Are there memory effects on greenhouse gas emissions following grassland restoration?

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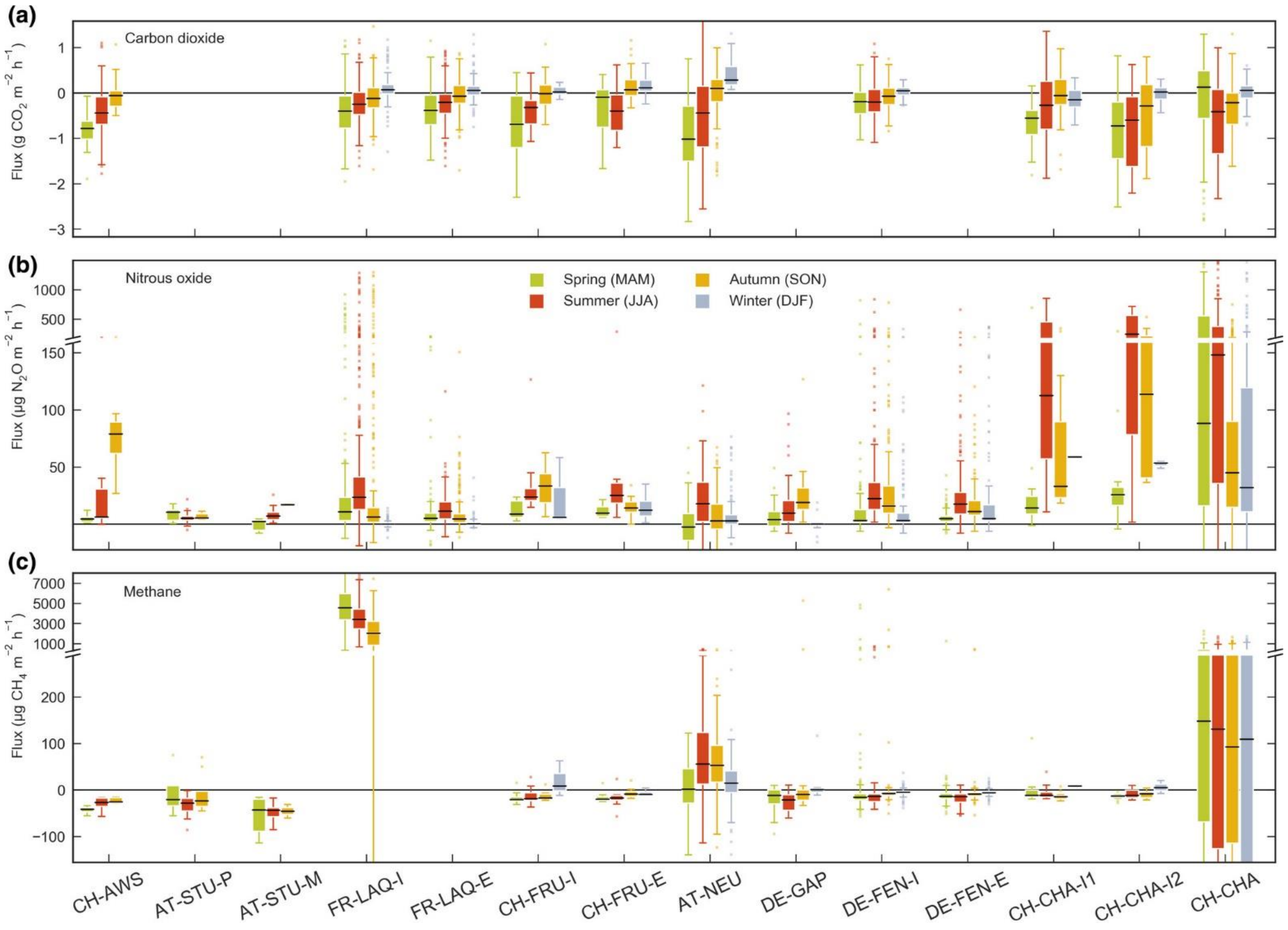
Grasslands in a wider context

- cover 25% of the global ice-free land surface,
- used for forage and livestock production
- considered to contribute to soil carbon (C) sequestration
- biodiversity hotspot

