Deutsche Forschungsgemeinschaft DFG

Human impact on soil organic carbon and nitrogen turnover in *Kobresia* pastures

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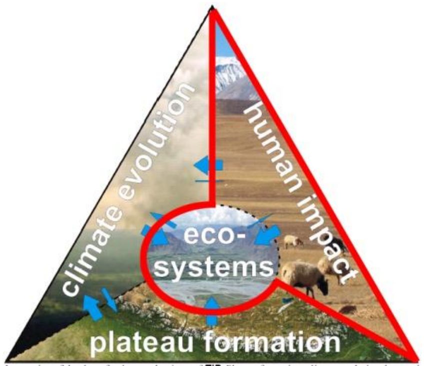
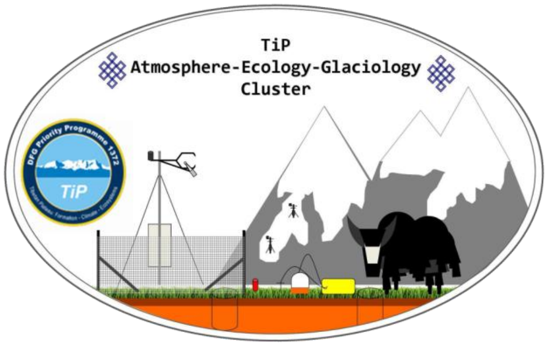




Universität Bayreuth · UBT AES · Leibniz Universität Hannover · Georg-August-Universität Göttingen · Institute of Geographic Sciences and Natural Resources Research, CAS

Introduction

Background

- Grasslands store a large amount of soil organic carbon (200 – 300 Pg C)
- The TP represents the largest connected alpine grassland storing about 23% of the Chinese soil organic carbon stocks (Wang et al, 2001)
- Since millenia animal husbandry is the typical land use
- Grazing pressure fostered *Kobresia* pastures, investigating much of their photosynthates belowground
- During the last decades management measures are carried out, including temporal exclosure of lifestock

Grazing yaks inducing *Kobresia* pastures with pronounced root mats

Introduction

Overarching goal

To understand the consequences of grazing pressure on C allocation to the soil and above- and belowground organic C and N stock

Hypotheses

Absence of grazing leads to:

H1: **Increase in aboveground biomass**

H2: **Decrease in belowground C allocation** due to larger investments into aboveground biomass

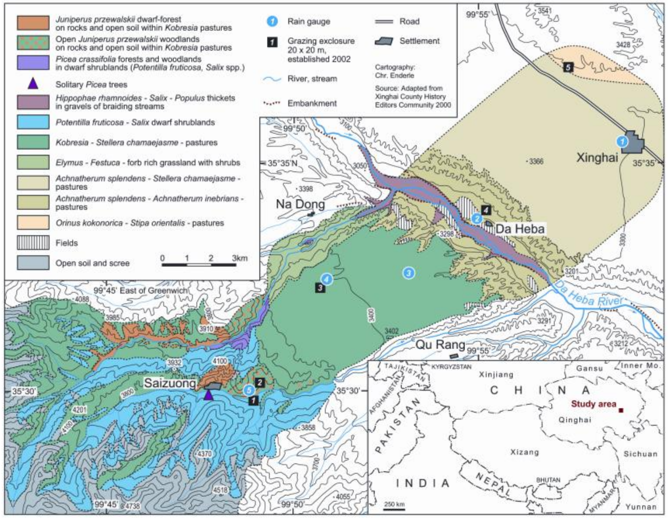
H3: **Decrease in soil organic C and N** due to smaller contribution of root-derived C

Study design

Qinghai Province

(close to city of Xinghai)

3000 – 3600 m asl



Exclosures for 7 years

Kobresia pastures, K1-3 (Kastanozem)

Stipa-dominated pastures, S1-3 (Cambisol)

Joint plant and soil studies were performed at subplots

Grazing effects on system carbon and nitrogen storage

Destructive sampling provides information on

- element storage in the system
- aboveground and belowground C investment of plants
- C sequestration in soils

depending on grazing regime

Becker L., Seeber E., Wesche K., Spielvogel S, Shibistova O, Kuzyakov Y, Miehe G, Li X & Guggenberger G. 2011. Non-uniform effects of grazing in upper montane grasslands of the Tibetan Plateau: contrasting changes in biodiversity, fodder quality and soil organic carbon stocks. *Plant and Soil* (submitted)


