

# **Multiple environmental factors interact to affect wet grassland greenhouse gas (GHG) fluxes**

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## **Ecosystems – multifactorial context:**

- direct and indirect effects
- need for multifactorial studies – few done
- realistic picture of ecosystem response

## **Complex systems**

## **GHG fluxes:**

- affected by biological processes
- interact with abiotic factors

## **Aim:**

- determine how multiple environmental factors may affect GHG fluxes both singly and due to their interactions
- importance of indirect effects

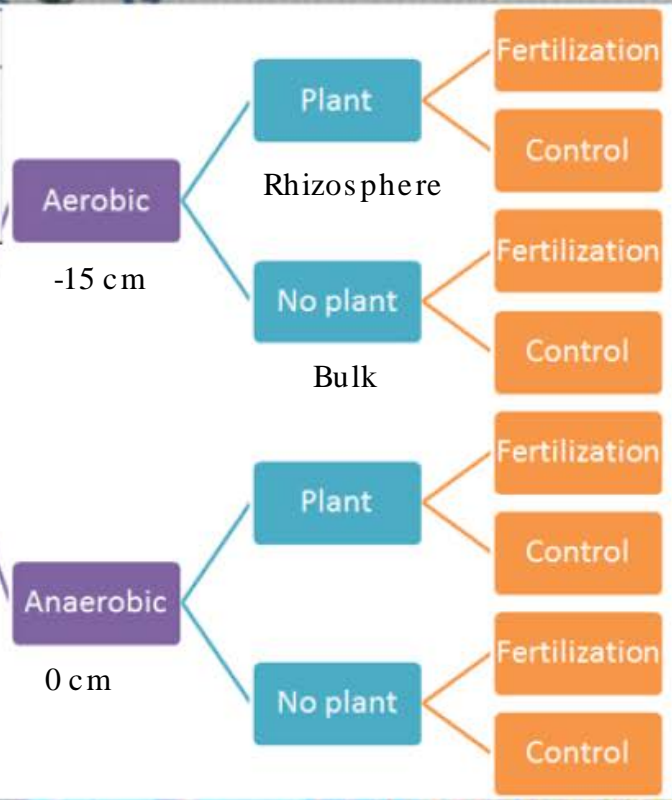


Initial chemical analyses		
	mineral soil	peat soil
Ctot (mg/g)	12,7	139,0
Ntot (mg/g)	0,6	5,4
Ptot (mg/g)	0,4	0,4
C/N	22	26
C/P	32	344
pH (KCl)	5,8	3,9
pH (H2O)	6,1	4,5

**Soil**  
(peat, mineral)

Cambisol +/-  
peat addition

2009-2013



= 300 kg NPK \* ha<sup>-1</sup> \* yr<sup>-1</sup>

= 0 kg NPK \* ha<sup>-1</sup> \* yr<sup>-1</sup>



**Mesocosm:**

- more control
- connections

**Abiotic factors:**

- soil type
- water level
- nutrient addition
- full factorial

With / without plants  
*Carex acuta*

**Four harvests:**  
March, May,

July, October



## **Analyses:**

- soil physico-chemical**
- plant biomass / production**
- soil microbial composition (qPCR)**
- GHG fluxes**

