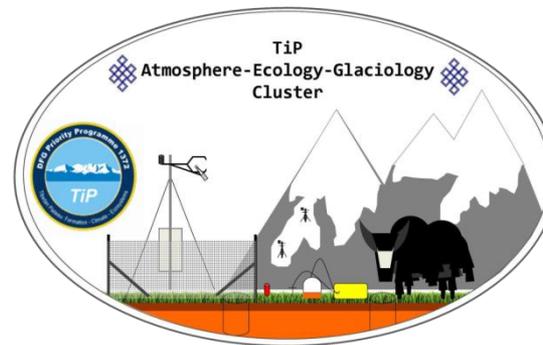
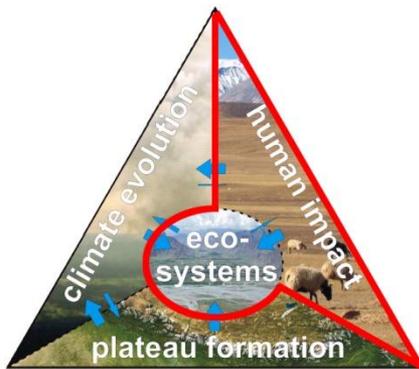


# Human impact on soil organic carbon and nitrogen turnover in *Kobresia* pastures

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 Yakov Kuzyakov  
 Georg Miehe  
 Karsten Wesche

Peili Shi  
 Xiaogang Li  
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# 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 enclosure of livestock



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:

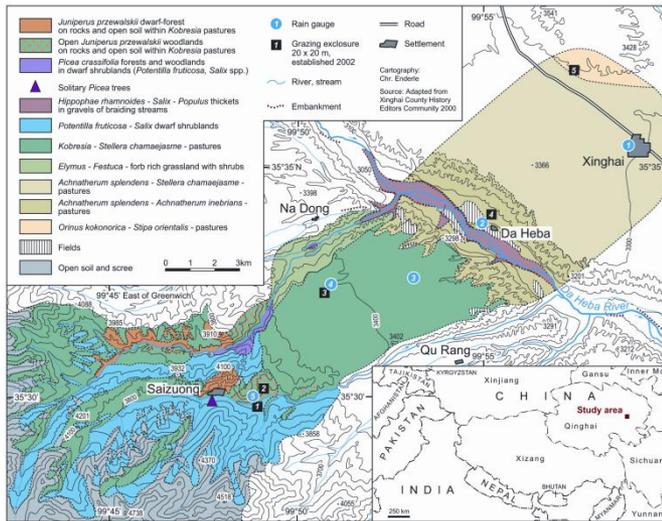
H1: **Increase in aboveground biomass**

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



Joint plant and soil studies  
 were performed at subplots

## Exclosures for 7 years

*Kobresia* pastures, K1-3 (Kastanozem)



