CROPLANDS GROUP

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Session 2 - Soil tillage

Chair: Pier Paolo Roggero

Co-chair: Joël Léonard

Key note lecture - Bruno Mary

Short presentations:

- Charles Rice
- Lutz Merbold
- Emma Suddick

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Key note lecture

Soil tillage and N2O emissions

Bruno Mary

INRA, France

Soil tillage and N2O emissions

B. Mary

INRA, AgroImpact

INRA SCIENCE & IMPACT

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General issues on soil tillage

Soil tillage may result in

- increased C storage?

- increased N2O emission?

What is the net balance?

Single tillage events

Long term tillage experiments

FIT = full inversion tillage (conventional)

ST = shallow tillage

NT = no-till

Many variants in tillage intensity and frequency

Examples with continuous contrasted tillage treatments

Soil tillage and N2O emissions

1. **Global results: meta-analysis**

2. Main factors affected by soil tillage and influencing nitrification and denitrification

Meta-analysis of van Kessel et al (2012)

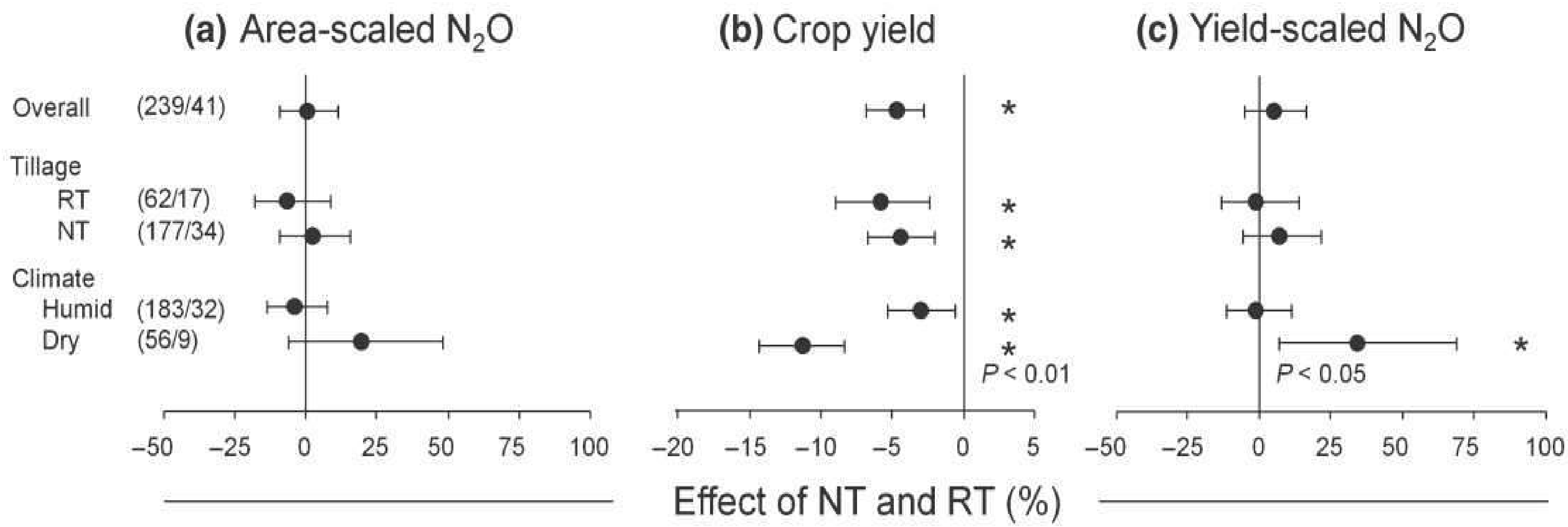
- Selection criteria
  - Measurements in situ during at least one crop cycle
  - Yield data available
  - Number of replicates known for FIT and NT/RT
  - Fertilisation/rotation identical

- Selection obtained (until 2011)

	Nb Sites	Nb comparisons
Origin		
All	**41**	**239**
North America	26	190
Europe	9	30
Treatments		
NT	24	139
NT/RT	11	74
RT	6	26

Meta-analysis of van Kessel et al (2012)

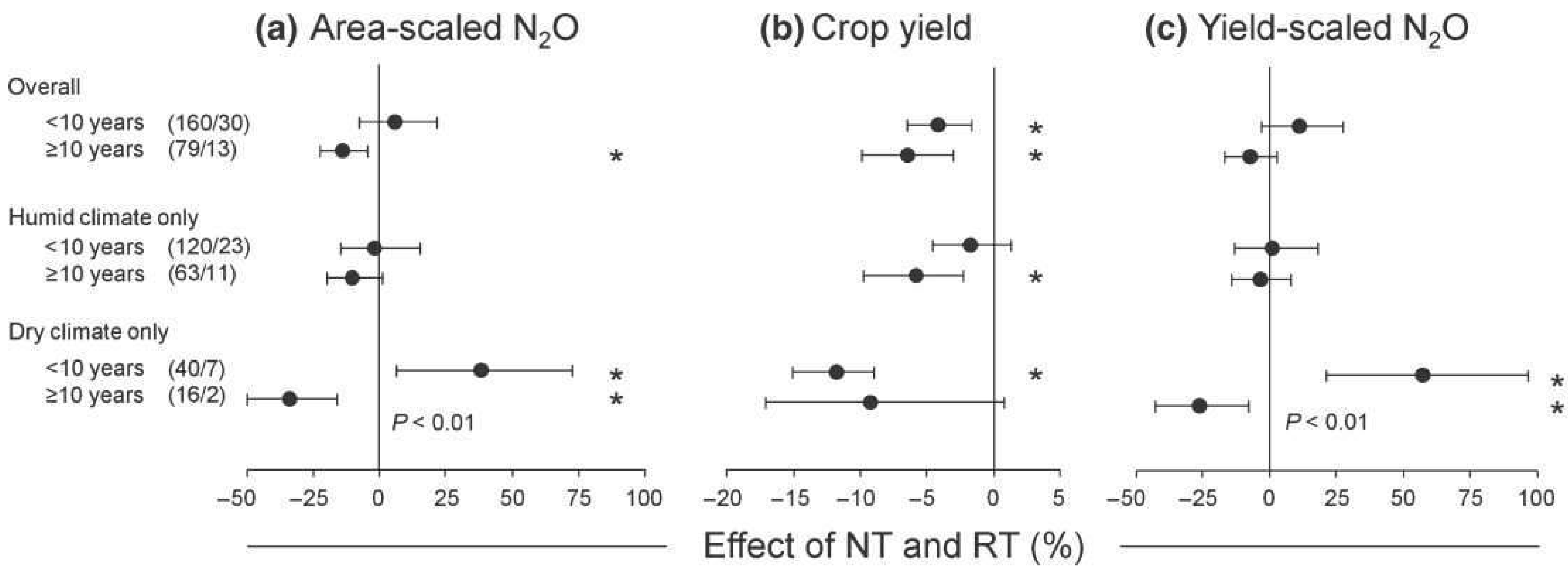
Effect of tillage and climate



No significant difference except for dry climates

Meta-analysis of van Kessel et al (2012)

Effect of duration and duration x climate

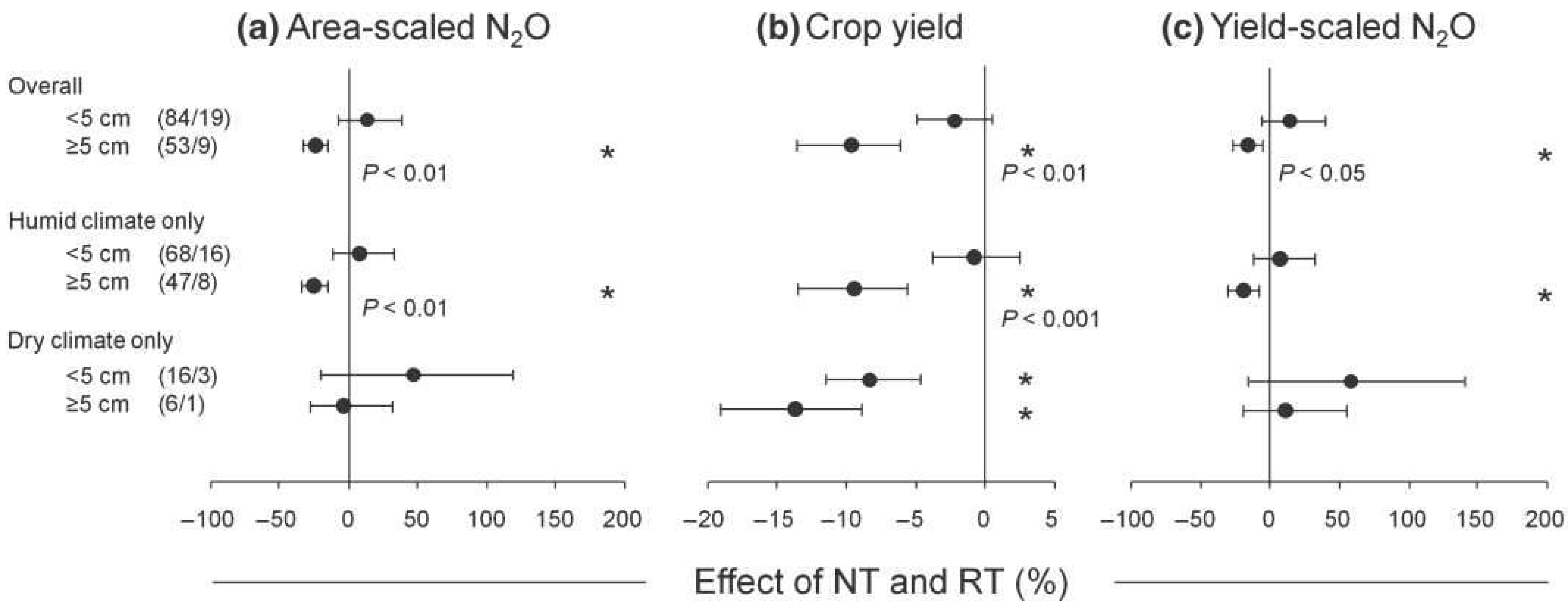


Increase in dry climates for recent conversions into reduced tillage

Decrease with older conversions

Meta-analysis of van Kessel et al (2012)

Effect of fertilizer placement and climate x fertilizer placement



Fertilizer placement at depth reduces N2O emissions

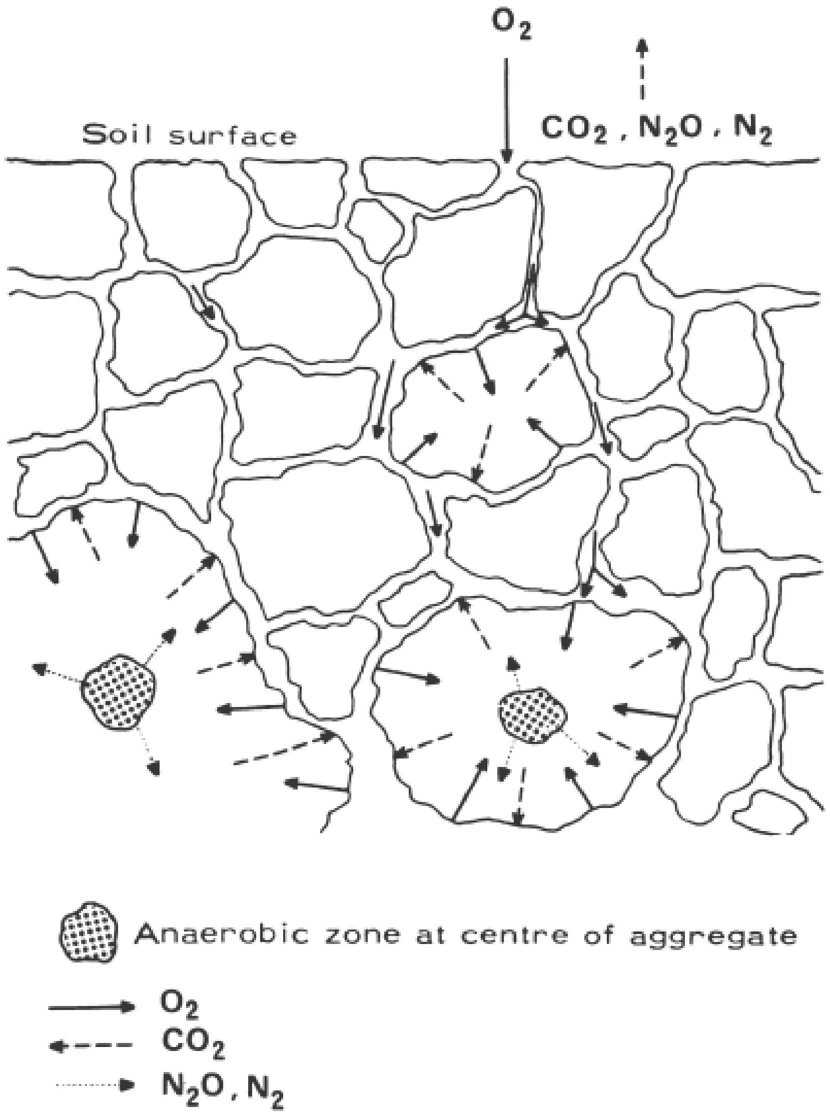
Soil tillage and N2O emissions

1. Global results: meta-analysis

2. Main factors affected by soil tillage and influencing nitrification and denitrification

- *Structure*
- *Mulch*
- *Temperature*
- *Moisture*
- *Mineral N*
- *pH*
- *Carbon distribution*
- *Microbial communities*

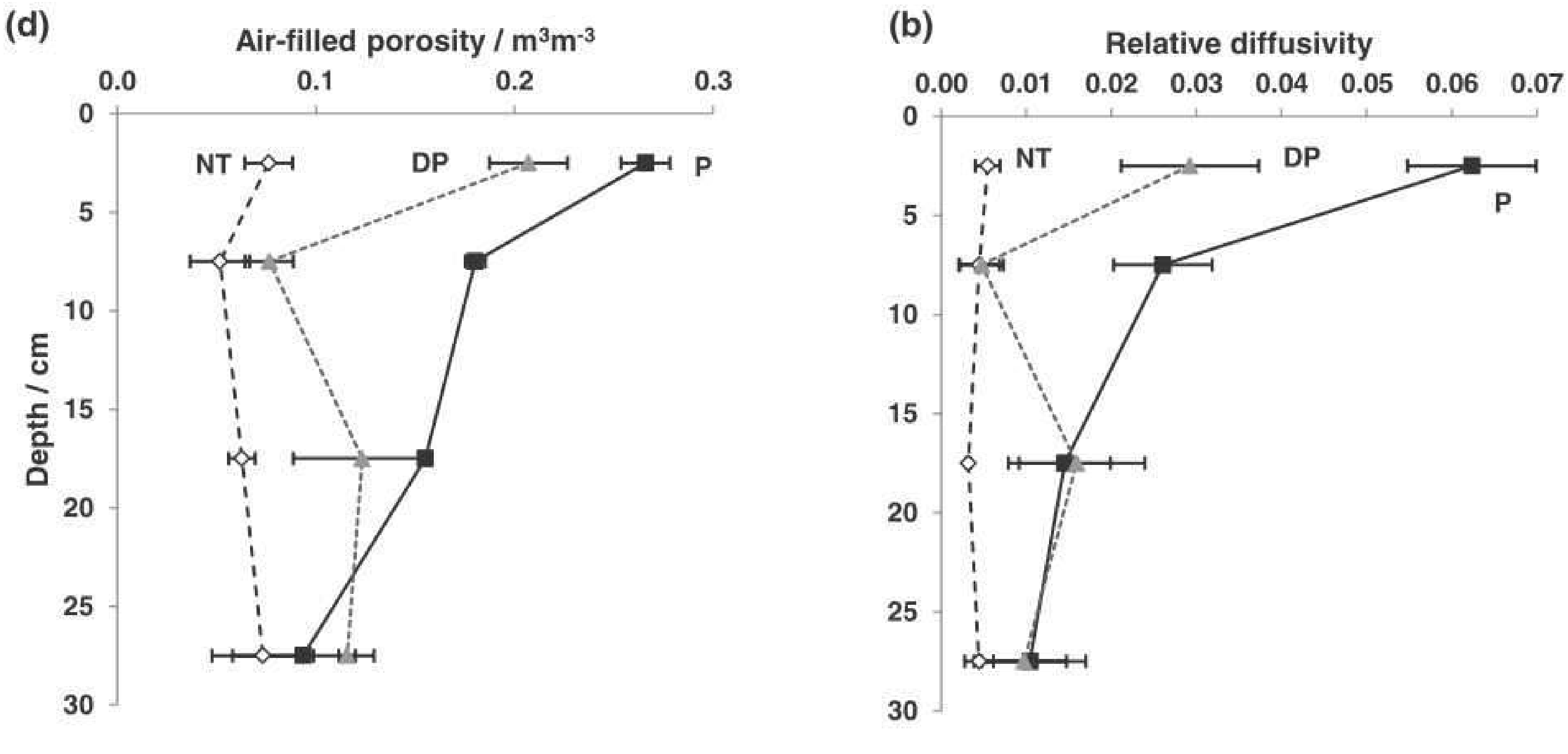
Soil structure



Ball (2013)