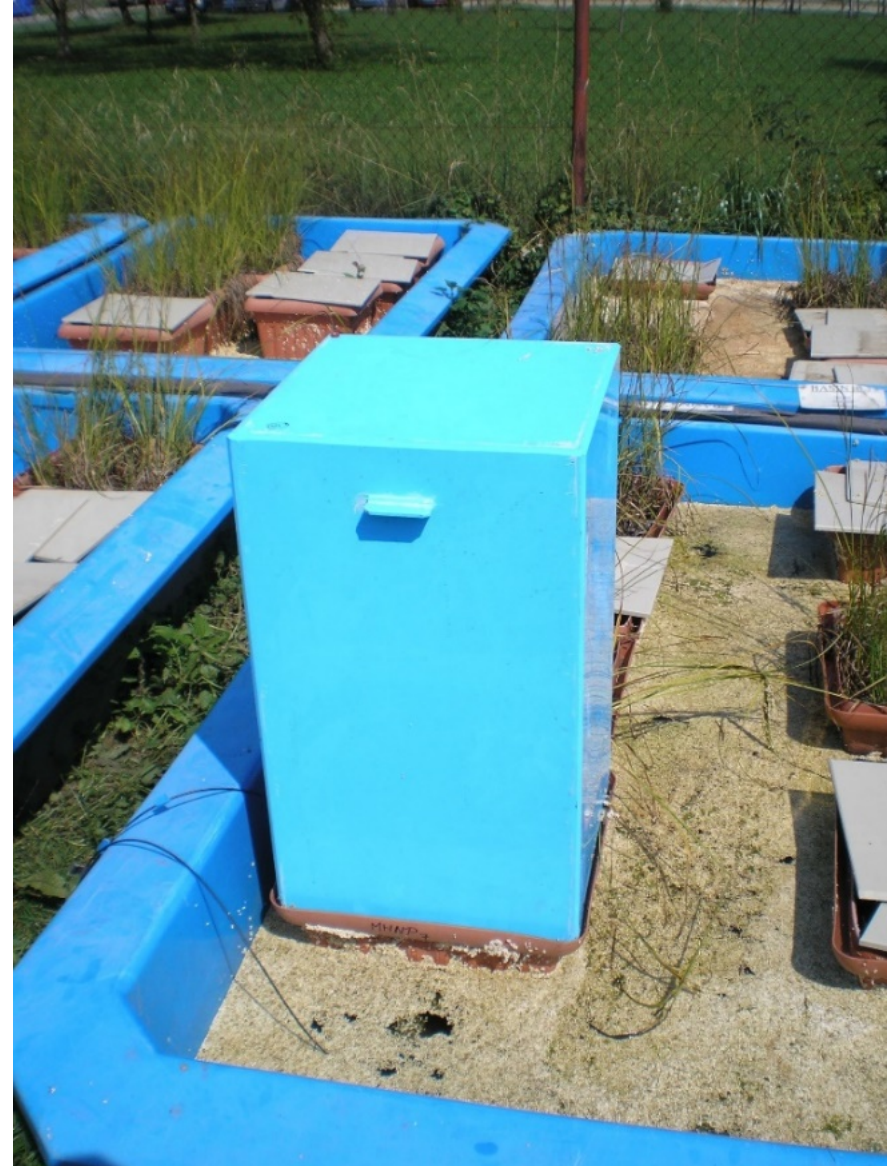


## GHG fluxes – static chamber



### Measured:

- autotrophic and heterotrophic respiration ( $R_{\text{ECO}}$ )
- methane ( $\text{CH}_4$ ) / nitrous oxide ( $\text{N}_2\text{O}$ ) emissions





## **Analyses:**

- plant biomass / production**
- soil physico-chemical**
- soil microbial composition (qPCR)**
- GHG fluxes**

## **Data analyses:**

- univariate – GLMM**
- SEM**

# Results

## Plants

Factor	Soil	Water	Fert	Season	S*W	S*F	W*F
Above Live, DW			F>UF ***	J>My>O>Mr ***			**
Above Dead, DW	O>M *	+	F>UF ***	My>O>Mr>J *			+
Below Live, DW			F>UF ***	+			
Below Dead, DW				J>O>My>Mr ***			
A:B			F>UF ***	J>My>O>Mr ***			
NAPP		+	F>UF **	-----			
NBPP	O>M **		F>UF ***	-----		*	

## Soil

Factor	Soil	Water	Fert	Plants	Season	S*W	S*F	S*P	W*F	W*P	F*P
pH, H <sub>2</sub> O	M>O ***		UF>F ***	UV>V ***	+	***	**	**		+	
Soil Respiration	O>M ***		F>UF *	V>UV ***	Mr>O>J>My ***	**		**			***
NO <sub>3</sub>	O>M ***	LW>HW **	F>UF ***	UV>V ***	Mr>O>J>My ***				**	+	**
NH <sub>4</sub>		HW>LW ***	F>UF *	UV>V ***	Mr>O>J>My **					***	
TSN	O>M ***	HW>LW ***	F>UF ***	UV>V ***	Mr>J>My>O ***				*	***	+
C <sub>extr</sub>	O>M ***	LW>HW **	F>UF ***	V>UV ***	O>J>Mr>My ***	***	*	***	*		
C <sub>mic</sub>	O>M ***	LW>HW *		V>UV ***	Mr>My>O>J ***	**					
N <sub>mic</sub>	O>M ***		F>UF ***							***	*

## Microbes

Factor	Soil	Water	Fert	Plants	Season	S*W	S*F	S*P	W*F	W*P	F*P
Bacteria (archaea+bacteria)	O>M*	LW>HW ***		V>UV*						***	
Fungi	O>M***	LW>HW*	+	V>UV**	Mr>My>J>O*	+				+	
B/F	M>O***			UV>V**	—	+				+	
Methanogens	M>O***	HW>LW ***		UV>V**	O>J>My*			*			

