

GHG exchange of grassland ecosystems along a climate sequence in the TERENO pre-Alps Observatory

Kiese R, Lu H, Fu J, Diaz-Pines E, Papen H, Schmid HP



Graswang (860m)



Rottenbuch (750m)



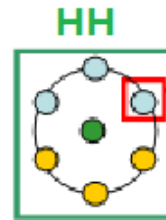
Fendt (600m)



Field Setup: In-situ climate change / space for time

Δ Temperature ~ 2.5 °C

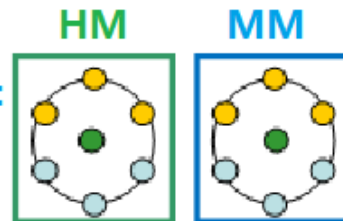
High (860m) /Graswang:
6 lysimeter
1600mm / 5°C



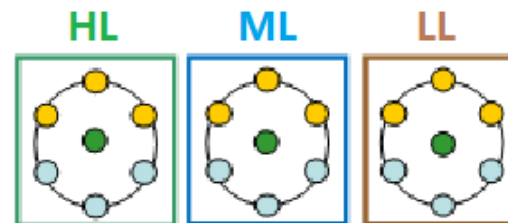
single lysimeter

lysimeter unit consisting of 6 single lysimeters and central service station

Medium (750m) Rottenbuch:
12 lysimeter
1400 / 6.5°C



Low (600m) /Fendt:
18 lysimeter
1030 / 8.2°C



-  = intensive management
-  = extensive management

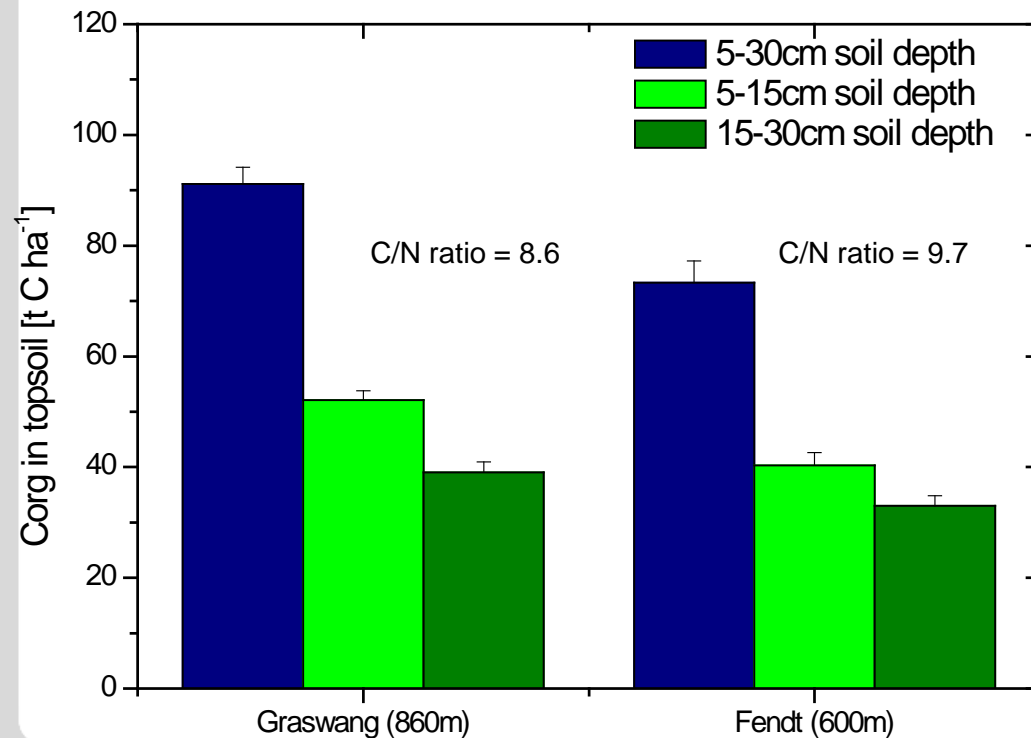
Δ Precipitation ~ 500 mm

Hypothesis

Climate change will...

- accelerate soil C-/N- turnover and associated soil emission of CO_2 and N_2O but will have less impact on soil CH_4 uptake

Why? → 20% higher SOC/ N_{tot} at higher altitude



soil parent material: **glacial till**
soil texture: **clay loam**

Main Objectives

Characterization and quantification of climate change effects on ...

- **biosphere-atmosphere exchange of greenhouse gases**
- changes of coupled C-/N-cycles/ storage of grassland ecosystems (see poster)
- vegetation and microbial biomass and diversity/ activity (see poster)
- terrestrial hydrology, C and N losses via seepage water (see poster)

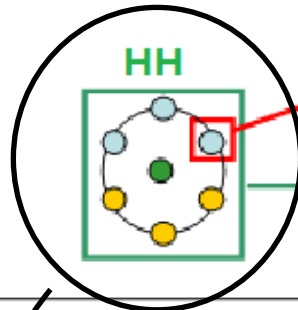


Results:

Δ Temperature ~ 2.5 °C

High (860m) /Graswang:
6 lysimeter
1600mm / 5°C

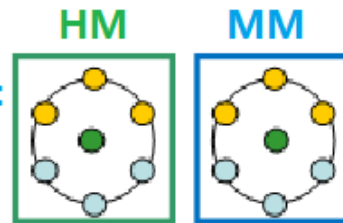
control



single lysimeter

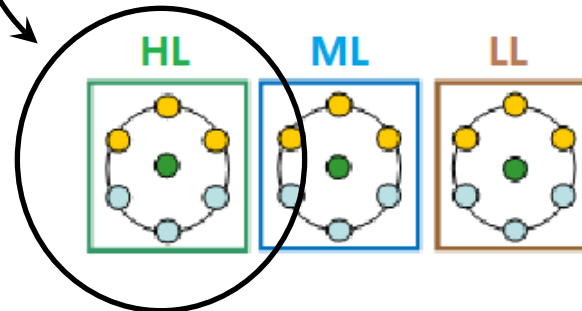
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Δ Precipitation ~ 500 mm