Soil structure

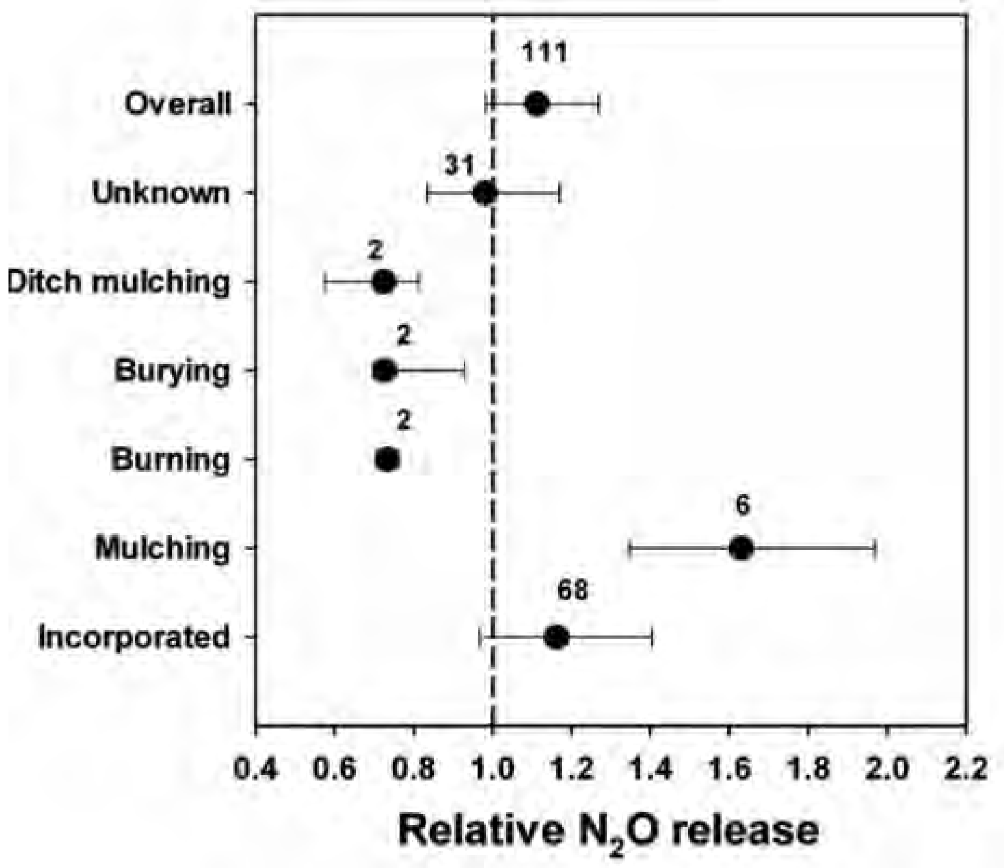
Ball (2013)



Tillage may drastically modify gas diffusion properties

Crop residues disposal

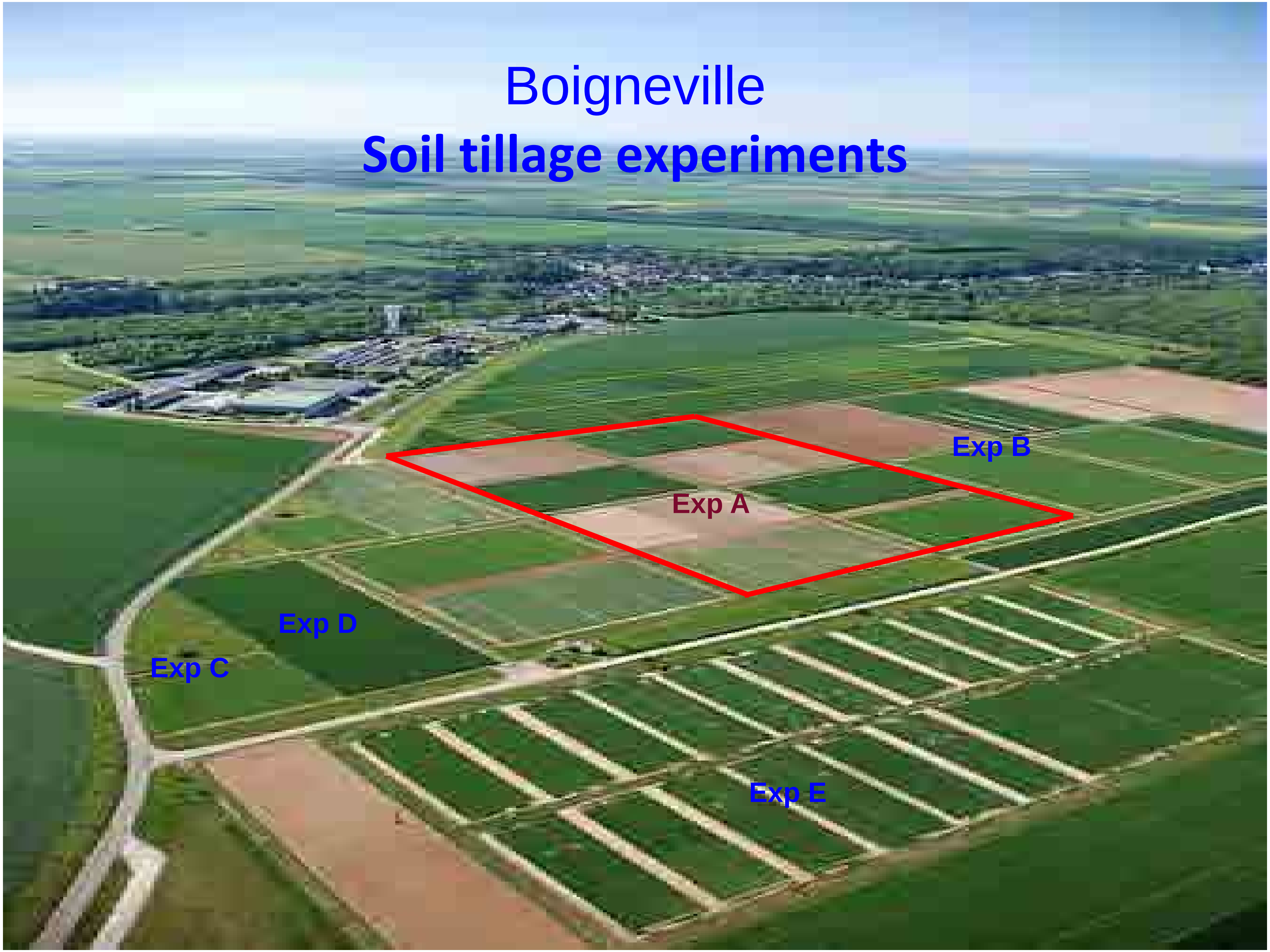
Meta-analysis of Shan & Yan (2013)



The presence of a plant mulch at soil surface enhances N2O emission

Boigneville

Soil tillage experiments




No-till
(NT)


Shallow tillage
(ST)


Full inversion
tillage (FIT)

Boigneville experiment A

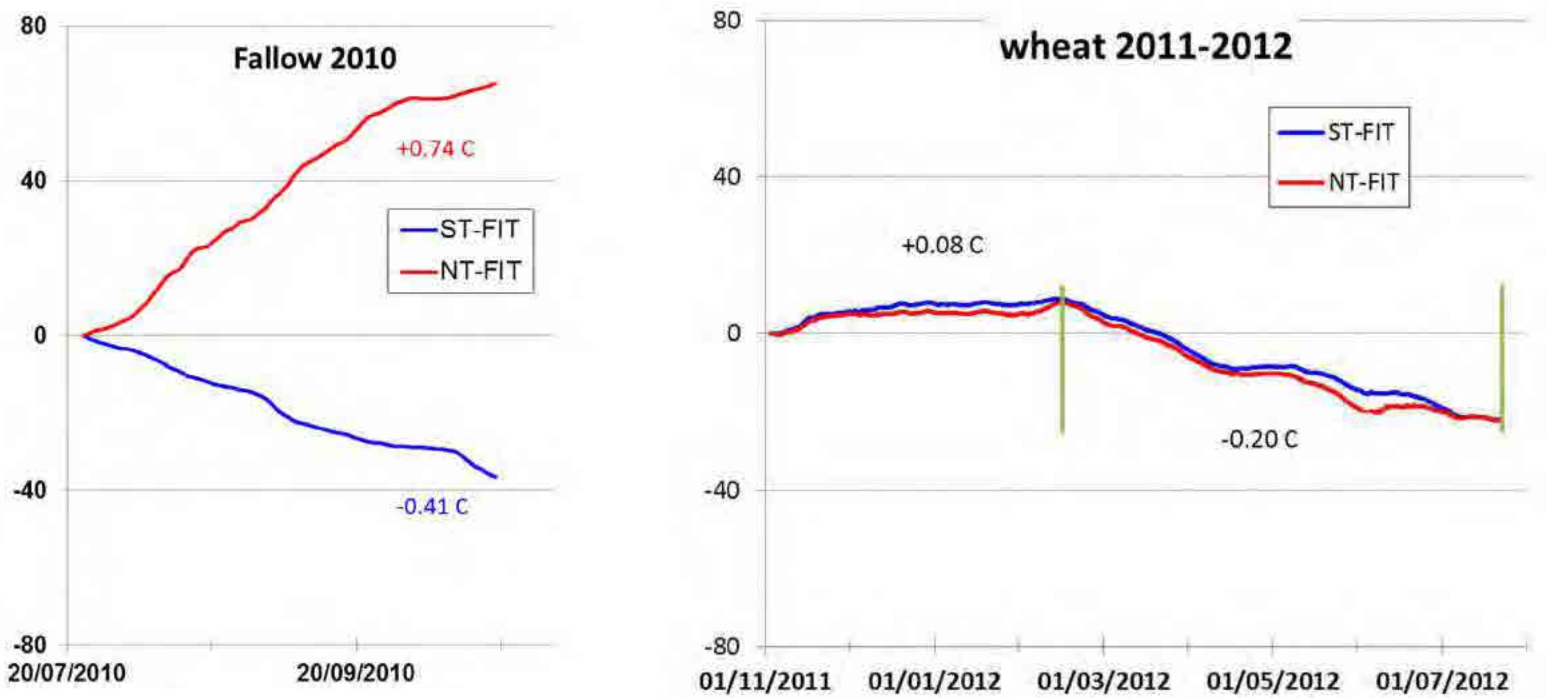
- Diachronic evolution of SOC stocks during 41 years (Dimassi et al, 2013, 2014)

- N_2O fluxes measured continuously during 3 years (2010-2013)

- Main drivers (T, SWC, …) measured during 3 years

Temperature regime

Cumulative difference in soil temperature between reduced and conventional tillage
Layer 0-10 cm

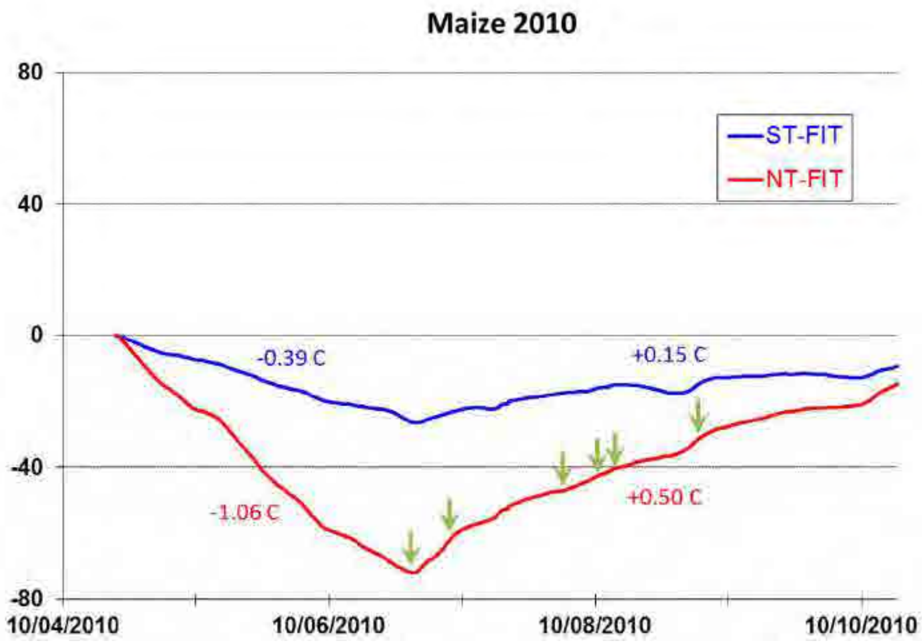


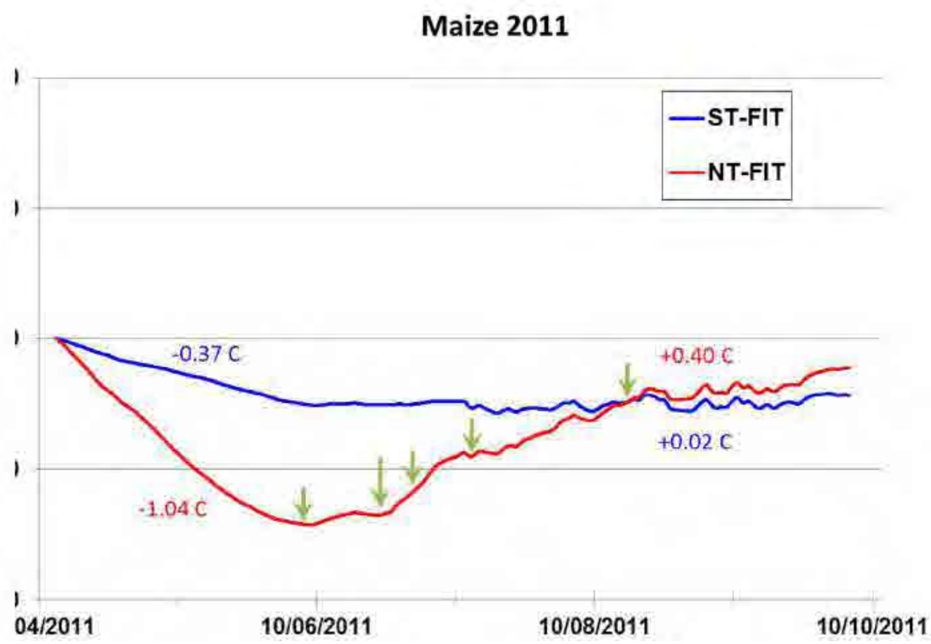
NT is warmer than FIT in summer/autumn under straw mulch

NT/ST are cooler in spring under winter wheat

Temperature regime

Cumulative difference in soil temperature between reduced and conventional tillage
Layer 0-10 cm





NT is colder than FIT in spring and becomes warmer in summer

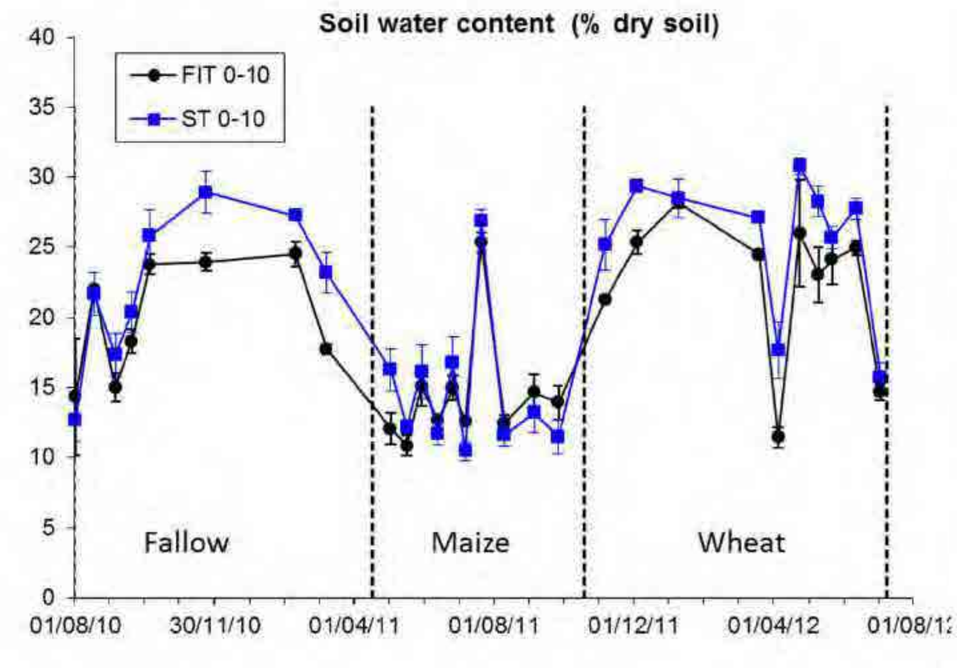
The inversion is linked with important precipitation or irrigation events