## GHG Fluxes

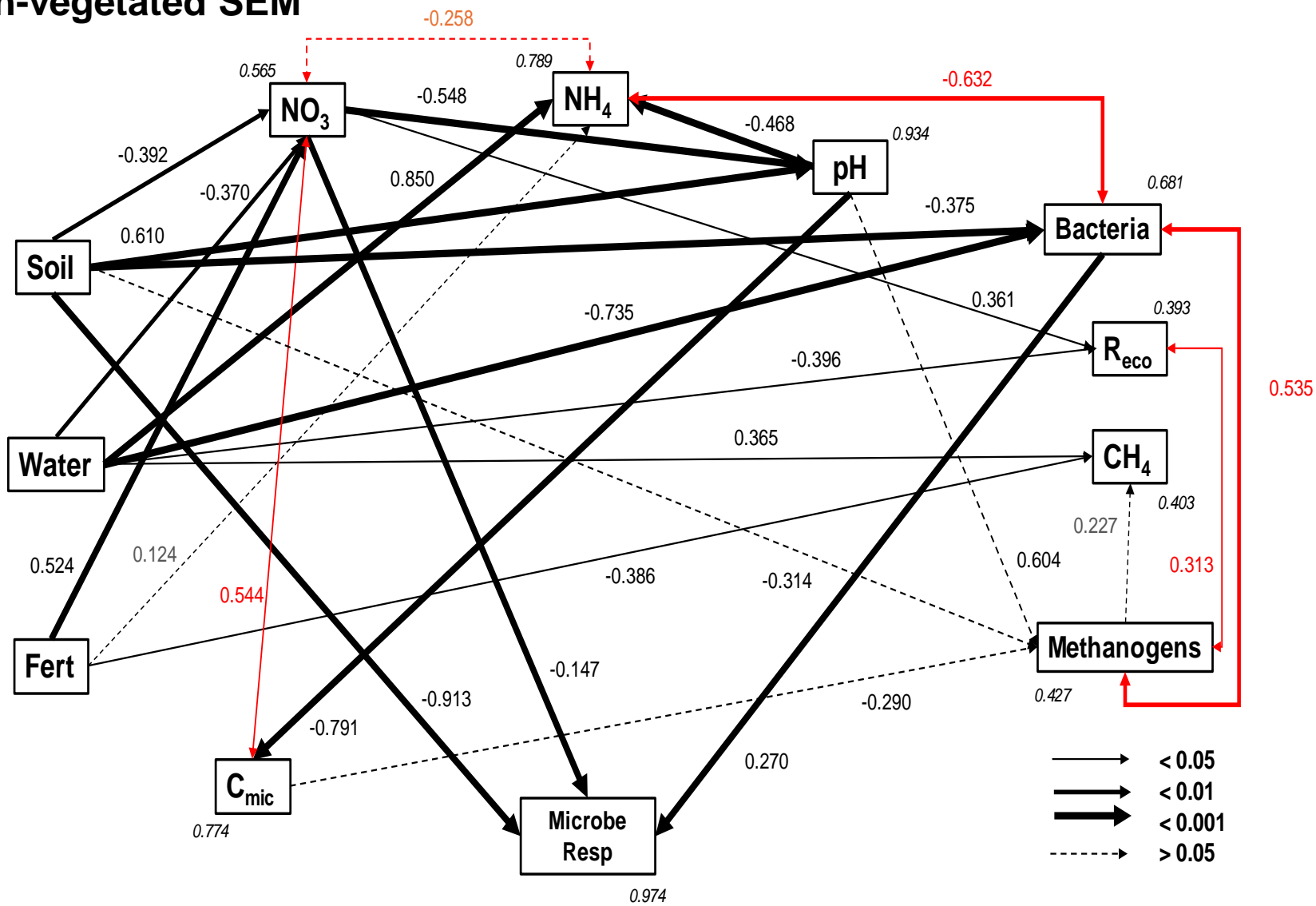
Factor	Soil	Water	Fert	Plants	Season	S*W	S*F	S*P	W*F	W*P	F*P
R <sub>ECO</sub>		LW>HW **	F>UF***	V>UV***	J>My>O ***					**	**
CH <sub>4</sub>		HW>LW ***	UF>F **	V>UV***	J>My>O ***			***	*	**	

CO<sub>2</sub> = 81.7% GWP

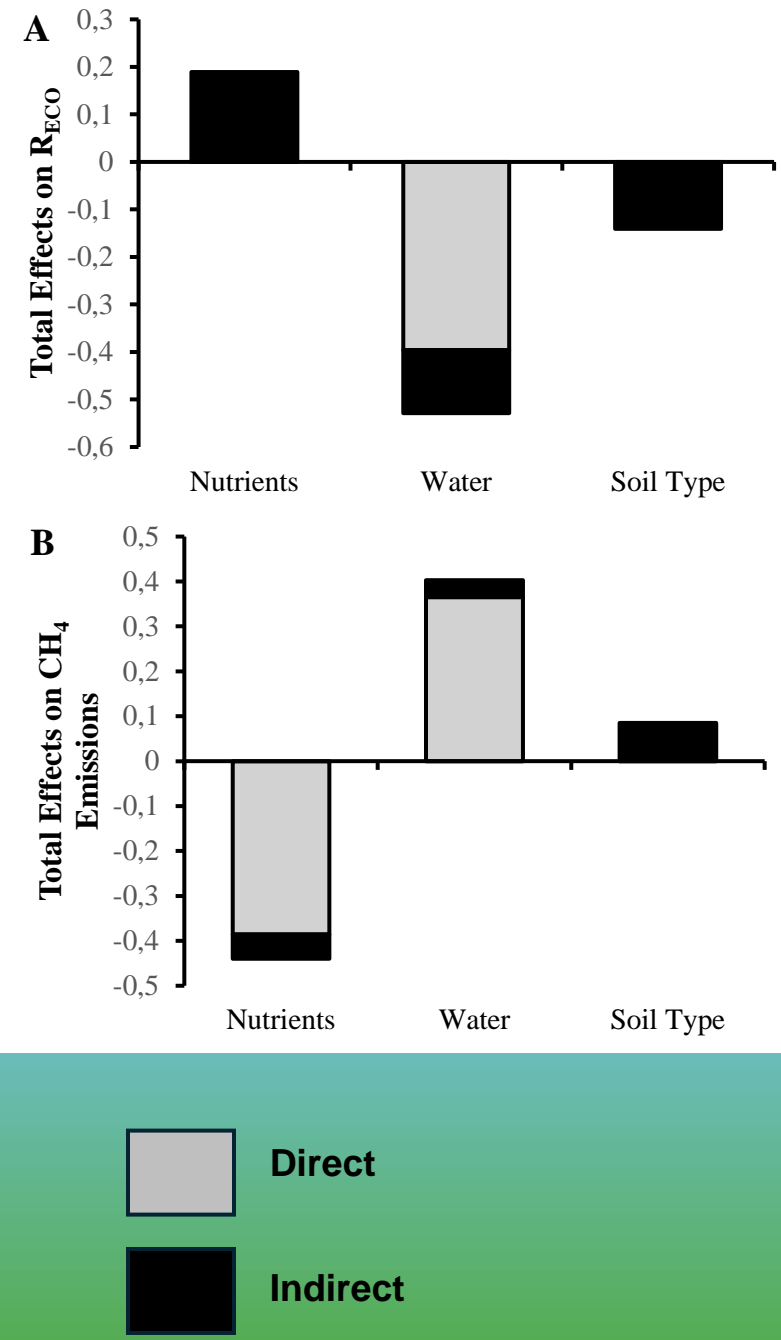
No N<sub>2</sub>O emissions – below background atmospheric levels