Vegetation clipping

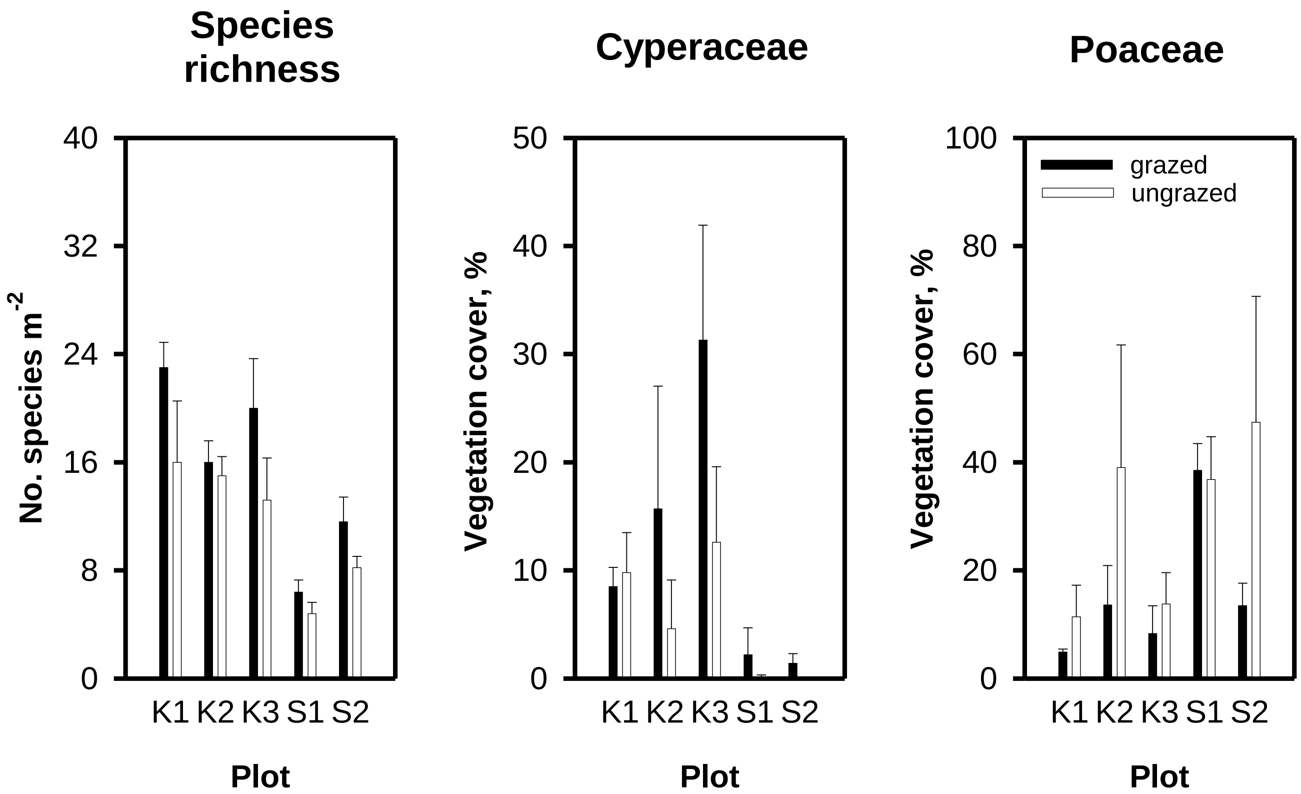

Vegetation description


Stratified soil sampling


Soil description

Grazing effects on plant community composition

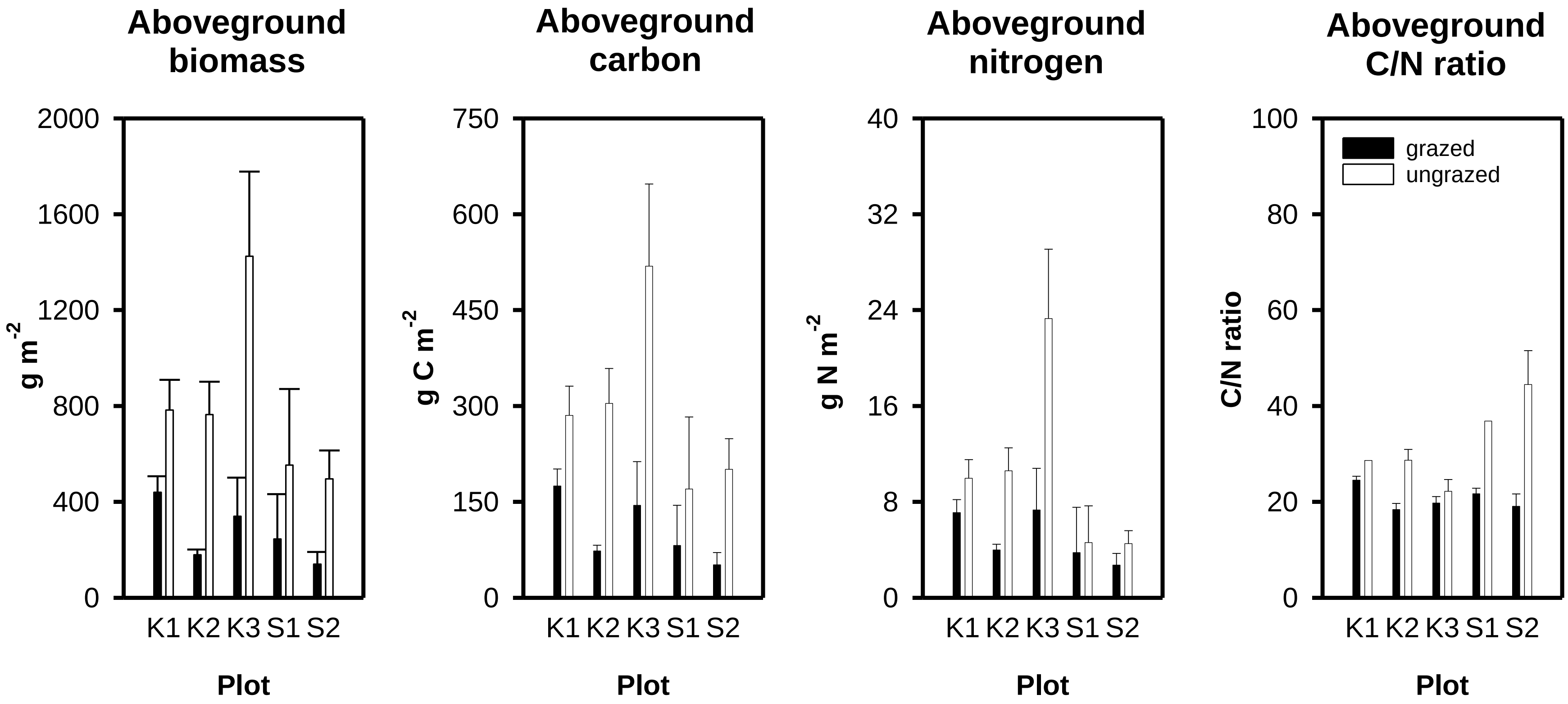
Species richness and vegetation cover of Cyperaceae and Poaceae inside and outside the exclosures (n=5)



Absence of grazing results in decreasing species richness and increasing vegetation cover of Poaceae

Grazing effects on aboveground biomass

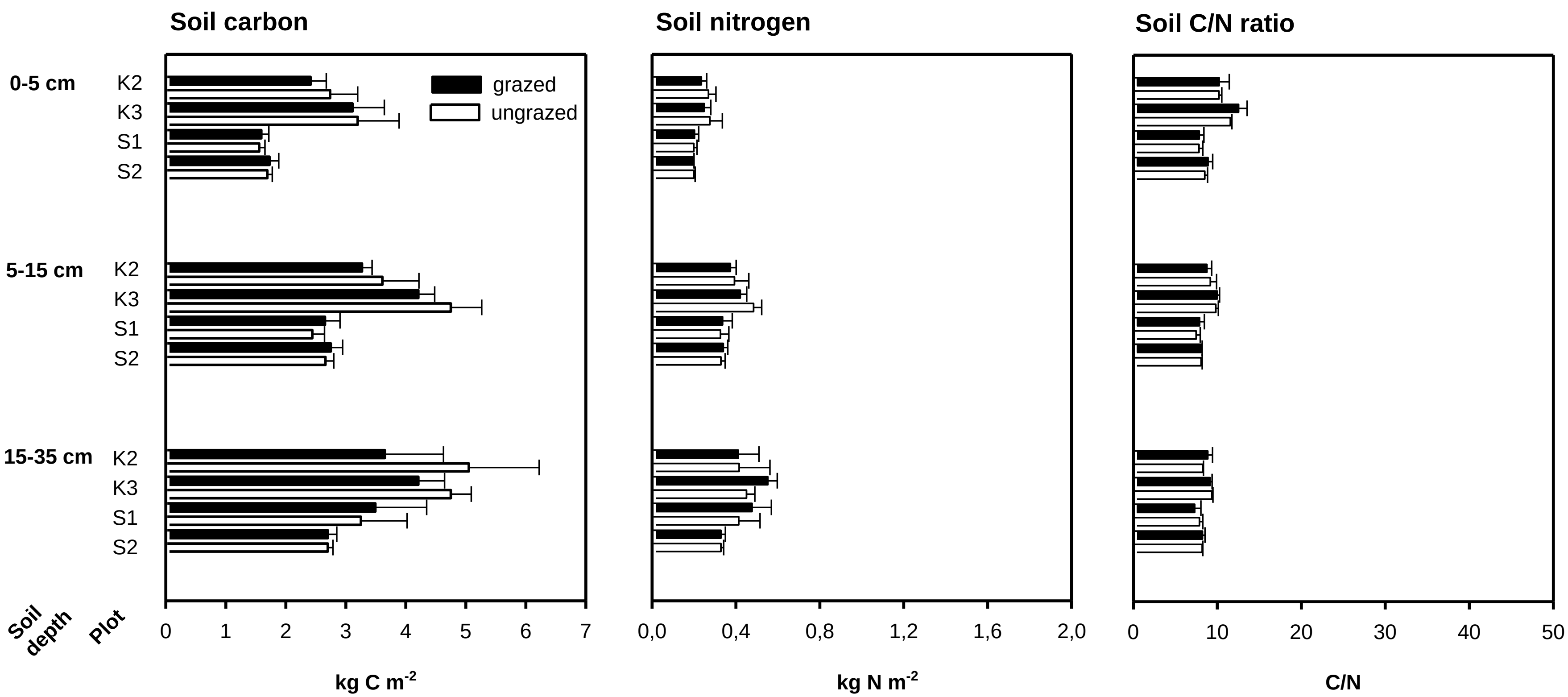
Aboveground biomass inside and outside the exclosures (n=5)



