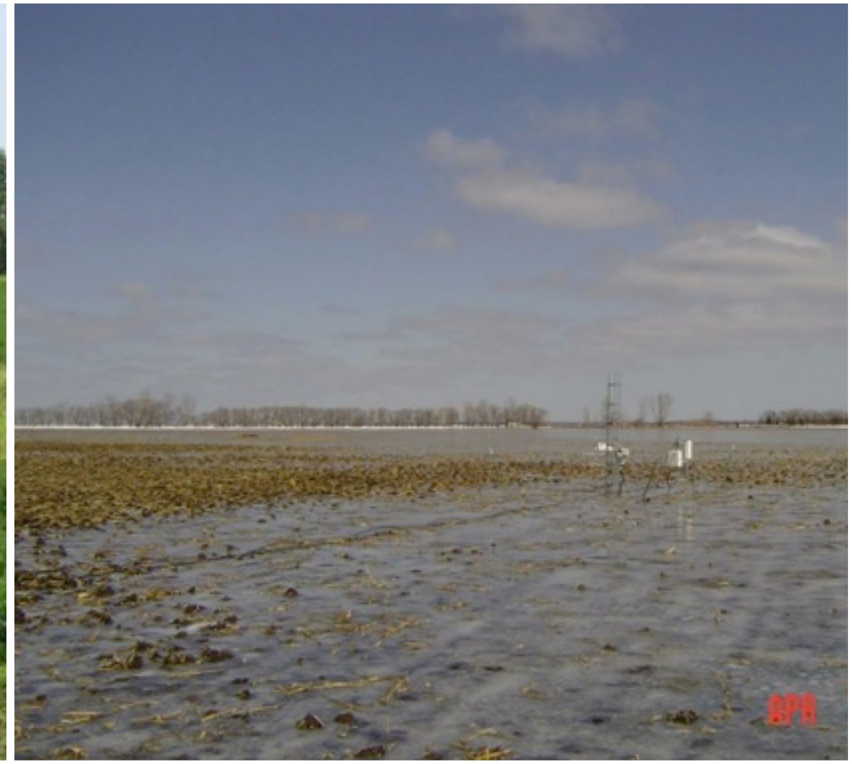
- Test and improve the ability of the DNDC model to simulate N_2O emission for two cropping systems on a poorly drained soil in western Canada.
  - Part of a major initiative of the assessment and development of GHG models using 30+ experimental studies across Canada
- Evaluate DNDC from a systems perspective considering soil hydrology, soil N dynamics, crop growth and GHG mechanisms.
  - The experimental site offers continuous measurements of soil water, soil temperature and N_2O+CO_2 emissions since 2006 (tower based fluxes)



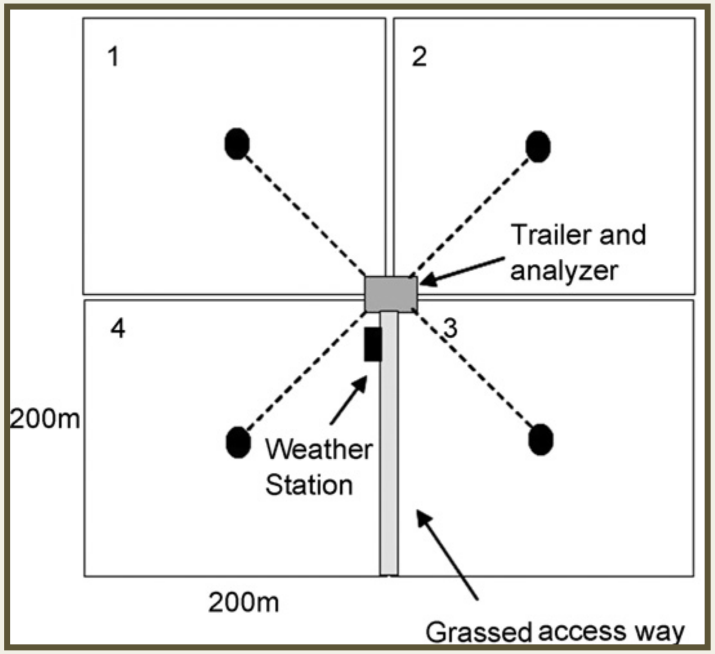
Location of study site

- Located at the University of Manitoba Glenlea Research Station (49.64°N, 97.16°W; 235m above sea level)
- In the Red River Valley of southern Manitoba glaciolacustrine clay floodplain
- Soils of Red River association, with 60% clay, 35% silt and 5% sand





Experimental Plot Setup



Soil management treatments consisted of :

- Annual Grain – Perennial Forage treatment on the two west side plots numbered 1 and 4
- Annual Grain treatment on two east side plots 2 and 3
- Towers and intakes are indicated by filled circles in the centre of each plot
- Micrometeorological equipment measured N_2O fluxes
- Flux gradient micrometeorological technique used to determine net exchange of N_2O over 30 minute intervals