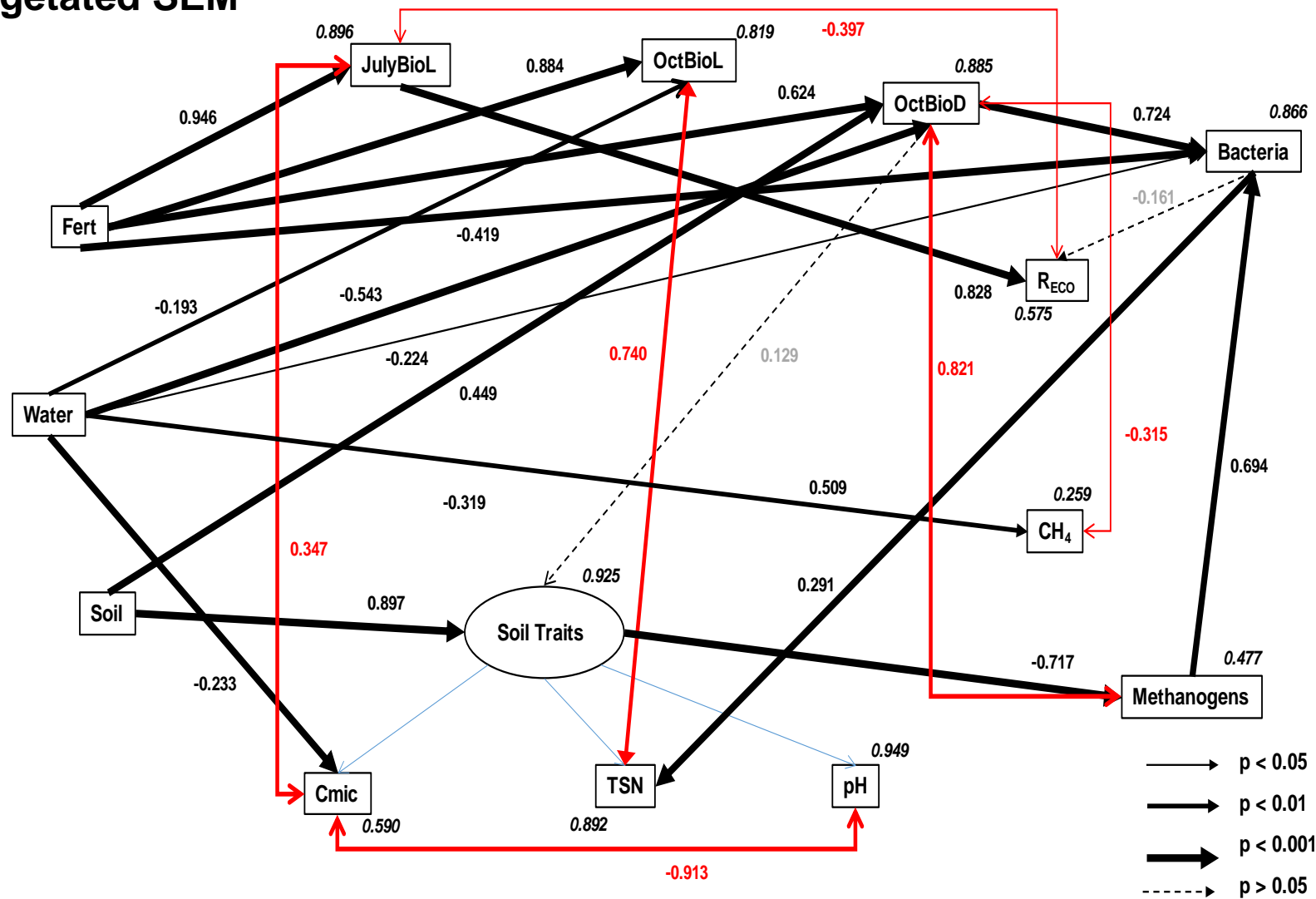
# Un-vegetated SEM



$\chi^2 = 36.006$  RMSEA = 0.001  
 $p = 0.607$   $p = 0.695$   
AIC = 114.006

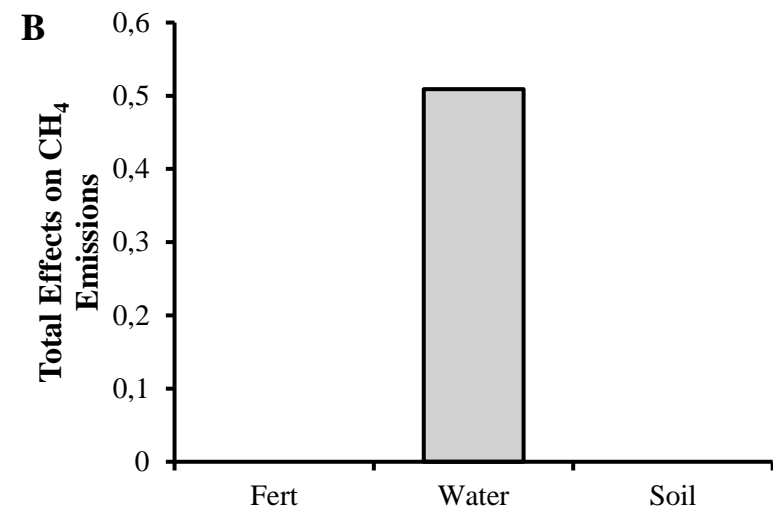