- large diversity of grassland (globally and across Europe)
- current functioning in terms of CC mitigation not fully understood
- widely differing management practices in near proximity in Europe
- effects of current management activities remains often unclear
- mitigation options can be considered/explored if we understand the current management

Cardenas et al. 2022, Hörtnagl et al. 2018, Peterson et al. 2021, Ammann et al. 2020, Sutton et al. 2020 and many more

GHG fluxes from Central European grasslands



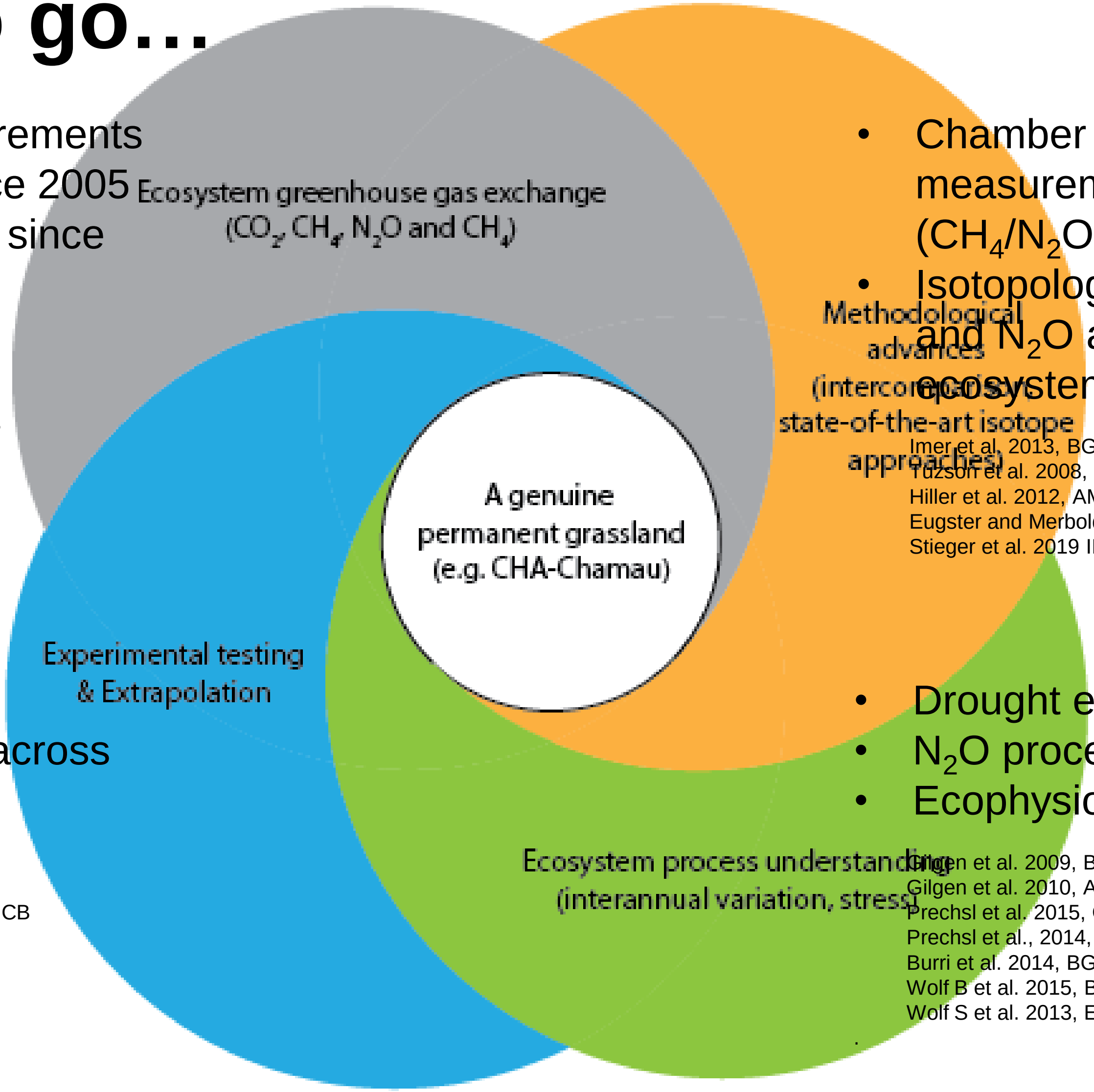
Hörtnagl et al. 2018

- Carbon dioxide exchange is dependent on Management frequency

- Nitrous oxide is highly variable across time and space