## *Stipa*-dominated pastures, S1-3 (Cambisol)



# 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



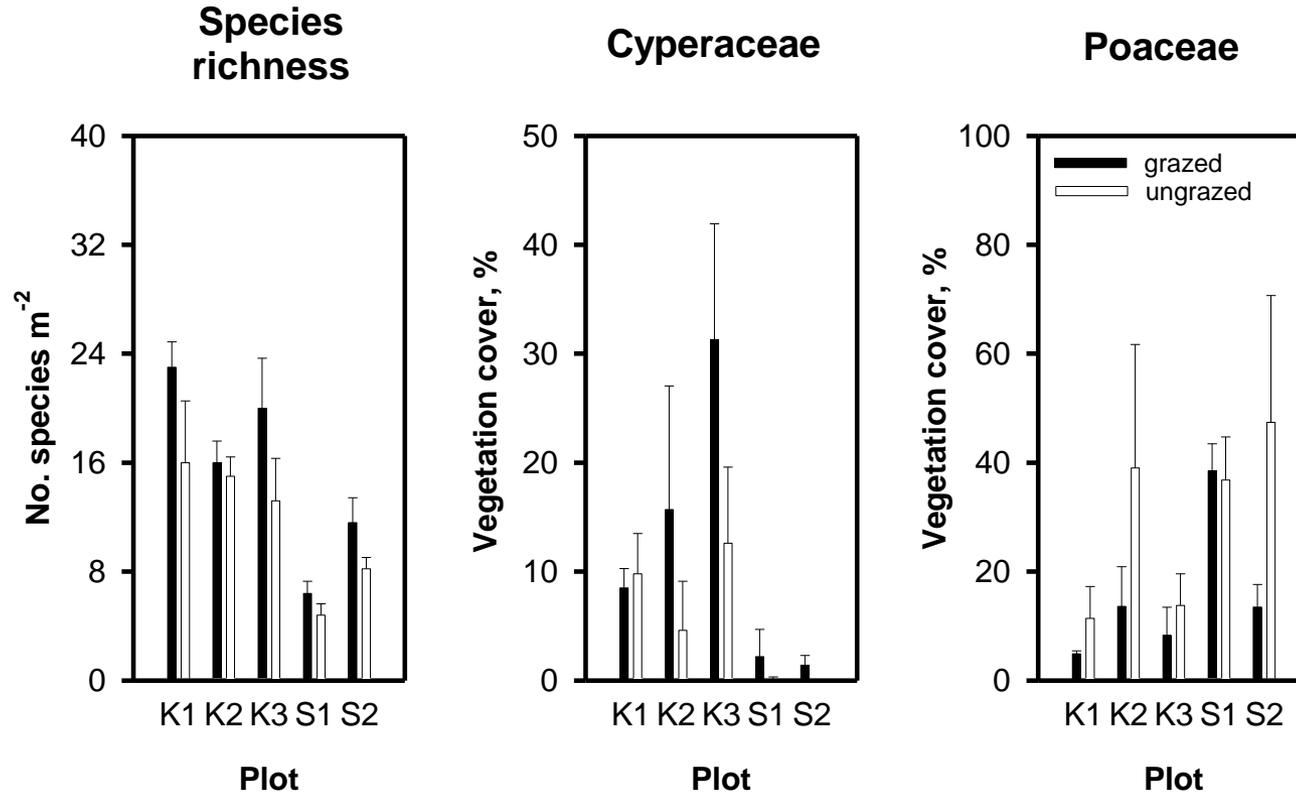
### Stratified soil sampling



### Soil description

# Grazing effects on plant community composition

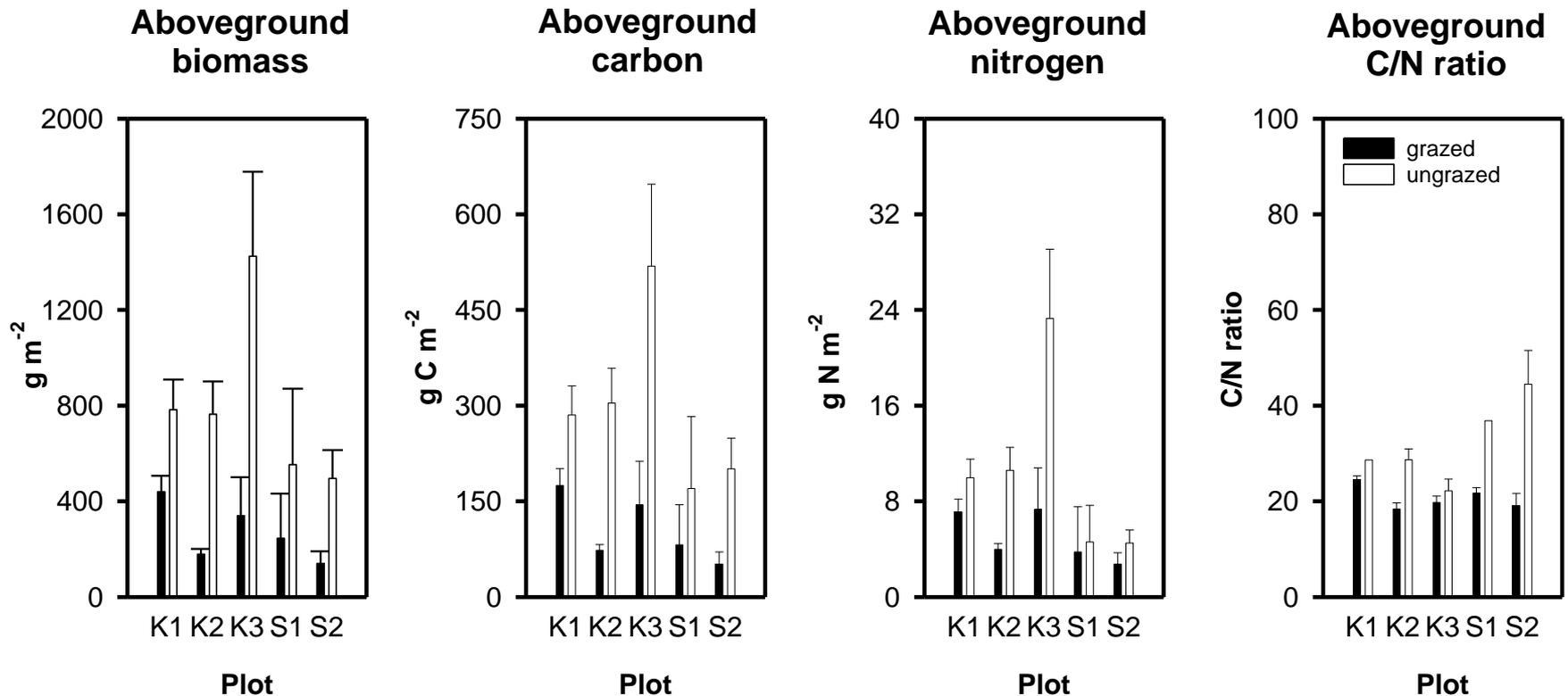
Species richness and vegetation cover of Cyperaceae and Poaceae inside and outside the exclosures (n=5)



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

# Grazing effects on aboveground biomass

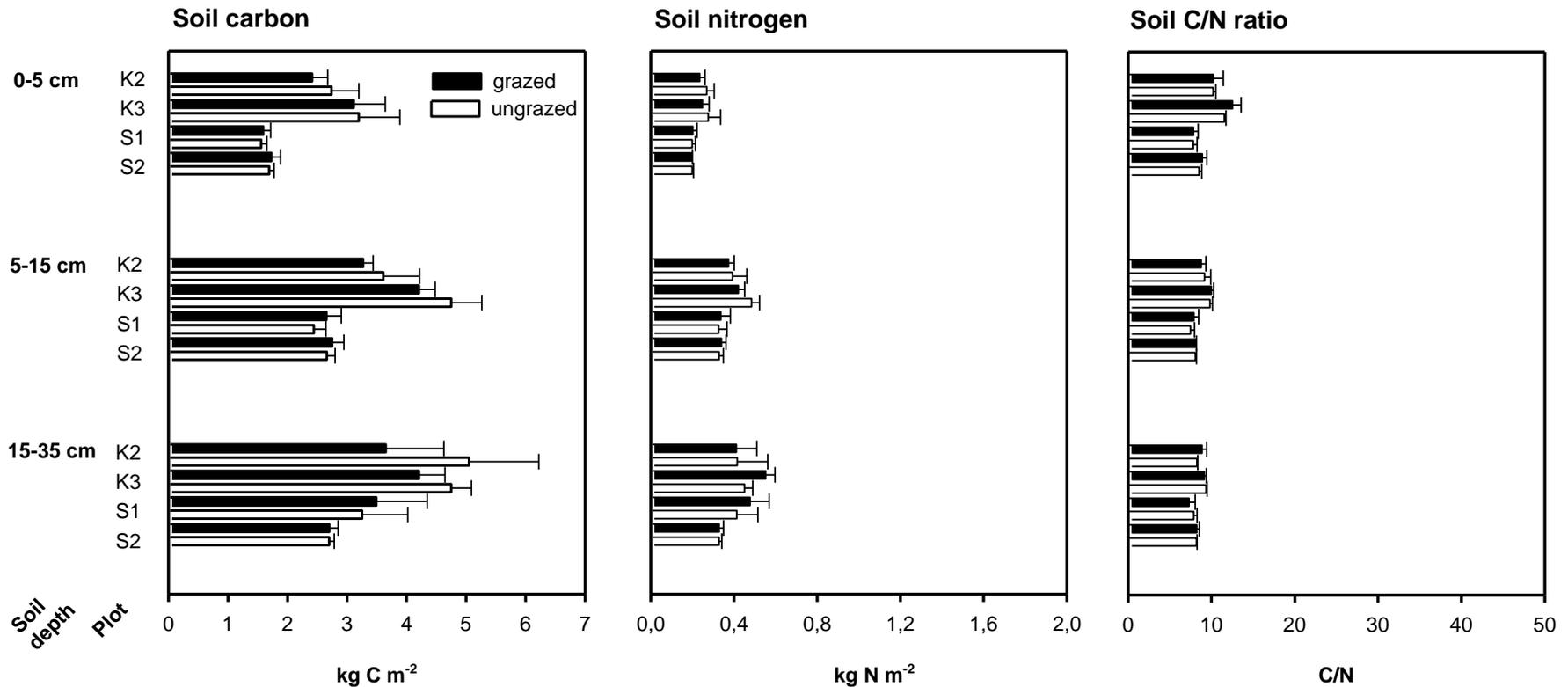
Aboveground biomass inside and outside the exclosures (n=5)