Absence of grazing leads to a larger aboveground biomass with wider C/N ratio

Grazing effects on soil organic carbon and nitrogen

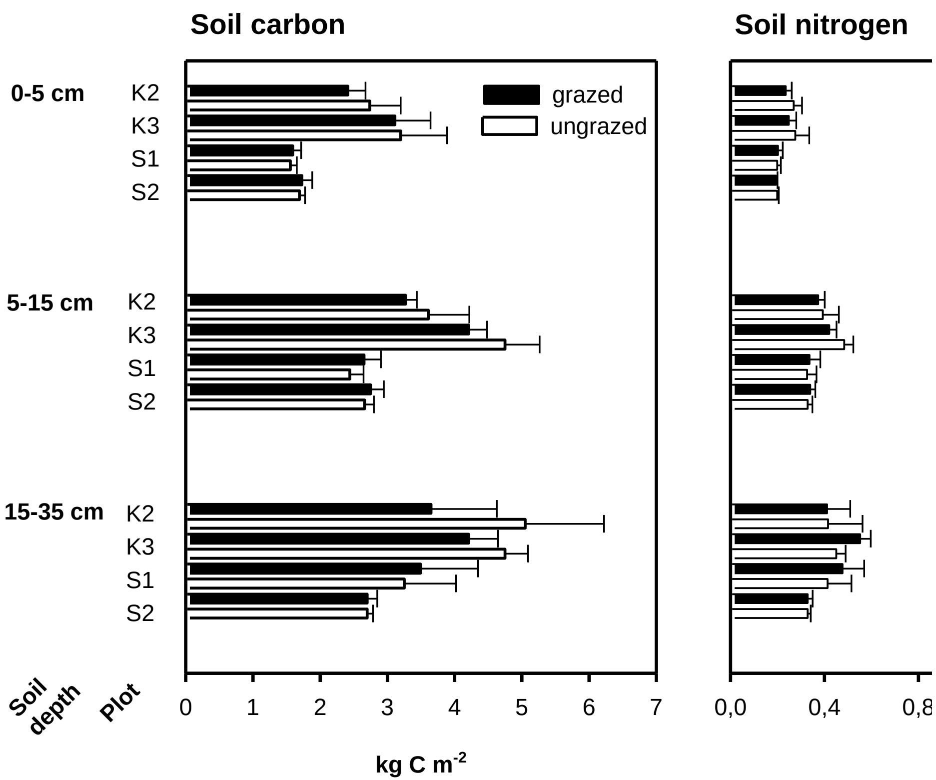
Soil organic carbon and nitrogen inside and outside the exclosures (n=5)

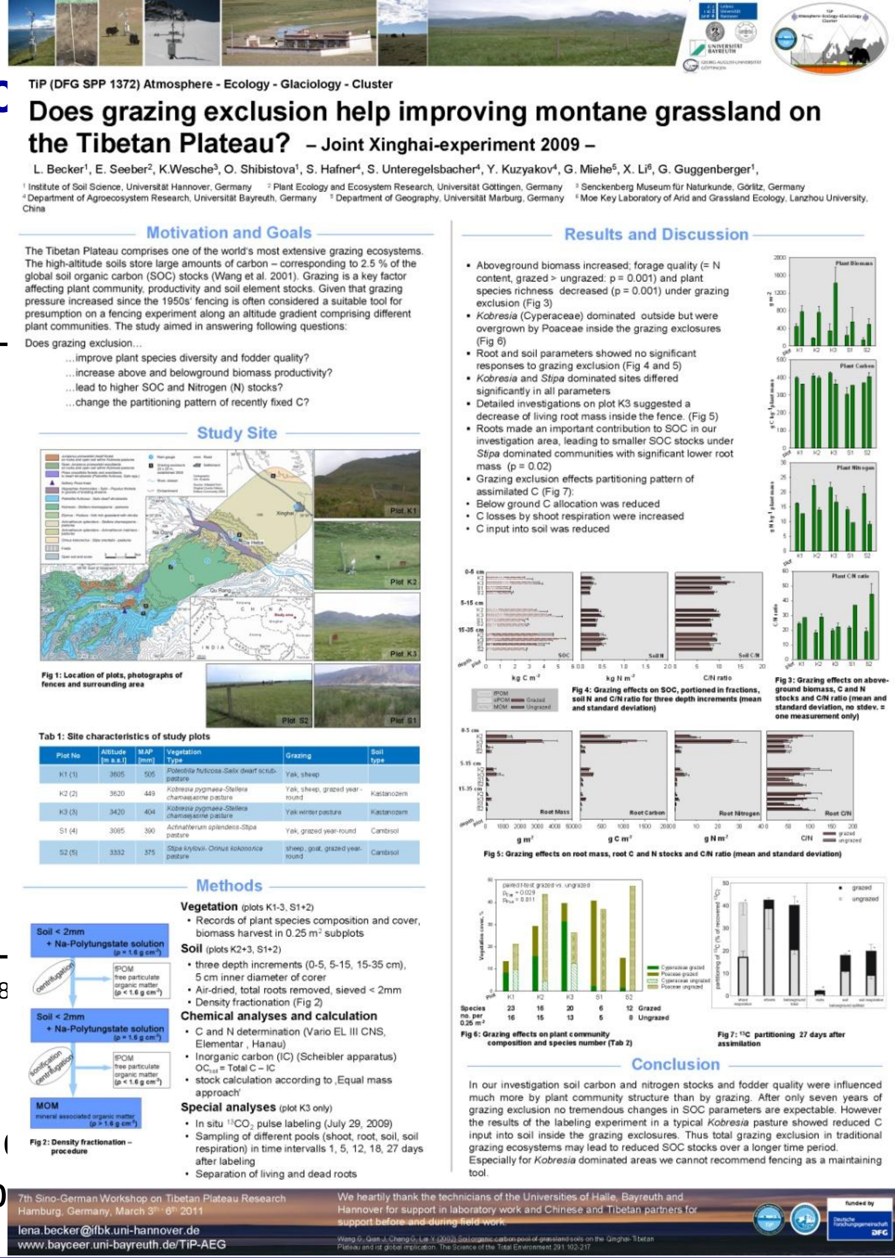


Soil organic carbon and nitrogen did not respond on absence grazing
But pasture types differ in their soil organic carbon storage