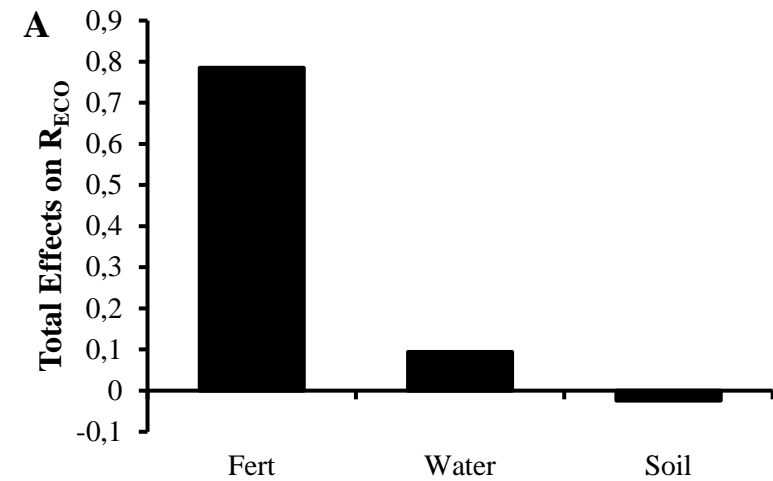


# Vegetated SEM

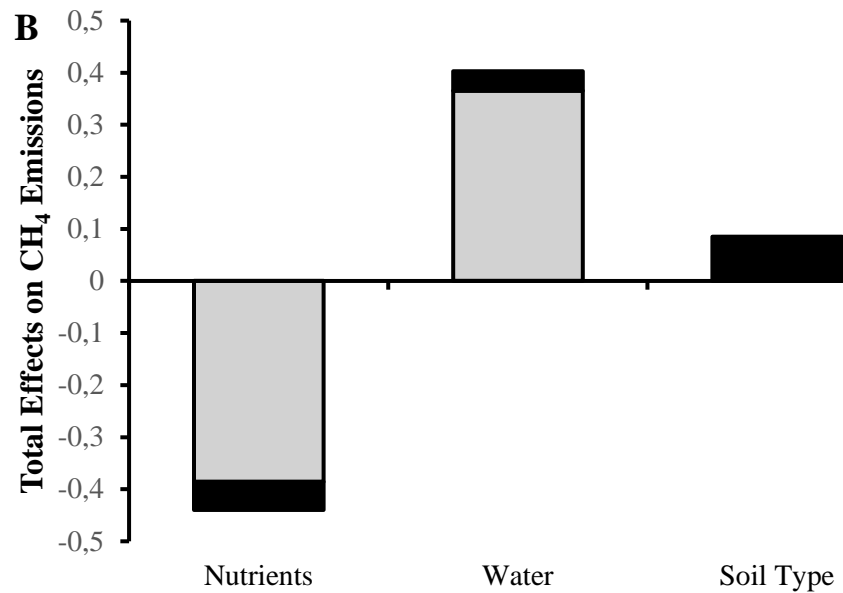
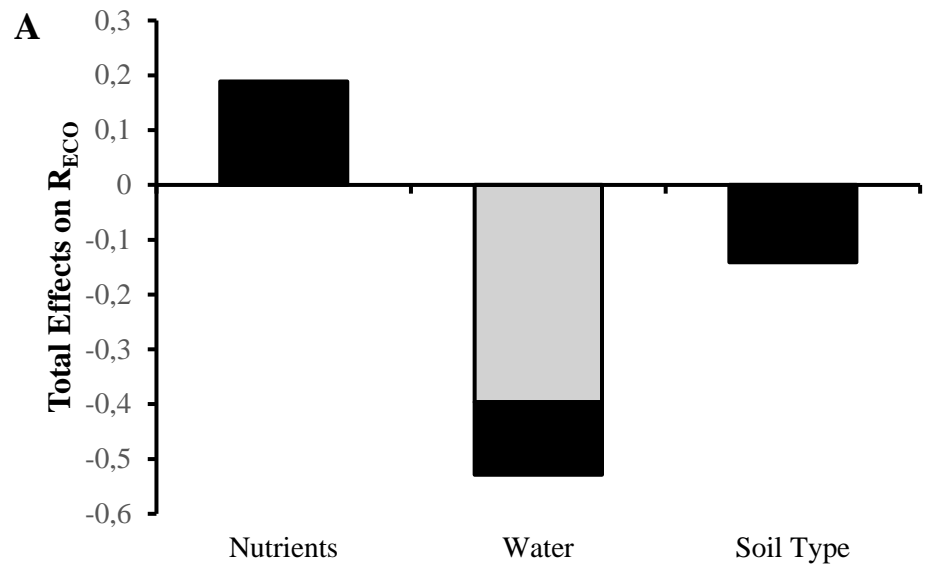