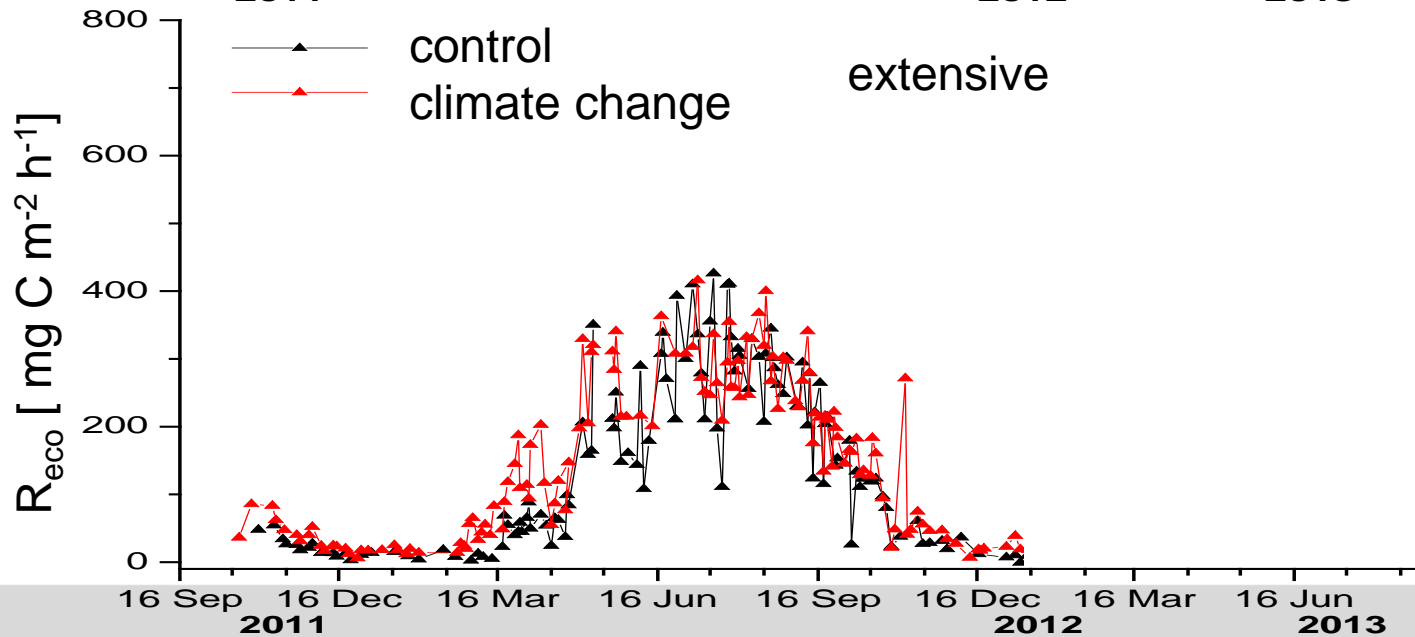
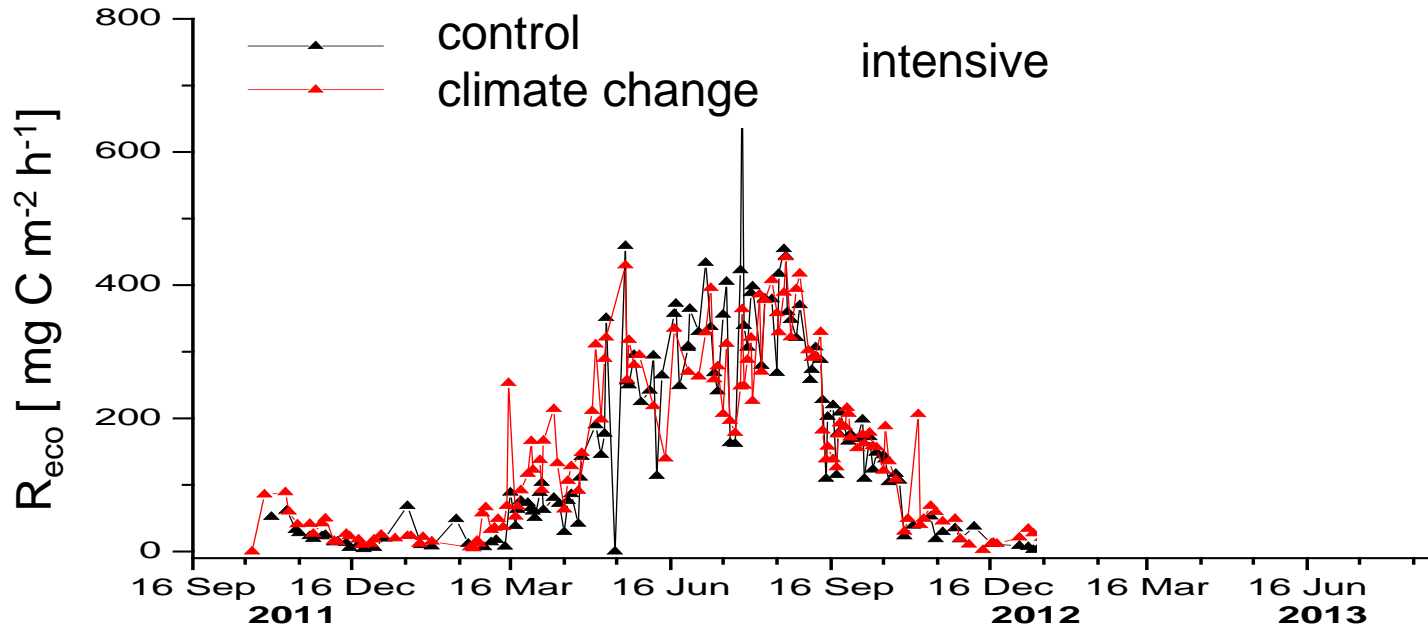
Low (600m) /Fendt:
18 lysimeter
1030 / 8.2°C



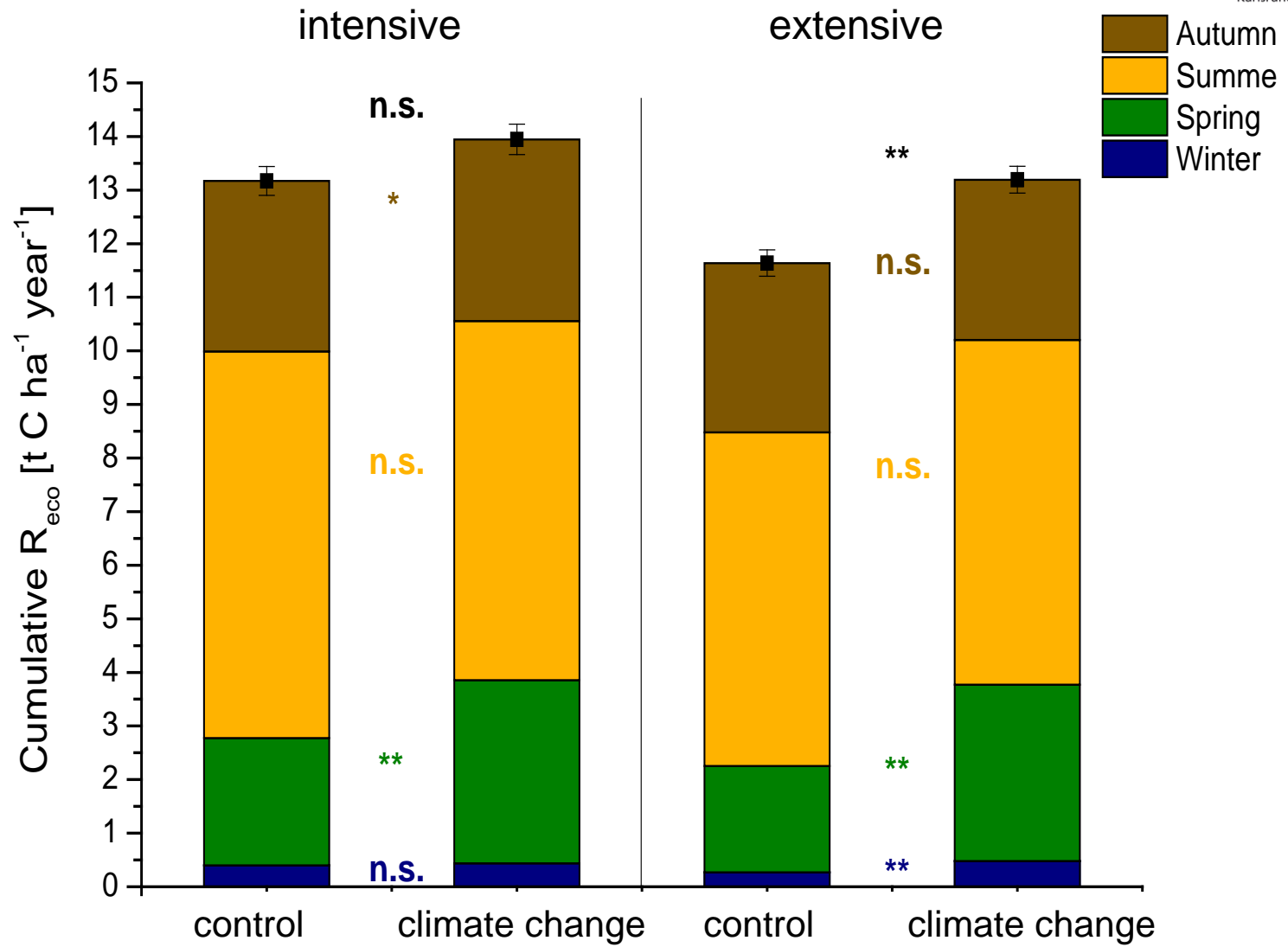
- = intensive management
- = extensive management