Grazing effects on soil organic c

Soil organic carbon and nitrogen inside and

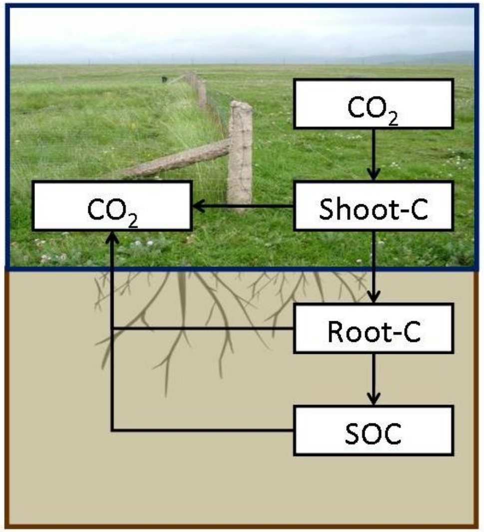


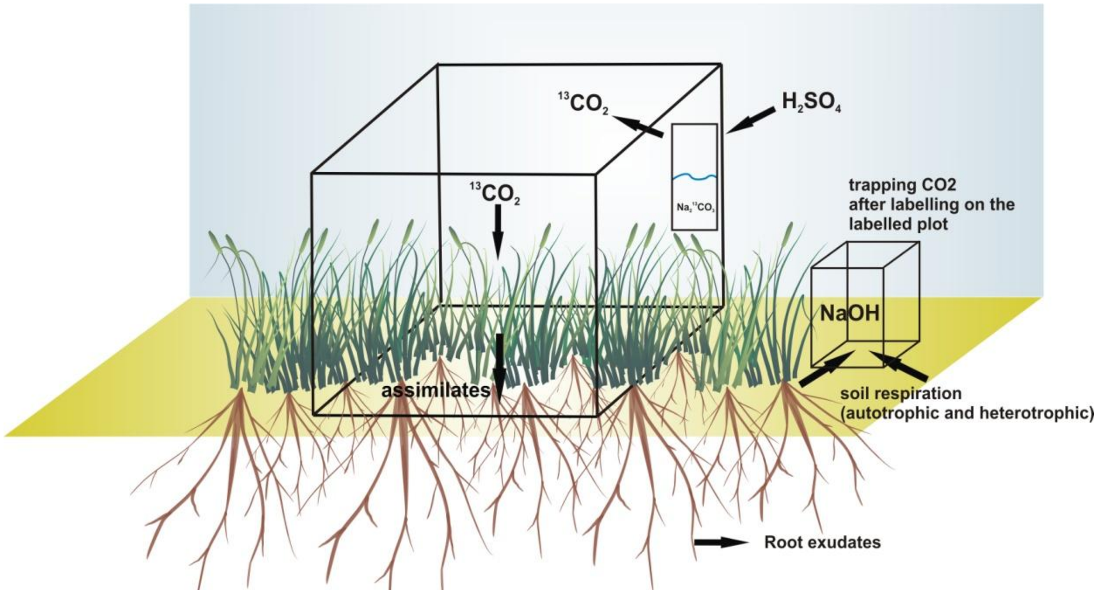


Soil organic carbon and nitrogen did not respon
But pasture types differ in their soil organic carb

Belowground carbon allocation of plant assimilates

^{13}C pulse-labeling experiment to identify belowground allocation of plant assimilates and source partitioning of CO_2 evolution





- Provides information on recent photosynthate distribution at specific development stages of plants
- The total amount of assimilated C is difficult to calculate
- Usefull tool for comparative C allocation studies

Hafner S., Unteregelsbacher S., Seeber E., Xu X., Li X., Guggenberger G., Miehe G., Kuzyakov Y. 2011. Effect of grazing on carbon stocks and assimilate partitioning in Tibetan montane pasture revealed by $^{13}CO_2$ pulse labeling. *Global Change Biology* (submitted).

Belowground carbon allocation of plant assimilates

1. preparating
the chambers

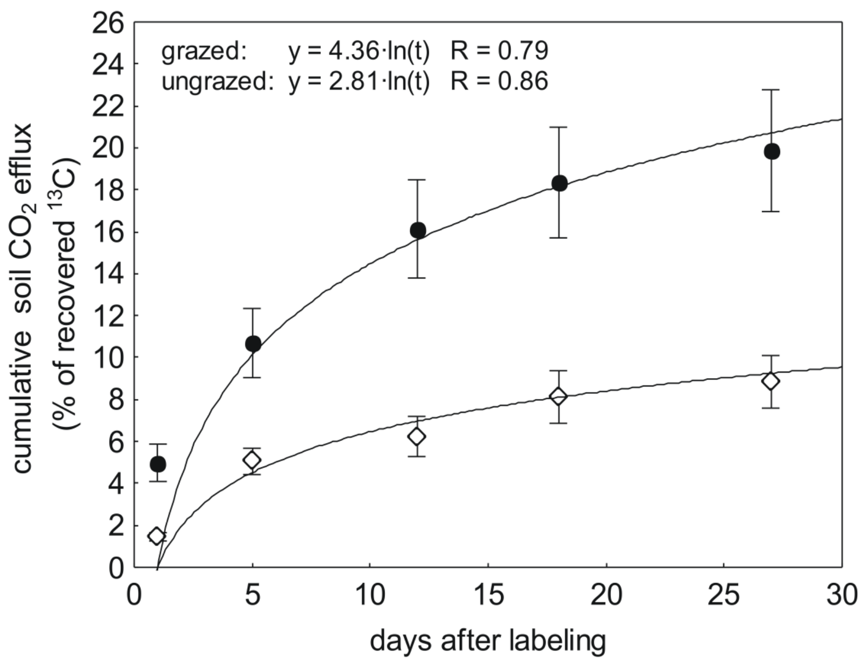
2. Closing the
chambers and
producing $^{13}CO_2$

3. waiting until
the label is
assimilated

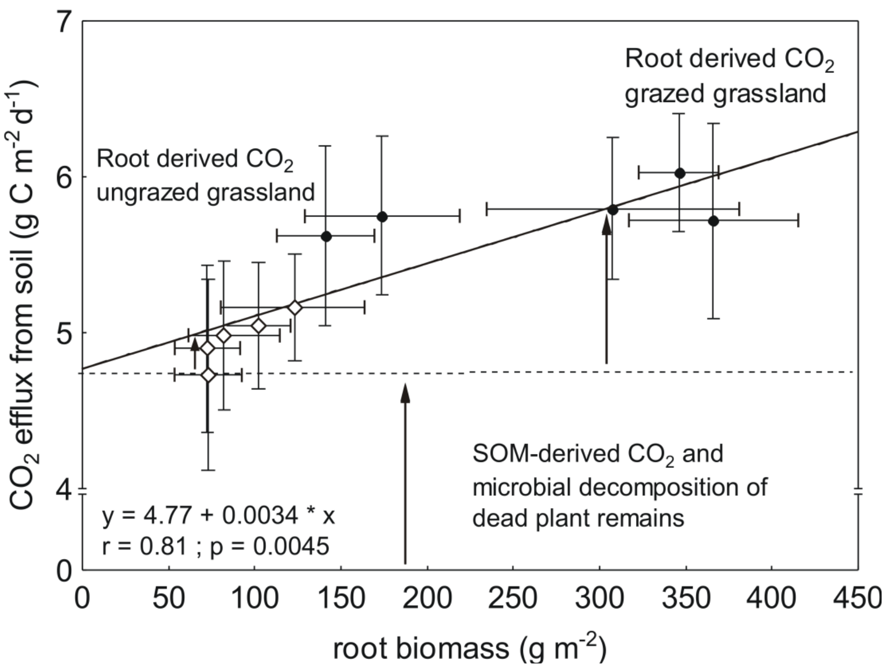
4. open the
chambers and
taking the samples

Soil CO_2 efflux (autotrophic and heterotrophic respiration)