- Methane only matters if livestock are part of the system

Study Design -> What we had and where we wanted to go…



- EC flux measurements (CO_2/H_2O) since 2005 and (CH_4/N_2O) since 2012

Zeeman et al. 2010, AFM
Imer et al. 2013, BG
Merbold et al. 2014, GCB
Osterwalder et al. 2020, AMT
Feigenwinter et al. 2022 in rev.

- Chamber vs EC flux measurements (CH_4/N_2O
- Isotopologues of CO_2 and N_2O at the ecosystem scale

Imer et al. 2013, BG
Tuzson et al. 2008, IPT; Wolf B et al. 2015, BG
Hiller et al. 2012, AMTD
Eugster and Merbold 2015, SOIL
Stieger et al. 2019 IEaHS

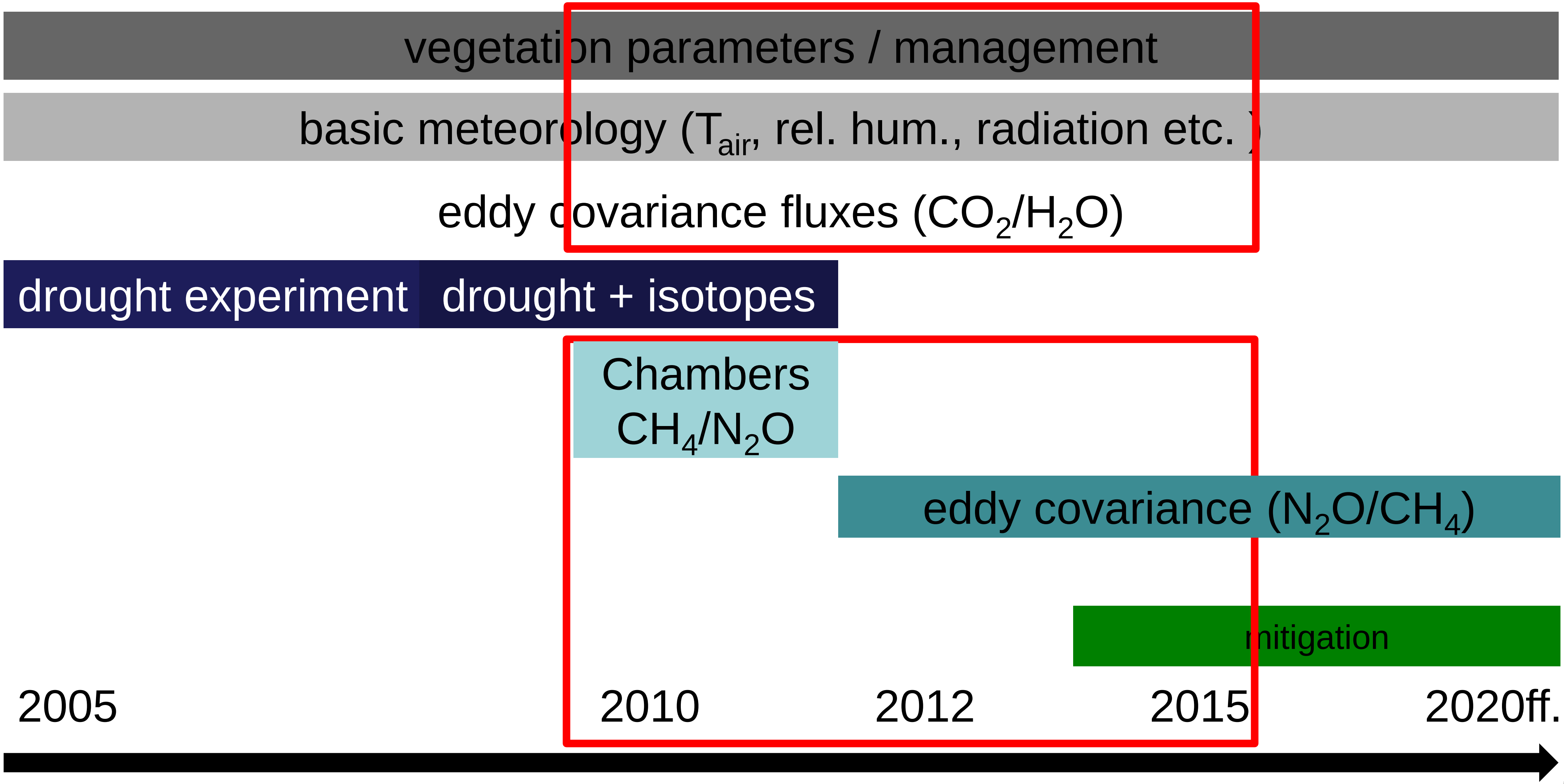
- CH_4 upscaling
- CO_2/CH_4/N_2O across sites