Climate change

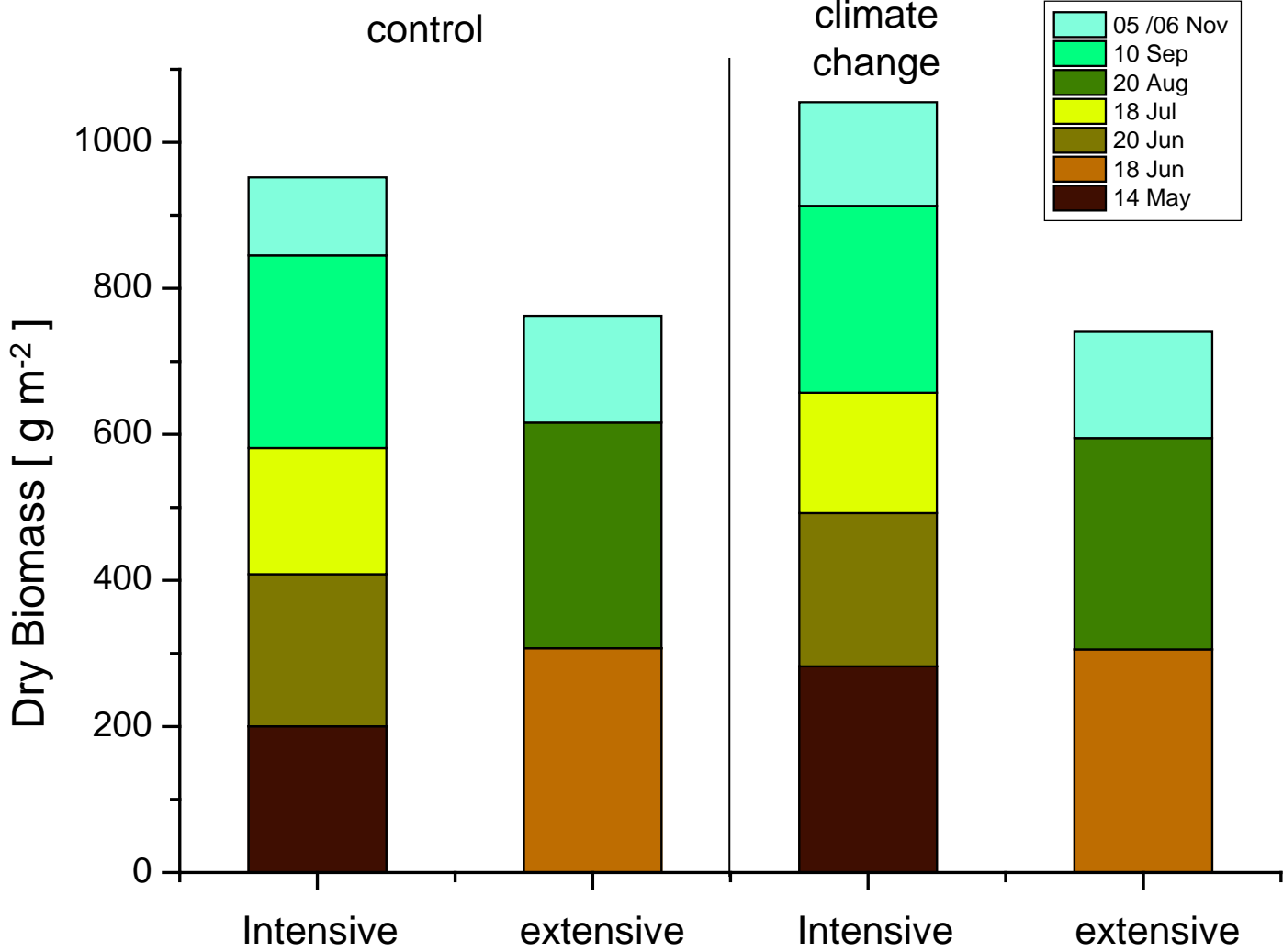
Results: Soil respiration (2-3 measurements pre week)



Results: Soil respiration (cumulative fluxes)