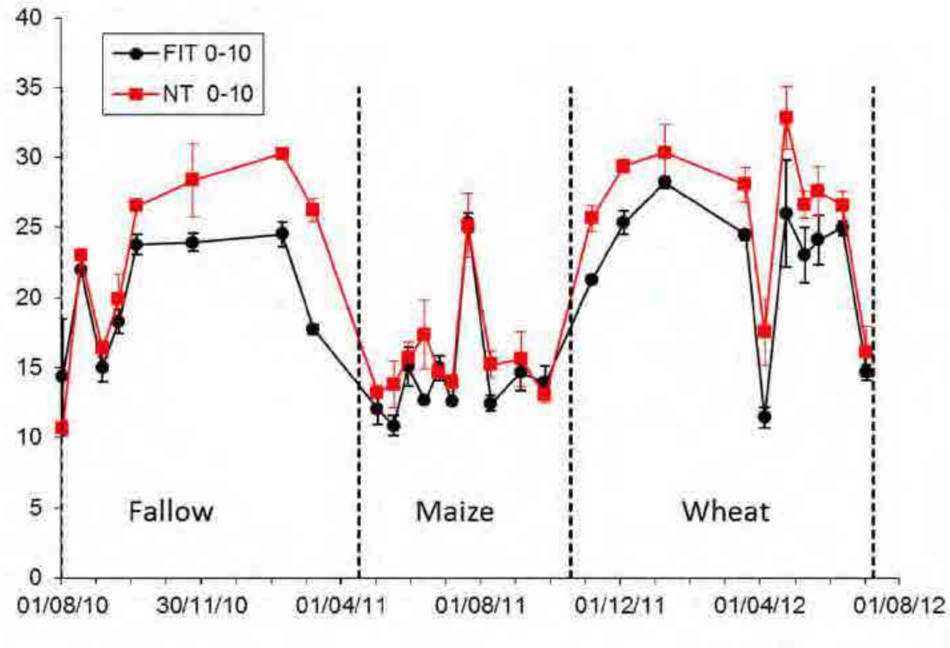
Soil water regime

Evolution of soil water contents during 2 years in **layer 0-10 cm**

Shallow *vs* conv tillage

No till *vs* conv tillage



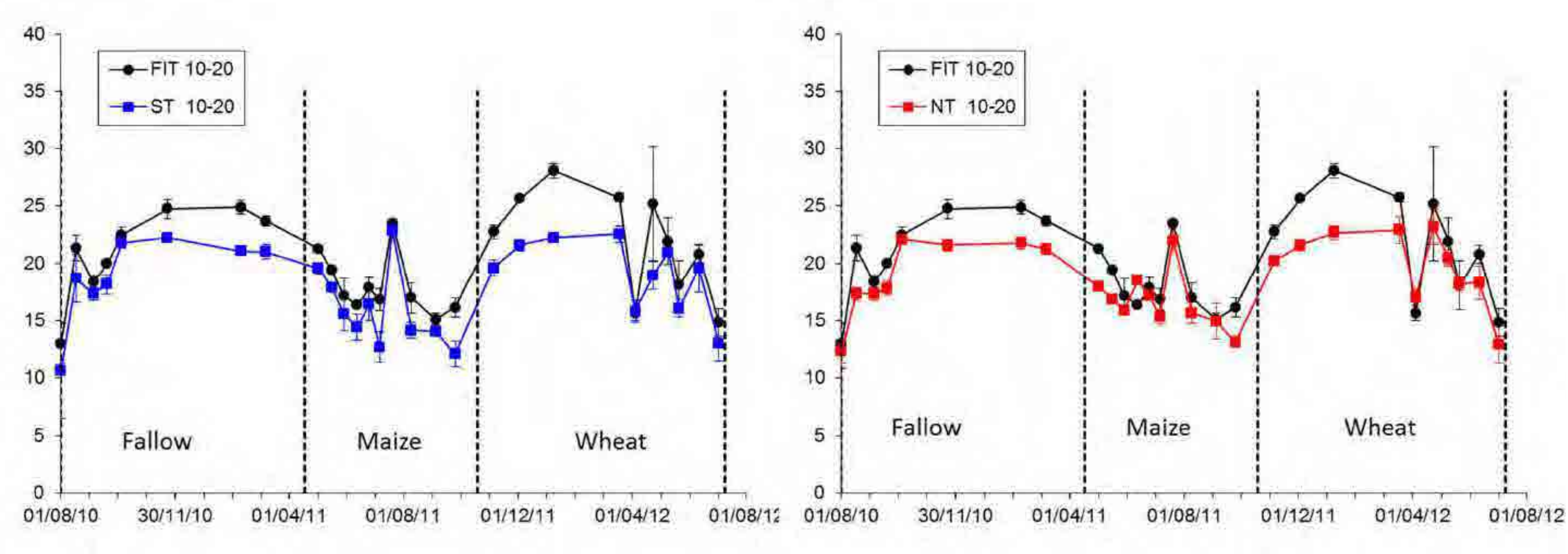


Higher SWC in reduced tillage, particularly under fallow or wet conditions
Link with SOC content