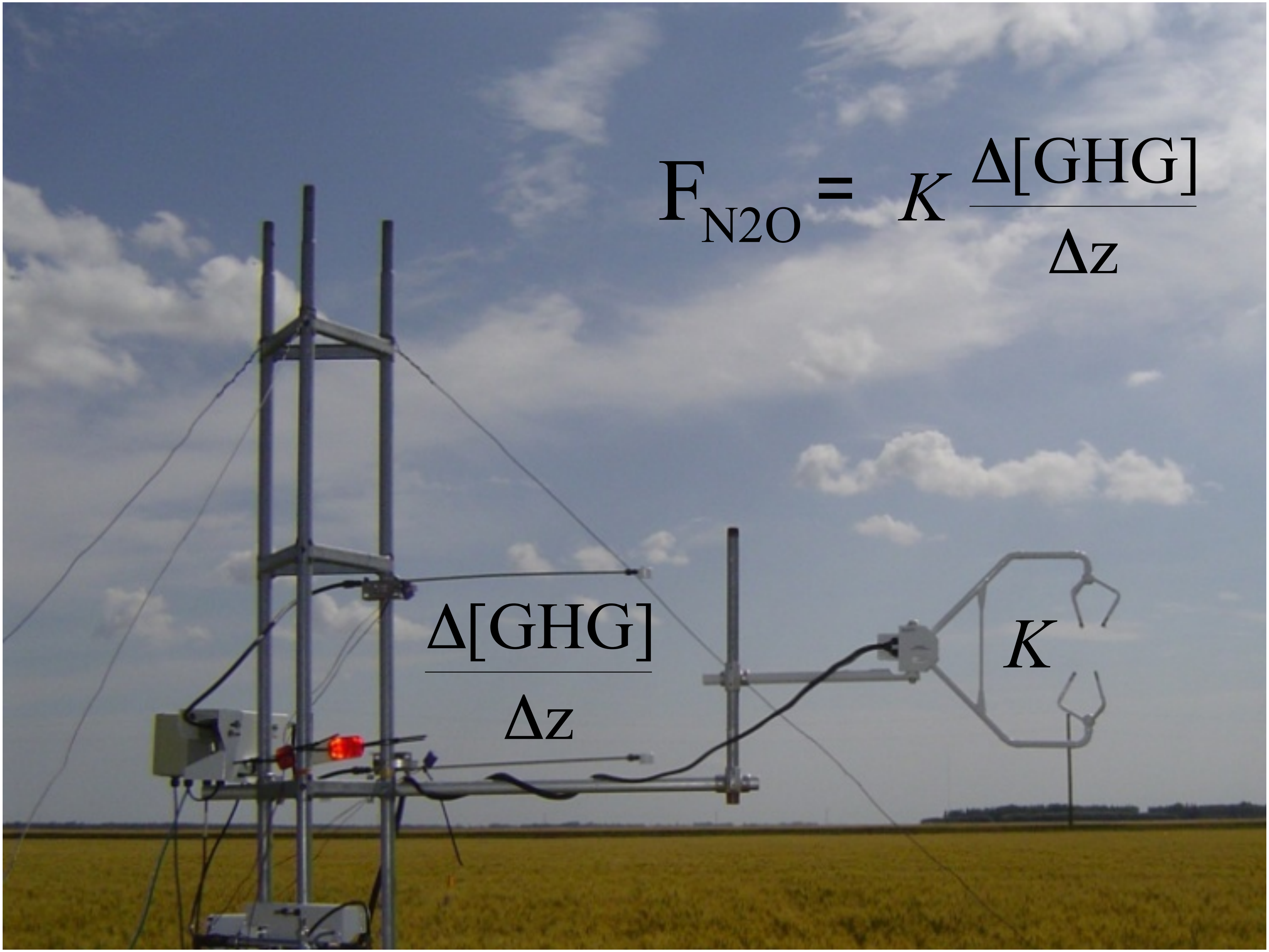
Year	Plot 1	Plot2	Plot 3	Plot 4
2006	Corn	Corn	Corn	Corn
2007	Faba bean	Faba bean	Faba bean	Faba bean
2008	Alfalfa	Spring wheat	Spring wheat	Alfalfa
2009	Alfalfa	Rapeseed	Rapeseed	Alfalfa
2010	Alfalfa	Barley	Barley	Alfalfa
2011	Alfalfa	Spring wheat	Spring wheat	Alfalfa
2012	Corn	Corn	Corn	Corn