$\chi^2 = 51.720$   
 $p = 0.446$   
AIC = 131.720

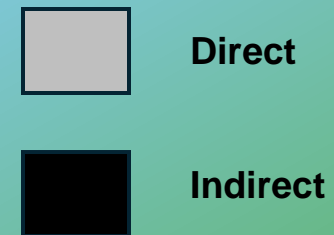
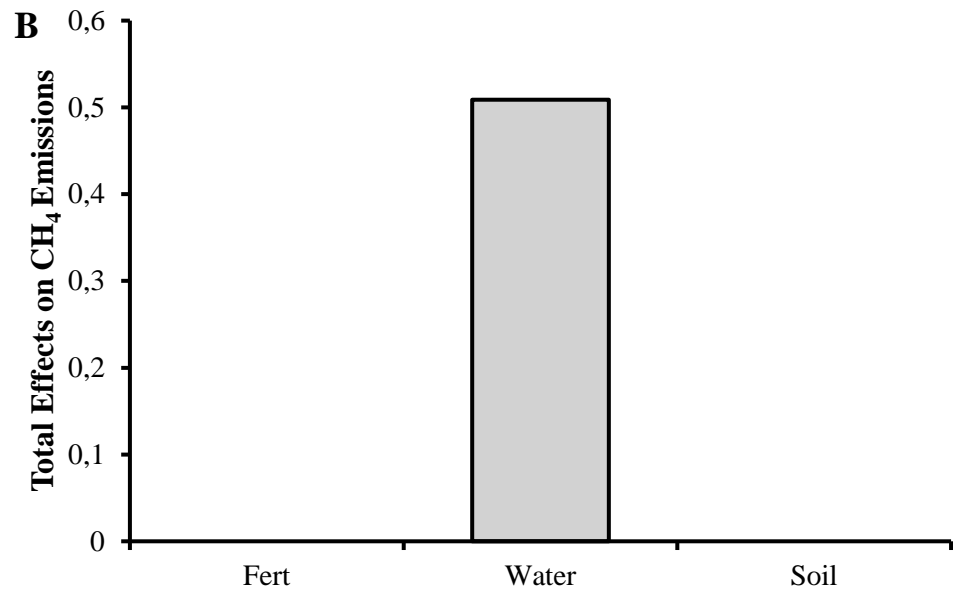
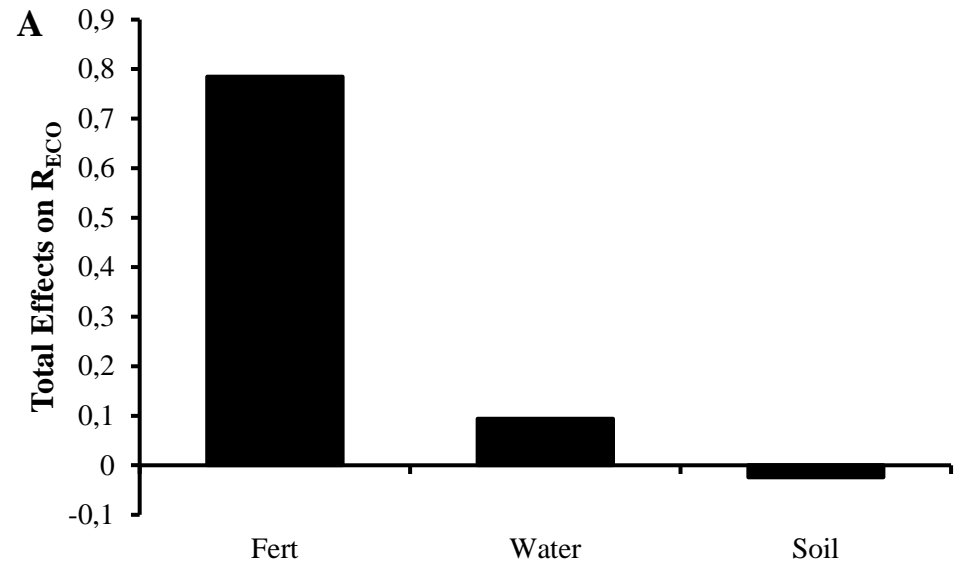
RMSEA = 0.025  
 $p = 0.557$