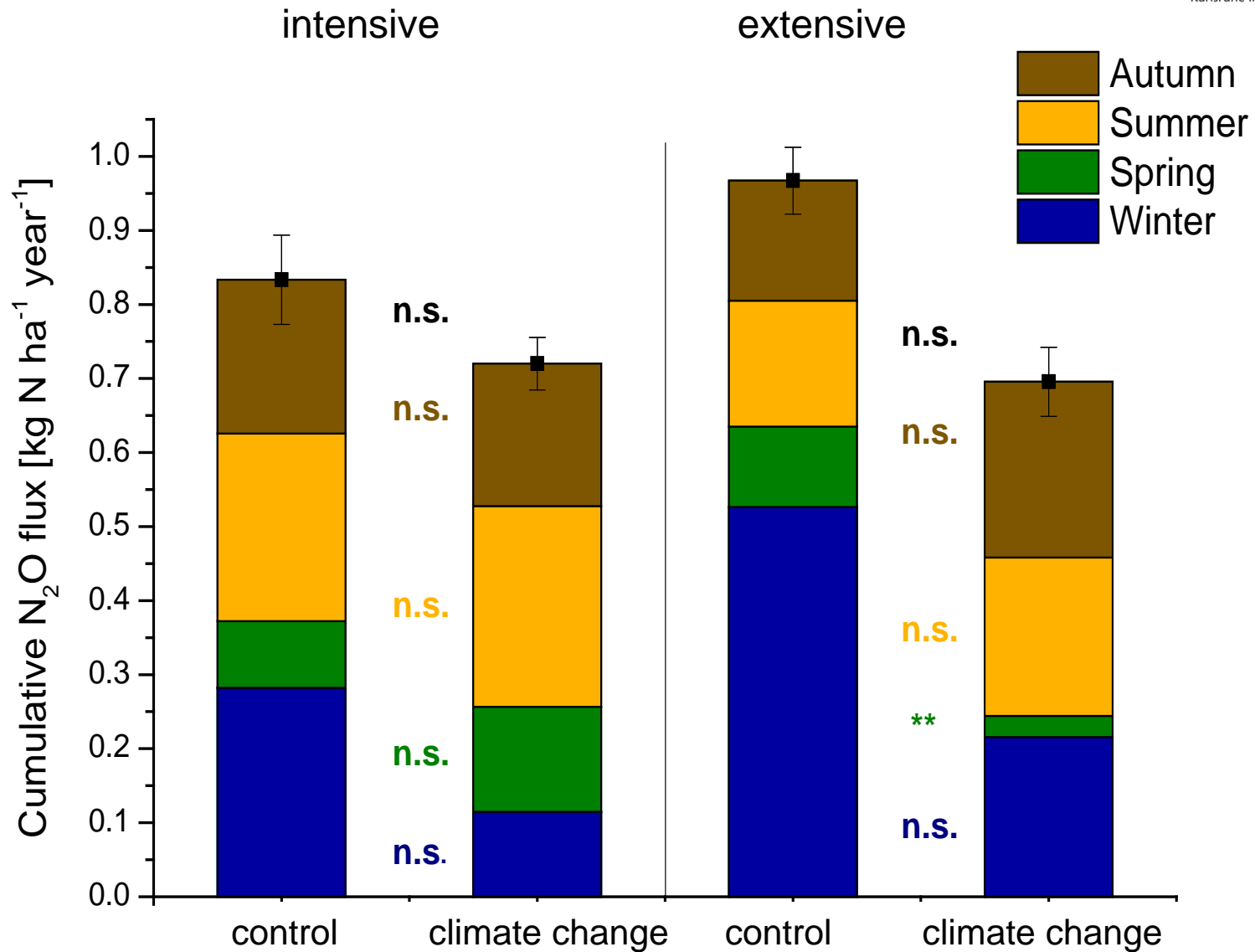
Results: Harvest of aboveground plant biomass



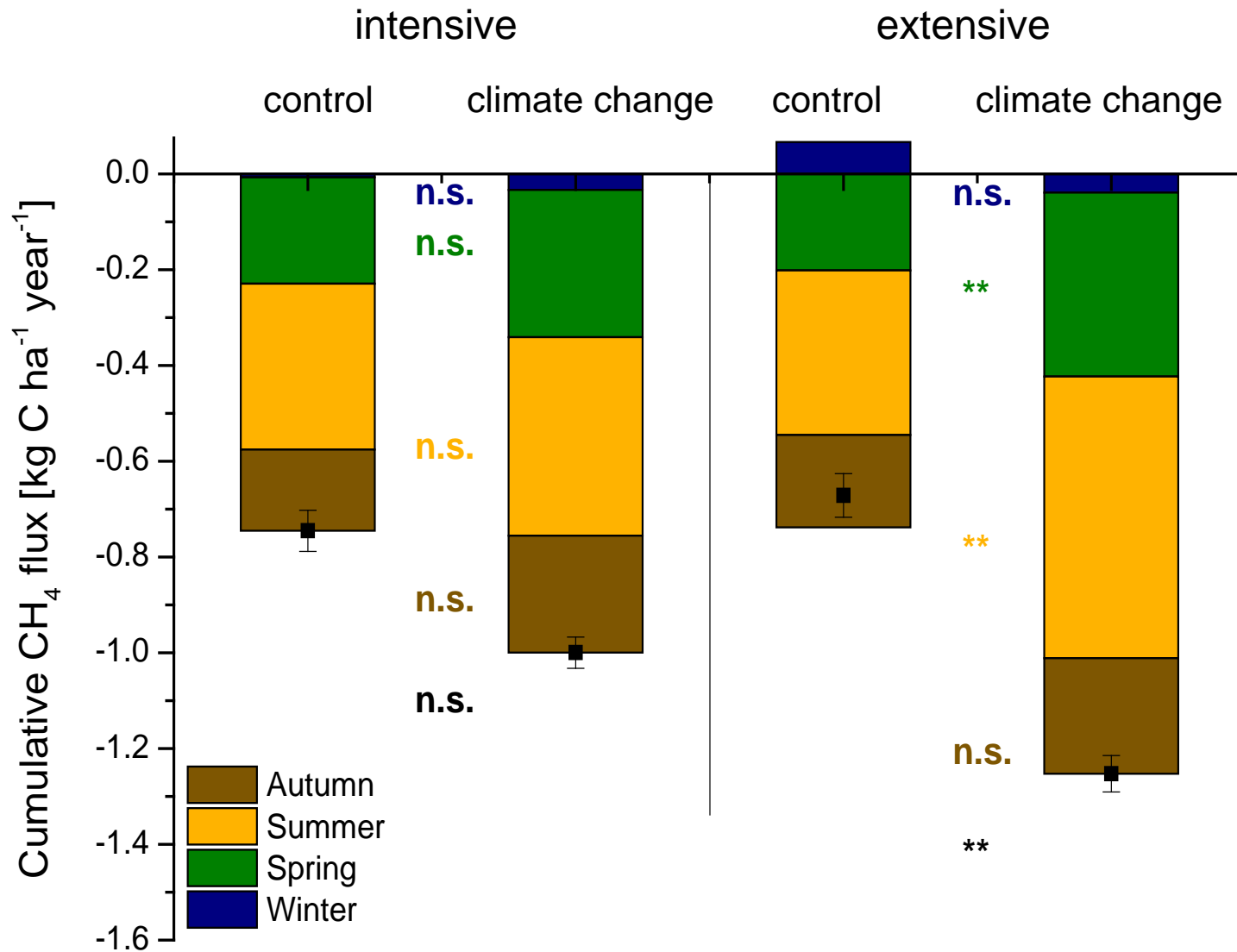
intensive management 4-5 t C ha⁻¹

extensive management 3.5 t C ha⁻¹

Results: N₂O flux (cumulative fluxes)



Results: CH₄ flux (cumulative fluxes)