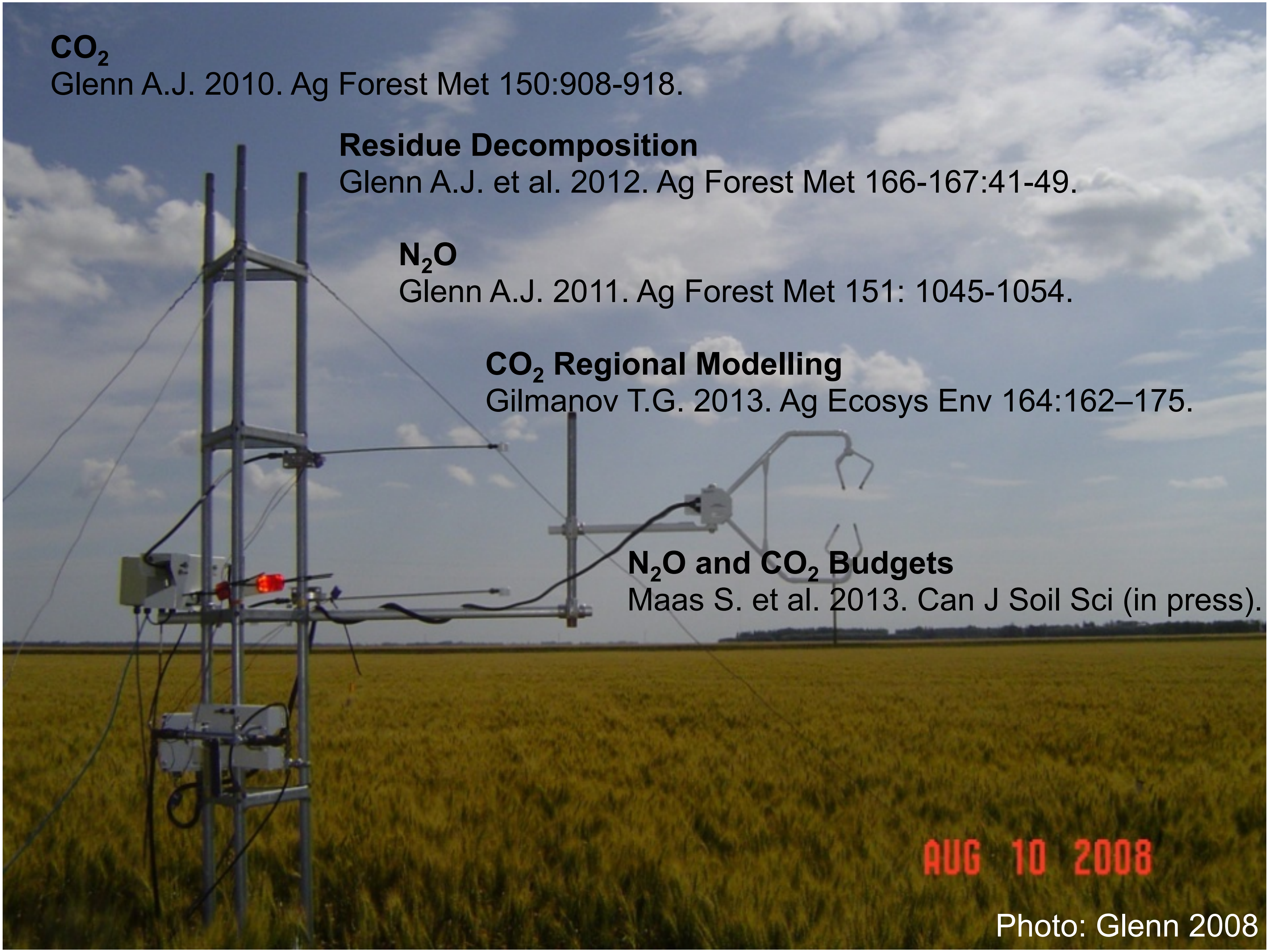
Instrumentation

TDL
Trace Gas
Analyzer

TDL Trailer

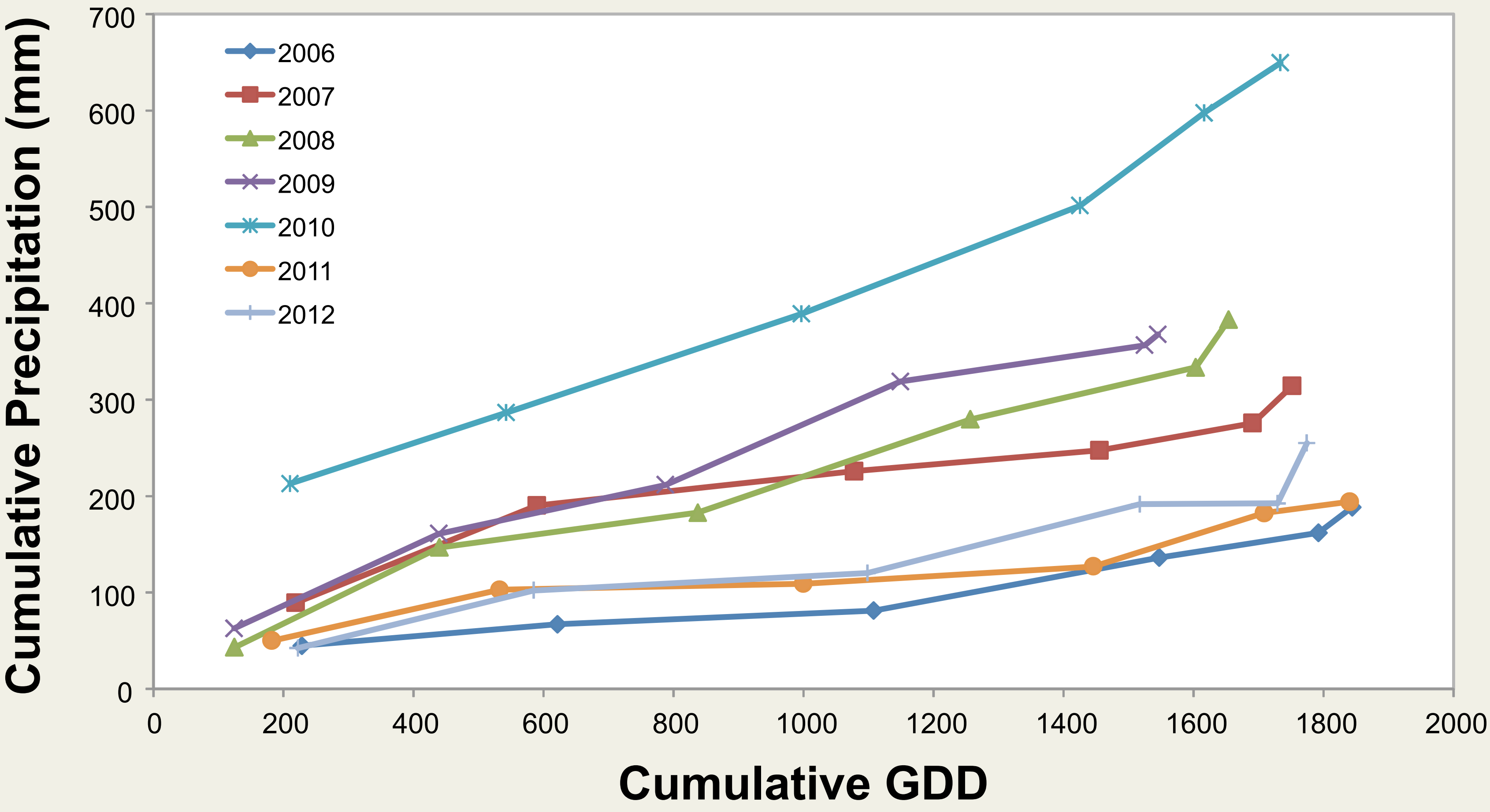
Tower


$F_{N2O} = K \frac{\Delta[GHG]}{\Delta z}$
$\frac{\Delta[GHG]}{\Delta z}$
K

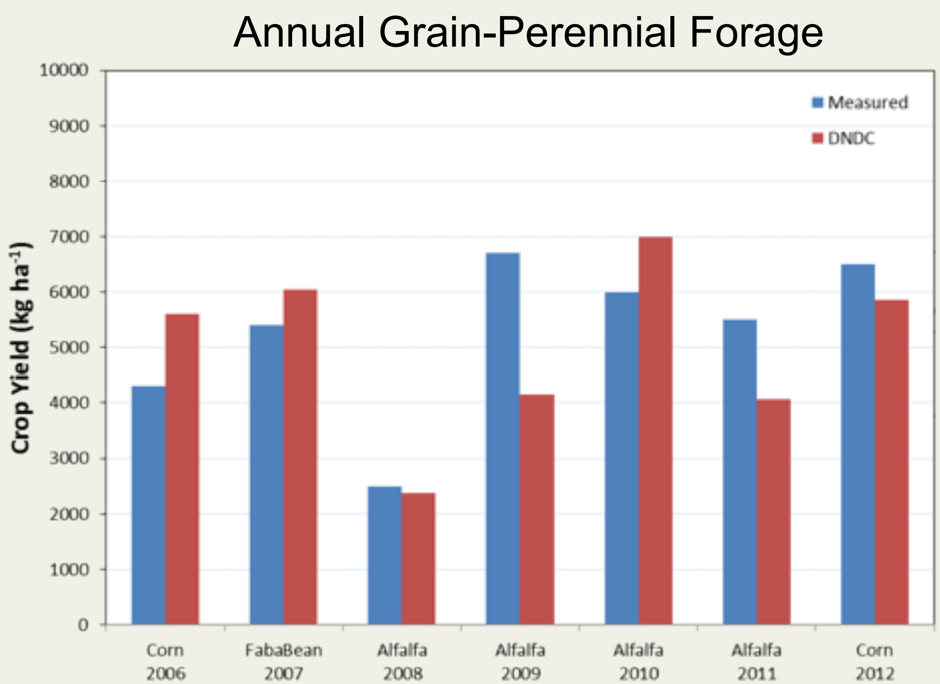

CO_2
Glenn A.J. 2010. Ag Forest Met 150:908-918.
Residue Decomposition
Glenn A.J. et al. 2012. Ag Forest Met 166-167:41-49.
N_2O
Glenn A.J. 2011. Ag Forest Met 151: 1045-1054.
CO_2 Regional Modelling
Gilmanov T.G. 2013. Ag Ecosys Env 164:162–175.
N_2O and CO_2 Budgets
Maas S. et al. 2013. Can J Soil Sci (in press).
AUG 10 2008
Photo: Glenn 2008