Imer et al. 2013, BG
Hiller et al. 2013, BG
Merbold et al. 2014,
GCB Hoertnagl. et al. 2018, GCB
Fuchs et al. 2018, BG
Fuchs et al. 2020 GBC
Fuchs et al. 2020, JGR-BG
Sandor et al. 2018, STOTEN

- Drought experiments
- N_2O processes
- Ecophysiology

Gilgen et al. 2009, BG,
Gilgen et al. 2010, AEE
Prechsl et al. 2015, OECOLOGIA
Prechsl et al., 2014, RCiMS
Burri et al. 2014, BG & IiEHS
Wolf B et al. 2015, BG
Wolf S et al. 2013, ERL

Study Design



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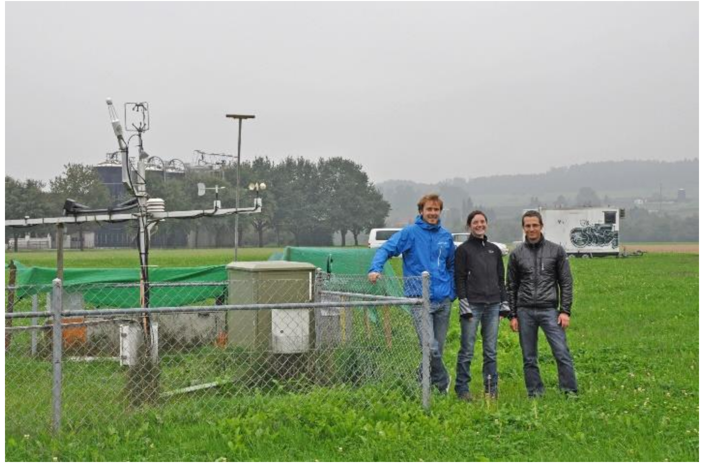
Study Site