Soil water regime

Evolution of soil water contents during 2 years in **layer 10-20 cm**

Shallow *vs* conv tillage | No till *vs* conv tillage

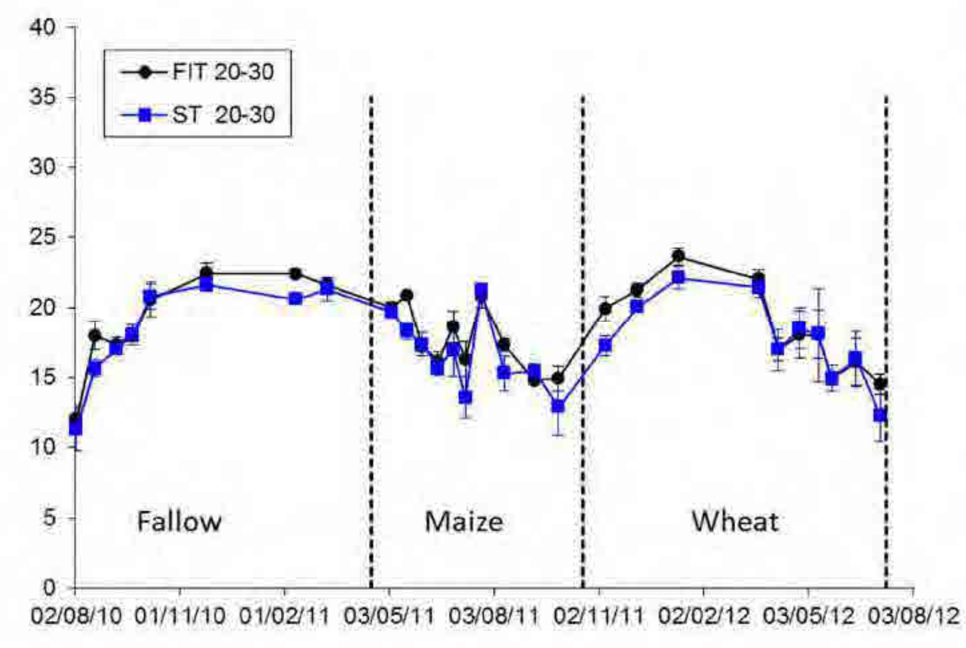


Lower SWC in reduced tillage, particularly under fallow or wet conditions

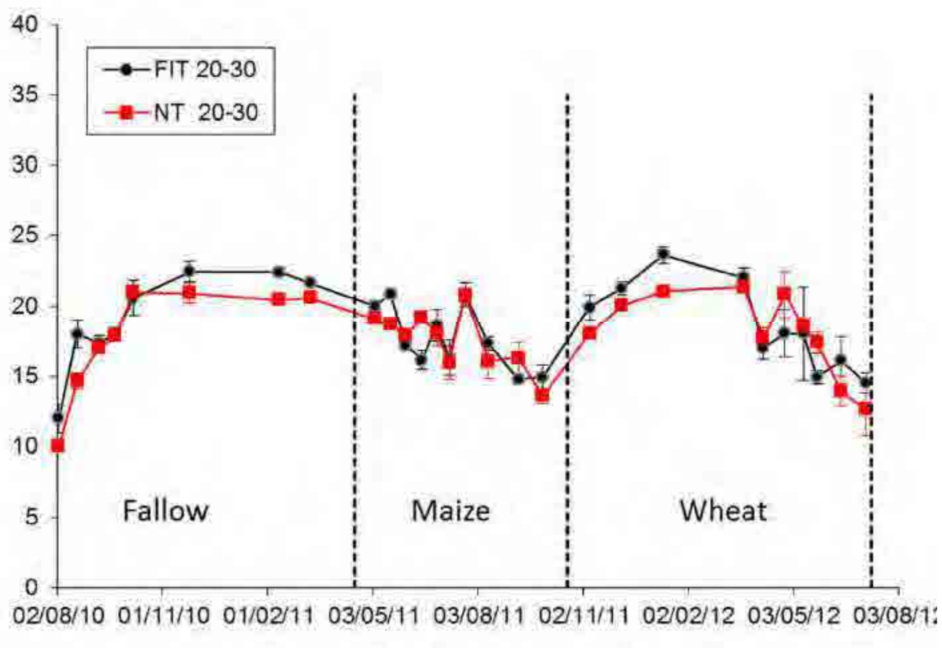
Soil water regime

Evolution of soil water contents during 2 years in **layer 20-30 cm**

Shallow *vs* conv tillage



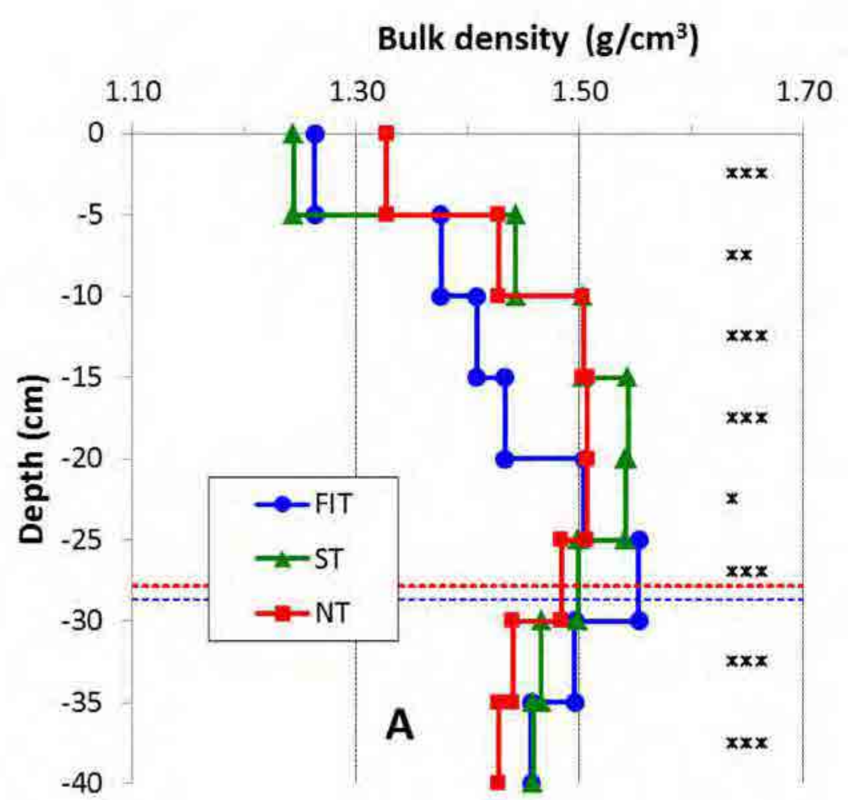
No till *vs* conv tillage



Lower SWC in reduced tillage, particularly under fallow or wet conditions

Bulk density

Profile measured after 41 years of continuous tillage treatments

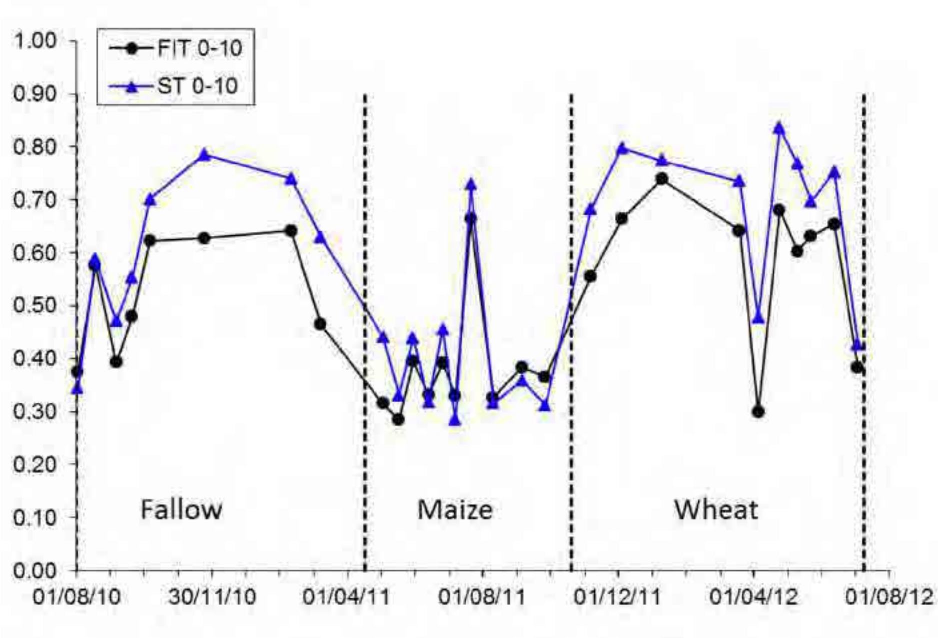


Greater compaction in reduced tillage

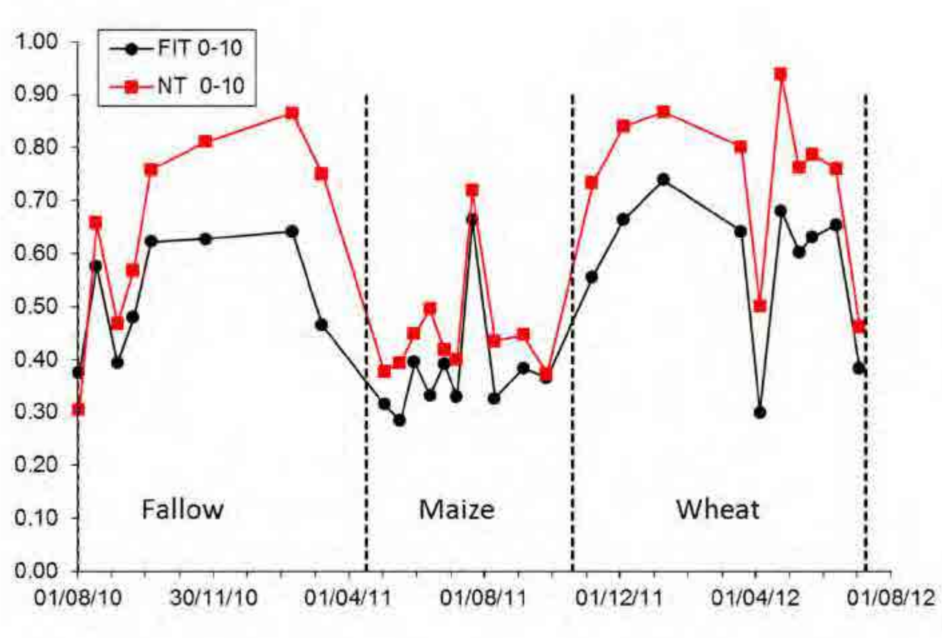
Soil WFPS

Evolution of WFPS during 2 years in **layer 0-10 cm**

Shallow *vs* conv tillage



No till *vs* conv tillage

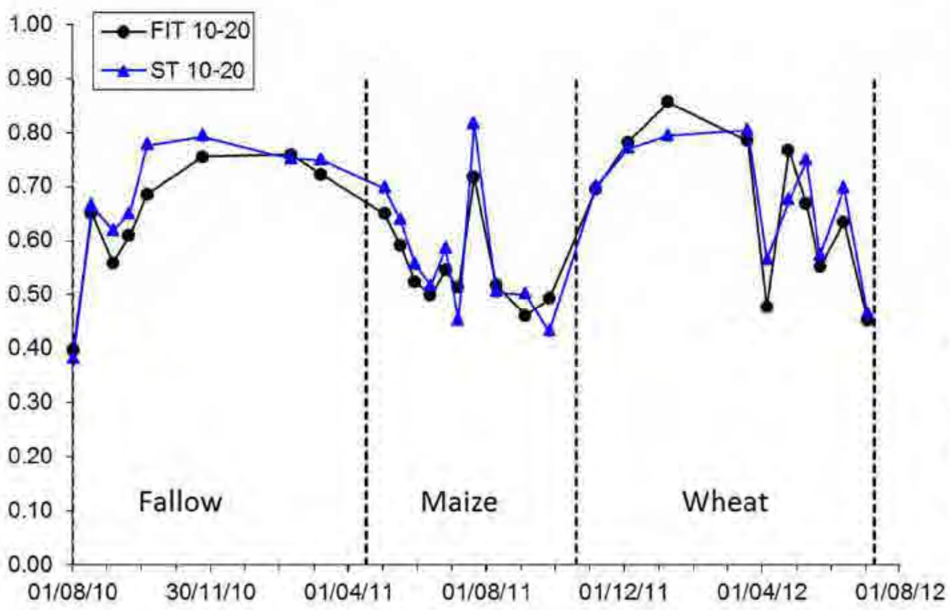


Higher WFPS in reduced tillage, often > 60%

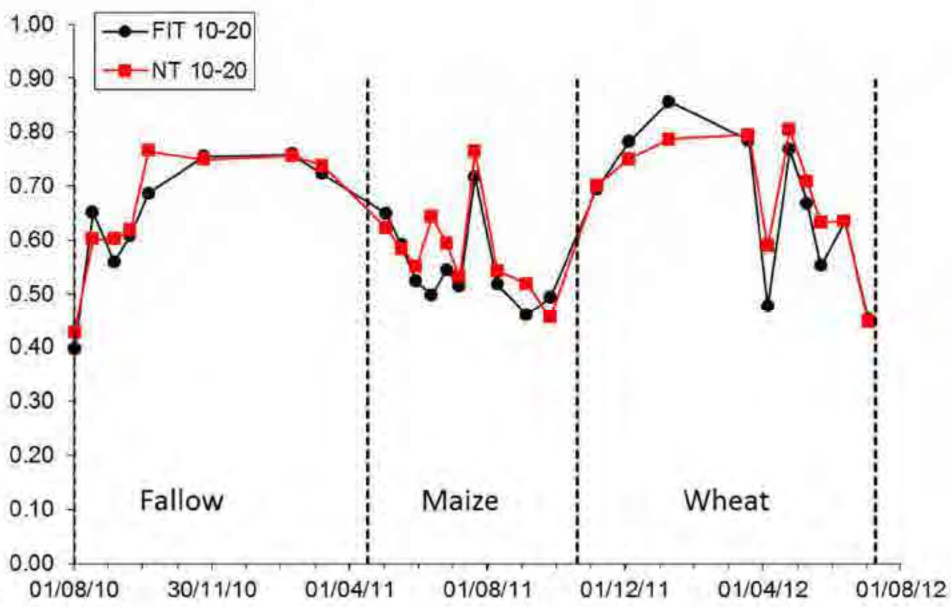
Soil WFPS

Evolution of WFPS during 2 years in **layer 10-20 cm**

Shallow *vs* conv tillage



No till *vs* conv tillage

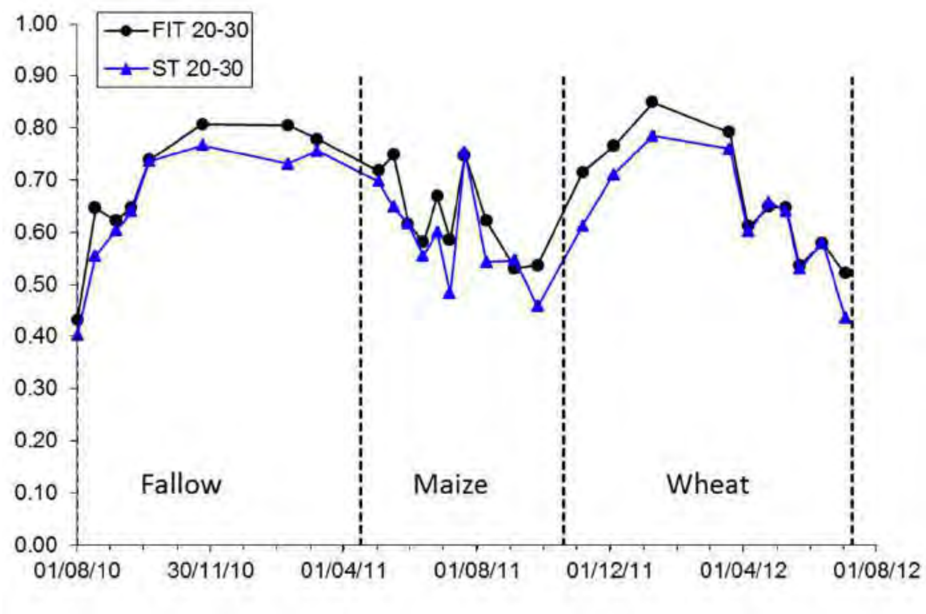


About same values of WFPS

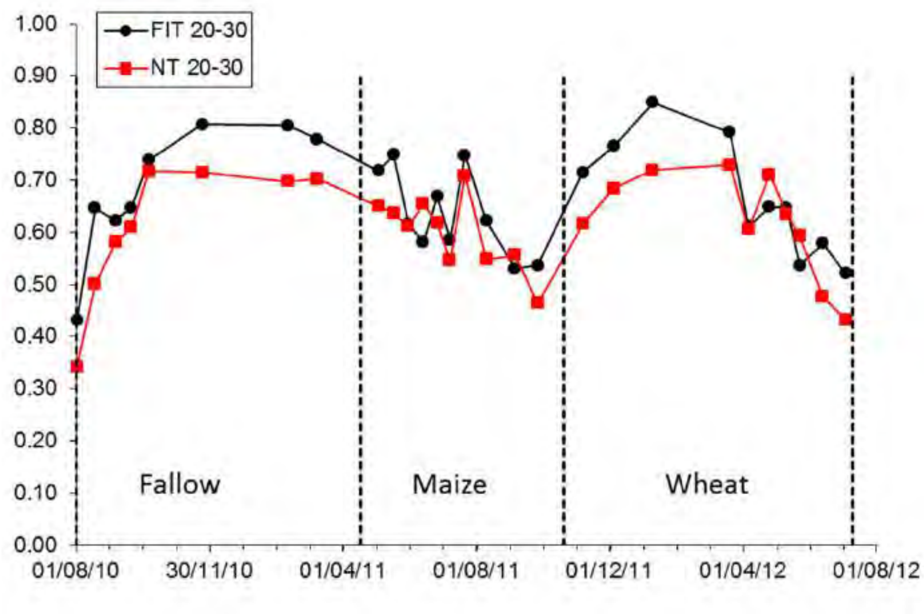
Soil WFPS

Evolution of WFPS during 2 years in **layer 20-30 cm**

Shallow *vs* conv tillage



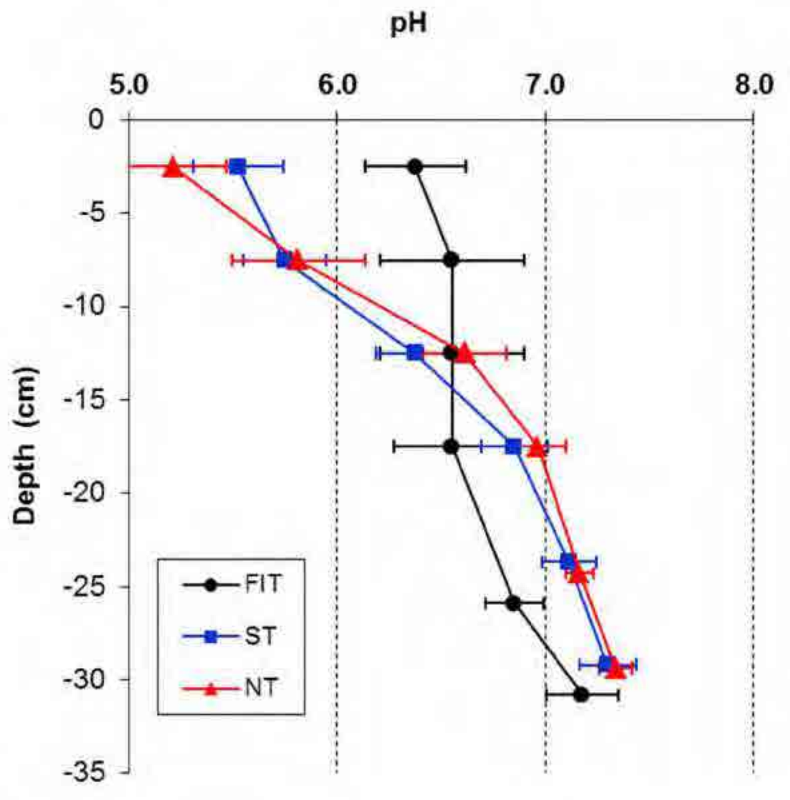
No till *vs* conv tillage



Lower WFPS in reduced tillage

Soil pH

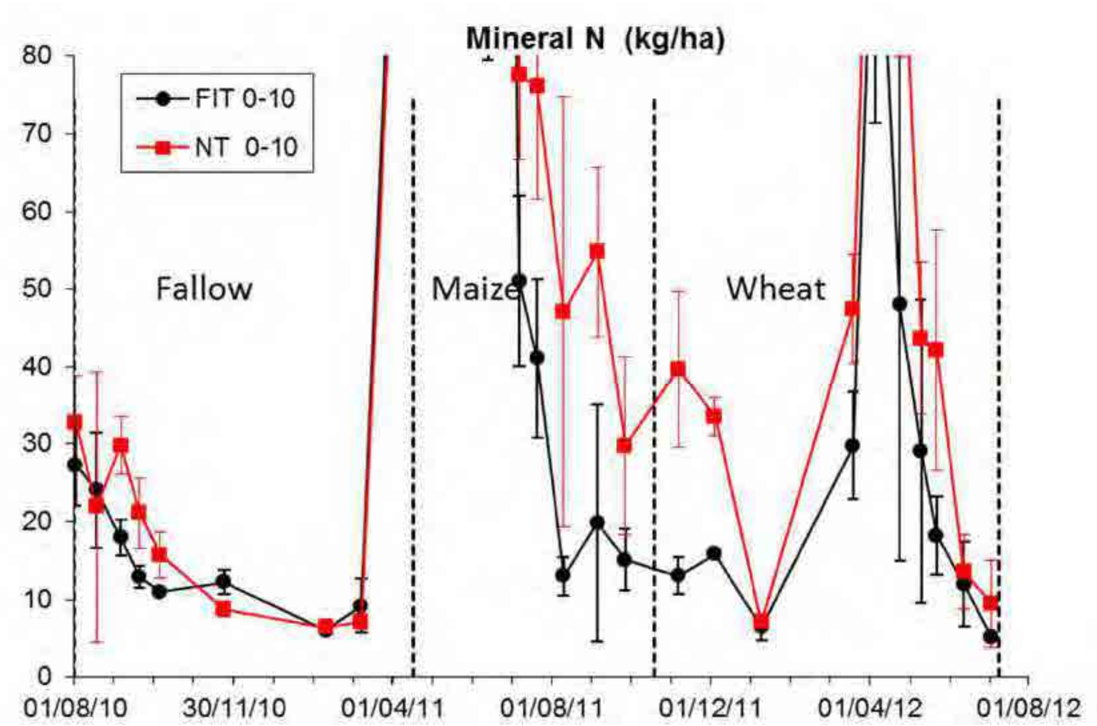
Soil pH measured after 37 years of continuous tillage treatments



Reduced tillage: **acidification** in surface soil, alcalinisation below
Link with SOC profile

Mineral N content

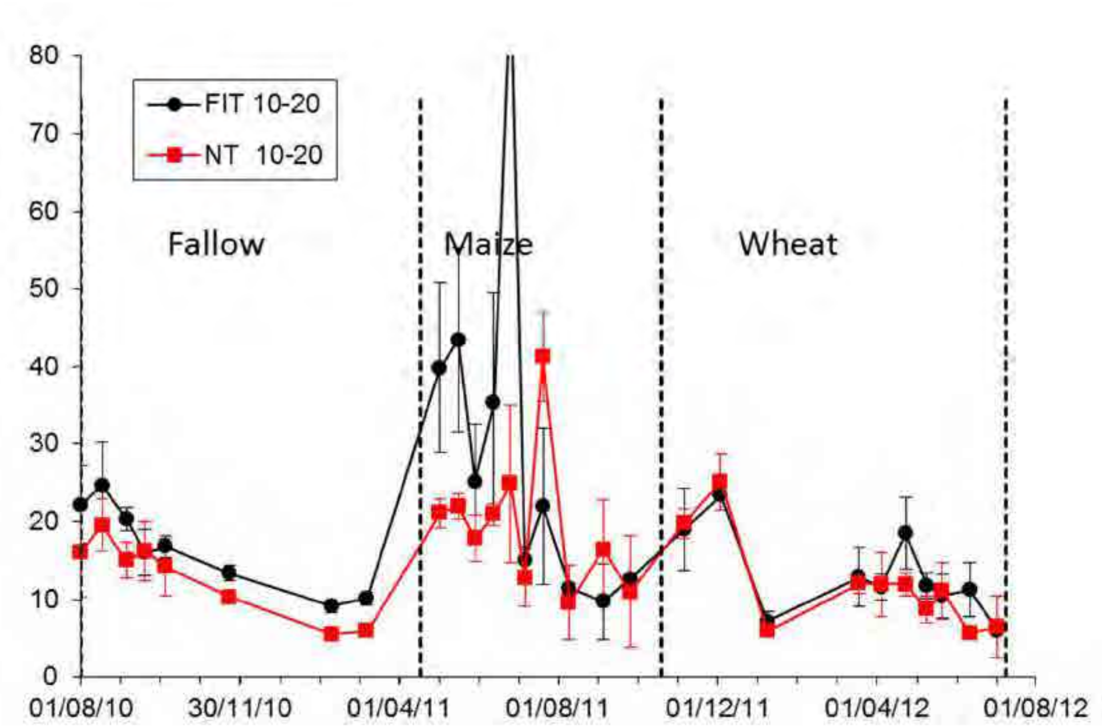
Evolution of mineral N (kg N/ha) during 2 years **Layer 0-10 cm**



Higher amounts of mineral N in NT , both NH4 and NO3

Mineral N content

Evolution of mineral N (kg N/ha) during 2 years **Layer 10-20 cm**



Lower amounts of mineral N in NT , both NH4 and NO3

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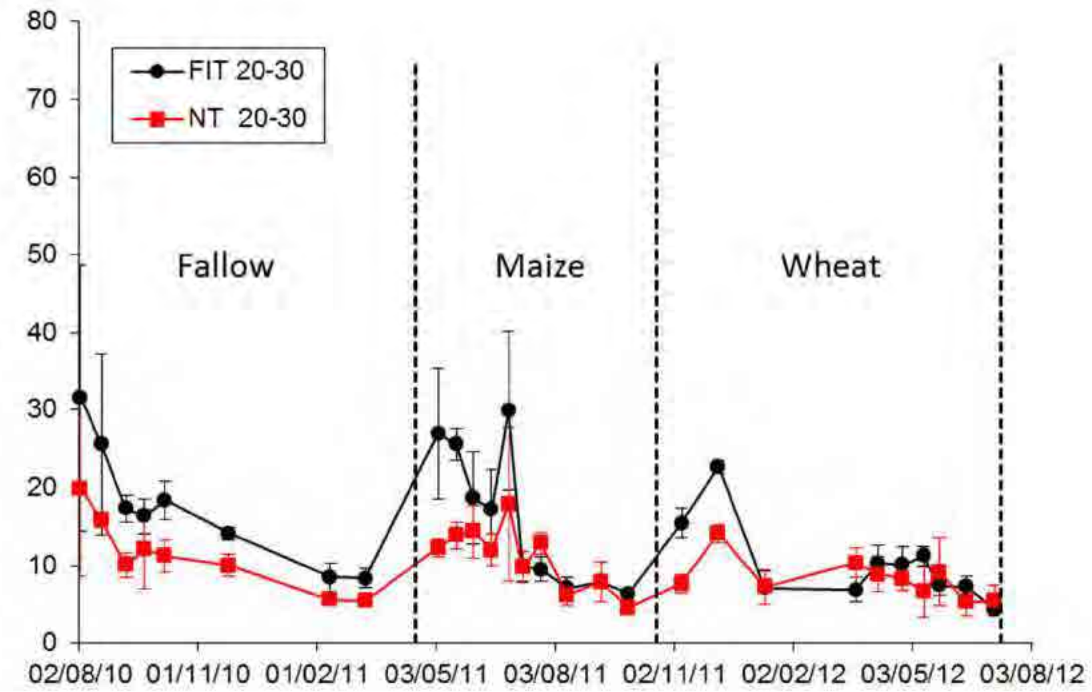
Mineral N content

Evolution of mineral N (kg N/ha) during 2 years **Layer 20-30 cm**



Lower amounts of mineral N in NT , both NH4 and NO3

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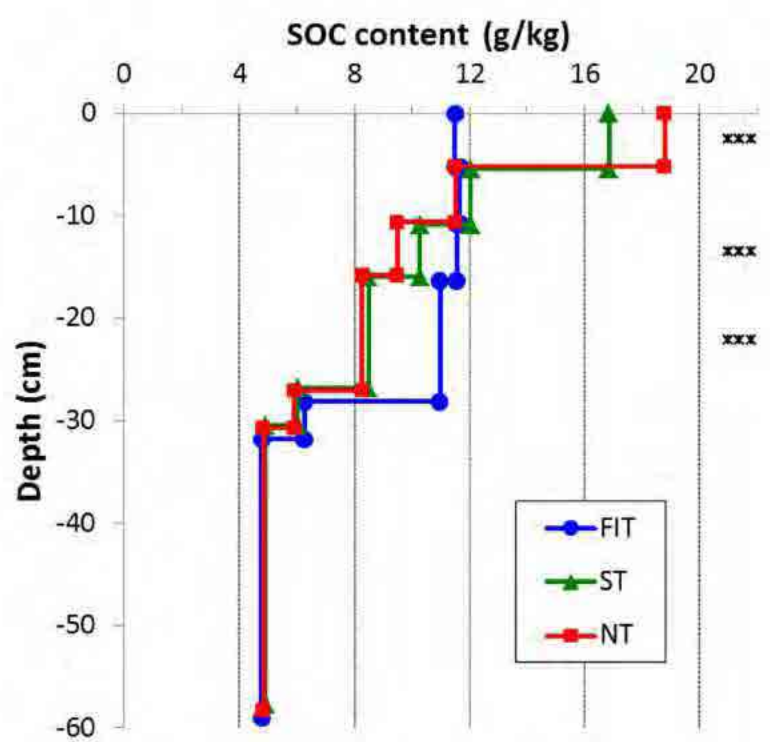
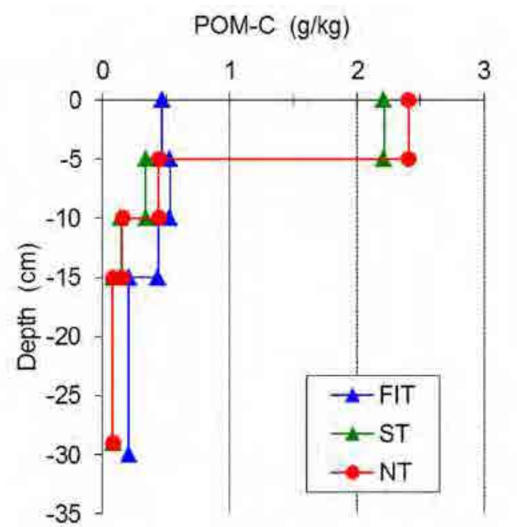
C content