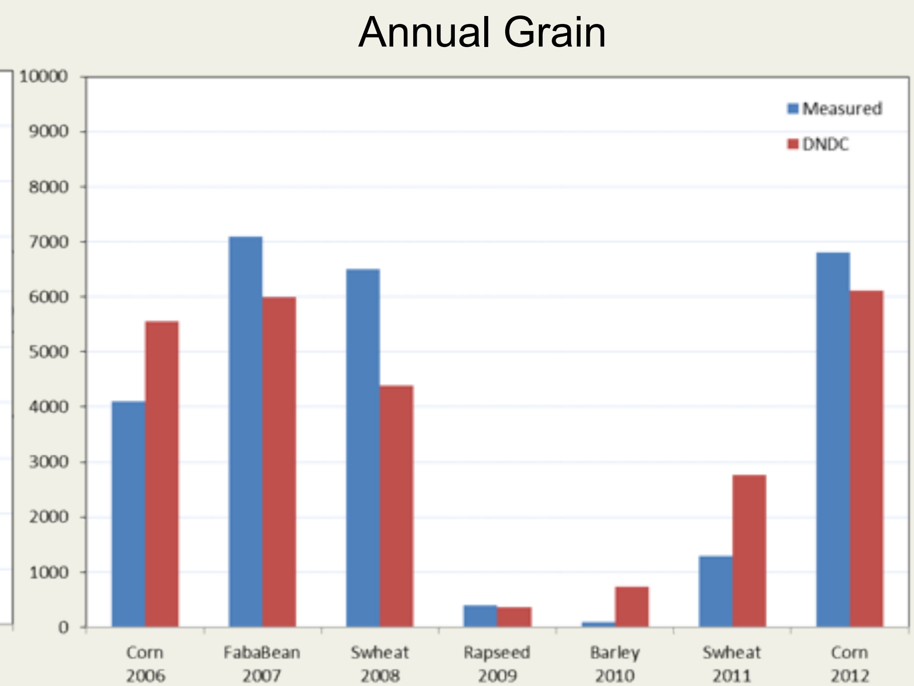
Climate Assessment

Cumulative precipitation vs. cumulative GDD during the growing seasons



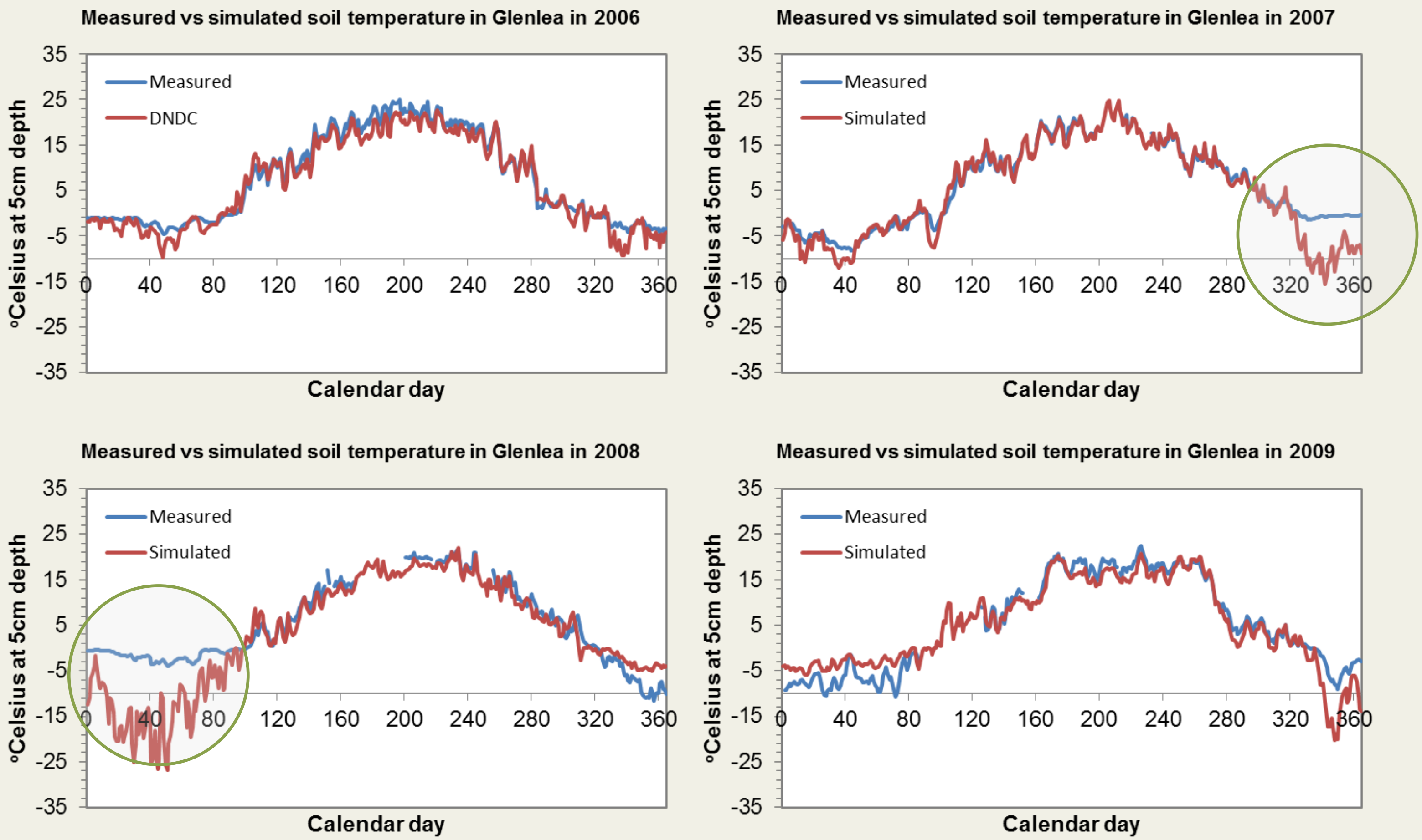
Estimated Crop Yields (Plot 1&2) Using CDN-DNDC