## Un-vegetated



## Vegetated







## Conclusions

1. Environmental factors affect GHG fluxes
  - direct water level effect – expected
    - LW increased respiration
    - HW increased  $\text{CH}_4$  emissions
  - nutrient addition:
    - direct impact  $\text{CH}_4$  emissions (un-vegetated)
    - indirect effect through plants /  $\text{NO}_3$ 
      - more important
  - soil type:
    - impact soil physico-chemical properties – indirect effects
2. Plant effects:
  - plant-soil interactions
    - root exudates increasing microbial biomass C
    - higher quality litter
      - priming effect
  - aerating rhizosphere (ROL)



## Conclusions

### 3. Environmental effects:

- single, additive effects
  - nutrients (plant biomass)
  - hydrology, plant presence (soil microbial abundance)
- interactions:
  - more effect on soil properties, GHG fluxes
  - soil\*water; soil\*plant; water\*plant

### So what?

- complex, integrated system
- change one factor has larger effects
- wet grasslands not major CH<sub>4</sub> source
- land use / management changes – large impacts



## Conclusions

### Management implications

- climate change – warmer, drier future
- decreased plant production
- greater allocation belowground (mineral)
- changed quantity / quality of plant inputs
- impact soil microbial structure / functions
- increase water supply - lower GHG but not if fertilized