Conclusions

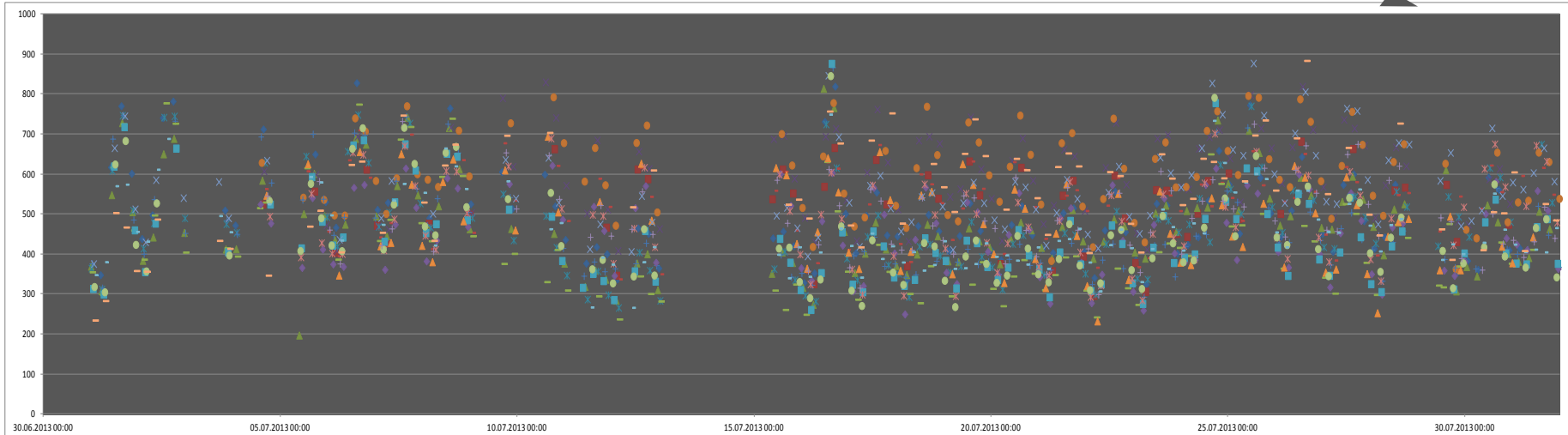
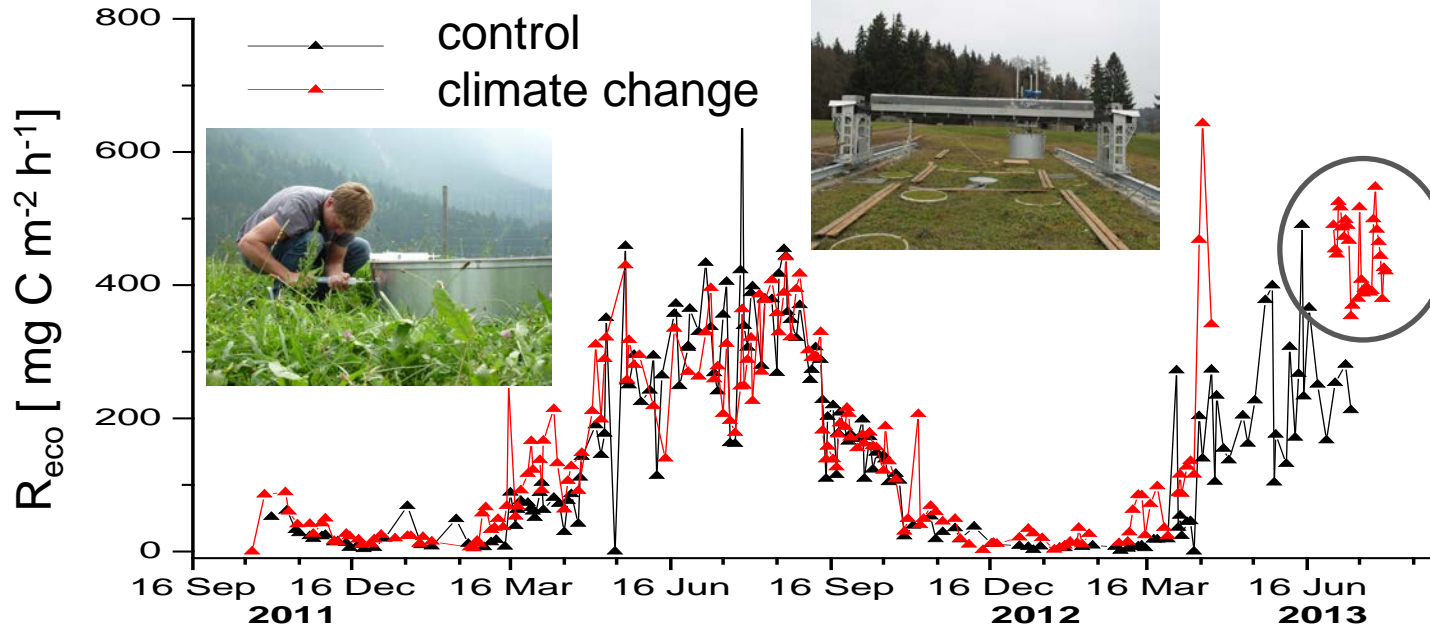
- ❖ **Climate change/ Translocation leads to...**
 - increased CH₄ uptake in all seasons
 - increased CO₂ emission mainly in spring and autumn
 - increased N₂O emission in spring-summer-autumn,
 - but overall higher at higher elevation due to significant winter emissions by freeze/ thaw events
 - elevated DOC and TN concentrations in the whole soil profile but export via seepage water is marginal

- **Influence of climate change is more pronounced under extensive management**

- ❖ **Seasonal and diurnal patterns of CO₂ emission**

- ❖ **Event based patterns of CH₄ and N₂O emission, i.e. rainfall, freeze-thaw, fertilization**

Results: Soil respiration continued



Thank you for your attention

TERENO Terrestrial Environmental Observatories

Pre-Alps Observatory



Graswang (860m)



Rottenbuch (750m)



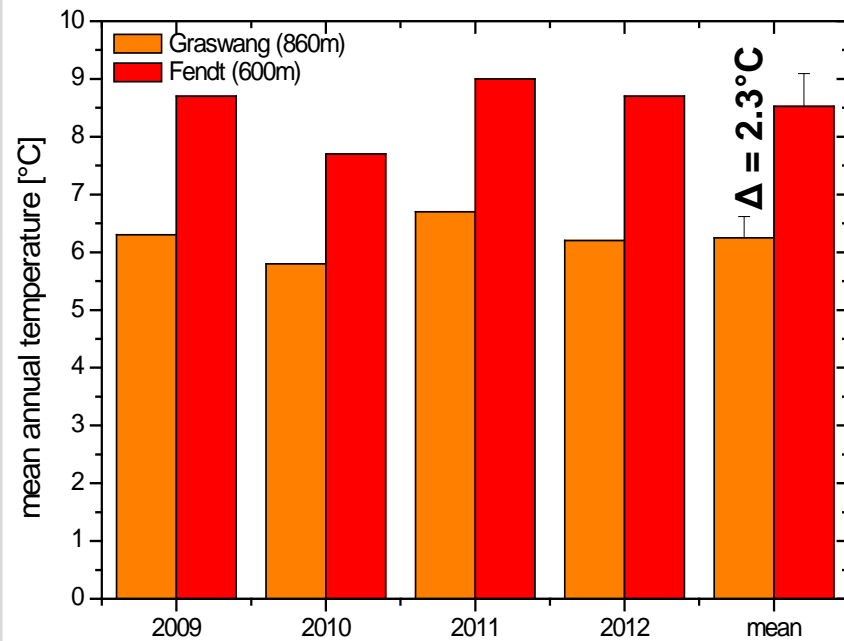
Fendt (600m)