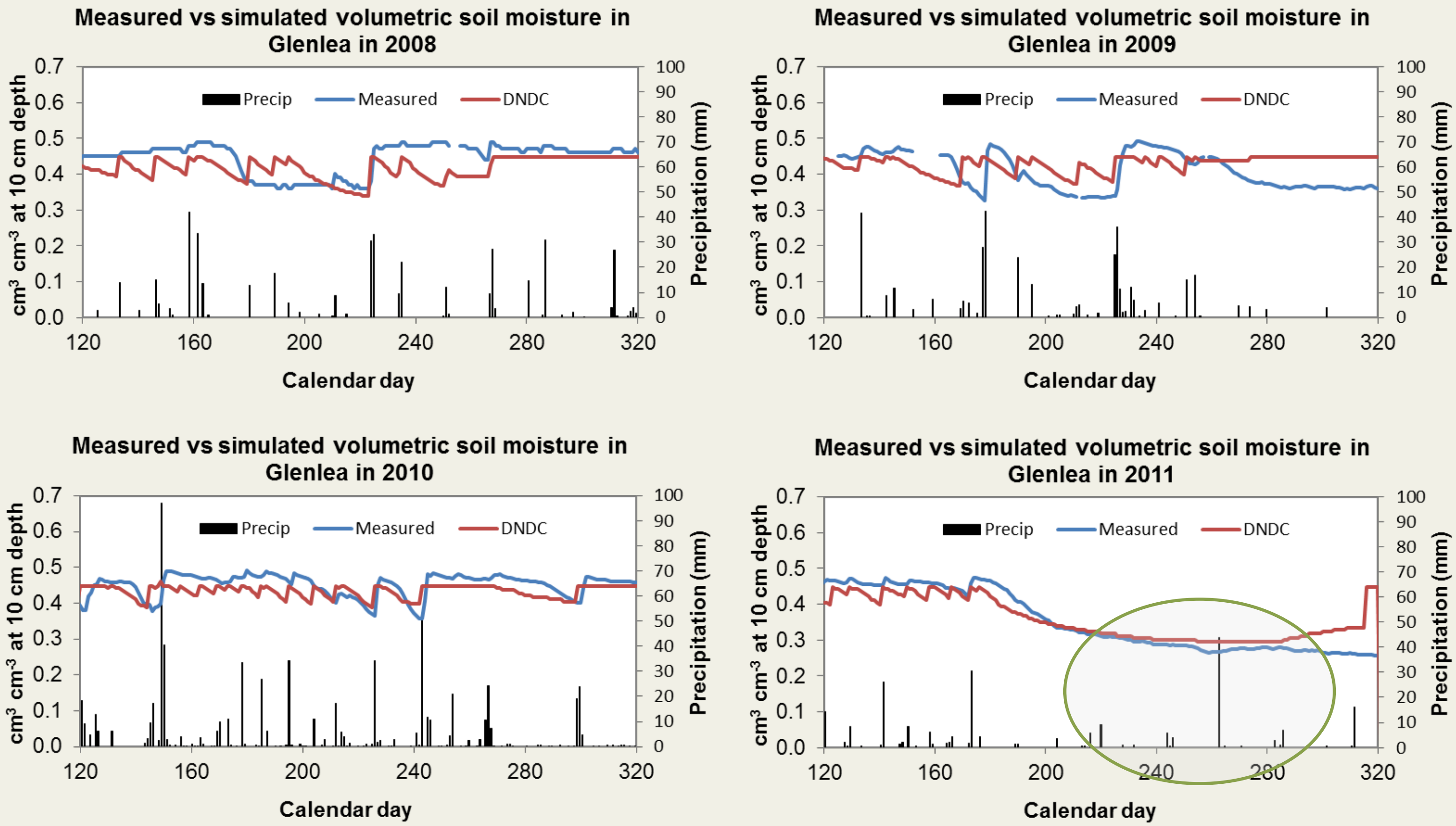
- Crop yields estimates were good on average although there was some difficulty in accurately predicting the inter-annual variation
- This soil has a very high clay content and is susceptible to preferential flow due to clay cracks which posed challenges from the crop water availability
- CDN-DNDC has accurately simulated biomass at several other sites in Canada

Estimated Soil Temperature (5cm) for a Annual Grain-Perennial Forage Plot using CDN-DNDC



- Soil Temperature – generally well simulated by DNDC across all plots
- Divergence between measured and simulated during winter attributed to sensor located at on-site weather station that is grassed

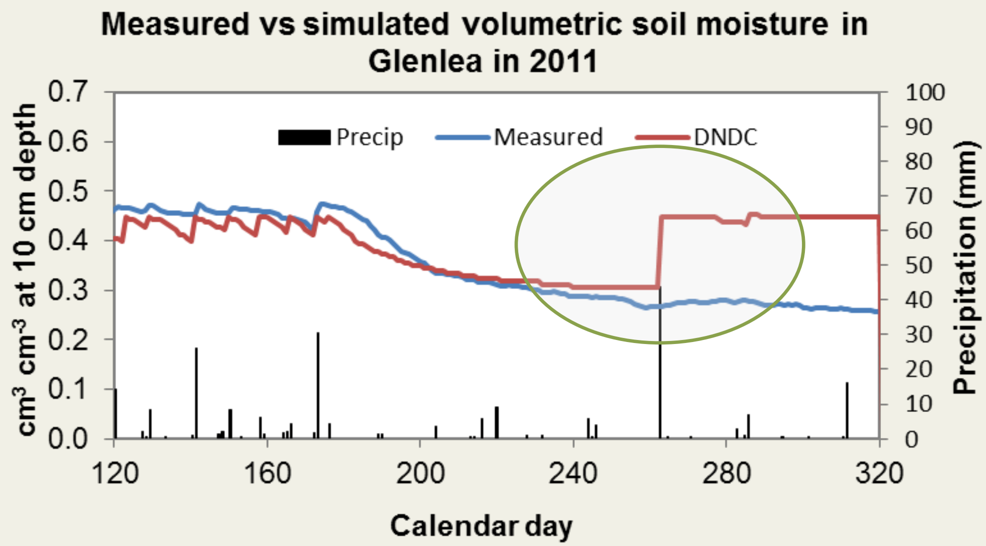
Estimated Soil Moisture (10 cm) Using CDN-DNDC