SOC and POM profiles after 41 years of continuous tillage treatments

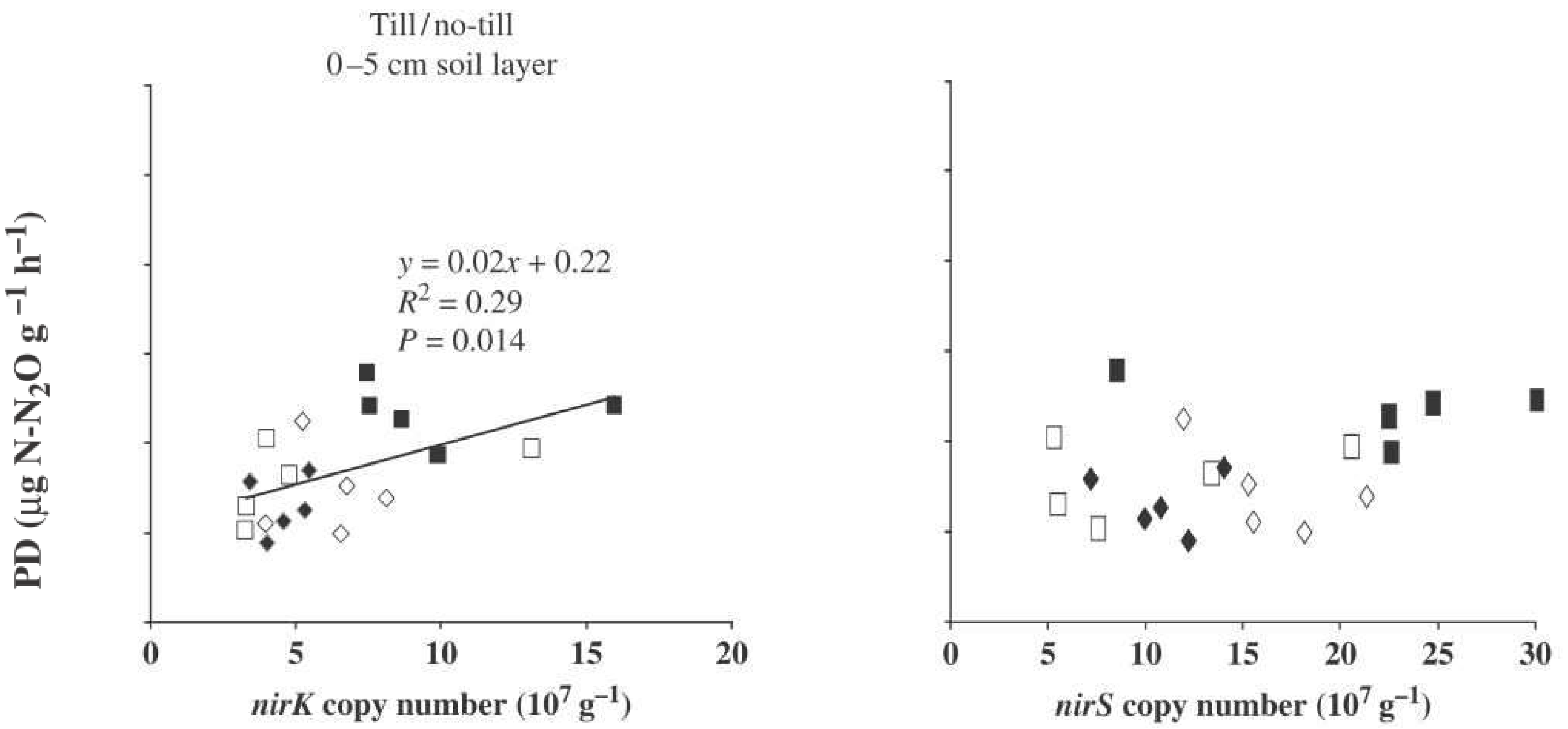




Marked gradient of total C and labile C in reduced tillage

Microbial abundance & diversity

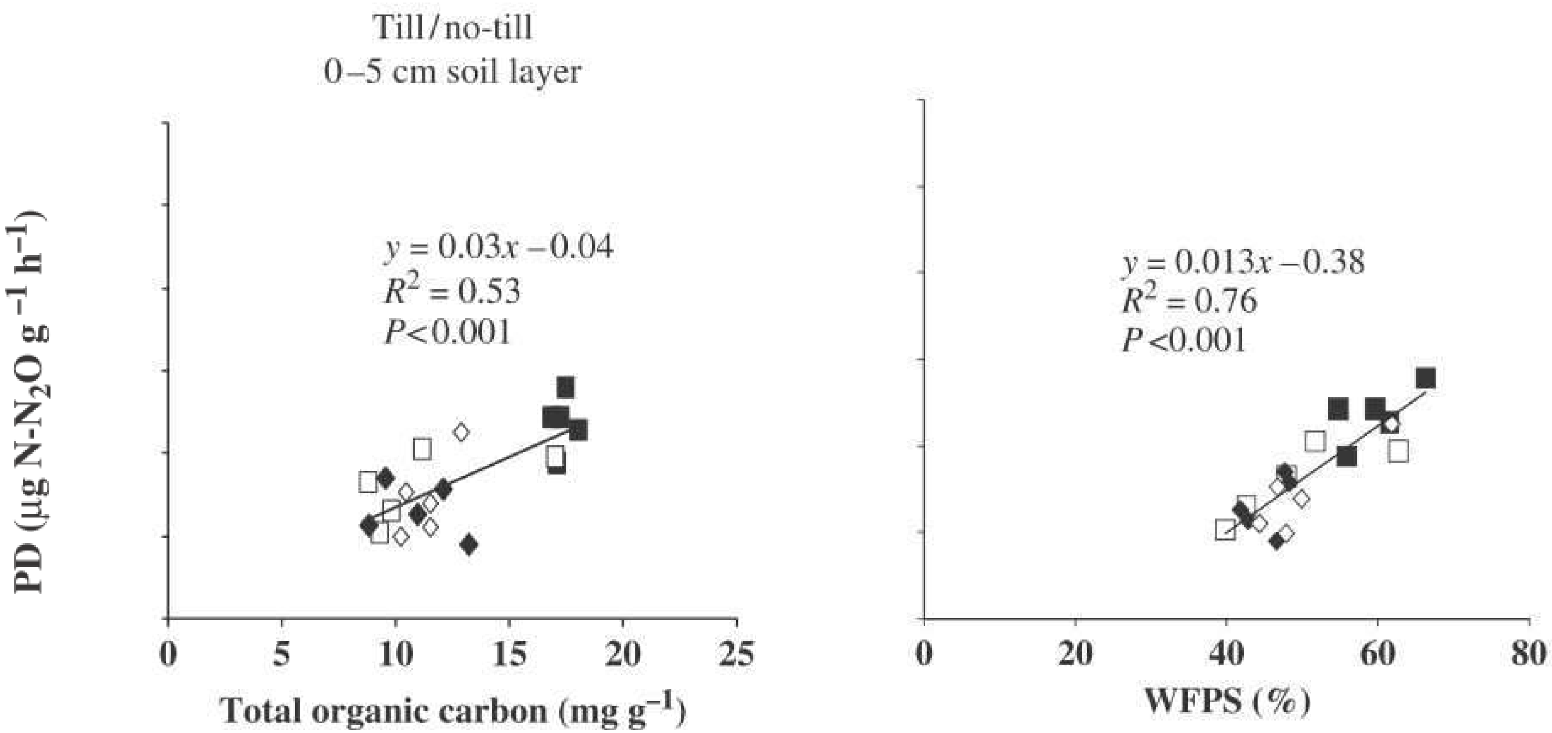
Potential denitrification vs nirK/nirS abundance (Attard et al, 2011)



Weak or no relationship

Microbial abundance & diversity

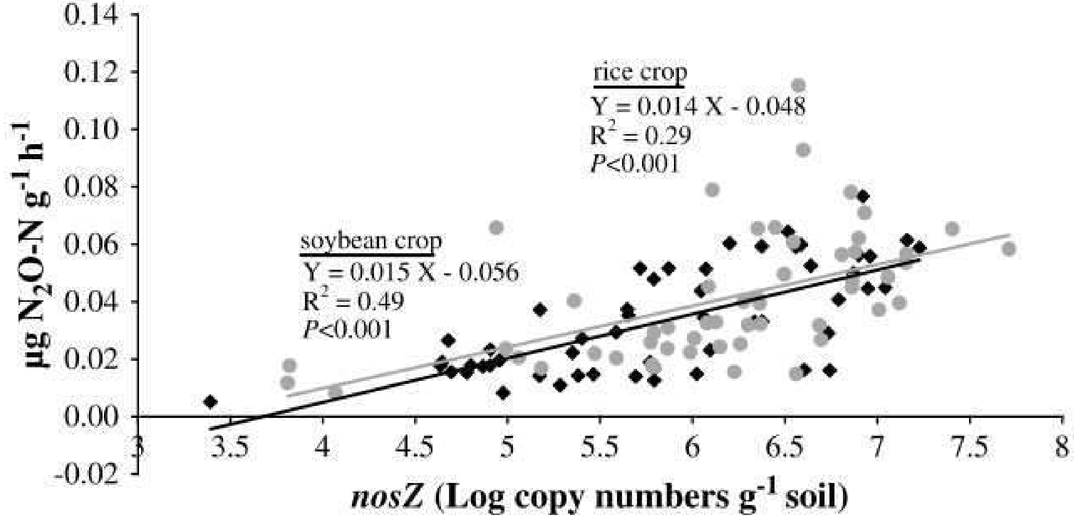
Potential denitrification vs organic C or WFPS (Attard et al, 2011)

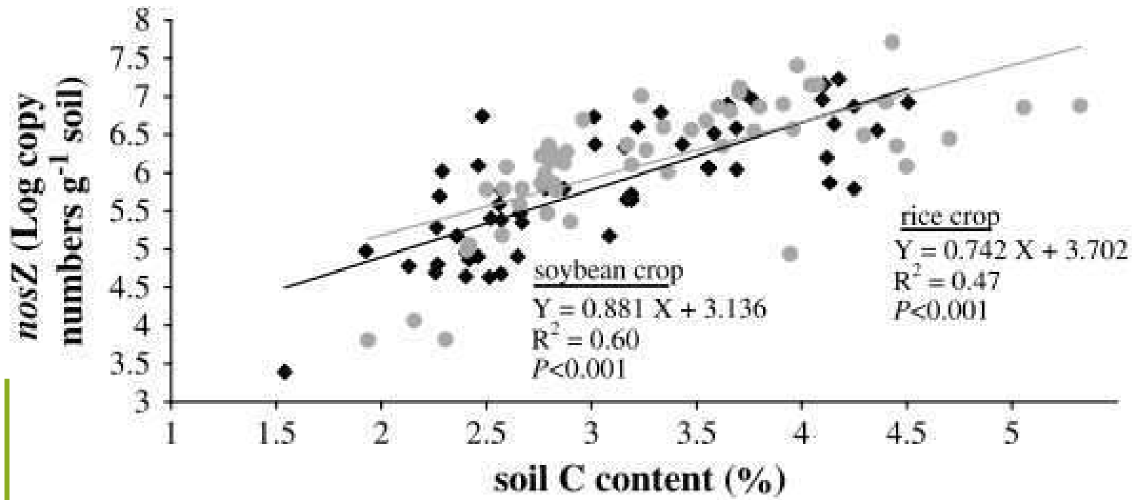


« Accurate simulation of C, O2 and NO3 availability to denitrifiers is more important than accurate simulation of denitrifier abundance and community structure to understand and predict changes in PD in response to land-use changes."

Microbial abundance & diversity

Denitrification enzyme activity vs nosZ abundance (Baudouin et al, 2009)





- DEA
- C content
- NosZ abundance

all increased by DMC (direct seeding mulch)

Which causal effect?
Which variable to enter in model?

Conclusions

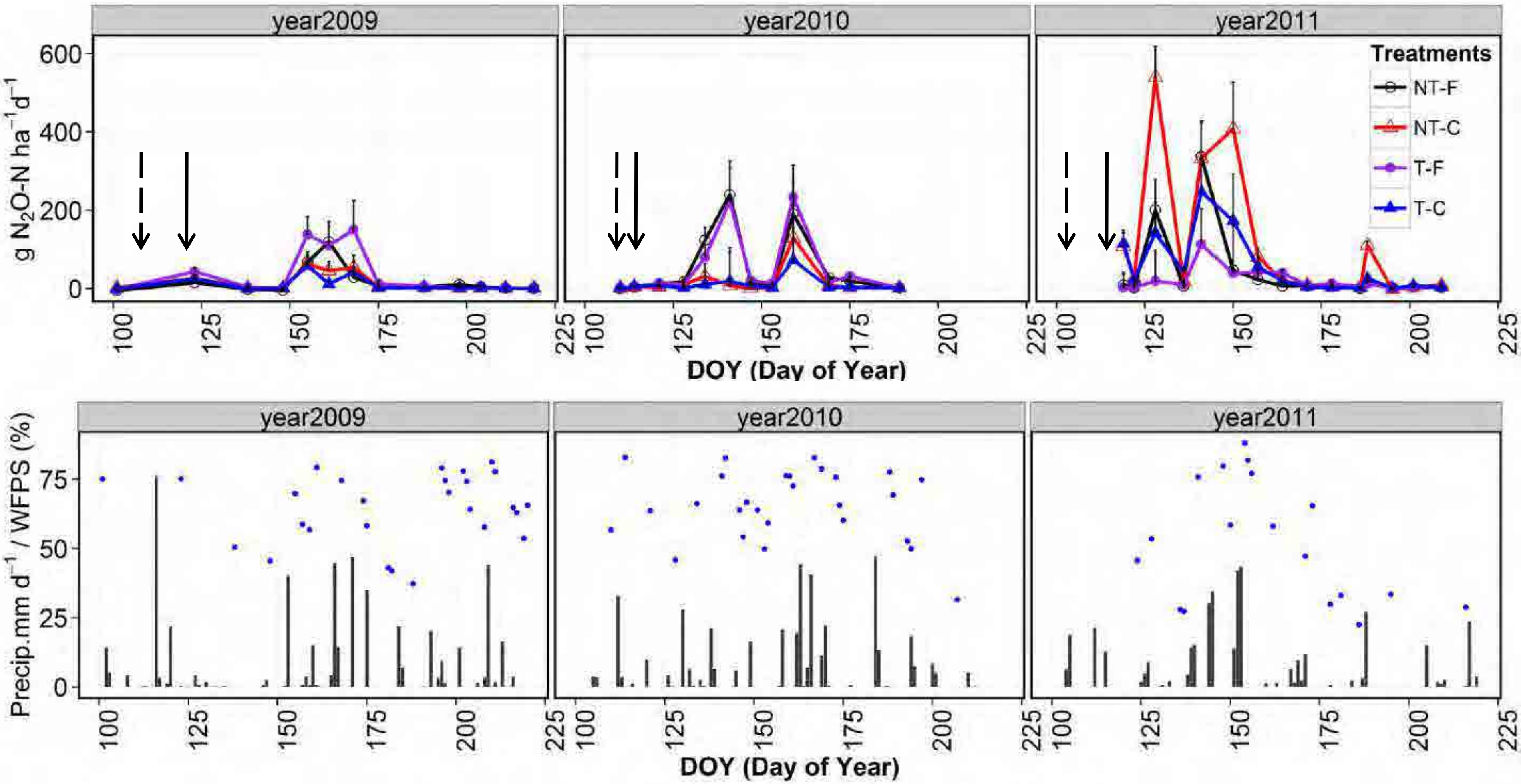
- Variations in soil tillage does not modify markedly N_2O emissions on the long term
- Although it modifies many factors acting on nitrification & denitrification
- Need to account for all factors simultaneously (models)
- Large variability in results not well understood (e.g. NT/ST)
- Large temporal variability for a given site and tillage treatment
- Difficulty: processes are not identified
  - Contribution of denitrification/nitrification
  - N_2O molar ratio
- Improve characterization of the tillage practices
- Adaptation/resilience of microbial communities to changes in land use or environmental conditions is not sufficiently explored yet

Short presentation

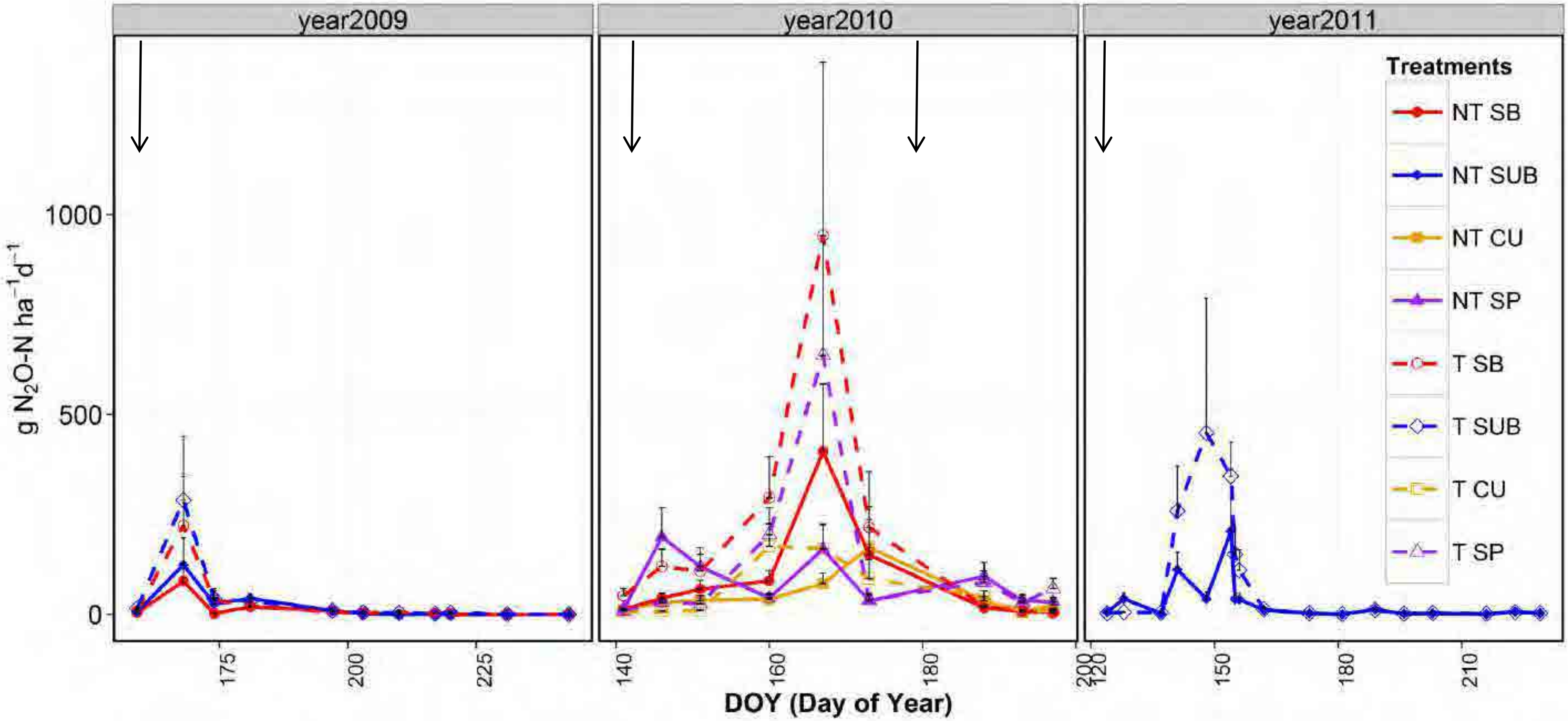
Nitrous Oxide Emissions: Measurements and simulations in corn