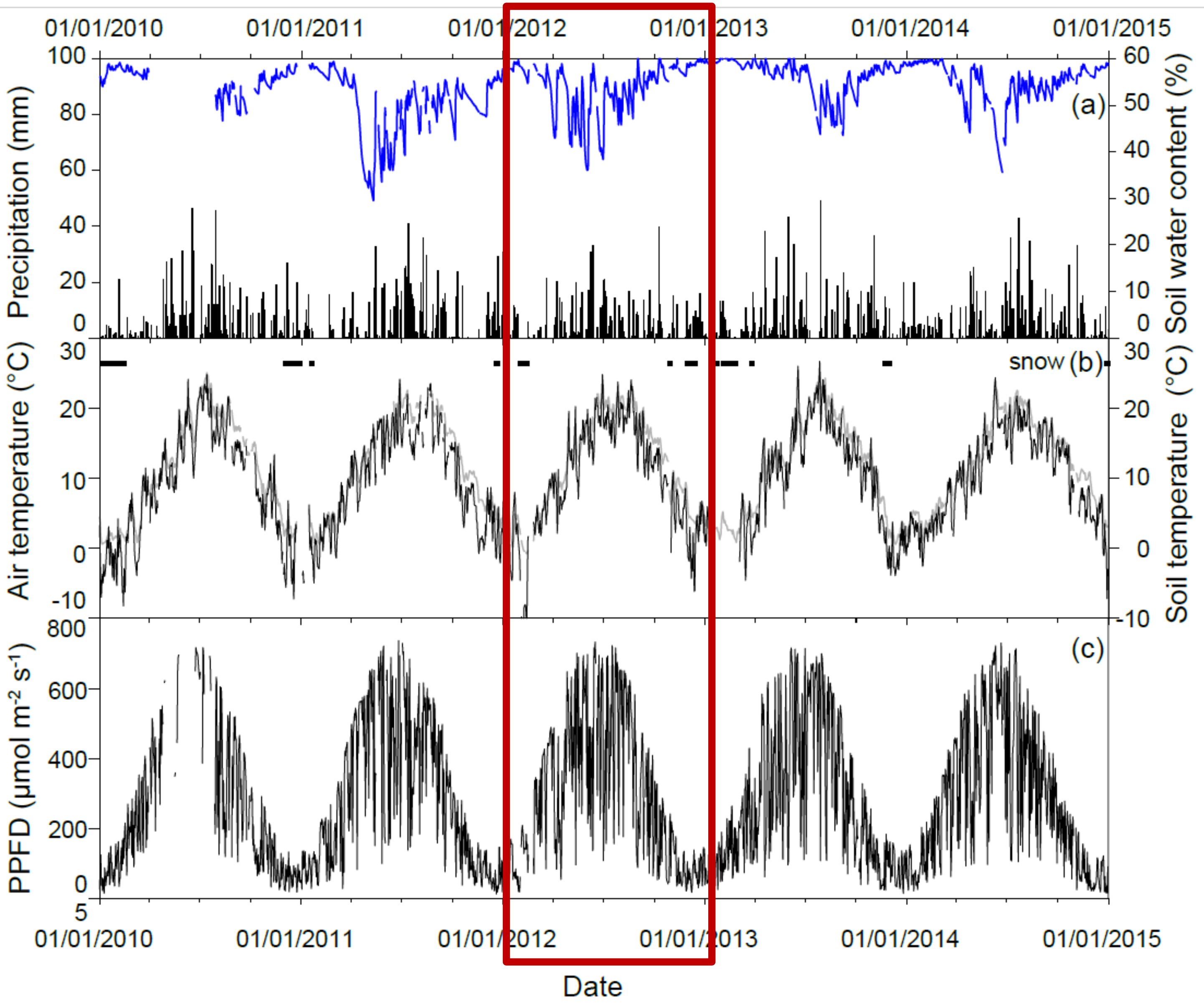
Transect A - 23rd April 2013

Transect A – 14th June 2013



EC Tower & Field Team

5 Years of observations



- similar environmental conditions

- 2 years business as usual, 1 yr restoration, 2 yrs business as usual