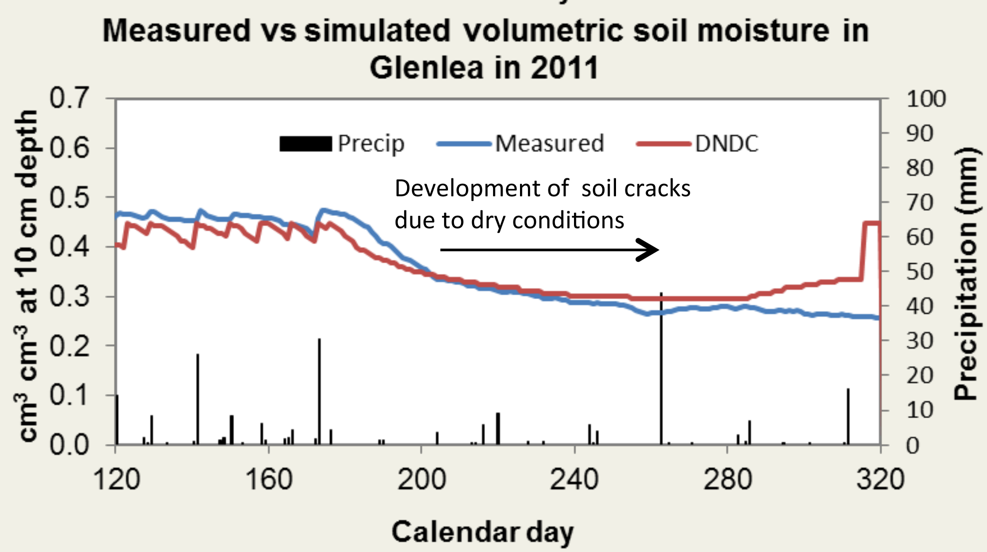
- DNDC generally captured trends in soil moisture well although it did not go as low as measurements
- In 2011 the formation of clay cracks resulted in increased preferential flow and the large precipitation event (day 263) bypassed the top of the soil profile (@10cm) according to measurements

Soil Cracking Mechanism (2011) Using CDN-DNDC

DNDC (without by-pass)



DNDC (with by-pass)

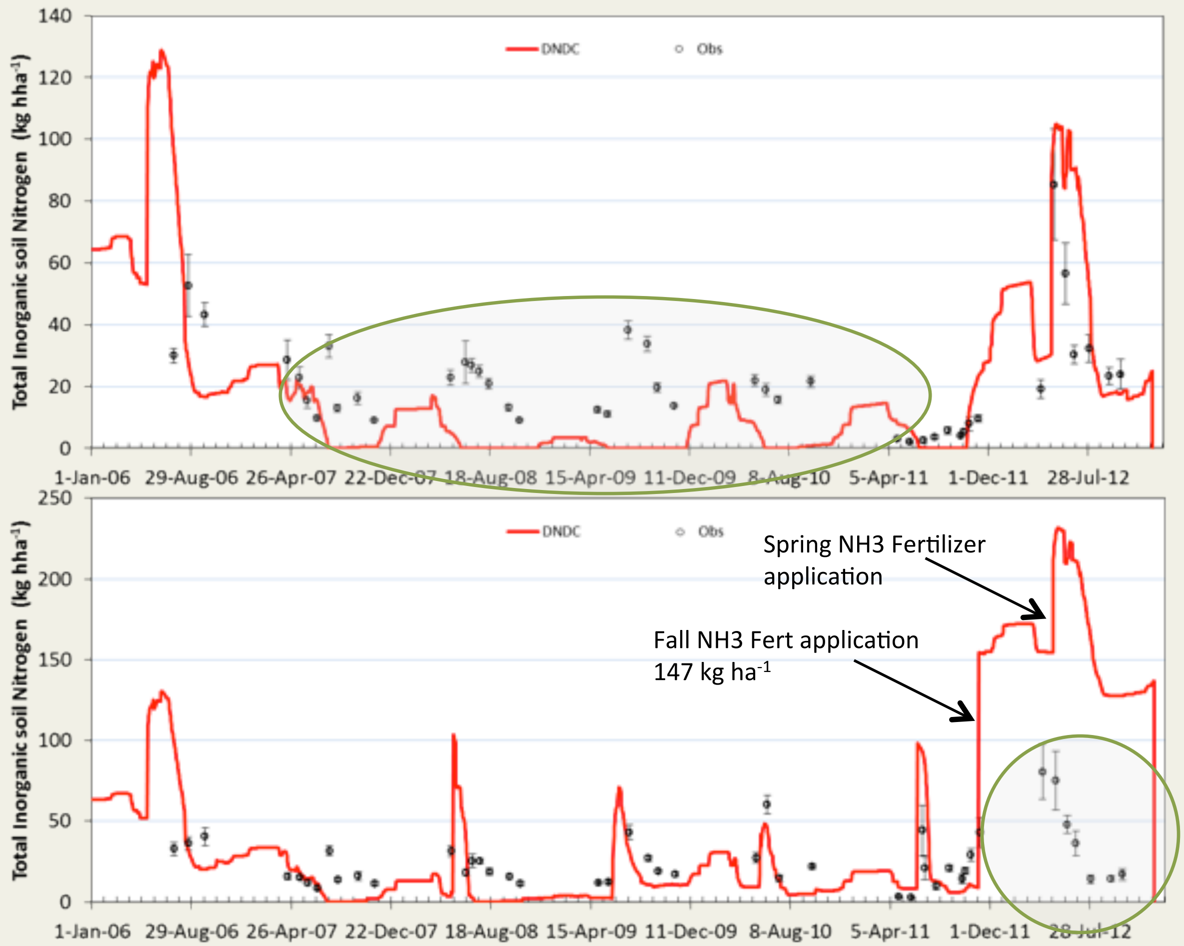


- Further development for (depth, growth, dissipation rate). Only enabled on heavy clay soil and disabled for the soil frozen in winter