Charles W. Rice
Miguel A. Arango
Kansas State University, USA

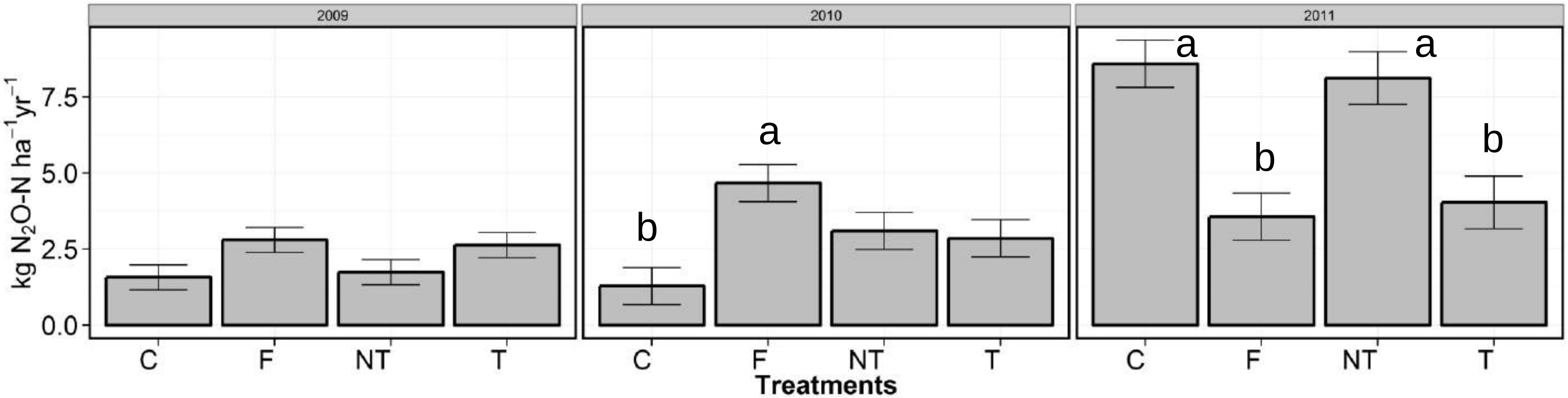
Tillage and N fertilizer effects in a long term experiment ~20 yr



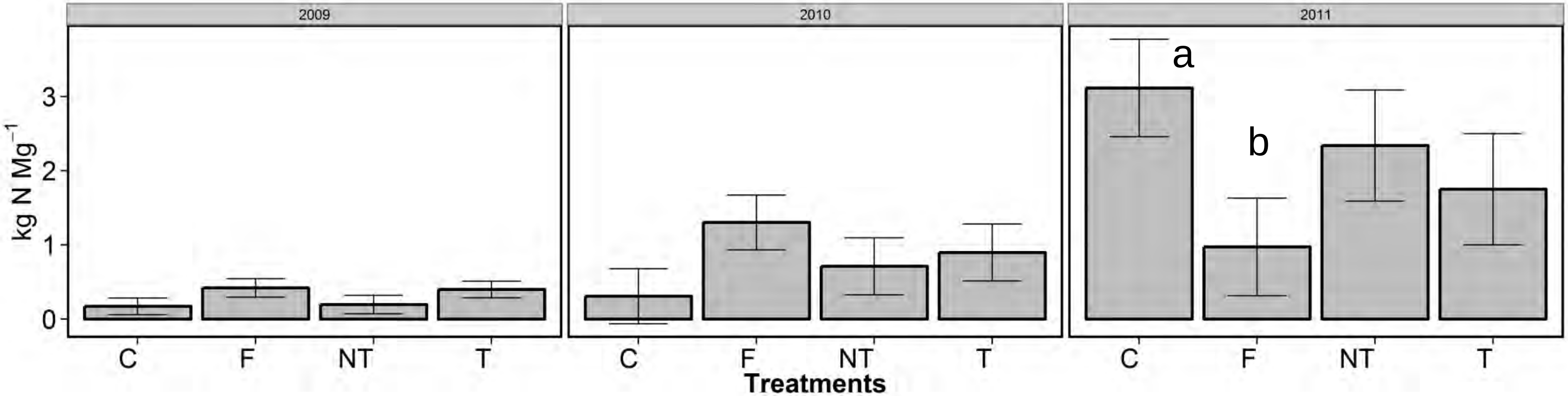
Tillage, placement and timing effects



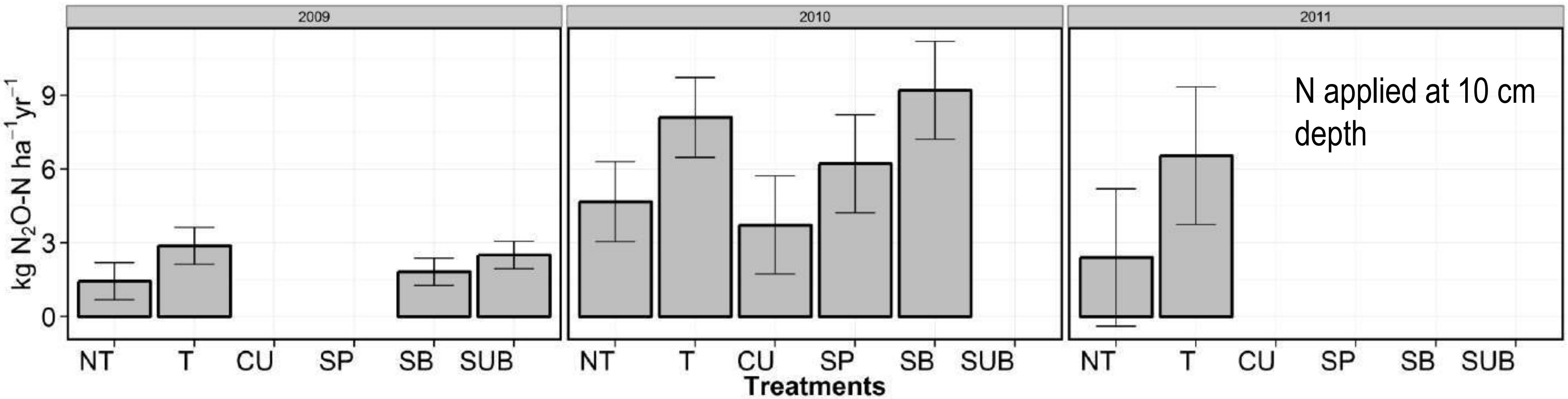
Total N_2O at the Long-term till experiment (~20 years)



N_2O emitted per Mg grain produced



Total N_2O long-term till experiment (~20 years)



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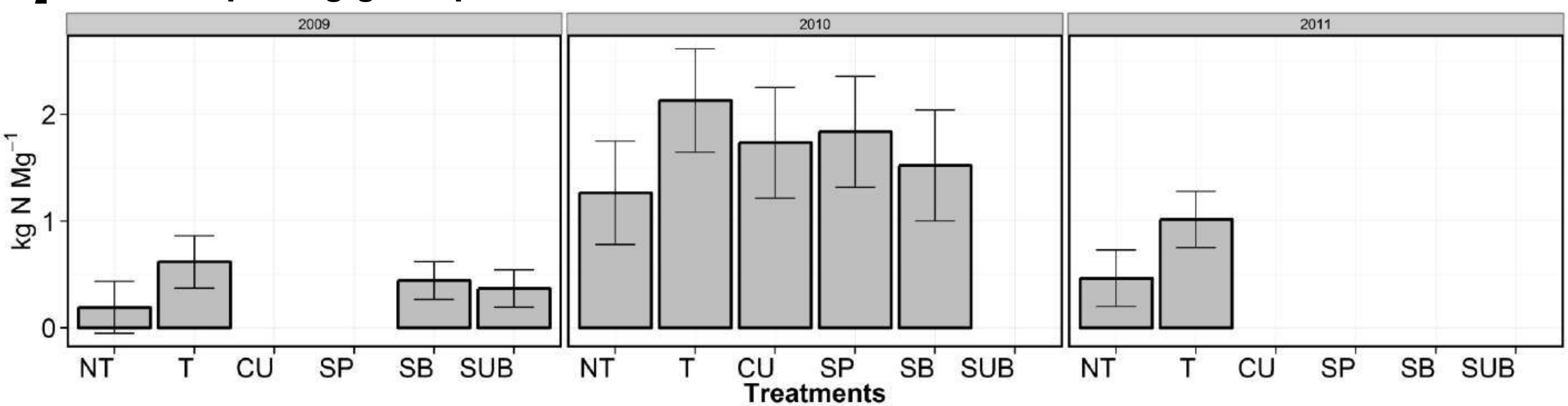
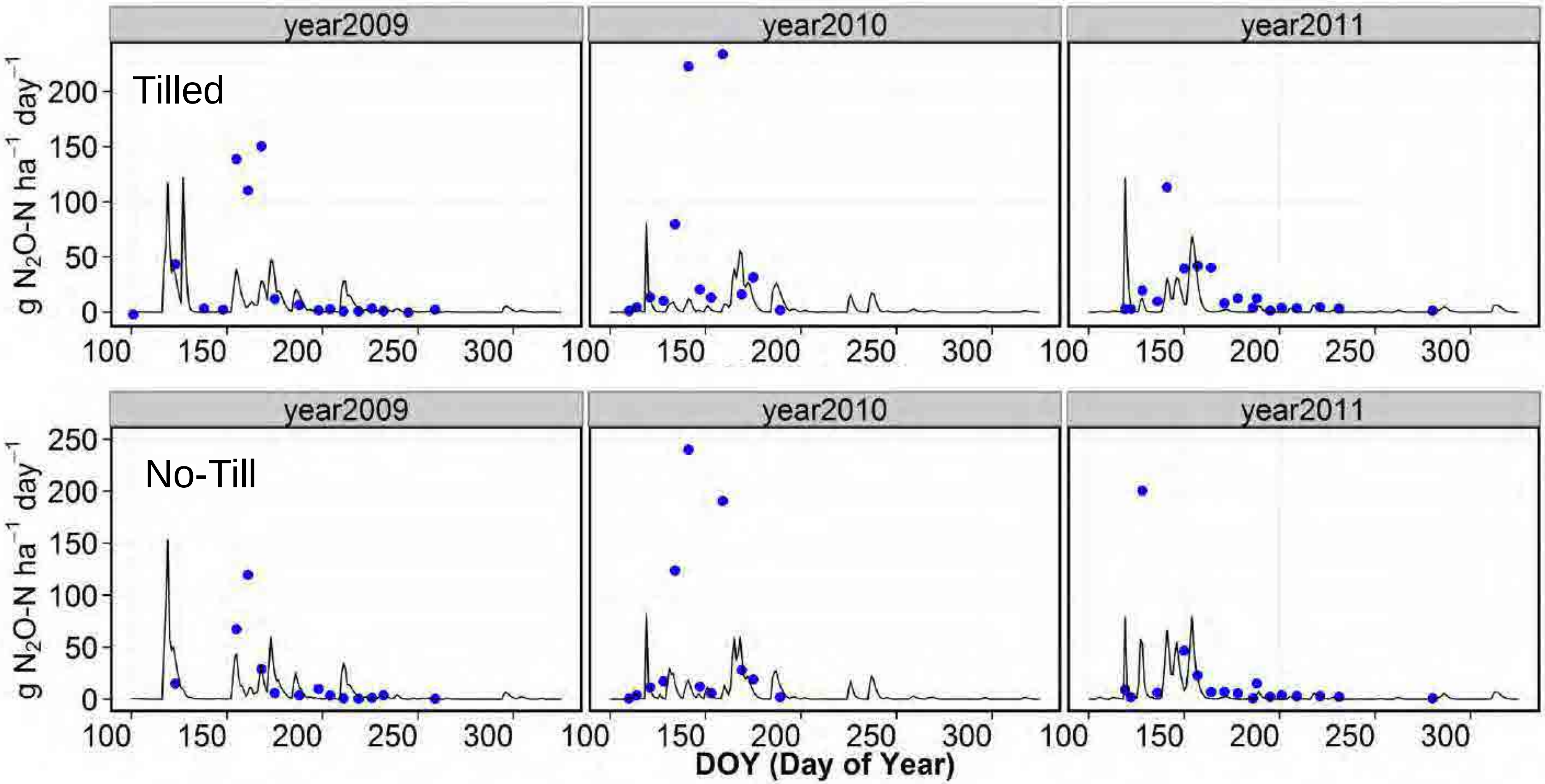
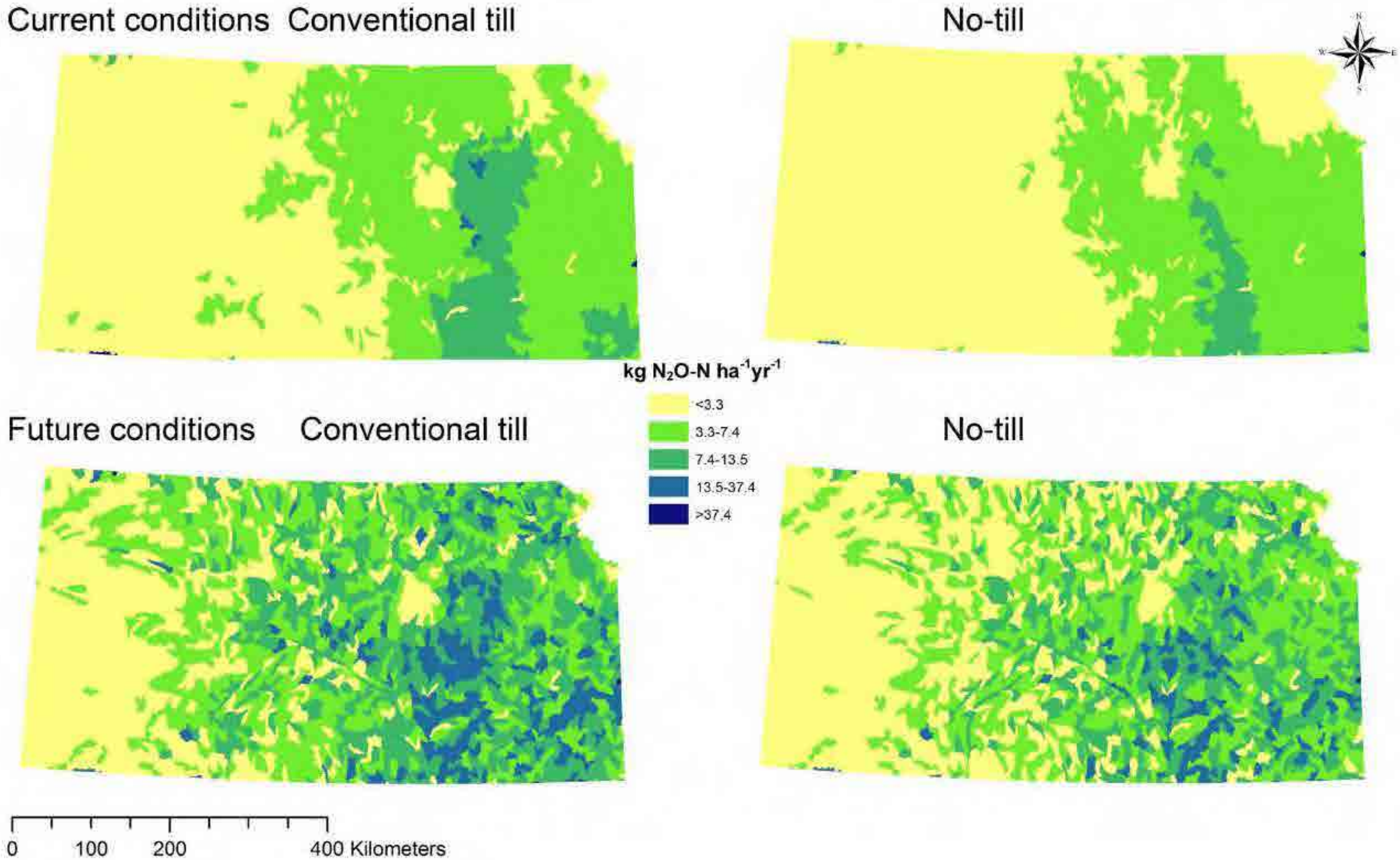


N_2O and NO_3 DNDC simulations : Tillage and Urea (168 kg N ha^{-1})



Regional N_2O simulations: N_2O from non-irrigated corn in Kansas



Summary

- No tillage had no effect on the total N_2O emissions relative to tillage.
- Cumulative N_2O values were significantly lower in Compost than Urea during 2009 and 2010. In 2011, opposite results were observed.
- Banded application of N increased N_2O-N flux with tillage but not no-tillage.
- Management N practices for N_2O reduction did not affect agronomical variables.

Summary

- DNDC predicted changes in N_2O emissions due to management.
  - A challenge to match temporal dynamics at a daily scale.
- N_2O emissions increased due to changes in future climate conditions.
- An overall statewide reductions in N_2O emissions per year (~20%) was simulated when management shifted from tillage to no-tillage..
- No-tillage coupled with practices that promote N-use efficiency such as efficiency-enhanced N fertilizers, reduced N rates, optimized N placement and timing will potentially have a major impact on reducing N_2O emissions.

Acknowledgements

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ON AGRICULTURAL GREENHOUSE GASES

Short presentation

Large peaks of N_2O emissions after grassland restoration

Lutz Merbold
ETH Zurich, Switzerland

Lutz Merbold, Werner Eugster, Jacqueline Stieger, Mark Zahniser and Nina Buchmann

GRA Workshop, 17-19 March, INRA, Paris

Large peaks of N_2O fluxes following grassland restoration

What are the impacts of grassland restoration on the total GHG budget of a managed grassland?