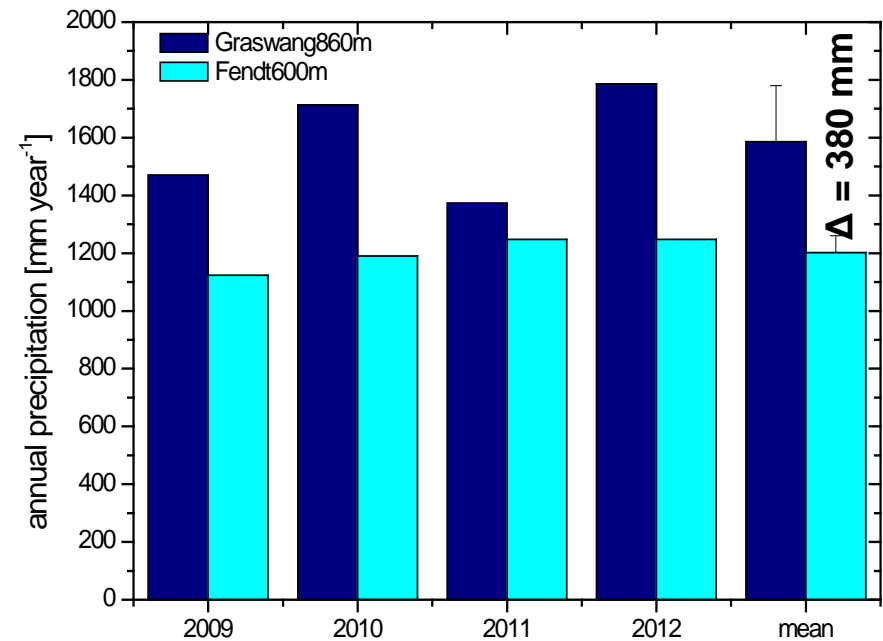
Climate characteristics



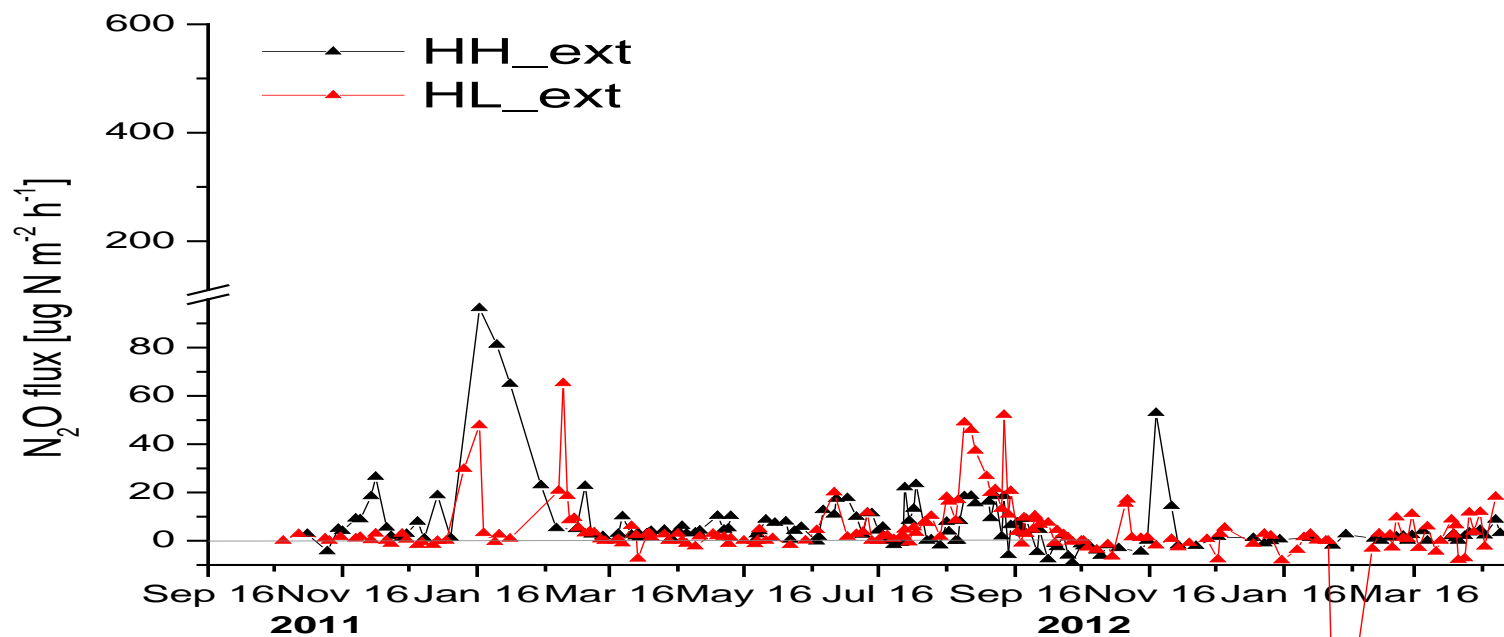
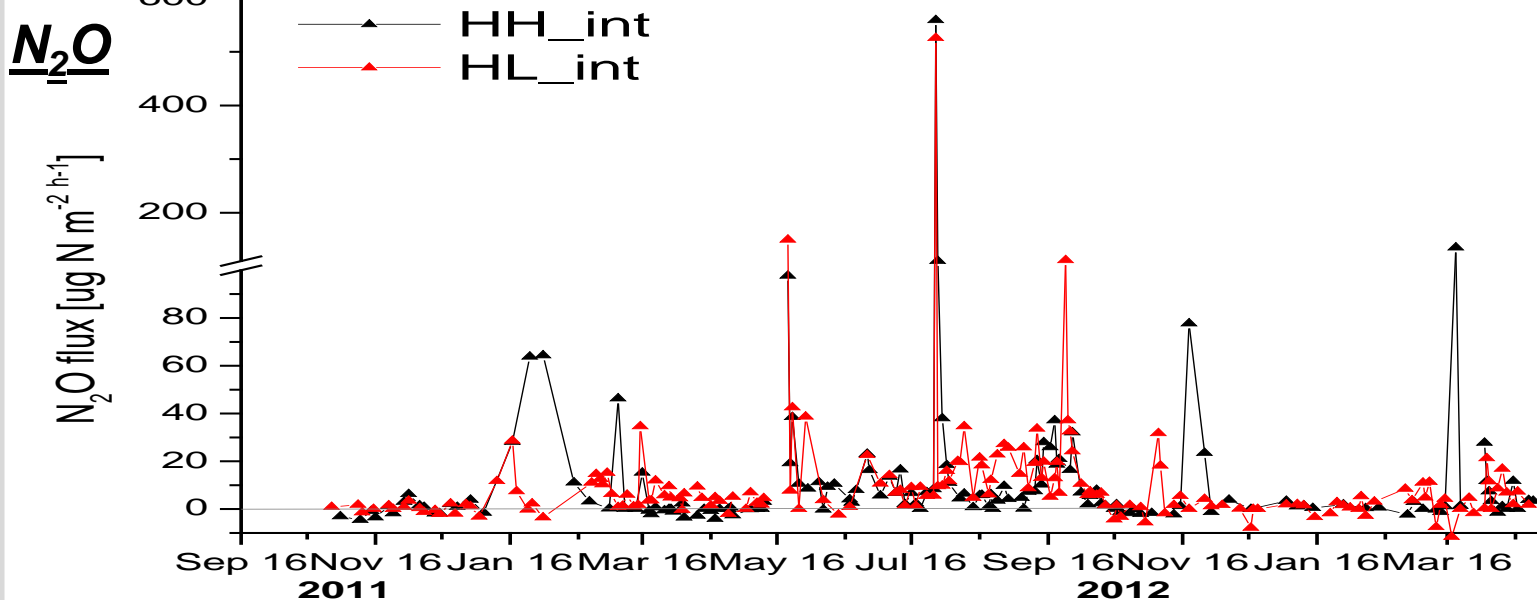
mean annual air temperature