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

# Grazing effects on soil organic carbon and nitrogen

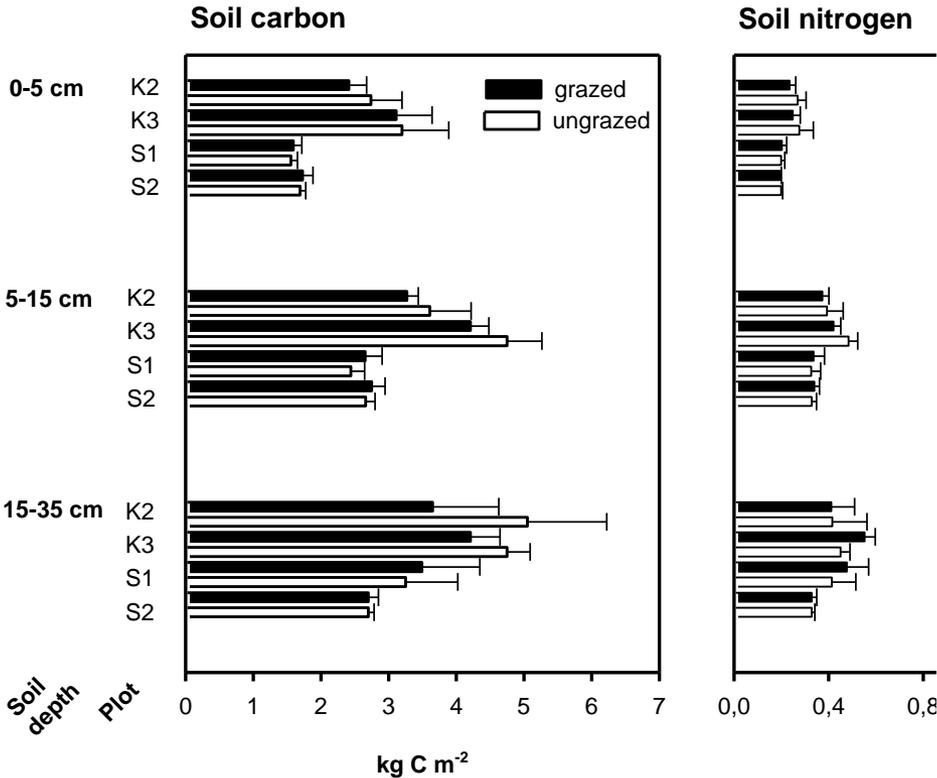
Soil organic carbon and nitrogen inside and outside the exclosures (n=5)



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 carbon

## Soil organic carbon and nitrogen inside and



Soil organic carbon and nitrogen did not respond to grazing exclusion. But pasture types differ in their soil organic carbon and nitrogen stocks.

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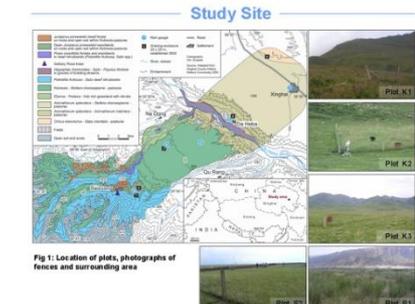
## Does grazing exclusion help improving montane grassland on the Tibetan Plateau? – Joint Xinghai-experiment 2009 –

L. Becker<sup>1</sup>, E. Seeber<sup>2</sup>, K. Wesche<sup>3</sup>, O. Shibistova<sup>1</sup>, S. Hafner<sup>4</sup>, S. Unterregelsbacher<sup>1</sup>, Y. Kuzayak<sup>1</sup>, G. Miehle<sup>5</sup>, X. Li<sup>6</sup>, G. Guggenberger<sup>1</sup>,  
<sup>1</sup>Institute of Soil Science, Universität Hannover, Germany <sup>2</sup>Plant Ecology and Ecosystem Research, Universität Göttingen, Germany <sup>3</sup>Senckenberg Museum für Naturkunde, Göttingen, Germany  
<sup>4</sup>Department of Agroecosystem Research, Universität Bayreuth, Germany <sup>5</sup>Department of Geography, Universität Marburg, Germany <sup>6</sup>Mo Key Laboratory of Arid and Grassland Ecology, Lanzhou University, China

### Motivation and Goals

The Tibetan Plateau comprises one of the world's most extensive grazing ecosystems. The high-altitude soils store large amounts of carbon – corresponding to 2.5 % of the global soil organic carbon (SOC) stocks (Wang et al. 2001). Grazing is a key factor affecting plant community, productivity and soil element stocks. Given that grazing pressure increased since the 1950s, fencing is often considered a suitable tool for preservation on a fencing experiment along an altitude gradient comprising different plant communities. The study aimed in answering following questions:

- Does grazing exclusion...
  - ...improve plant species diversity and fodder quality?
  - ...increase above and belowground biomass productivity?
  - ...lead to higher SOC and Nitrogen (N) stocks?
  - ...change the partitioning pattern of recently fixed C?



Tab 1: Site characteristics of study plots

Plot No.	Altitude (m a.s.l.)	MAP (m²)	Vegetation Type	Grazing	Soil Type
K1 (1)	3955	305	<i>Kobresia tibetica</i> - <i>Stipa capillaris</i> - <i>Stipa capillaris</i>	Yak, sheep	Podzol
K2 (2)	3620	449	<i>Kobresia pygmaea</i> - <i>Stipa chamoensis</i> pasture	Yak, sheep, grazed year-round	Kalderon
K3 (3)	3420	404	<i>Kobresia pygmaea</i> - <i>Stipa chamoensis</i> pasture	Yak winter pasture	Kalderon
S1 (4)	3085	300	<i>Adiantum platyneuron</i> - <i>Stipa capillaris</i> pasture	Yak, grazed year-round	Carbuncle
S2 (5)	3332	375	<i>Stipa tibetica</i> - <i>Cladonia</i> pasture	sheep, goat, grazed year-round	Carbuncle

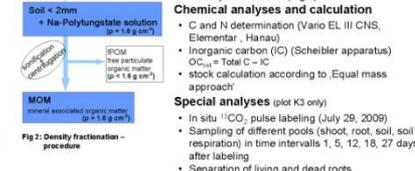
### Methods

**Vegetation** (plots K1-3, S1+2)  
 • Records of plant species composition and cover, biomass harvest in 0.25 m<sup>2</sup> subplots

**Soil** (plots K2-3, S1+2)  
 • three depth increments (0-5, 5-15, 15-35 cm), 5 cm inner diameter of corer  
 • Air-dried, total roots removed, sieved < 2mm  
 • Density fractionation (Fig 2)

**Chemical analyses and calculation**  
 • C and N determination (Vario EL III CNS, Elementar, Hanau)  
 • Inorganic carbon (IC) (Scheibler apparatus)  
 • OC<sub>org</sub> = Total C – IC  
 • stock calculation according to Equal mass approach