Motivation & Research Question

- (few) grassland studies including the three major GHGs (CO_2, CH_4 and N_2O)

  e.g. Soussana et al. 2007, AEE

- largest uncertainties associated with CH_4 and N_2O emissions across Europe

  e.g. Schulze et al. 2009, Nature-Geoscience

- the effect of grassland restoration on the GHG budget has only poorly been investigated

  e.g. Ball 2013, EJSS

- the eddy covariance technique to estimate CH_4 and N_2O exchange

  e.g. Kroon et al. 2010, AFM

Hypothesis

(1) considerable emissions of N_2O after ploughing and fertilizer application

(2) increased CH_4 uptake due to aeration of the soil after ploughing

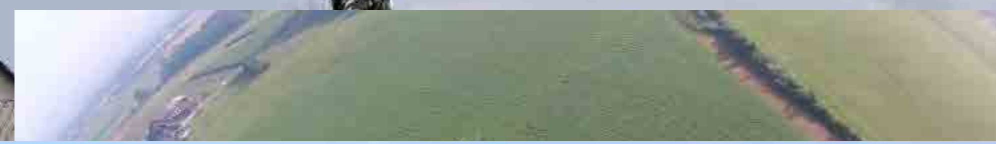
(3) enhanced CO_2 uptake due to re-sowing of the typical species composition and associated higher productivity

Experimental Setup

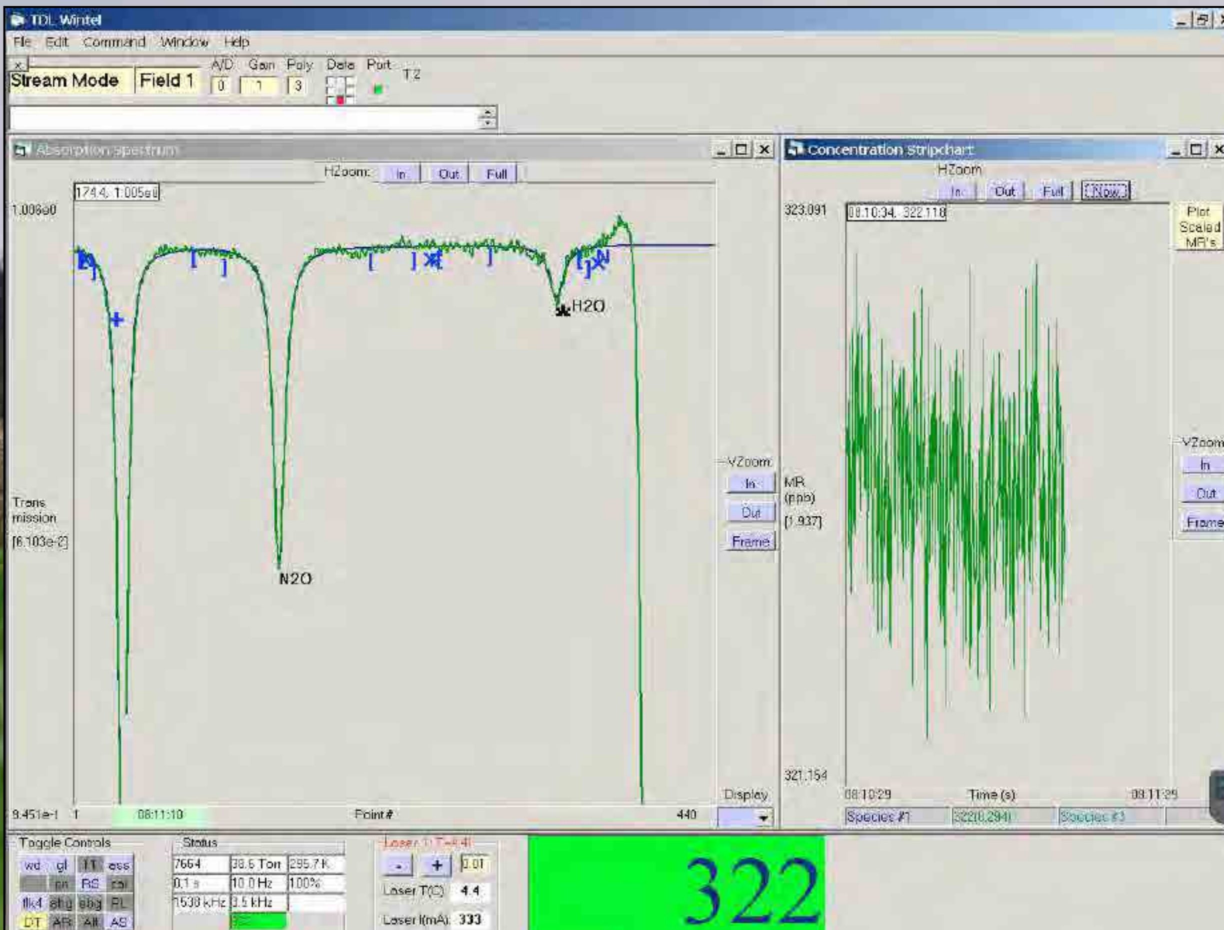
The Chamau (CH-CHA) site is part of the regional network Swiss FluxNet

intensively managed grassland (AFM, Zeeman at al. 2010)

lowlands of Switzerland



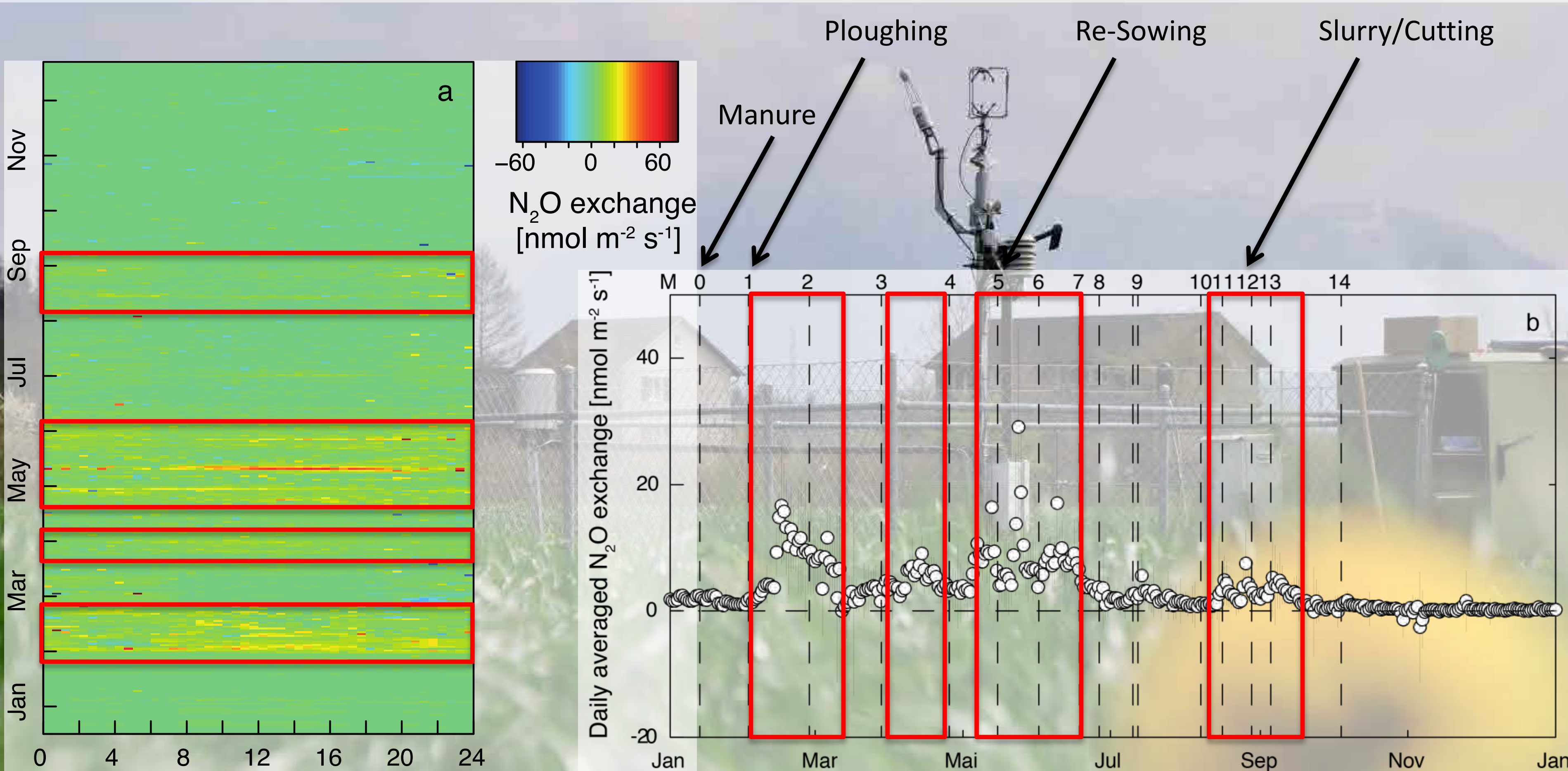
Experimental Setup



Restoration/Management activities

ID	Date	Management	Specification
M0	**13.01.2012**	organic fertilizer	manure application
M1	**02.02.2012**	ploughing	
M2	**28.02.2012**	no management	breakdown of the laser spectrometer
	16.03.2012	no management	restart of the laser spectrometer
M3	**28.03.2012**	harrowing	power harrow
		harrowing	power harrow
		sowing	OH 440 Extra - grass & white clover mixture[a]
	29.03.2012	sowing	OH 440 Extra
		sowing	OH 440 Extra
		rolling	
M4	**25.04.2012**	inorganic fertilizer	calcium ammonium nitrate fertilizer (13.5 % nitrate, 13.5 % ammonium, Flora Düngemittel, Hanweller, Saar, Germany)
		molluscicide	snail bait (Steiner Ultra W-4935, Omya AG, Switzerland)
M5	**15.05.2012**	resowing	

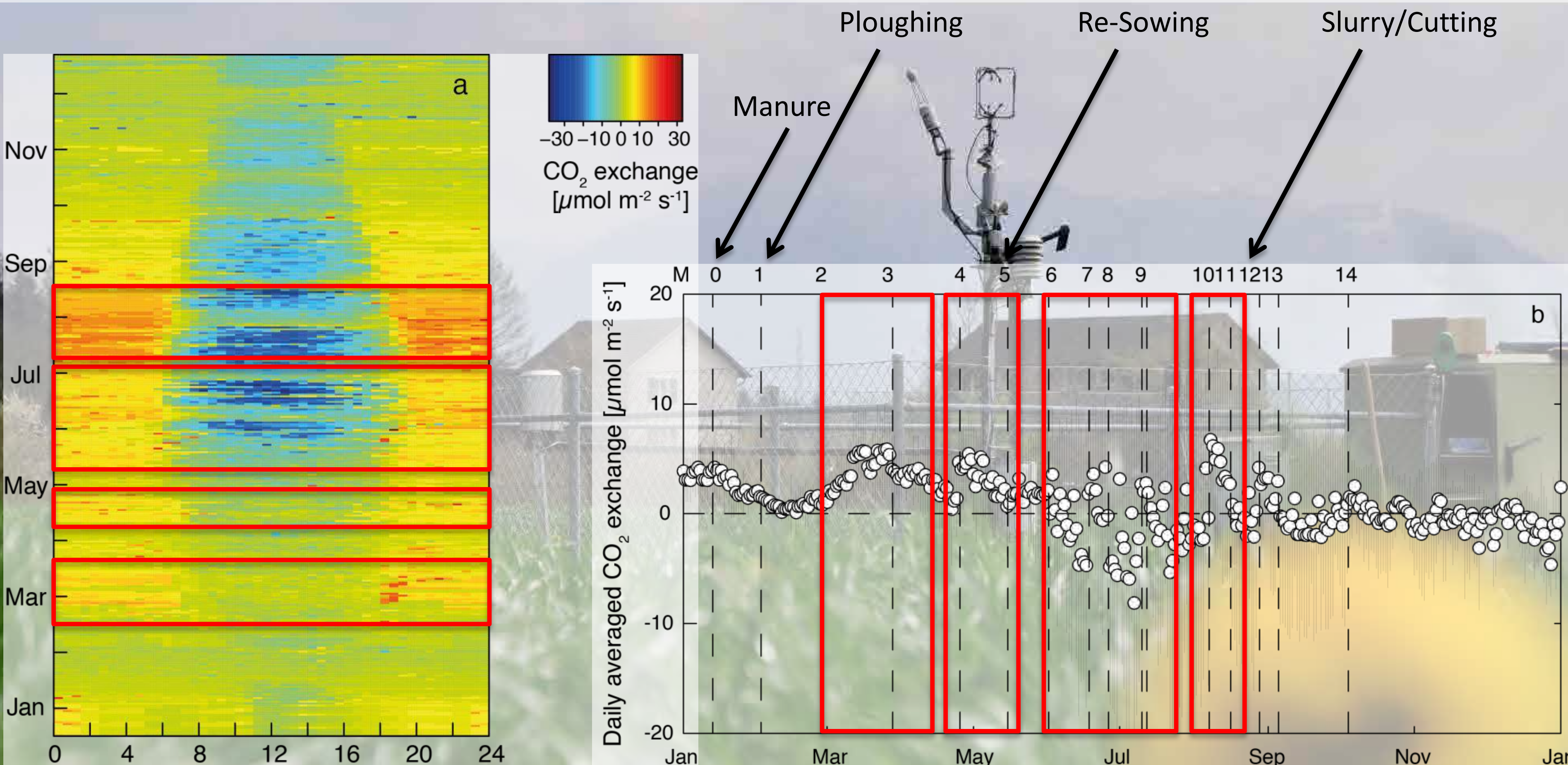
Temporal variation of N_2O exchange



Net ecosystem exchange of nitrous oxide: **(a)** flux fingerprint visualizing gap-filled 30min averaged N_2O fluxes across each day in 2012 in nmol m^{-2} s^{-1},**(b)** daily averaged gap-filled N_2O fluxes (± SD). The vertical dashed lines represent the specific management activities (M0 - M14).

GCB Merbold et al. 2014

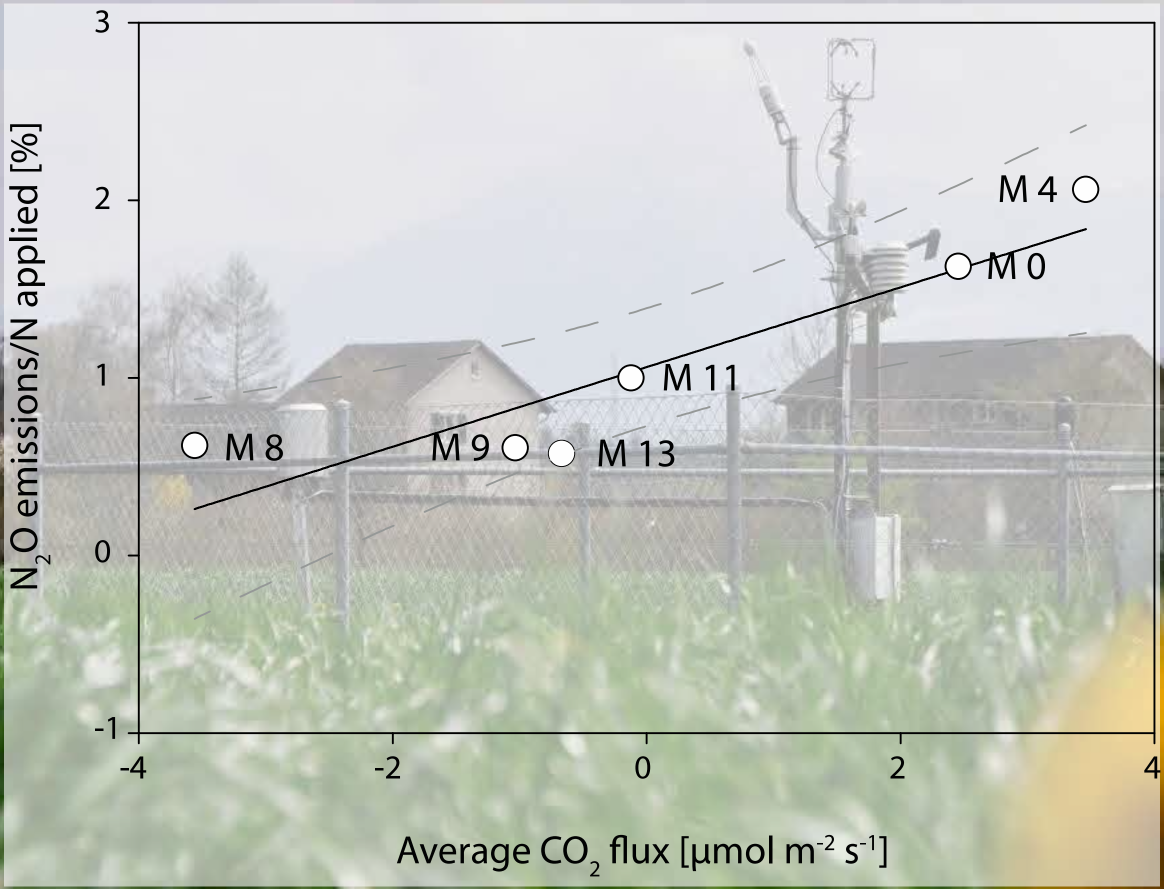
Temporal variation of CO_2 exchange



Net ecosystem exchange of carbon dioxide, **(a)** flux fingerprint visualizing gap-filled 30min averagedCO_2 fluxes across each day in 2012, **(b)** daily averaged gap-filled CO_2 fluxes (± SD). The vertical dashed lines represent the specific management activities (M1 - M14). Negative fluxes indicated net uptake of CO_2 and positive values indicate net release of CO_2.

GCB Merbold et al. 2014

Effects of fertilization on N_2O fluxes vs. plant productivity



Relationship between the ratio of N emissions (N_2O) and N input and productivity (NEE of CO_2) of the grassland for management periods including fertilization. Net ecosystem exchange was used as proxy for plant productivity ($y = 0.22x + 1.06$, $r^2 = 0.78$). More negative values indicate a larger photosynthetic flux compared to the respiratory flux.