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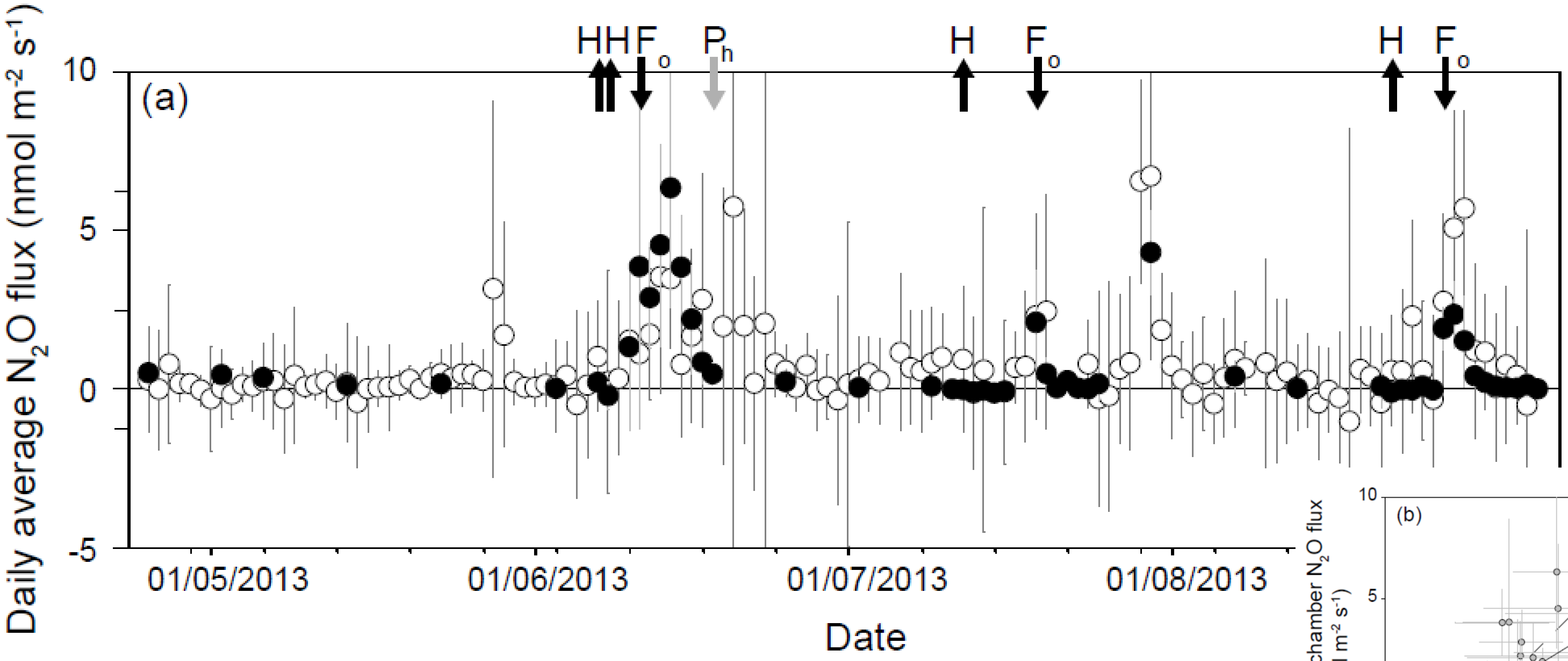
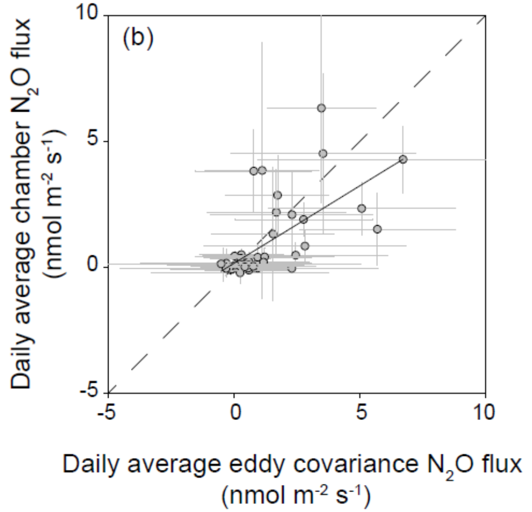
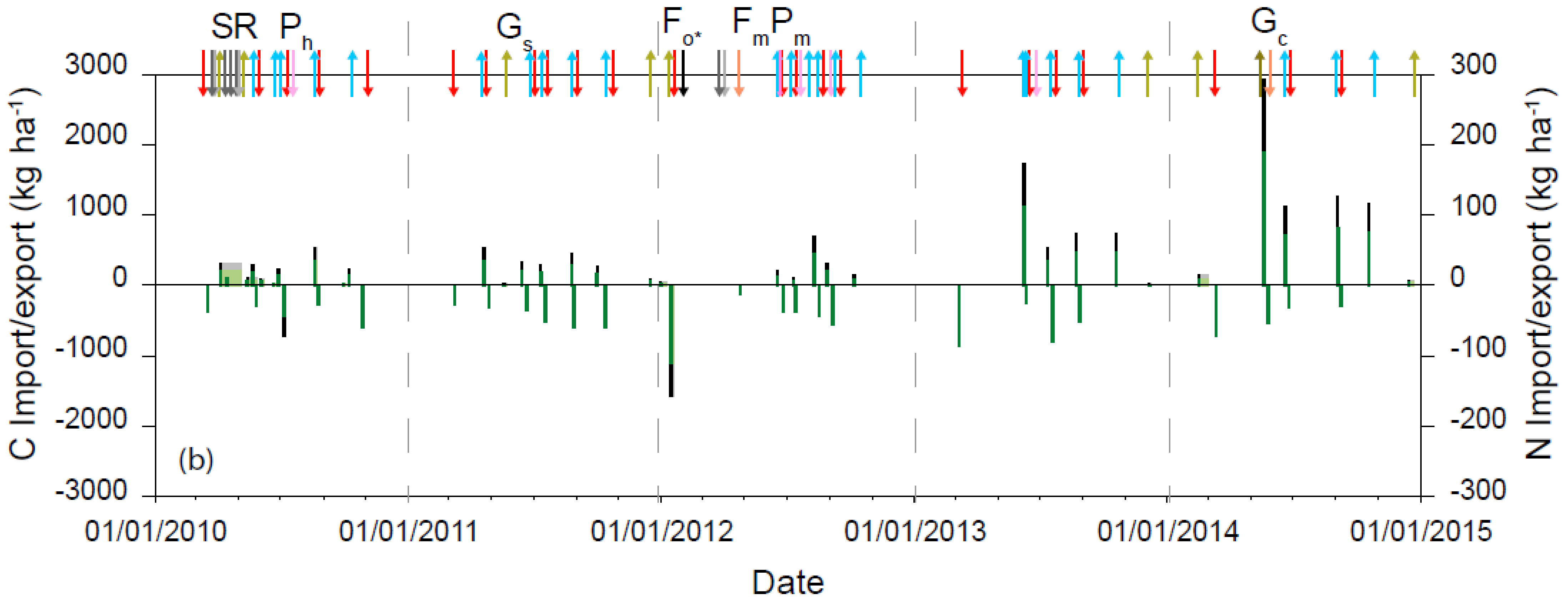
5 Years of observations, different methods





