Grasslands & Climate Change Mitigation

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**Motivation**
- Permanent grasslands and ecosystem services for climate mitigation

**Climate Regulation**
- Net grassland CO$_2$ fluxes and resilience to extreme droughts
- Long-term carbon sequestration

**Driver of Climate Change**
- Impact of restoration

**Option for Climate Mitigation**
- N$_2$O mitigation experiment

**Lessons Learned**
Permanent Grassland (PG)

CH: 70% UAA
Ecosystem Services: “Multifunctionality” of PG

How can these services contribute to climate change mitigation?
(Millenium Ecosystem Assessment 2005)
Climate Change: Challenges Now and in the Future

- Annual temperatures increased by almost 2 °C since 1864 in Switzerland (global: 0.9 °C)
Climate Change: Challenges Now and in the Future

- Warmer throughout the year
- Drier summers in future

Changes in Temperature (°C)

Changes in Precipitation (%)

(MeteoSwiss 2019; CH2018)
Observational Approach to Measure the «Breathing of the Biosphere»

OEN2: since 12/2003

CHA, FRU: since 7, 8/2005

LAE: since 4/2004

DAV: since 1/1997

Continuous CO₂, H₂O vapor fluxes, meteo available (… plus much more …)

- Response to environmental change and management
- Use as a research platform (isotopes, phenology, remote sensing…)

Long-term data sets (> 99 site-years)

- Response to slow changes, e.g., climate change; provision of climate regulation
Grassland CO$_2$ Fluxes = function of (Environment, Management)

- Cold long winter 2005/06
- Mild winter 2006/2007
- Frequent cuts & manure applications during growing season

Similar uptake in early summer

- Strong impacts by environment and management
- High resolution insight into ecosystem physiology, beyond carbon budgets

(Zeeman et al. 2010, AFM; Buchmann et al. 2019)
Long-term Carbon (C) Sequestration (NBP)

Net biome productivity $\text{NBP} = -\text{NEE} + C_{\text{fertilizer}} - C_{\text{harvest}}$

Grey: modeled

- Over 14 years: small annual C sinks
- Sink = f (Environment, Management)
Impact of Restoration on Grassland N$_2$O Fluxes

Merbold et al. (2014) GCB

- Very large N$_2$O fluxes during restoration year
- One restoration event in 10 years sets off a 5-yr C sink

Chamau, 400 m

Restoration: ploughing, harrowing, resowing and fertilisation

Resilience to Extreme Droughts

**Summer drought** 2018: annual precip -30% (CHA), -27% (FRU), +3% (AWS)

- Strong link between carbon and water fluxes
- No acclimation of grasslands to drought, WUE stayed the same
- Grasslands transpire more than forests during drought
- Thus, they cool the atmosphere more than forests until they dry out

(Gharun et al. 2020, PTRS)
Drivers of Climate Change: Greenhouse Gas Emissions

Greenhouse gas emissions in Switzerland (2017)

- Agriculture: 12.9%
- \( \text{CH}_4, \text{N}_2\text{O}, \text{CO}_2 \)

(FOEN 2019)
Can legume fractions substitute N fertilization & reduce N\textsubscript{2}O emissions?
N\textsubscript{2}O Mitigation Experiment

Higher fraction of legumes in sward:

- 40-50\% lower N\textsubscript{2}O emissions
- 10\% lower yields, but higher forage quality

(Fuchs et al. 2018, BG)
Grasslands and Climate Change Mitigation

Ecosystem Services of Permanent Grasslands
• Permanent grasslands provide multiple services, incl. climate regulation.
• High-resolution flux measurements are key to collect data on „Breathing of Biosphere“.

Climate Regulation of Permanent Grasslands
• Management and environment affect ecosystem greenhouse gas exchange.
• Permanent grassland soils are small annual C sinks.
• Restoration events can offset long-term soil carbon sinks.

Resilience to Drought Extremes and Option for Climate Mitigation
• Resilience of grassland productivity is high.
• Strong link between carbon and water fluxes at ecosystem level.
• Grasslands cool the atmosphere longer than forests during a drought.
• Mixtures with legumes can strongly reduce N₂O emissions w/out trade-offs for yield or quality.