**Special analyses** (plot K3 only)  
 • In situ <sup>14</sup>C<sub>2</sub> pulse labeling (July 29, 2009)  
 • Sampling of different pools (shoot, root, soil, soil respiration) in time intervals 1, 5, 12, 18, 27 days after labeling  
 • Separation of living and dead roots



### Results and Discussion

- Aboveground biomass increased, forage quality (= N content, grazed > ungrazed; p = 0.001) and plant species richness decreased (p = 0.001) under grazing exclusion (Fig 3)
- Kobresia* (Cyperaceae) dominated outside but were overgrown by Poaceae inside the grazing enclosures (Fig 6)
- Root and soil parameters showed no significant responses to grazing exclusion (Fig 4 and 5)
- Kobresia* and *Stipa* dominated sites differed significantly in all parameters
- Detailed investigations on plot K3 suggested a decrease of living root mass inside the fence (Fig 5)
- Roots made an important contribution to SOC in our investigation area, leading to smaller SOC stocks under *Stipa* dominated communities with significant lower root mass (p = 0.02)
- Grazing exclusion effects partitioning pattern of assimilated C (Fig 7)
- Belowground C allocation was reduced
- C losses by shoot respiration were increased
- C input into soil was reduced

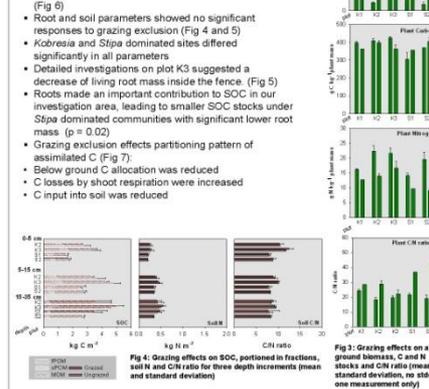


Fig 3: Grazing effects on aboveground biomass, C and N stocks and C:N ratio (mean and standard deviation, n = 5, one measurement only)

Fig 4: Grazing effects on SOC, partitioned in fractions, soil N and C:N ratio for three depth increments (mean and standard deviation, n = 5, one measurement only)

Fig 5: Grazing effects on root mass, root C and N stocks and C:N ratio (mean and standard deviation, n = 5, one measurement only)

Fig 6: Grazing effects on plant community composition and species number (Tab 2)

Fig 7: <sup>14</sup>C partitioning 27 days after assimilation

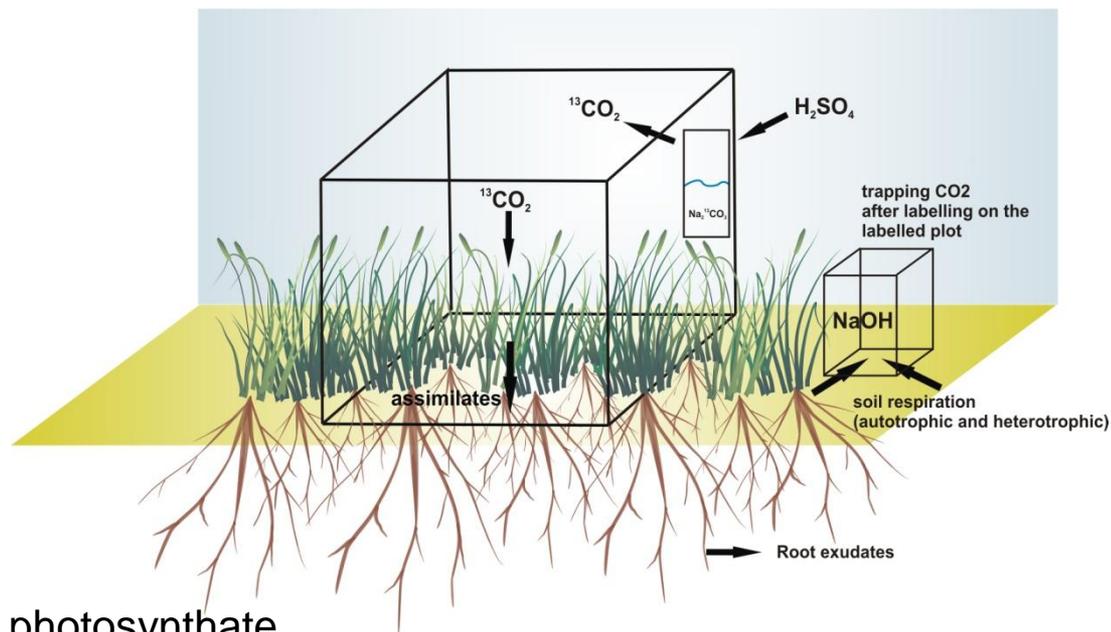
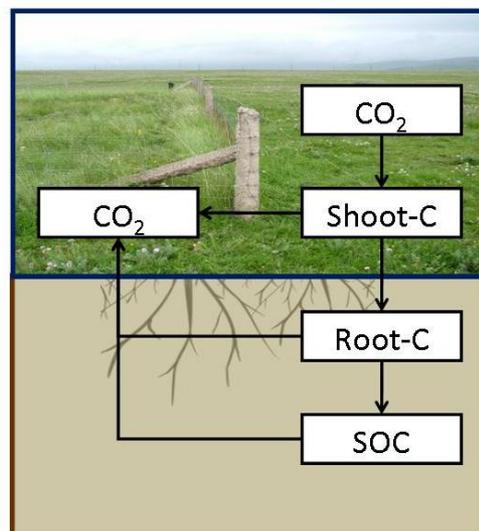
### Conclusion

In our investigation soil carbon and nitrogen stocks and fodder quality were influenced much more by plant community structure than by grazing. After only seven years of grazing exclusion no tremendous changes in SOC parameters are expectable. However the results of the labeling experiment in a typical *Kobresia* pasture showed reduced C input into soil inside the grazing enclosures. Thus total grazing exclusion in traditional grazing ecosystems may lead to reduced SOC stocks over a longer time period. Especially for *Kobresia* dominated areas we cannot recommend fencing as a maintaining tool.

Introduction C and N storage C allocation Conclusions Future plans

# Belowground carbon allocation of plant assimilates

$^{13}\text{C}$  pulse-labeling experiment to identify belowground allocation of plant assimilates and source partitioning of  $\text{CO}_2$  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., Miede G., Kuzyakov Y. 2011. Effect of grazing on carbon stocks and assimilate partitioning in Tibetan montane pasture revealed by  $^{13}\text{CO}_2$  pulse labeling. *Global Change Biology* (submitted).