Recovery of the added ^{13}C label in soil CO_2



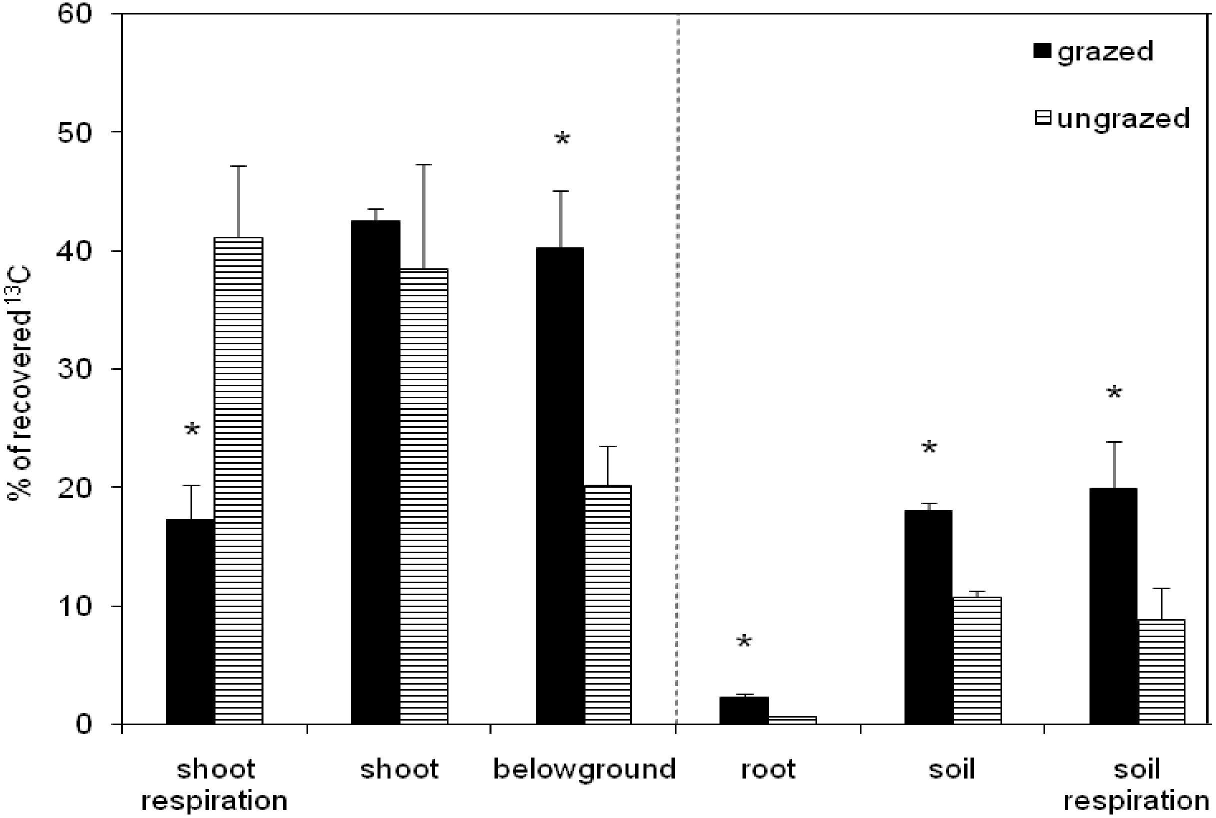
Source separation of soil CO_2 efflux



Due to larger C allocation under grazing the soil CO_2 efflux is larger (autotrophic component)

Belowground carbon allocation of plant assimilates

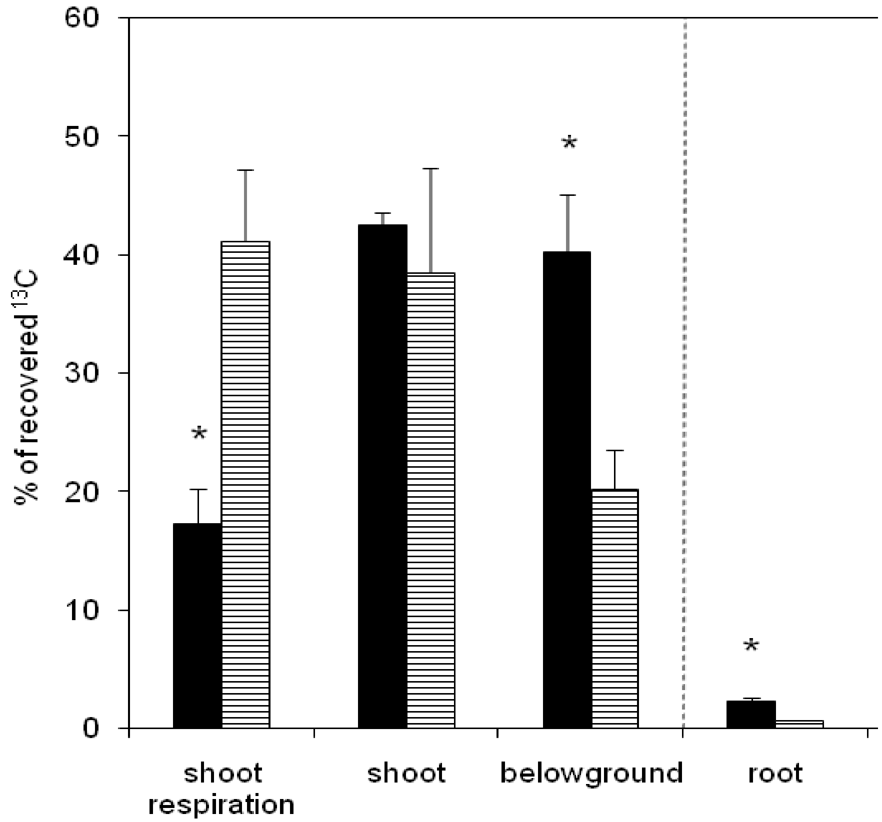
Partitioning of ^{13}C label 27d after labeling



Twice as much C was allocated belowground in the grazed pasture

Belowground carbon allocation

Partitioning of ^{13}C label 27d after labeling



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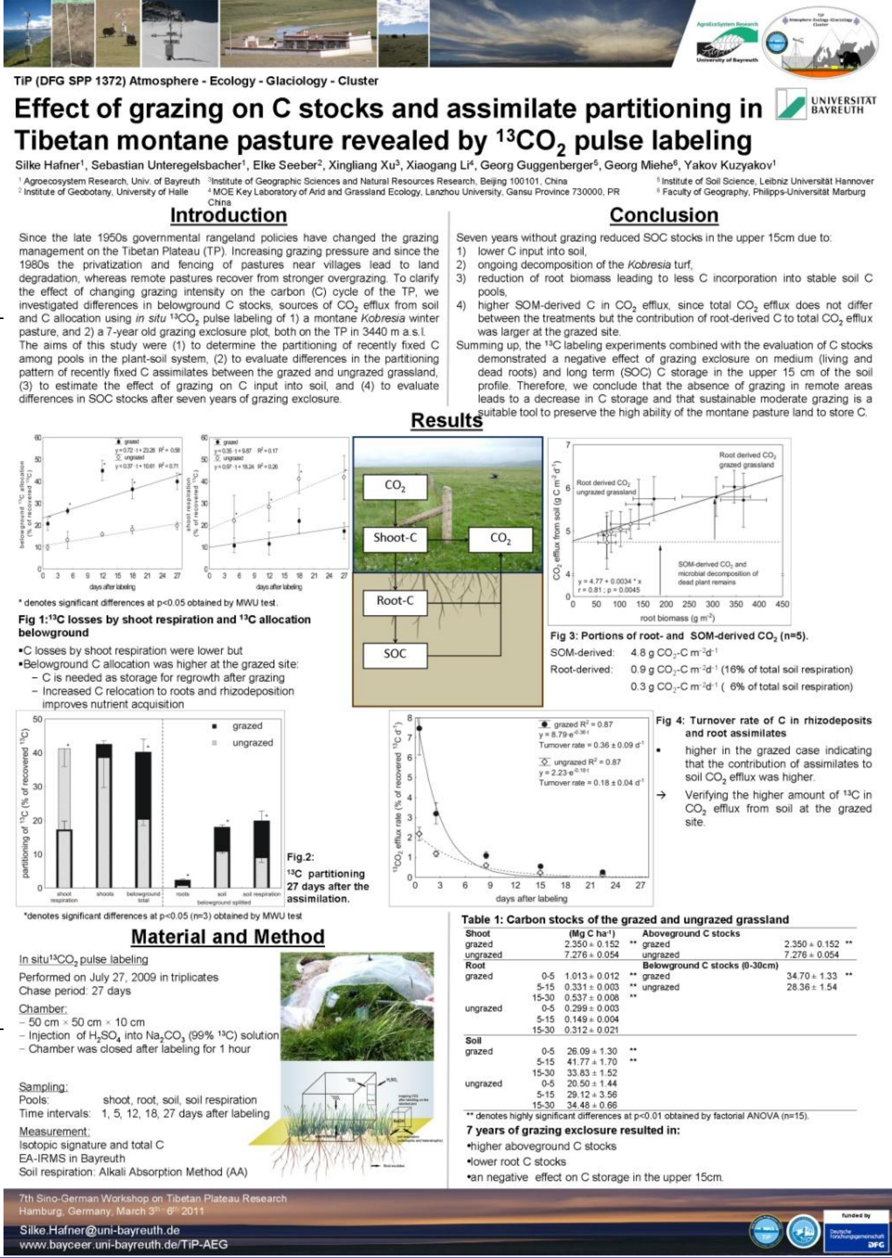