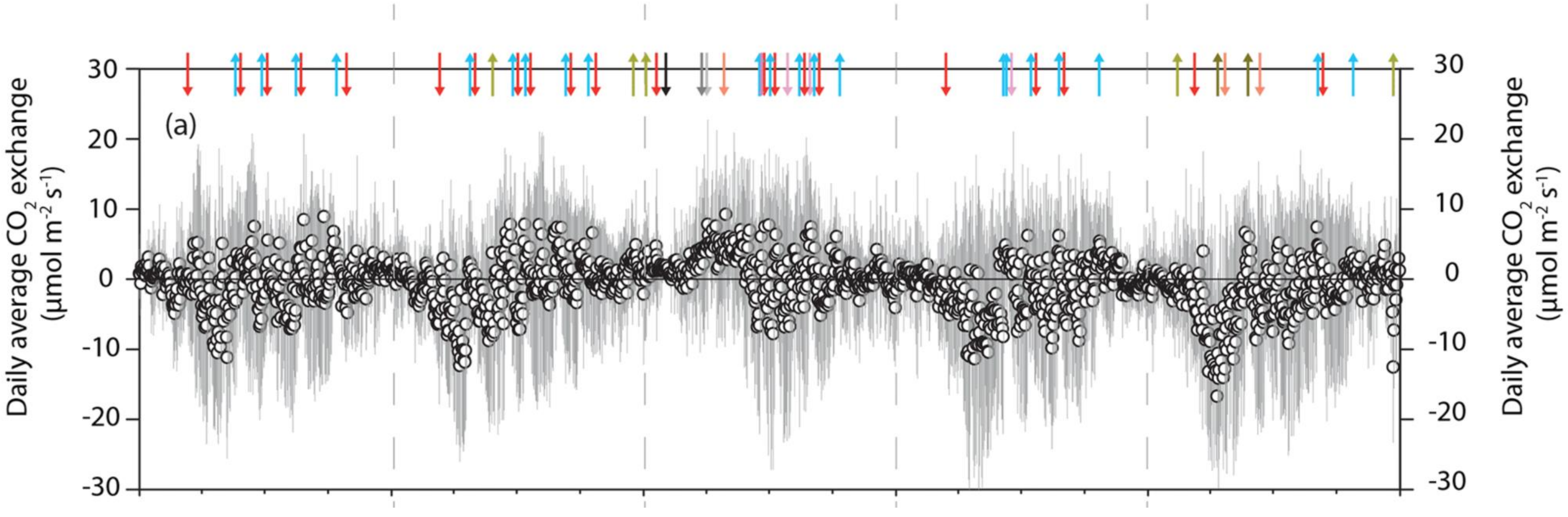
both methods compare relatively well, with expected deviations due to scale, no consistent offset