### Plants important component

- management should increase plant cover and growth

**Managers – focus on factors that most increase system resilience**



# **Thank you for your attention**

**Now a major published article!!**

**Edwards et al. 2025. Ecological Engineering  
212: 107511.**

# Factors related (r) to GHG fluxes

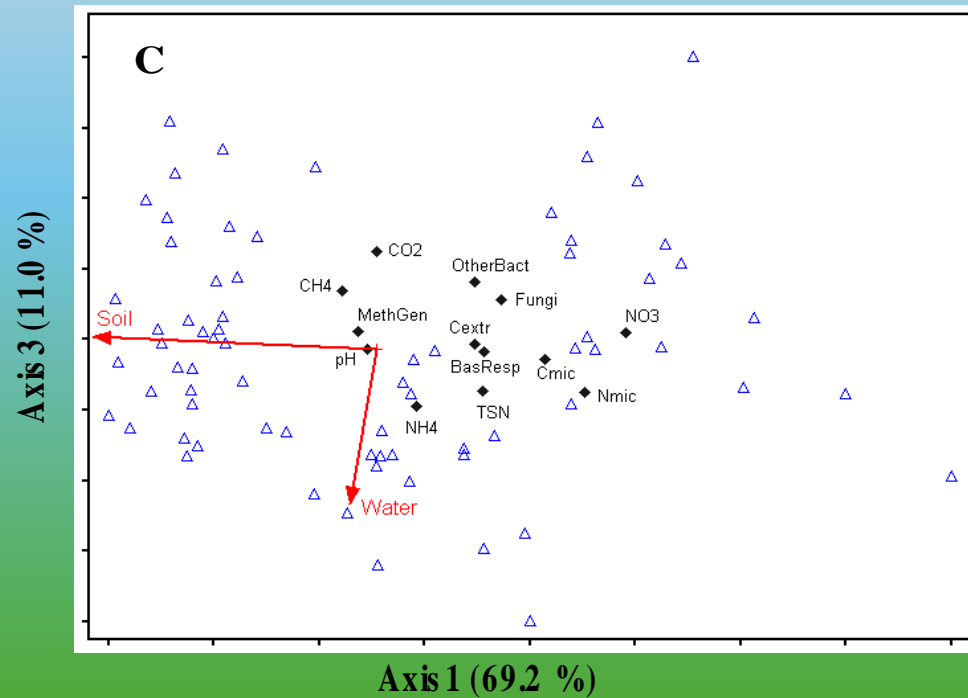
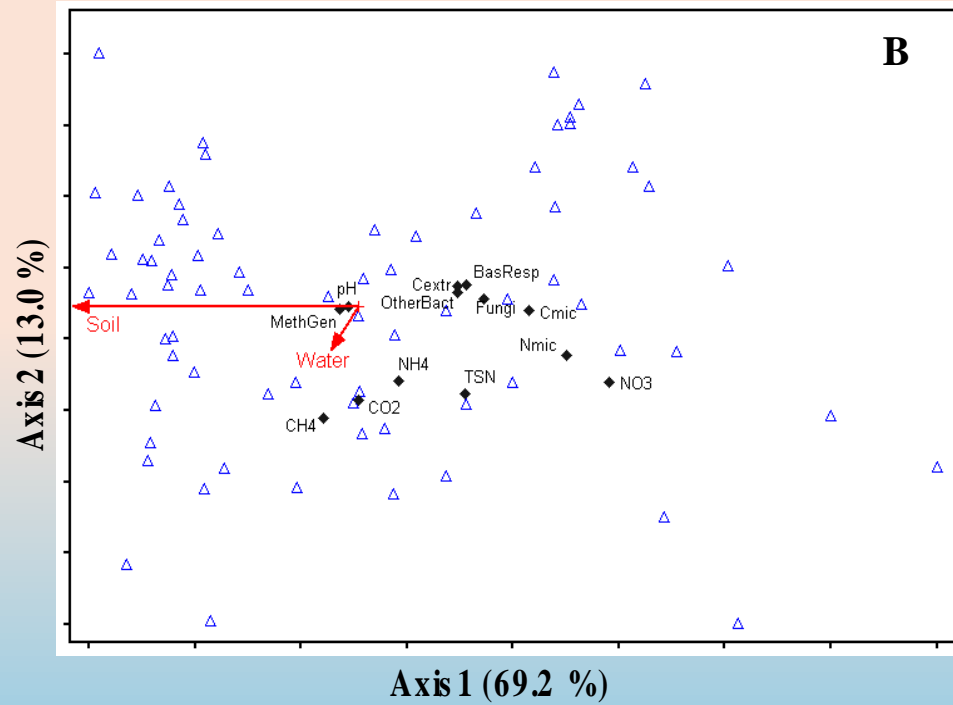
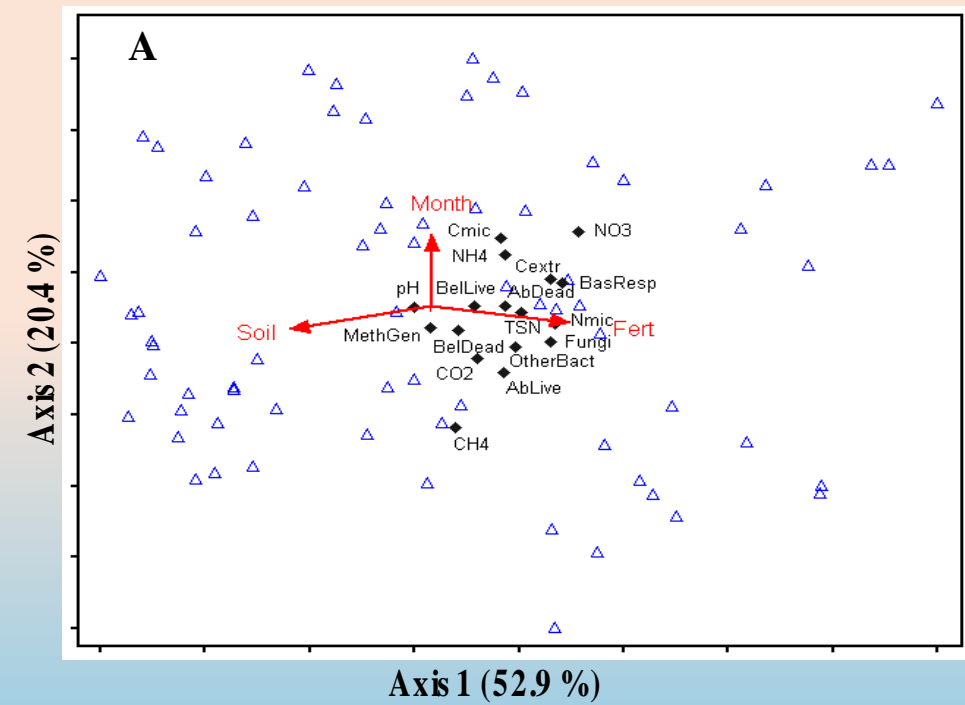
	AboveL	AboveD	BelowL	BelowD	pH	Res p	C <sub>mic</sub>	N <sub>mic</sub>	C <sub>extr</sub>	NO <sub>3</sub>	NH <sub>4</sub>	TSN	Bact	Fungi
R <sub>ECO</sub>	0.531***	0.237+			-0.251*									
May	0.495*													
July	0.483*		0.594**		-0.485*			0.439*			0.455*			
Oct			0.446*			0.431*			0.427*					
CH <sub>4</sub>	0.476***			0.284*			-0.410***			-0.248*				
May														
July														-0.503*
Oct														

Vegetated

Un-vegetated

Significance: \* < 0.05;  
\*\* < 0.01;  
\*\*\* < 0.001;  
+ < 0.10

	pH	Res p	C <sub>mic</sub>	N <sub>mic</sub>	C <sub>extr</sub>	NO <sub>3</sub>	NH <sub>4</sub>	TSN	Bact	Fungi
R <sub>ECO</sub>						0.281*			0.268*	0.218+
May						0.340+				
July									0.437*	
Oct						0.343+				
CH <sub>4</sub>					-0.241*					
May										
July	0.365+			-0.360+						
Oct						0.360+				



**NMS results:**

**A – vegetated**

**B, C – un-vegetated**