TiP (DFG SPP 1372) Atmosphere - Ecology - Glaciology - Cluster

Effect of grazing on C stocks and assimilate partitioning in Tibetan montane pasture revealed by $^{13}CO_2$ pulse labeling

Silke Hafner[1], Sebastian Unteregelsbacher[1], Elke Seeber[2], Xingliang Xu[3], Xiaogang Li[4], Georg Guggenberger[5], Georg Miehe[6], Yakov Kuzyakov[1]

[1] Agroecosystem Research, Univ. of Bayreuth [2] Institute of Geobotany, University of Halle [3] Institute of Geographic Sciences and Natural Resources Research, Beijing 100101, China [4] MOE Key Laboratory of Arid and Grassland Ecology, Lanzhou University, Gansu Province 730000, PR China [5] Institute of Soil Science, Leibniz Universität Hannover [6] Faculty of Geography, Philipps-Universität Marburg

Introduction

Since the late 1950s governmental rangeland policies have changed the grazing management on the Tibetan Plateau (TP). Increasing grazing pressure and since the 1980s the privatization and fencing of pastures near villages lead to land degradation, whereas remote pastures recover from stronger overgrazing. To clarify the effect of changing grazing intensity on the carbon (C) cycle of the TP, we investigated differences in belowground C stocks, sources of CO_2 efflux from soil and C allocation using *in situ* $^{13}CO_2$ pulse labeling of 1) a montane *Kobresia* winter pasture, and 2) a 7-year old grazing exclosure plot, both on the TP in 3440 m a.s.l.

The aims of this study were (1) to determine the partitioning of recently fixed C among pools in the plant-soil system, (2) to evaluate differences in the partitioning pattern of recently fixed C assimilates between the grazed and ungrazed grassland, (3) to estimate the effect of grazing on C input into soil, and (4) to evaluate differences in SOC stocks after seven years of grazing exclosure.

Conclusion

Seven years without grazing reduced SOC stocks in the upper 15cm due to:
1) lower C input into soil,
2) ongoing decomposition of the *Kobresia* turf,
3) reduction of root biomass leading to less C incorporation into stable soil C pools,
4) higher SOM-derived C in CO_2 efflux, since total CO_2 efflux does not differ between the treatments but the contribution of root-derived C to total CO_2 efflux was larger at the grazed site.

Summing up, the ^{13}C labeling experiments combined with the evaluation of C stocks demonstrated a negative effect of grazing exclosure on medium (living and dead roots) and long term (SOC) C storage in the upper 15 cm of the soil profile. Therefore, we conclude that the absence of grazing in remote areas leads to a decrease in C storage and that sustainable moderate grazing is a suitable tool to preserve the high ability of the montane pasture land to store C.

Results

* denotes significant differences at p<0.05 obtained by MWU test.

Fig 1: ^{13}C losses by shoot respiration and ^{13}C allocation belowground

- C losses by shoot respiration were lower but
- Belowground C allocation was higher at the grazed site:
  - C is needed as storage for regrowth after grazing
  - Increased C relocation to roots and rhizodeposition improves nutrient acquisition

CO2 | Shoot-C | CO2 | Root-C | SOC

Fig 3: Portions of root- and SOM-derived CO_2 (n=5).

SOM-derived: 4.8 g CO_2-C $m^{-2}d^{-1}$

Root-derived: 0.9 g CO_2-C $m^{-2}d^{-1}$ (16% of total soil respiration)

0.3 g CO_2-C $m^{-2}d^{-1}$ (6% of total soil respiration)

Fig.2: ^{13}C partitioning 27 days after the assimilation.

*denotes significant differences at p<0.05 (n=3) obtained by MWU test

Fig 4: Turnover rate of C in rhizodeposits and root assimilates

- higher in the grazed case indicating that the contribution of assimilates to soil CO_2 efflux was higher.

→ Verifying the higher amount of ^{13}C in CO_2 efflux from soil at the grazed site.

Table 1: Carbon stocks of the grazed and ungrazed grassland

Shoot		($Mg\ C\ ha^{-1}$)		Aboveground C stocks		
grazed		2.350 ± 0.152	**	grazed	2.350 ± 0.152	**
ungrazed		7.276 ± 0.054		ungrazed	7.276 ± 0.054	
Root				**Belowground C stocks (0-30cm)**		
grazed	0-5	1.013 ± 0.012	**	grazed	34.70 ± 1.33	**
	5-15	0.331 ± 0.003	**	ungrazed	28.36 ± 1.54	
	15-30	0.537 ± 0.008	**			
ungrazed	0-5	0.299 ± 0.003				
	5-15	0.149 ± 0.004				
	15-30	0.312 ± 0.021				
Soil						
grazed	0-5	26.09 ± 1.30	**			
	5-15	41.77 ± 1.70	**			
	15-30	33.83 ± 1.52				
ungrazed	0-5	20.50 ± 1.44				
	5-15	29.12 ± 3.56				
	15-30	34.48 ± 0.66				

** denotes highly significant differences at p<0.01 obtained by factorial ANOVA (n=15).

7 years of grazing exclosure resulted in:
- higher aboveground C stocks
- lower root C stocks
- an negative effect on C storage in the upper 15cm.

Material and Method

In situ $^{13}CO_2$ pulse labeling

Performed on July 27, 2009 in triplicates
Chase period: 27 days

Chamber:
- 50 cm × 50 cm × 10 cm
- Injection of H_2SO_4 into Na_2CO_3 (99% ^{13}C) solution
- Chamber was closed after labeling for 1 hour

Sampling:
Pools: shoot, root, soil, soil respiration
Time intervals: 1, 5, 12, 18, 27 days after labeling

Measurement:
Isotopic signature and total C
EA-IRMS in Bayreuth
Soil respiration: Alkali Absorption Method (AA)

7th Sino-German Workshop on Tibetan Plateau Research
Hamburg, Germany, March 3th - 6th 2011

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www.bayceer.uni-bayreuth.de/TiP-AEG

funded by Deutsche Forschungsgemeinschaft DFG

Low molecular organic substances in root mats

Vegetation free patches covered by lichens and blue-green algae are a result of overgrazing

This affects the carbon cycling, e.g. of low molecular organic substances (plant exudates)

Labeling procedure

– 2 treatments
  - plants (*Kobresia pygmaea* and *Stipa*)
  - blue-green algae and crustose lichens
– 3 substance groups

^{13}C-glucose	$(^{15}NH_4)_2SO_4$
^{13}C-glycine	^{15}N-glycine
^{13}C-acetic acid	$K^{15}NO_3$

– 4 replications (24 plots)