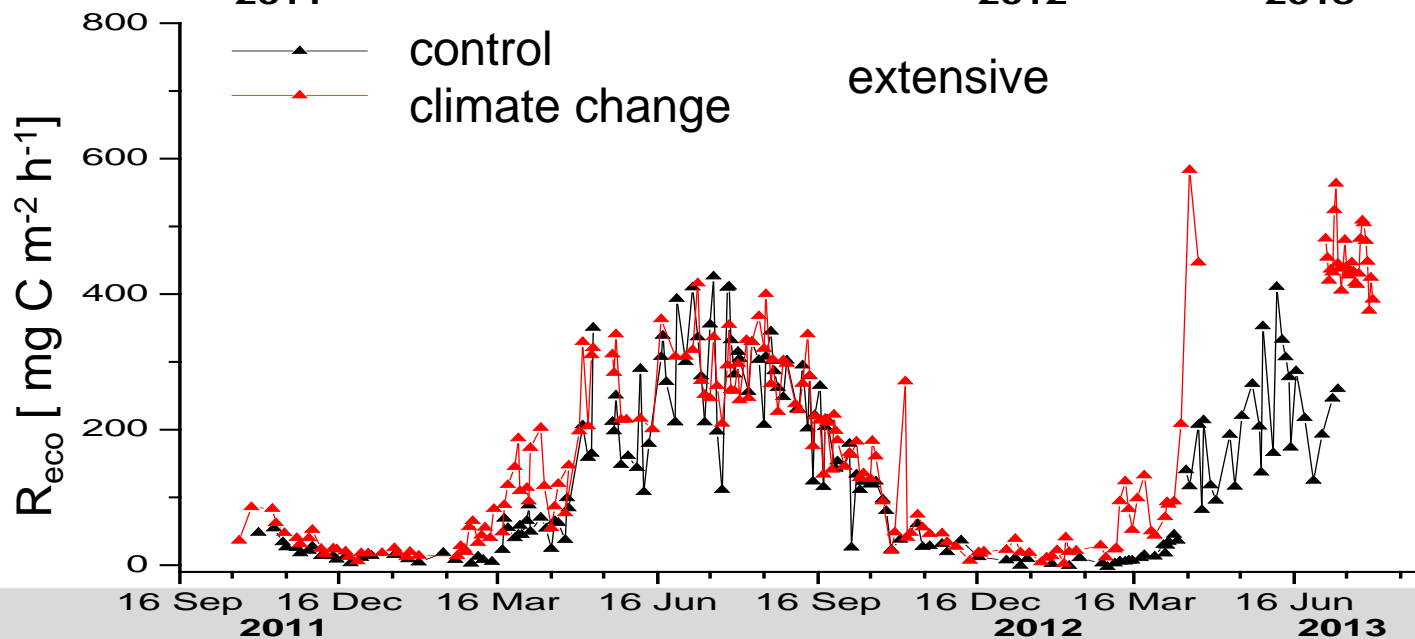
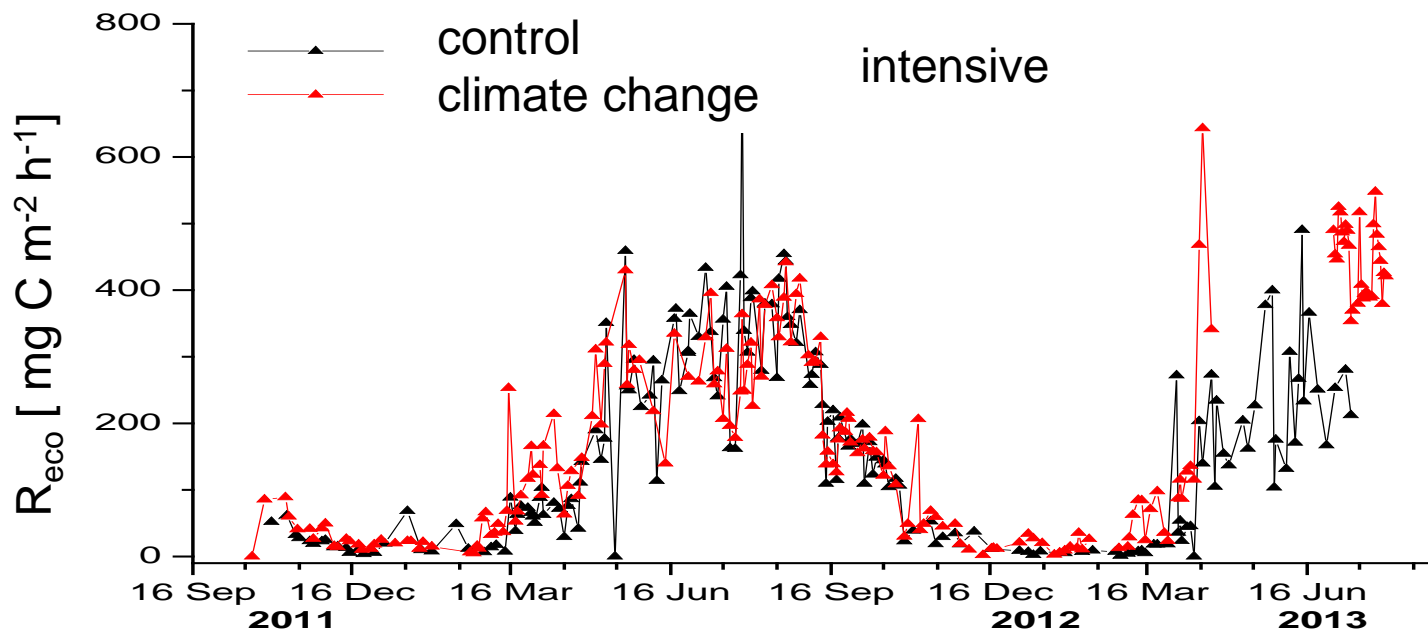
annual precipitation



Results I: manual chamber measurement HH& HL



Results: Soil respiration (2-3 measurements pre week)



Additional work on posters

Nutrient leaching

N turnover processes

Terrestrial Environmental Observatories

Federal Ministry of Education and Research

HELMHOLTZ ASSOCIATION

Karlsruhe Institute of Technology

Impact of climate change on water balance and nutrient leaching of (pre-) alpine grassland soils

J. Fu, H. Lu, R. Gasche, K. Butterbach-Bahl, R. Kiese

Motivation
Long term observations are indispensable to improve our knowledge of the complex interactions of the biosphere-hydrosphere-atmosphere and to detect and analyze impacts of climate change as well as to develop, improve and validate process model systems.