# Belowground carbon allocation of plant assimilates

1. preparing the chambers



2. Closing the chambers and producing  $^{13}\text{CO}_2$



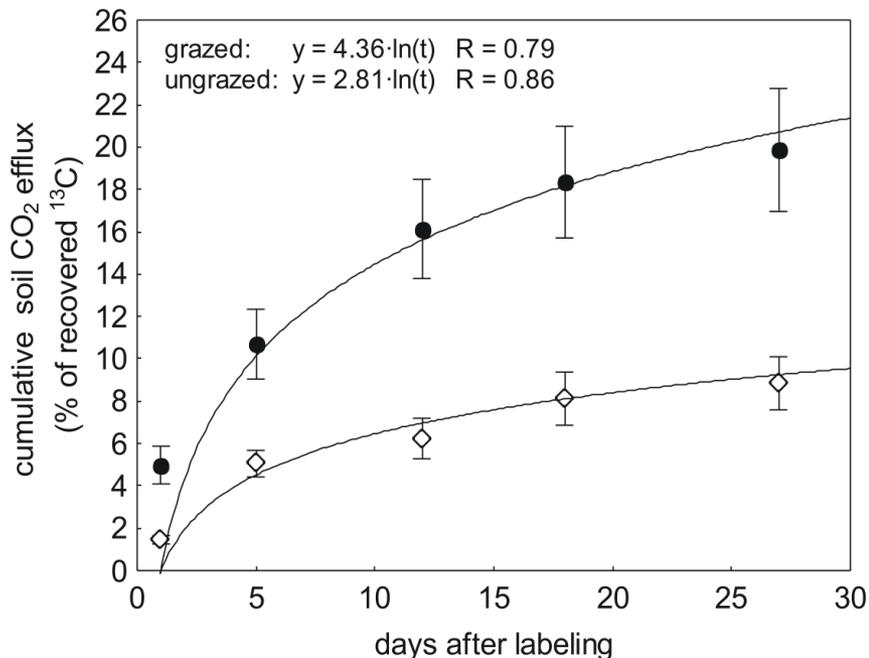
4. open the chambers and taking the samples



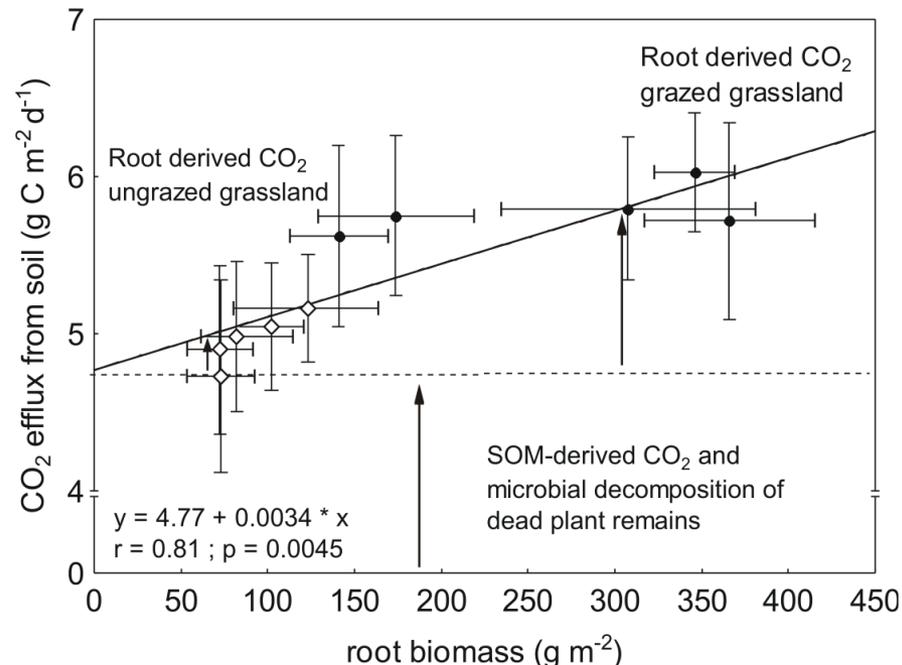
3. waiting until the label is assimilated

# Soil CO<sub>2</sub> efflux (autotrophic and heterotrophic respiration)

## Recovery of the added <sup>13</sup>C label in soil CO<sub>2</sub>



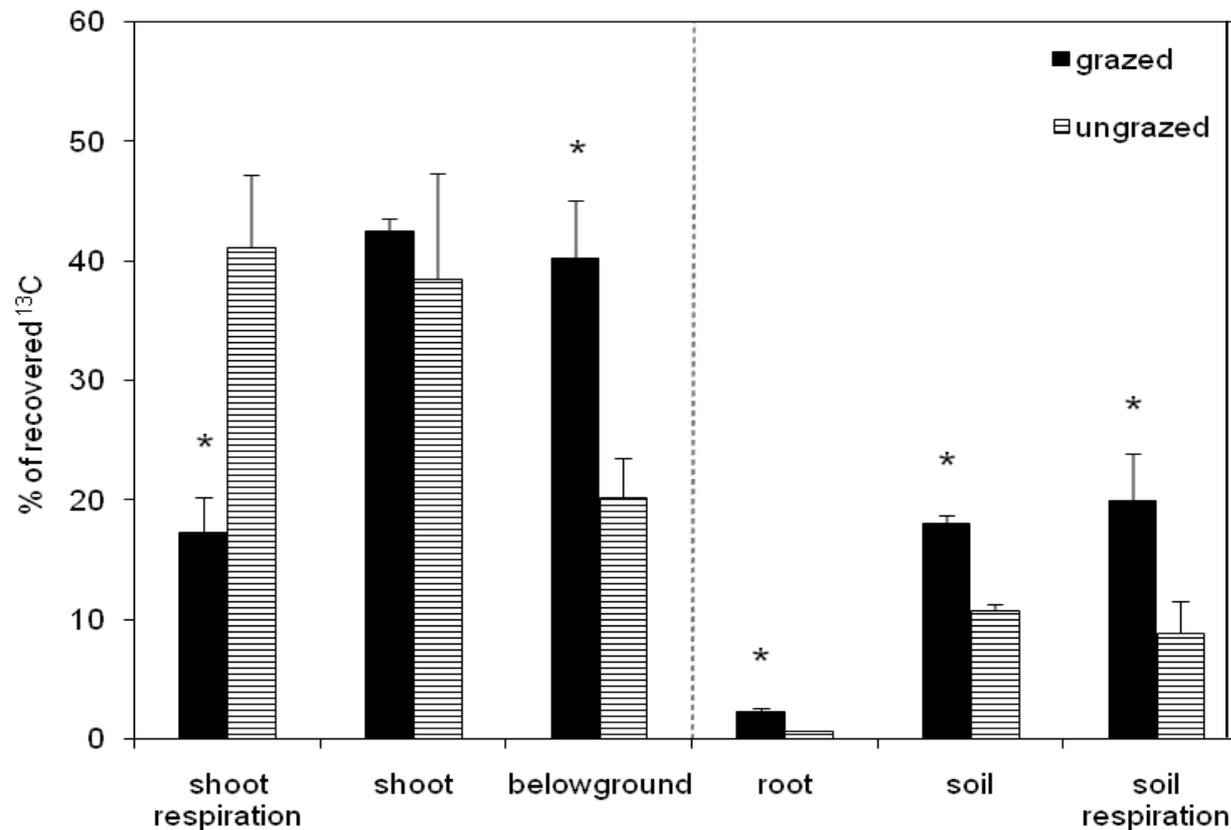
## Source separation of soil CO<sub>2</sub> efflux