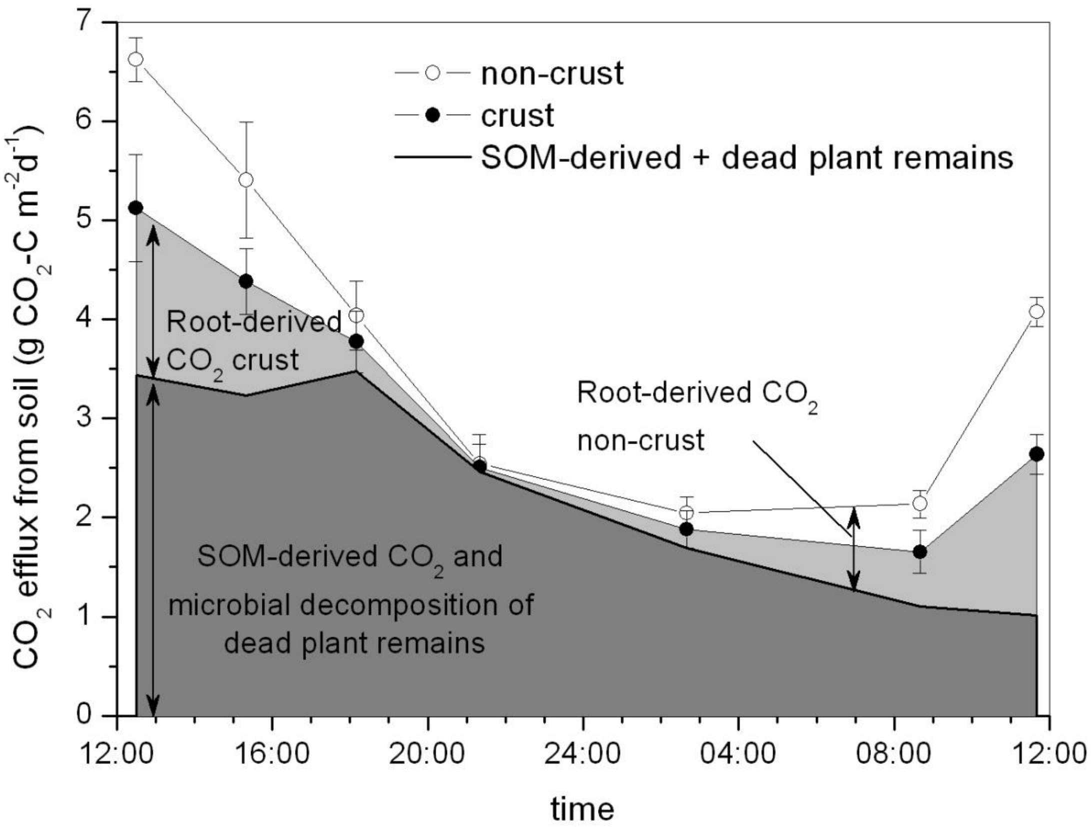
plant cover 100%

plant cover <50%

Unteregelsbacher S., Hafner S., Guggenberger G., Miehe G., Xu X., Liu J., Kuzyakov Y. 2011. Response of long-, medium- and short-term turnover processes of the carbon budget to overgrazing on the Tibetan Plateau. *Biogeochemistry* (submitted).

Partitioning of CO_2 fluxes

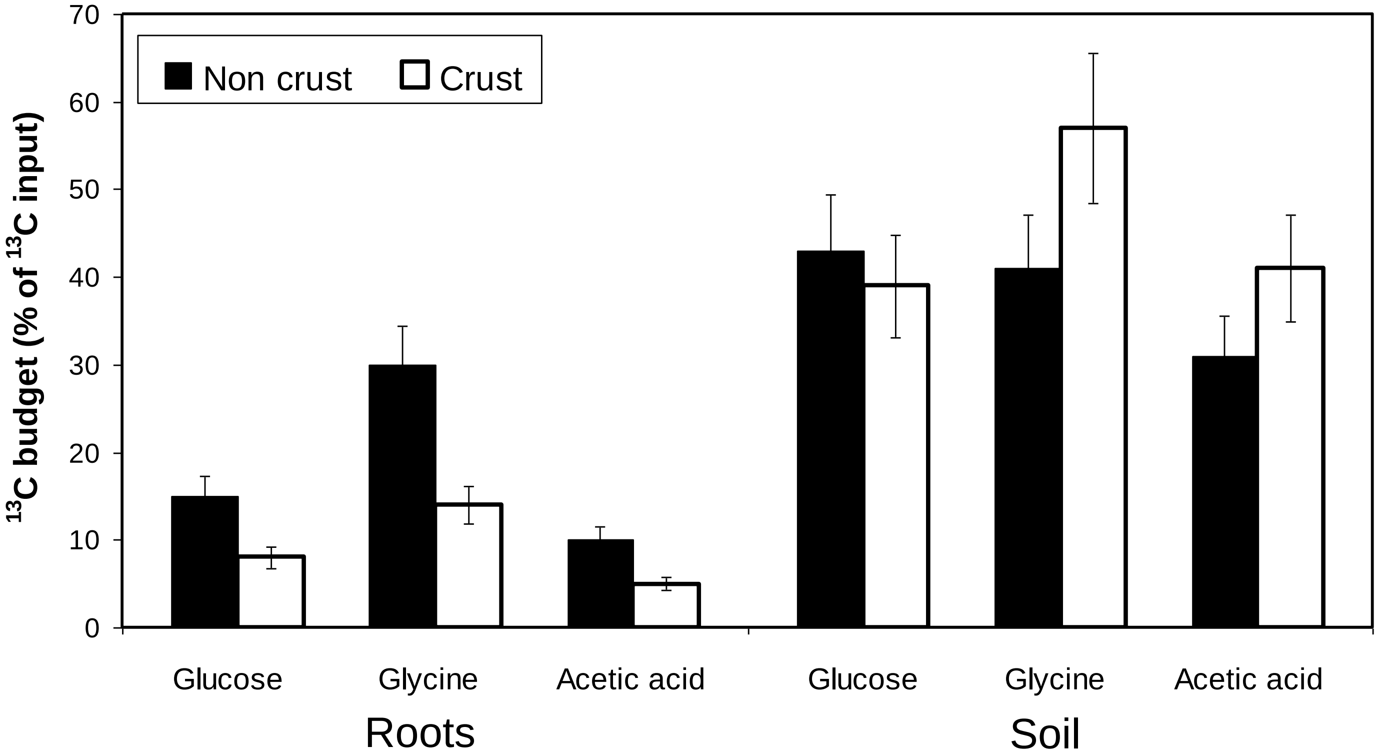
Diurnal dynamics of CO_2 efflux from crust and non-crust soil based on regression approach



Root-derived soil CO_2 efflux is repressed under crusts (less C allocation to roots)

^{13}C budget of low molecular organic substances

Distribution of ^{13}C among roots and soil 27d after labeling



Crust decrease ^{13}C from low molecular organic substances in roots
Crust increase ^{13}C from low molecular organic substances in soil

Conclusions

Coming back to hypotheses on consequences of absence of grazing

H1: **Increase in aboveground biomass**

- **Yes** – trivial; but consequences for fodder quality (wider CN/ ratio)

H2: **Decrease in belowground carbon allocation** due to larger investments into aboveground biomass

- **Yes** – absence of grazing decreased belowground carbon input to soil by 50%
- Despite an increase in soil CO_2 efflux, this leads to soil organic carbon built-up
- The carbon allocation experiment is having an indicator function for possible modification in the soil organic matter storage and, hence, soil quality