Due to cool and moist climatic conditions (sub-)alpine grassland soils are rich in soil organic carbon and associated nitrogen and therefore particularly prone to climate change.

Objectives
Characterization and quantification of climate change effects on

- soil hydrology (Prec = ETP + Groundwater Recharge + dSoil)
- nutrient export by seepage water (NO₃, NH₄, DON, DOC)
- changes of the coupled C-N-cycles and C-N-storage
- biosphere-atmosphere exchange of greenhouse gases
- vegetation/microbial biodiversity and biomass

Results: Soil nutrient concentration in diff. soil depths
NO₃ (mg N l⁻¹) -10cm -> 30cm -> 50cm -> 140cm | FerriBABA

Field Setup
In the Ammer catchment a lysimeter network, consisting of 36 soil monoliths at three locations differing in altitude is realized. Soil monoliths are kept as control at their origin and translocated along the existing natural gradient in temperature and precipitation.

Instrumentation

- Steering of lower boundary condition (hPa) of lysimeters (red) with water
- tension measurements (N=3, blues; mean green) in 140cm of undisturbed soil
- Precision weighting (in kg) of lysimeters (red) and seepage water tank (blue)

Key findings

- Climatic gradient in the investigated year: +2.4°C (mean annual soil temperature in 5 cm depth); -20% soil moisture. Reduced or absent snowcover enabled soil frost at low elevation climate change site only but not at high elevation (control site).
- Climate change effects: Persistent increase of gross ammonification by 250%. Gene abundances of ammonia oxidizing archaea (AOA) and bacteria (AOB) were also increased in the climate change treatment with gross rates of nitrification responding positively to imposed climate change conditions in frozen winter soil of the low elevation site and in summer. Nitrifier gene abundances were strongly related to gross N turnover with presumably high importance of AOA for gross nitrification in the control treatment and high importance of AOB in the climate change treatment.
- Seasonal variability of gross N turnover: Both summer and winter were key periods for gross ammonification and gross nitrification. Frozen soil (occurs in the climate change treatment only) is a hot moment of gross N turnover, probably due to liberation of soluble organic matter, as indicated by DOC and DON in soil.
- Importance of topsoil: Both gross N turnover and gene abundances were generally several fold larger in 0-10 cm depth than in 10-20 cm depth. Almost all climate change effects were observed in 0-10 cm depth only.

Conclusions (very preliminary)

- Decrease of NO₃, DON and DOC concentration with soil depth
- Nitrogen leaching: NO₃ > DON > NH₄ (values < 1 mg N L⁻¹)
- DOC leaching: so far only of minor importance in the grassland C balance
- Climate impact: elevated concentration only for intensive management

- Matrix potential (Tensiometers)
- Suction cups for soil water sampling

Karlsruhe Institute of Technology

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Rapid and persistent increase of gross N turnover in pre-alpine grassland under simulated climate change conditions

Changhui Wang^{1,2}, Zhe Chen¹, Sebastian Untereggersbacher¹, Silvia Gschwendtner¹, Michael Schloter¹, Klaus Butterbach-Bahl¹, Michael Dannenmann¹

Goals, experimental design and methods

Our goals were to investigate

- effects of projected climate change on gross nitrogen turnover in pre-alpine grassland
- spatiotemporal variability of gross N turnover as affected by climate change conditions (seasonal variability, topsoil vs. deeper soil)
- relationships between abundances of N cycle genes and associated gross N transformations as affected by climate change.

Experimental approach and methods In order to simulate climate change we transferred 150 mini lysimeters of 17 cm diameter and 25 cm height from a high altitude pre-alpine grassland (Graswang site) to lower altitude (Wielenschbach site) following the slope for time approach. This given climatic gradient equals predicted climatic changes in the following decades. The same amount of lysimeters was transferred within the high altitude site, serving as control. After a pre-cultivation of three years, a full annual cycle of gross ammonification and nitrification was determined in intact soil cores in two soil layers (0-10 and 10-20 cm), accompanied by analysis of N cycle gene abundance.

Results: Increased gross N turnover under simulated climate change

Key findings

- Climatic gradient in the investigated year: +2.4°C (mean annual soil temperature in 5 cm depth); -20% soil moisture. Reduced or absent snowcover enabled soil frost at low elevation climate change site only but not at high elevation (control site).
- Climate change effects: Persistent increase of gross ammonification by 250%. Gene abundances of ammonia oxidizing archaea (AOA) and bacteria (AOB) were also increased in the climate change treatment with gross rates of nitrification responding positively to imposed climate change conditions in frozen winter soil of the low elevation site and in summer. Nitrifier gene abundances were strongly related to gross N turnover with presumably high importance of AOA for gross nitrification in the control treatment and high importance of AOB in the climate change treatment.
- Seasonal variability of gross N turnover: Both summer and winter were key periods for gross ammonification and gross nitrification. Frozen soil (occurs in the climate change treatment only) is a hot moment of gross N turnover, probably due to liberation of soluble organic matter, as indicated by DOC and DON in soil.
- Importance of topsoil: Both gross N turnover and gene abundances were generally several fold larger in 0-10 cm depth than in 10-20 cm depth. Almost all climate change effects were observed in 0-10 cm depth only.

Conclusions: Nitrogen cycling in pre-alpine grassland is vulnerable to projected climate change

- Three years of exposure to climate change conditions (increased temperature, reduced precipitation) prior to our analyses were sufficient to cause a massive perturbation of the N cycle with several fold increased gross N mineralization and also increased abundance of nitrifier genes and gross nitrification. This could lead to more mineral N supply for plants, but on the other hand may increase N loss along hydrological and gaseous pathways.
- Via reduced snow cover, climate change may lead to more soil frost, i.e. result in colder soils in winter via reduced or absent insulation of snowpack. The high importance of winter periods for gross N turnover found in this study implies that the frequent neglect of winter in such studies is not appropriate.
- The close relationships between gene abundances of the N cycle and associated gross N turnover implies that molecular analyses have a large potential to predict actual gross N turnover, which needs to be further explored.

KIT – University of the State of Baden-Württemberg and National Research Center of the Helmholtz Association
Contact: michael.dannenmann@kit.edu
www.kit.edu

- ❖ Correction of manual CO₂ emission measurements taking into account diurnal patterns of the automatic measurements
- ❖ Potentially revise of presented findings of soil CO₂ emissions
- ❖ Situation will be improved with automatic system in Fendt (low elevation)
- ❖ Measurement will be continued (long term effect of translocation ?) and supported by studies on
 - nutrient leaching (DIN, DON, DIC, DOC)
 - NEE / plant biomass / ¹²C/¹³C for separation of autotrophic vs. heterotrophic respiration (Na Wang)