Estimated Total Inorganic Soil Nitrogen (0-30cm) Plot 1 & 2 using CDN-DNDC

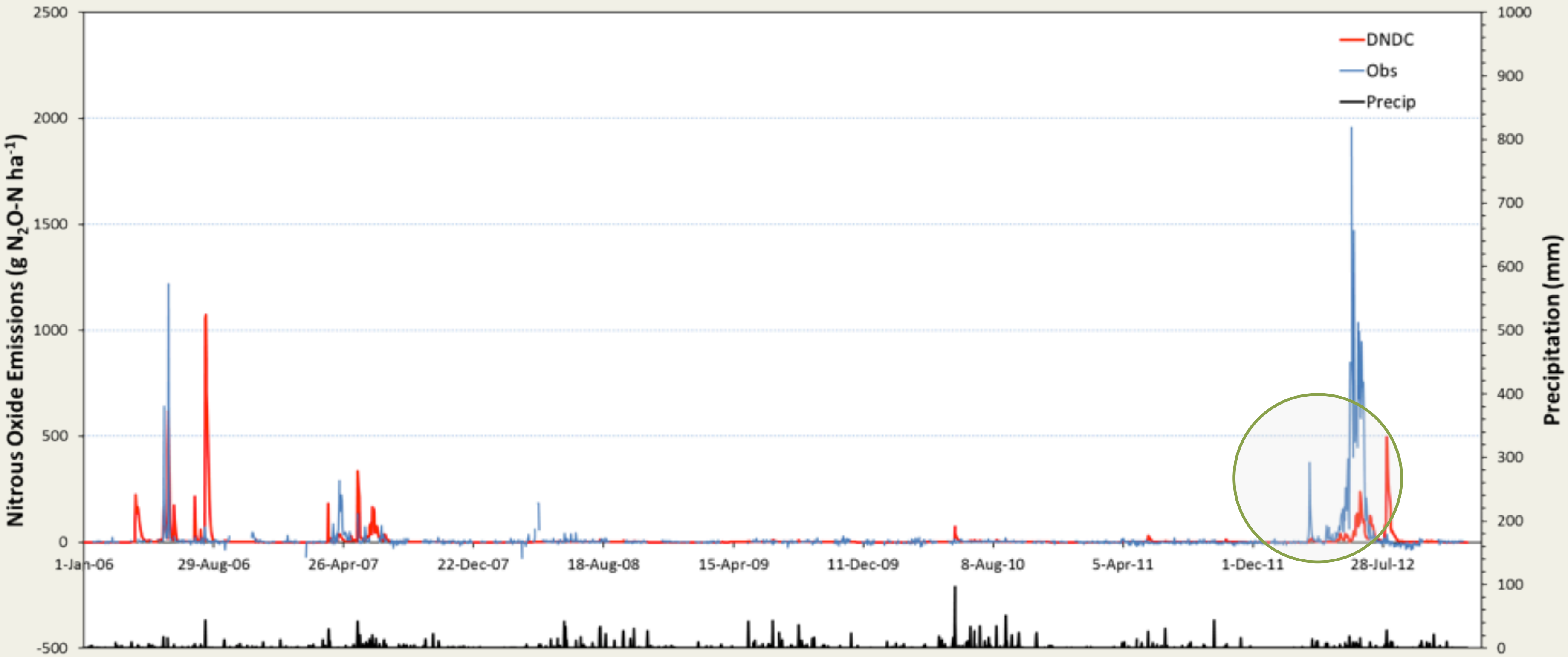
Annual Grain – Perennial Forage (Plot 1)

Annual Grain (Plot 2)



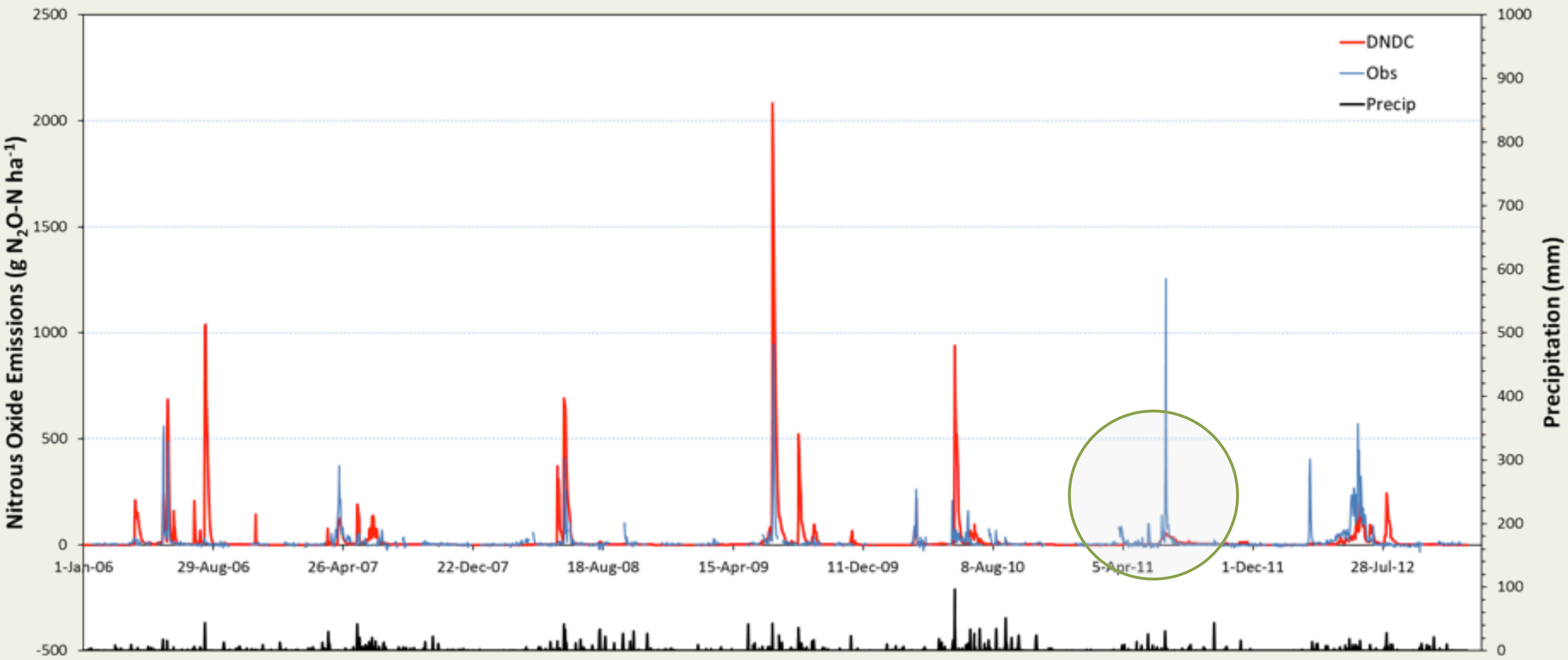
- Under N fixing crops soil N was underestimated. DNDC has demonstrated a difficulty in simulating enough soil N for low fertilizer input systems at other sites in Canada
- Measurements include extractable but not fixed ammonium but DNDC categorizes all exchangeable and fixed ammonium into one pool along with N in soil solution

Estimated Nitrous Oxide Emissions (Plot 1) for Annual Grain – Perennial Forage using CDN-DNDC