Management & Productivity



Year 2012 sticks out with different management (restoration in 2012)
Productivity was much higher after 2012

Greenhouse gas exchange



01.01.2010 01.01.2011 01.01.2012 01.01.2013 01.01.2014 01.01.2015

Greenhouse gas budget

	2010 (MC)	2010 (EC)	2011 (MC)	2011 (EC)	2012 (MC)	2012 (EC)	2013 (MC)	2013 (EC)	2014 (MC)	2014 (EC)
Average CO_2 flux ($\mu mol\,m^{-2}\,s^{-1}$)		−0.5		−0.7		1.04		−1.4		−1.98
SD of average CO_2 flux ($\mu mol\,m^{-2}\,s^{-1}$)		3.11		3.63		3.02		3.52		3.9
$g\,CO_2\,m^{-2}$		−695.23		−978.16		1447.16		−2047.8		−2751.66
$g\,CO_2–C\,m^{-2}$		−189.6		−266.77		394.68		−558.49		−750.45
Global warming potential in $g\,CO_2$ eq. m^{-2}		−695.23		−978.16		1447.16		−2047.8		−2751.66
% of the total budget		69.2		91.6		55.1		92.3		94
Average CH_4 flux ($nmol\,m^{-2}\,s^{-1}$)	n.c.		n.c.			1.91		3.67		3.92
SD of average CH_4 flux ($nmol\,m^{-2}\,s^{-1}$)	n.c.		n.c.			11.8		9.77		20.61
$g\,CH_4\,m^{-2}$	n.c.		n.c.			0.96		1.85		1.97
$g\,CH_4–C\,m^{-2}$	n.c.		n.c.			0.72		1.39		1.48
Global warming potential in $g\,CO_2$ eq. m^{-2}	n.c.		n.c.			26.88		51.8		55.16
% of the total budget	n.c.		n.c.			1		2.3		1.9
Average N_2O flux ($nmol\,m^{-2}\,s^{-1}$)	*0.84*		*0.25*			3.13	0.28	0.32		0.32
SD of average N_2O flux ($nmol\,m^{-2}\,s^{-1}$)	*0.84*		*0.2*			4.35	0.6	0.73		0.68
$g\,N_2O\,m^{-2}$	*1.17*		*0.34*			4.36	0.39	0.45		0.45
$g\,N_2O–N\,m^{-2}$	*0.74*		*0.22*			2.77	0.25	0.28		0.28
Global warming potential in $g\,CO_2$ eq. m^{-2}	310.05		90.1			1155.4	103.35	119.25		119.25
% of the total budget	30.8		8.4			43.9		5.4		4.1
Total GWP potential	−385.18		−888.06			2629.44	−1892.65	−1876.75		−2577.25

- C budget is dominated by CO_2 exchange, N_2O fluxes are minor, except during low frequency management events

Take Home Message

- The Chamau site assimilated on average -441 ± 260 g CO_2–C m^{-2} yr^{-1} during the "business-as-usual" years (2010 and 2011 as well as 2013 and 2014)
- During the restoration year the site lost 395 g CO_2–C m^{-2} (Merbold et al. 2014 and 2021)
- The nitrous oxide budget reported for the years without plowing in this study coincides with values reported for other grasslands in Europe. (Hörtnagl et al. 2018)
- Longterm observations allow to reveal patterns as observed in 2012 and also that this is where the biggest mitigation potential lies (Feigenwinter et al. in review)

What is missing/critical questions to ask:

- Field scale assessment vs farm scale assessments – livestock have to be included
- Are permanent grasslands the best option for fertile soils such as found at our site, or should these rather be used for crop production? How to mitigate the consequences of conversion?
- Climate impact is one environmental dimension, we need to include others: ie biodiversity, soil health etc.














Questions?

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