Due to larger C allocation under grazing the soil CO<sub>2</sub> efflux is larger (autotrophic component)

# Belowground carbon allocation of plant assimilates

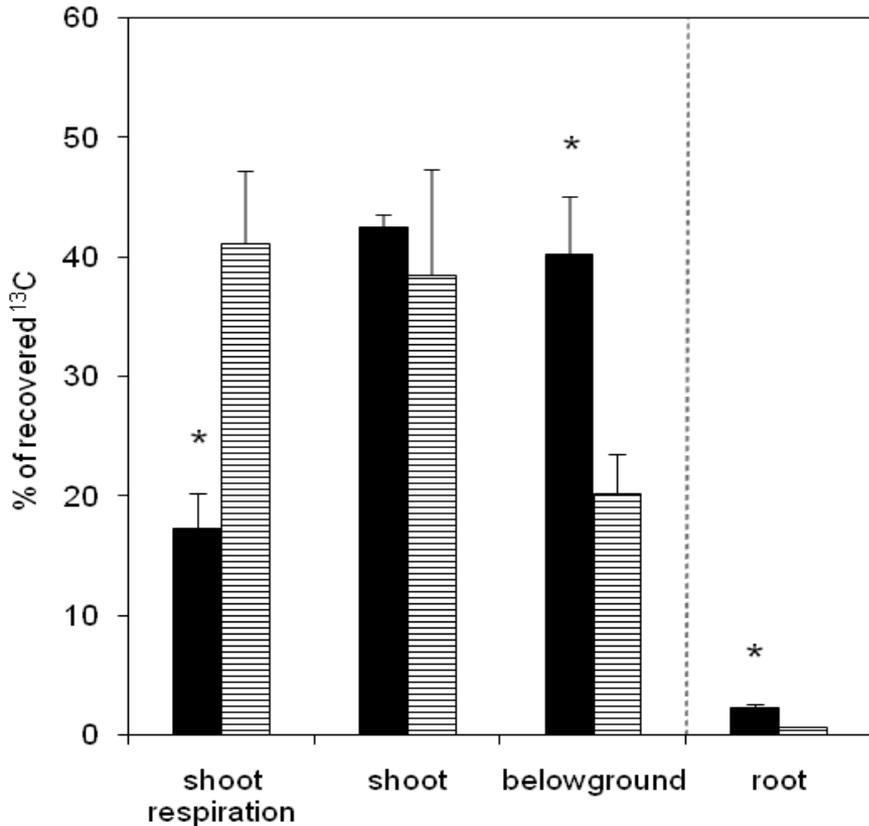
## Partitioning of $^{13}\text{C}$ label 27d after labeling



Twice as much C was allocated belowground in the grazed pasture

# Belowground carbon allocation

## Partitioning of $^{13}\text{C}$ label 27d after labeling



Twice as much C was allocated belowground in



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

## Effect of grazing on C stocks and assimilate partitioning in Tibetan montane pasture revealed by $^{13}\text{C}\text{O}_2$ pulse labeling

Silke Hafner<sup>1</sup>, Sebastian Untereggsbacher<sup>1</sup>, Elke Seebert<sup>2</sup>, Xingliang Xu<sup>3</sup>, Xiaogang Li<sup>4</sup>, Georg Guggenberger<sup>5</sup>, Georg Mehe<sup>6</sup>, Yakov Kuzakov<sup>1</sup>

<sup>1</sup> Agroecosystem Research, Univ. of Bayreuth; <sup>2</sup> Institute of Geographic Sciences and Natural Resources Research, Beijing 100101, China; <sup>3</sup> Institute of Soil Science, Leibniz Universität Hannover; <sup>4</sup> Institute of Geobotany, University of Halle; <sup>5</sup> MOE Key Laboratory of Arid and Grassland Ecology, Lanzhou University, Gansu Province 730000, PR China; <sup>6</sup> Faculty of Geology, 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  $\text{CO}_2$  efflux from soil and C allocation using *in situ*  $^{13}\text{C}\text{O}_2$  pulse labeling of 1) a montane *Kobresia* winter pasture, and 2) a 7-year old grazing enclosure plot, both on the TP in 5440 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 exclusion.

### 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  $\text{CO}_2$  efflux, since total  $\text{CO}_2$  efflux does not differ between the treatments but the contribution of root-derived C to total  $\text{CO}_2$  efflux was larger at the grazed site.

Summing up, the  $^{13}\text{C}$  labeling experiments combined with the evaluation of C stocks demonstrated a negative effect of grazing exclusion 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.

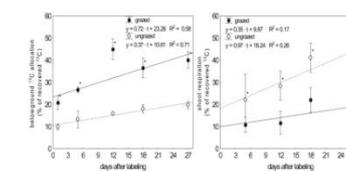


Fig 1:  $^{13}\text{C}$  losses by shoot respiration and  $^{13}\text{C}$  allocation belowground

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

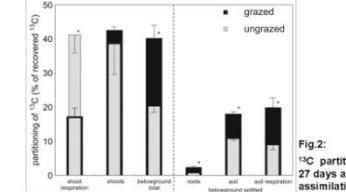


Fig 2:  $^{13}\text{C}$  partitioning 27 days after the assimilation.

### Material and Method

**In situ  $^{13}\text{C}\text{O}_2$  pulse labeling**  
 Performed on July 27, 2009 in triplicates  
 Chase period: 27 days  
**Chamber:**  
 - 50 cm x 50 cm x 10 cm  
 - Injection of  $\text{H}_2\text{SO}_4$  into  $\text{Na}_2^{13}\text{CO}_3$  (99%  $^{13}\text{C}$ ) 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)

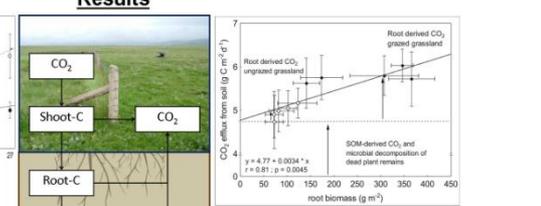


Fig 3: Portions of root- and SOM-derived  $\text{CO}_2$  (n=5).  
 SOM-derived:  $4.8 \text{ g CO}_2\text{-C m}^{-2} \text{ d}^{-1}$   
 Root-derived:  $0.9 \text{ g CO}_2\text{-C m}^{-2} \text{ d}^{-1}$  (16% of total soil respiration)  
 $0.3 \text{ g CO}_2\text{-C m}^{-2} \text{ d}^{-1}$  (% of total soil respiration)

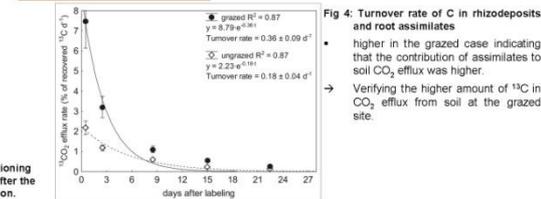


Fig 4: Turnover rate of C in rhizodeposits and root assimilates

• higher in the grazed case indicating that the contribution of assimilates to soil  $\text{CO}_2$  efflux was higher.  
 → Verifying the higher amount of  $^{13}\text{C}$  in  $\text{CO}_2$  efflux from soil at the grazed site.