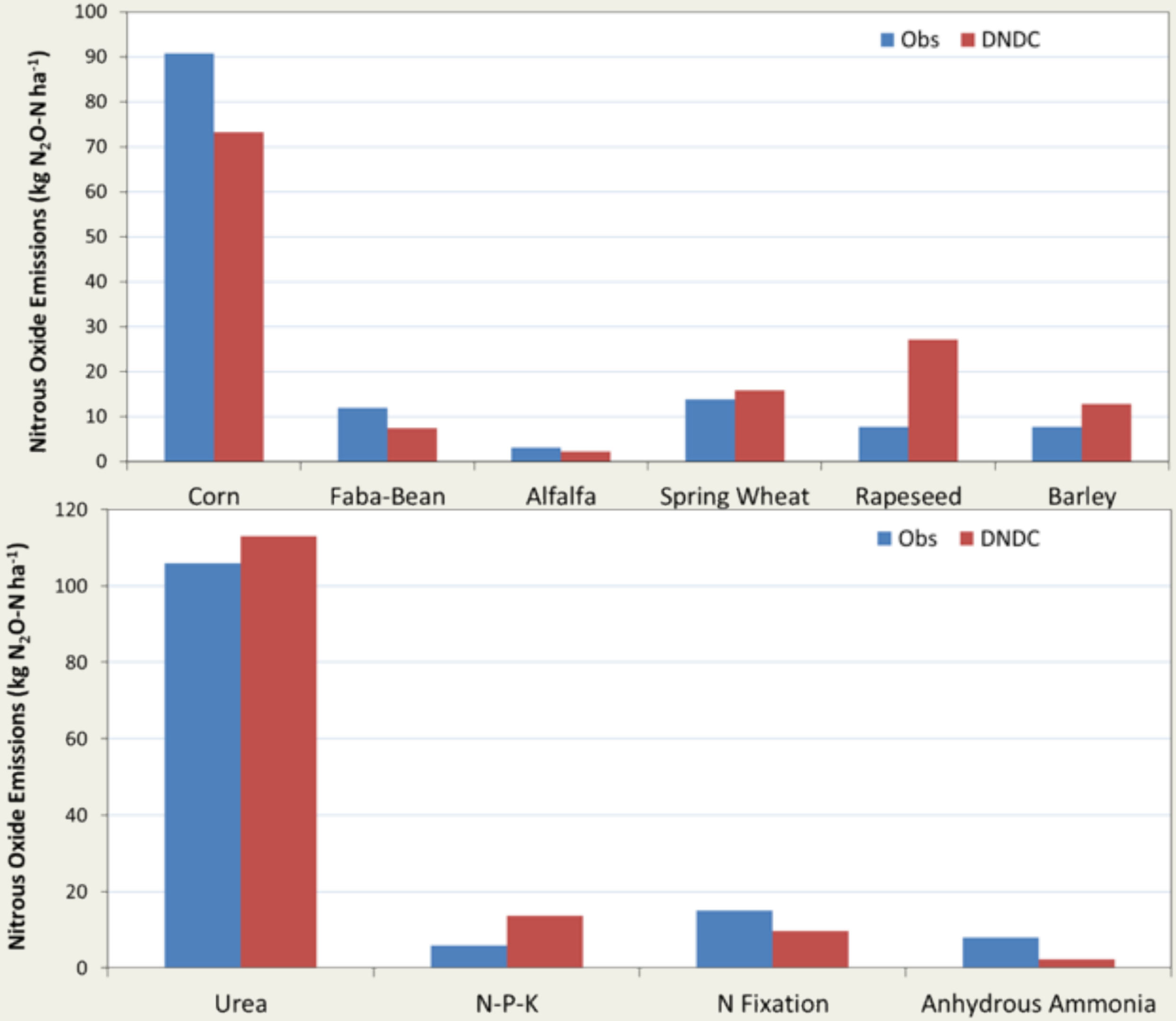
- Simulated N_2O corresponded well with measures during perennial years but were somewhat inconsistent in terms of the magnitude and timing annual crops
- Magnitude of emissions due to Alfalfa plow down in 2011 were not well captured by CDN-DNDC in the summer of 2012 even though the increase in soil N due to alfalfa incorporation was well simulated. (Indicates that another driver was limiting in the spring/summer of 2012 for the model i.e. DOC)

Estimated N_2O Emissions (Plot 2) for an Annual Grain Rotation using CDN-DNDC



- Nitrous oxide estimates generally corresponded well for the timing of emissions but the magnitude for individual crop years differed from measurements
- Measured poor 2011 spring wheat yield in 2011 compared to DNDC's higher yield contributed to difference in plant N uptake, soil N availability and N_2O fluxes

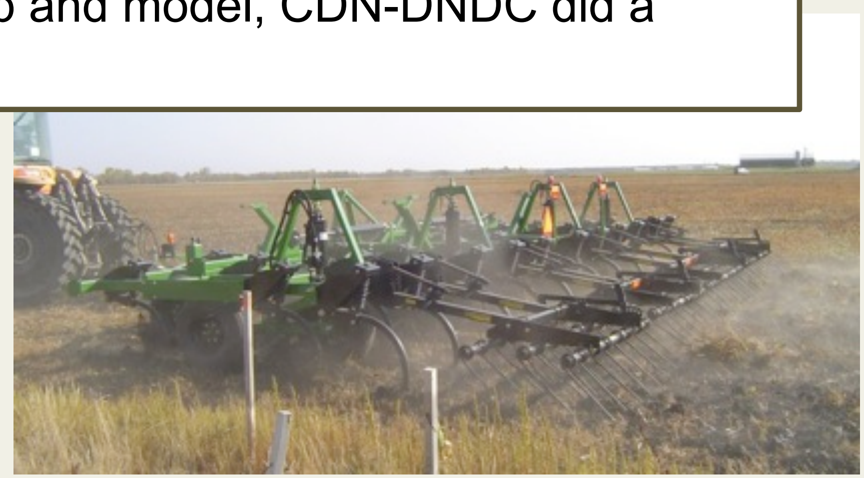
Estimated Total N2O Emissions (per crop and N source) All Plots (2006-2012)



- Crops with high fertilizer application rates or yields poorly estimated tended to show greatest divergence between measured and simulated emissions
- N_2O emissions from anhydrous ammonia were underestimated (nitrification rate may need adjustment)

Conclusions

- CDN-DNDC simulated the response/timing of fertilizer and crop management well for N_2O although the magnitude of emissions was often over/under estimated
- Our "proof of concept" mechanism to describe the preferential flow of water through clay cracks requires further development/validation
- Investigate under-prediction of soil N in the alfalfa years. DNDC and DayCent have demonstrated a difficulty in simulating enough soil N for low fertilizer input systems at other sites in Canada
- DNDC underestimated emissions from terminated alfalfa
- DNDC underestimate spring thaw emisisons
- This clay soil is challenging to crop and model, CDN-DNDC did a decent job



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