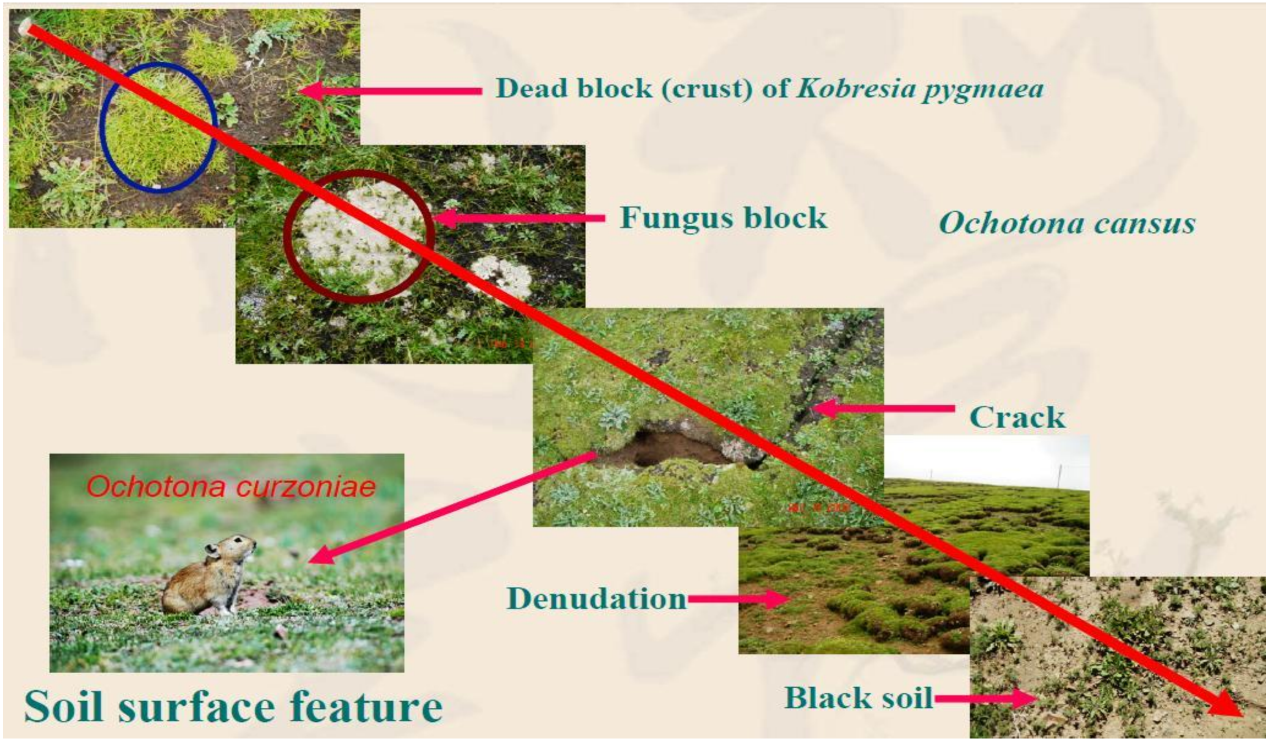
H2: **Decrease in soil organic carbon and nitrogen** due to smaller contribution of root-derived carbon

- **No** – but duration of the experiment (7 years only) must be considered
- Large and slowly turning over root carbon and soil organic carbon *versus* relatively small carbon fluxes to the soil
- But different grassland communities showed different soil organic carbon storage

General conclusions

- Moderate grazing is an optimum land use for Tibetan grasslands with respect to
  - Soil organic carbon storage
  - Nutrient cycling (is accelerated by grazing; problem might be nutrient return)
  - *Kobresia* root mats protects against degradation

- In consequence, degradation of *Kobresia* root mats by land use and climate change will lead to soil degradation



Suggested degradation sequence of *Kobresia* pastures;

Photos and processes: Chao Guangmin

Future plans

Aim

To evaluate the development and degradation of *Kobresia* root mats, their effects on C and N turnover and on C sequestration

Hypotheses

H1: *Kobresia* pastures are anthro-zoological induced pseudoclimax, but accentuated by climate

H2: *Kobresia* root mats consist of stratified subhorizons, and are built up within a decade or so by growing up from the mineral soil surface

H3: The different subhorizons of the *Kobresia* root mats provide different functions, incl. mechanical protection, C storage, prevention of nutrient losses and regrowth after heavy overgrazing

H4: Abiotic drivers (e.g., ice wedges, frost/dryness cracks) are more important in *Kobresia* root mat degradation than biotic ones (e.g., pikas)

Approach

Work packages

WP 1: Historical development of *Kobresia* pastures

WP 2: Morphology, development and origin of *Kobresia* root mats

WP 3: Functions of *Kobresia* root mats

WP 4: Degradation of *Kobresia* root mats

Methods

- Space-for-time approach
- Suberin, lignin, polysaccharide biomarker
- ^{13}C and ^{15}N labeling
- ^{14}C analysis
- Incubation experiments
- Morphological studies

Approach

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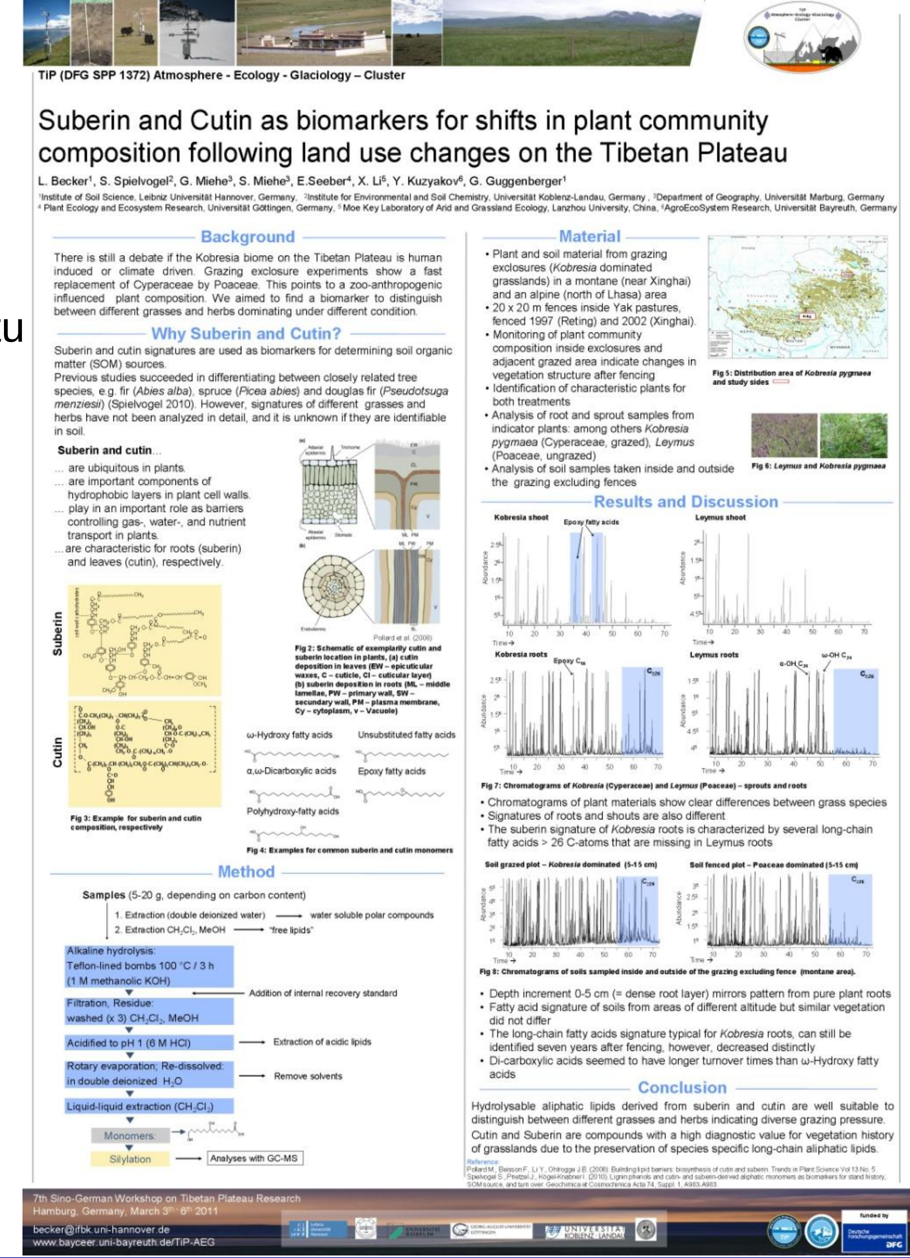


Thanks to:
- DFG
- you