Pool	Grazed (g C m <sup>-2</sup> )	Ungrazed (g C m <sup>-2</sup> )
Shoot	2.350 ± 0.152	2.350 ± 0.152
Root	7.276 ± 0.054	7.276 ± 0.054
Belowground C stocks (<30cm)	34.70 ± 1.33	28.36 ± 1.54
Soil	26.09 ± 1.30	41.77 ± 1.70
Soil respiration	5.15 ± 0.331 ± 0.003	5.15 ± 0.331 ± 0.003
Soil C stocks	15.30 ± 0.537 ± 0.008	15.30 ± 0.537 ± 0.008
Soil C stocks (>15cm)	0.5 ± 0.299 ± 0.003	0.5 ± 0.299 ± 0.003
Soil C stocks (>30cm)	5.15 ± 0.149 ± 0.004	5.15 ± 0.149 ± 0.004
Soil C stocks (>45cm)	15.30 ± 0.312 ± 0.021	15.30 ± 0.312 ± 0.021

\*\* denotes highly significant differences at  $p < 0.01$  obtained by factorial ANOVA (n=15).  
**7 years of grazing exclusion resulted in:**  
 • higher aboveground C stocks  
 • lower root C stocks  
 • a negative effect on C storage in the upper 15cm.

Introduction C and N storage C allocation C allocation Conclusions Future plans

# Low molecular organic substances in root mats

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

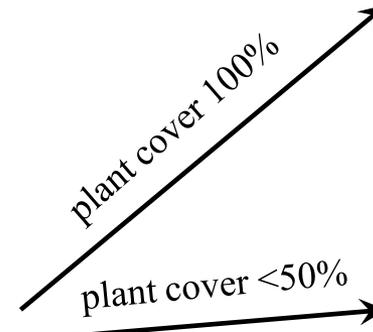
This affects the carbon cycling, e.g. of low molecular organic substances (plant exudates)

## Labeling procedure

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

$^{13}\text{C}$ -glucose	$(^{15}\text{NH}_4)_2\text{SO}_4$
$^{13}\text{C}$ -glycine	$^{15}\text{N}$ -glycine
$^{13}\text{C}$ -acetic acid	$\text{K}^{15}\text{NO}_3$

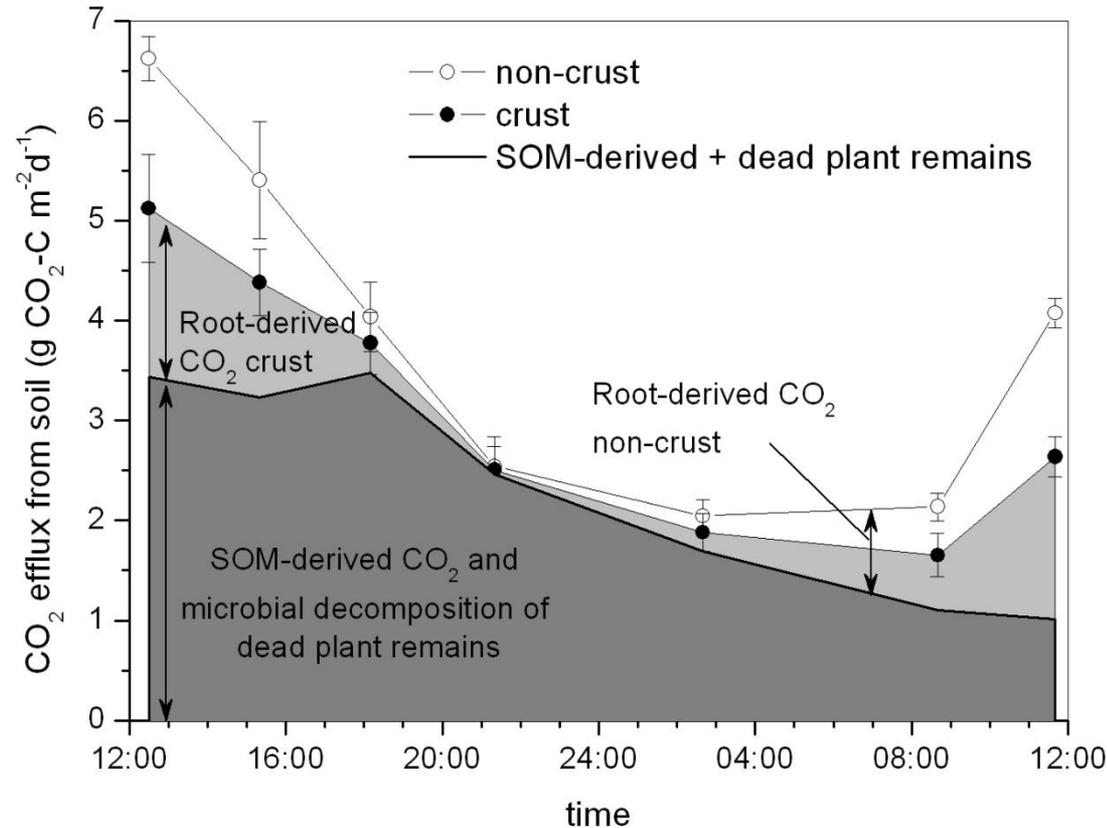
- 4 replications (24 plots)