GCB Merbold et al. 2014

Total GHG budget of the site in 2012

- 339 g CO_2-C, 2.65 g CH_4-C and 2.91 g N_2O-N m^{-2}
- 1245 g CO_2-eq., 243 g CO_2-eq. and 1363 g CO_2-eq. m-2 **2851 g CO_2-eq.**
- 44 % (CO_2) , 8 % (CH_4) and 48 % (N_2O) contribution to the total budget

Results vs. Hypothesis

(1) Larger N_2O fluxes after fertilization

-> partly true, time lags

(2) Increased CH_4 uptake after ploughing due to aeration

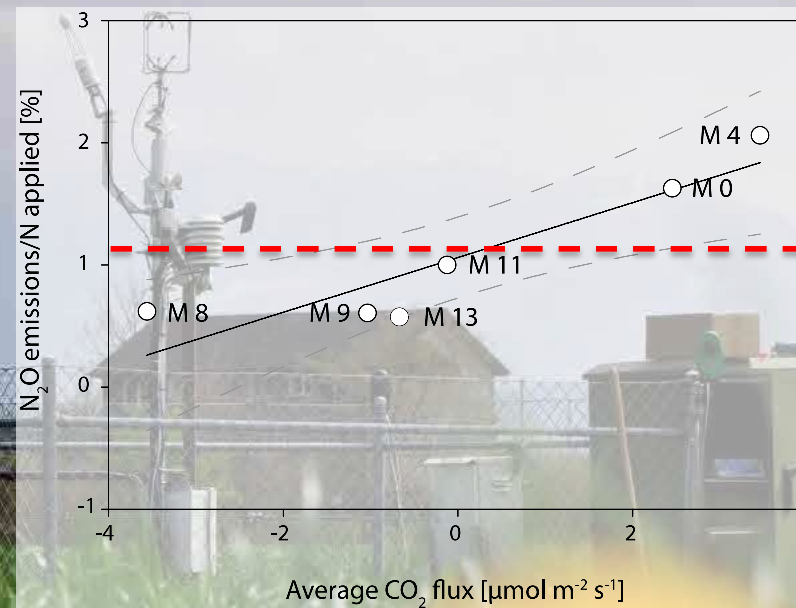
-> CH_4 efflux instead of uptake

(3) Larger productivity after re-sowing

-> environmental conditions vs. management

Implications for national GHG inventories and future research

- IPCC (2007) emission factor for N_2O emissions is 1.25 % of the applied N
- The Swiss National GHG inventory calculates with 1.1 % of the applied N



but (2012 as a whole year)

N application:	**197.1 kg ha^{-1} + >100kg ha^{-1} from ploughing**
N loss via N_2O:	**29.1 kg ha^{-1}**
EF:	**≈ 10 %**

Implications for national GHG inventories and future research

- The site used to be carbon sink of 60 to 70 g CO_2-C m^{-2} in 2006 and 2007

  Zeeman et al. 2010, AFM

- The site lost 339 g CO_2-C m^{-2} in 2012

  Merbold et al. 2014, GCB

- approx. 5 years of C gain are needed to offset the loss from restoration

- including N_2O and CH_4, 10 years as an approximate interval for grassland restoration in Switzerland are insufficient to compensate the losses of C after ploughing.

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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

Short presentation

Validation of the DNDC model in order to simulate nitrous oxide emissions and soil carbon changes from the Prairie-Pothole (PPR) region of North Dakota following conversion to agriculture

Emma C. Suddick, Eric A. Davidson
Woods Hole Research Center, USA

Prairie Pothole Region

http://www.npwrc.usgs.gov/resource/wetlands/pothole/prairie.htm

- **Formed through glacial deposits , PPR region covers an area of over 900,000 km^2.**
- **Globally recognized as a critically important wetland and grassland habitat region for many species of birds .**
- **Experiencing losses in habitat due to intensification of agriculture .**

Scope of Study

- Study ***motivation***
  - Future intensification of agriculture in the PPR region may lead to a loss of an important wildlife habitat, which is also an important sink of SOC.
  - Conversion will result in a loss of carbon to the atmosphere.
- Study ***objectives***
  - Validate the DNDC model and its ability to predict SOC losses from native prairie conversion to agriculture.
  - As well as predicting greenhouse gas emissions under business as usual (BAU) scenarios at the site specific scale.

DNDC Model Input Parameters

DNDC initial input data	Site H5 – Alfalfa	Site P23 – Prairie
Climate data		
Latitude	46.7667	46.7699
Annual average daily minimum temperature (°C)	-0.8	-0.8
Annual average daily maximum temperature (°C)	11.1	11.1
Annual average Precipitation (mm)	1.3	1.3
Soil properties		
Soil texture / type/ order	Silt loam / Temvik-Wilton / Mollisols	Clay loam / Temvik-Wilton / Mollisols-urdolls
Bulk density (g cm^{-3})	1.36	1.100
pH	5.72	5.33
Surface SOC (kg C kg^{-1})	0.019	0.033
Soil C:N	-	12.1
Clay fraction (%)	30-35 %	8.0 %
Slope	0-3 %	0-3 %
Management practices		
Cropping system	Alfalfa cropping field	Native prairie grassland
Years in a cropping cycle	5 total, year 1 planted in 2009	Continuous
Yearly average biomass (kg dry matter ha^{-1})	7500	3500
Tillage depth (cm)	0	0
Fertilizer amount (kg N ha^{-1})	8.41	0
Number of fertilizer applications	1 (surface application)	0

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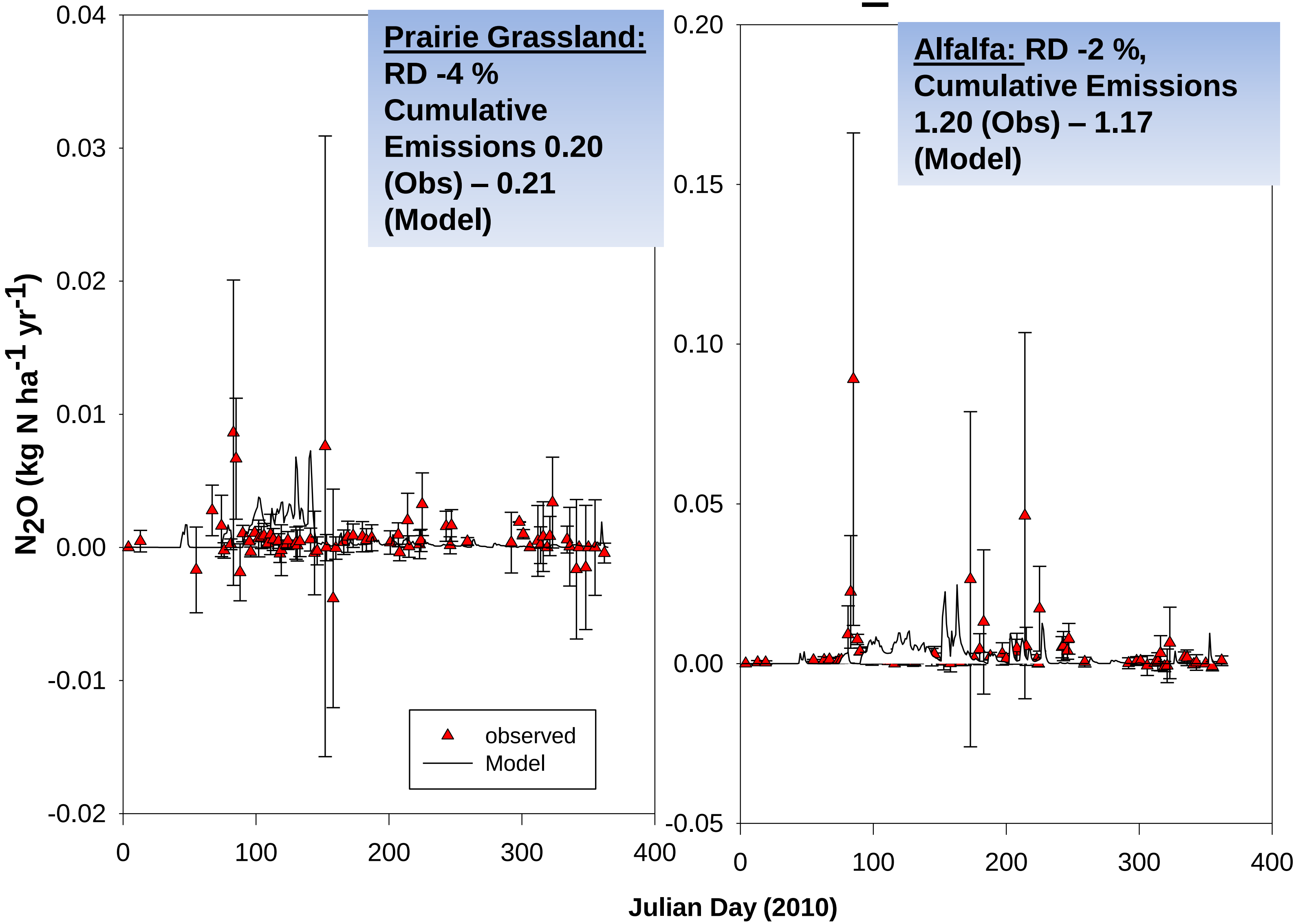
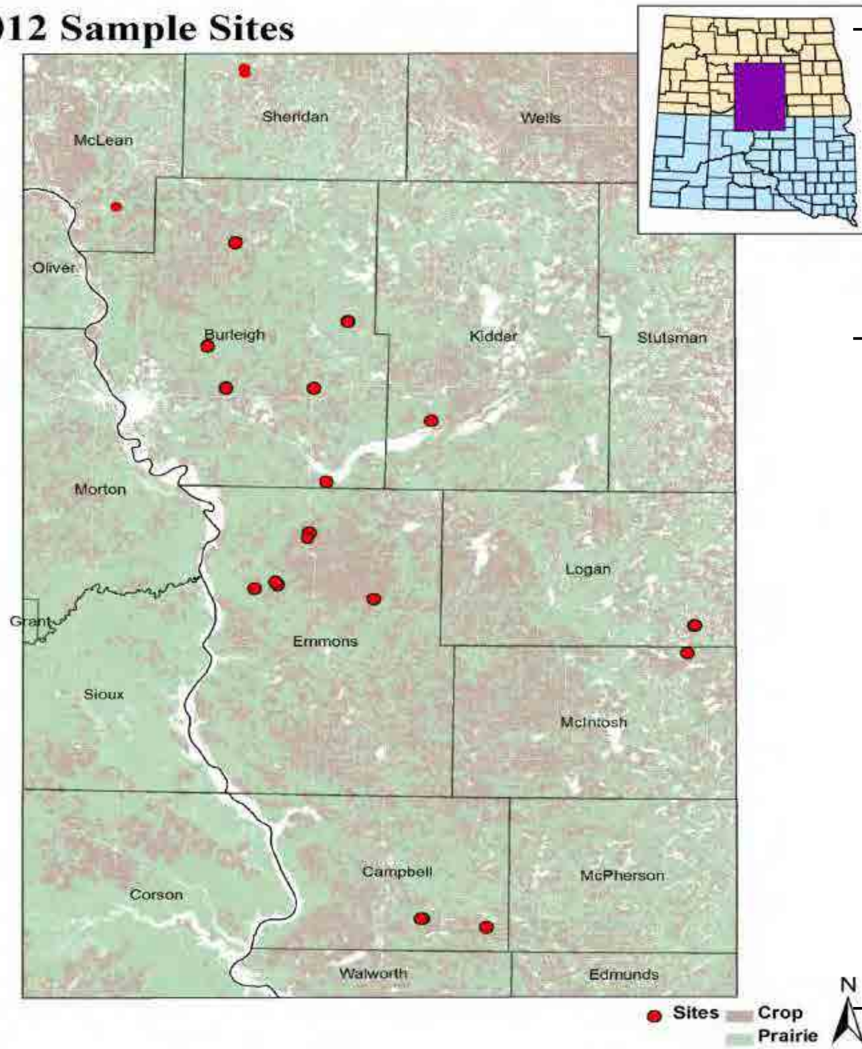
Emissions of N_2O



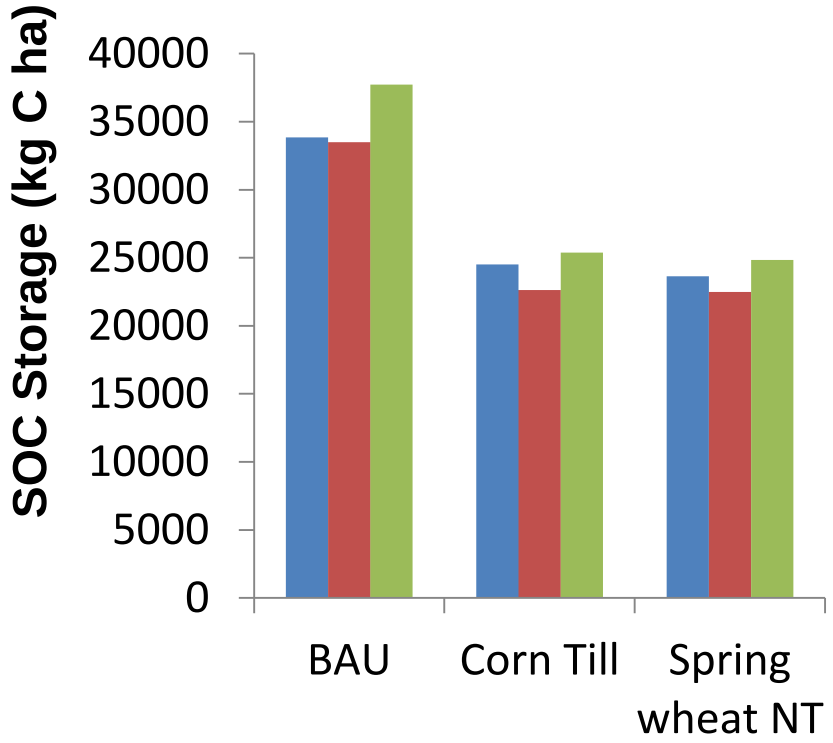
Future land conversion of Prairie systems

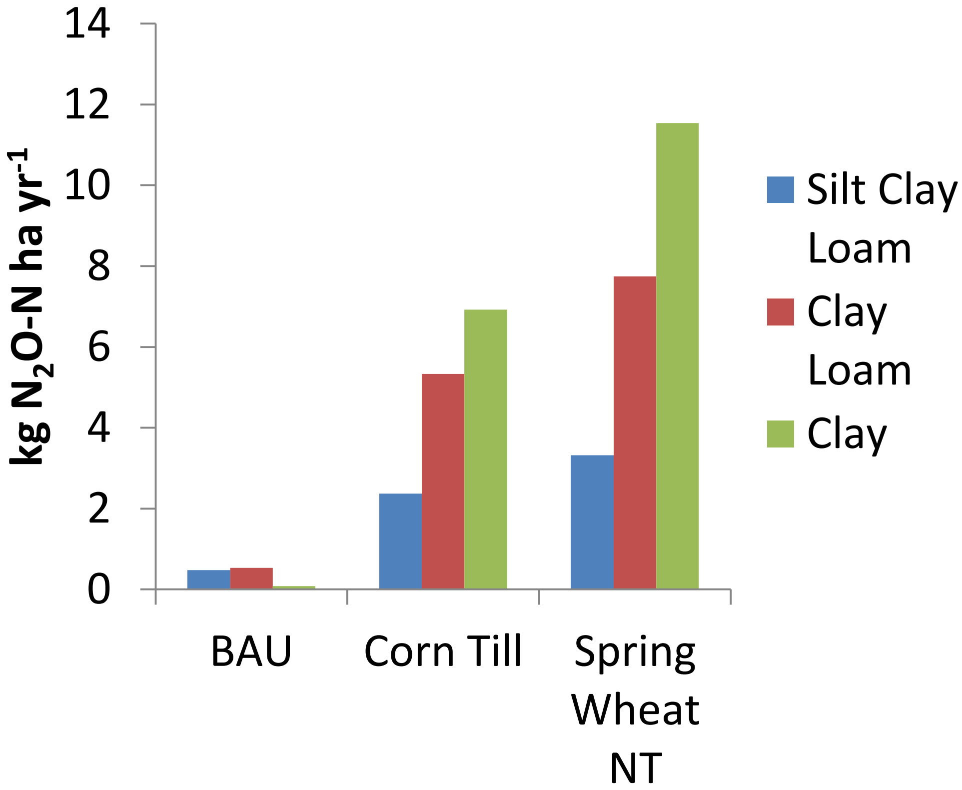
2012 Sample Sites



Rotation Scenario	Crop Sequence	Management practices (based on cost and return studies and typical production practices for the region)	Nitrogen fertilizer amounts (lbs/acre)
BAU	Native Prairie – no change	**None**	None
CORN	Native Prairie to Corn	**Crop terminating tillage to plant corn with** pre, plant and post plant fertilization with urea	0-60
SPRING	Native Prairie – spring wheat	**No Till operations** – direct seed with pre, plant and post broadcast fertilizer with urea.	0-100

Simulated Initial Loss of SOC & N_2O After Prairie Conversion to Cropland





Summary

- DNDC shows consistent seasonality for N_2O when compared to observed data, fluxes are slightly overestimated by the DNDC in prairie systems and underestimated in alfalfa. Better fit with alfalfa compared to native prairie.

- Approximately 30 % of SOC could be initially lost following conversion of native prairie to cropland, regardless of soil texture class or cropping system scenario. Similar results were found between 20-50% for this region (Leibig et al. 2005).

- Emissions of N_2O were increased following conversion in both the corn and the spring wheat rotations, most likely due to increase in N fertilizer use. Greater emissions in spring wheat likely due to greater input of N. Further studies and modeling needed to separate out impacts of N and tillage on emissions and to represent changes in soil structure with tillage.

- Longer term model simulations to understand the extended impact on SOC storage and GHG emissions.

- Field data on tillage practices are needed to validate model further after conversion of prairie to agriculture – real world situations.

Thank you
Any Questions?

Acknowledgments

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