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<sub>2</sub> fluxes

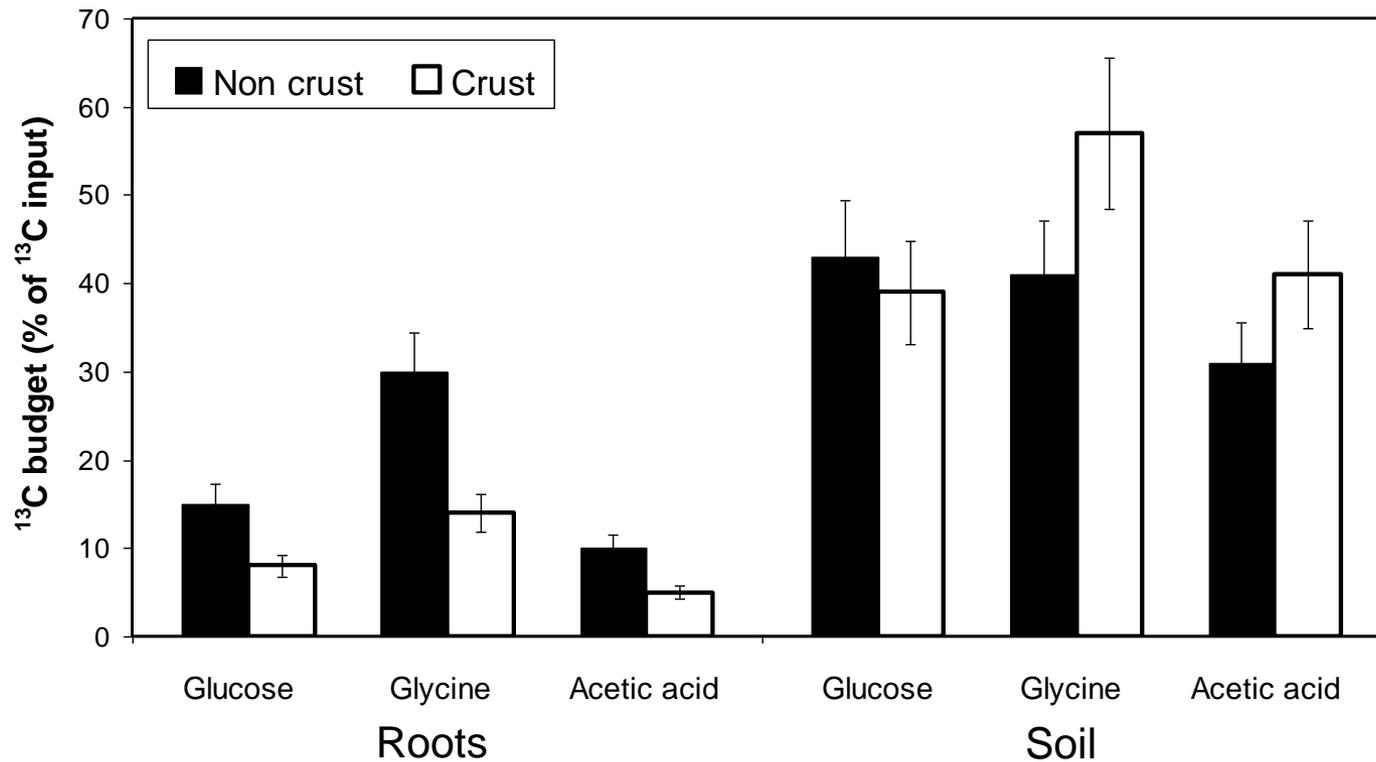
Diurnal dynamics of CO<sub>2</sub> efflux from crust and non-crust soil based on regression approach



Root-derived soil CO<sub>2</sub> efflux is repressed under crusts (less C allocation to roots)

# $^{13}\text{C}$ budget of low molecular organic substances

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



Crust decrease  $^{13}\text{C}$  from low molecular organic substances in roots  
Crust increase  $^{13}\text{C}$  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<sub>2</sub> 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

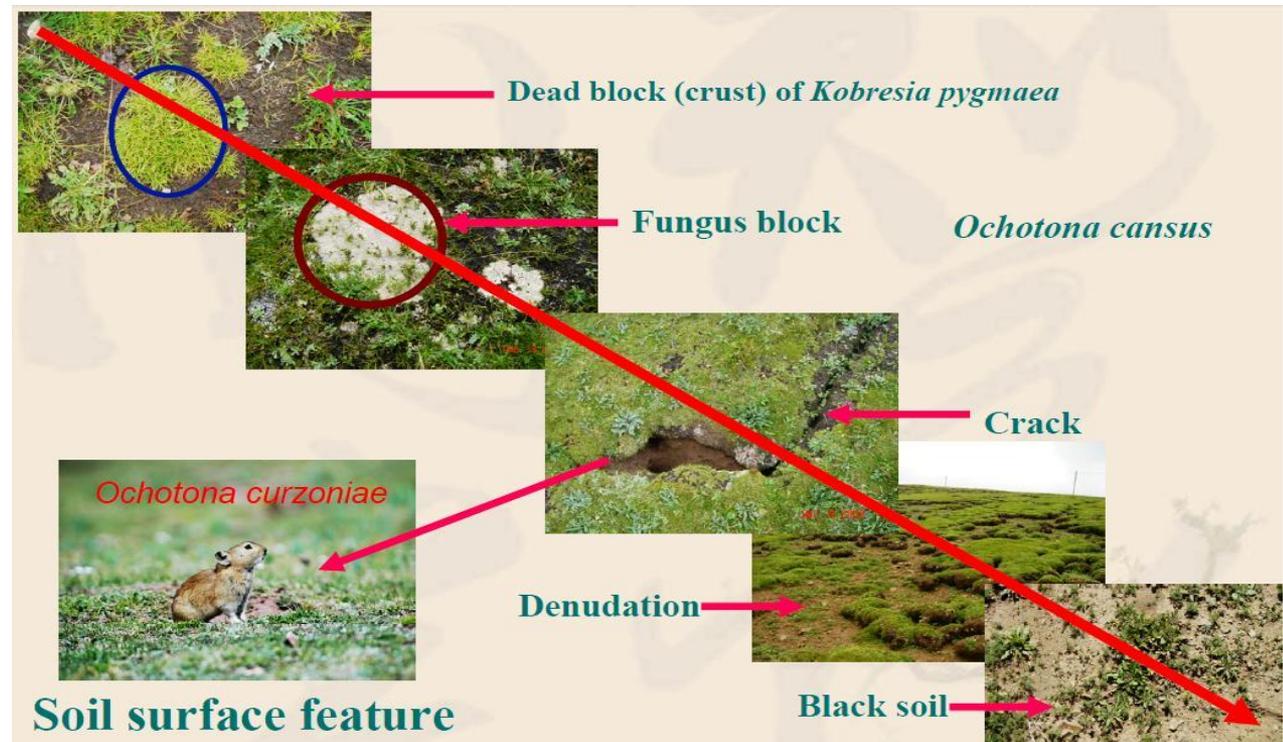
- **No** – but duration of the experiment (7 years only) must be considered
- Large and slowly turning over root carbon and soil organic carbon *versus* relatively small carbon fluxes to the soil
- But different grassland communities showed different soil organic carbon storage

# 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
- $^{13}\text{C}$  and  $^{15}\text{N}$  labeling
- $^{14}\text{C}$  analysis
- Incubation experiments
- Morphological studies



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- <sup>14</sup>C analysis
- Incubation experiments
- Morphological studies



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

## Suberin and Cutin as biomarkers for shifts in plant community composition following land use changes on the Tibetan Plateau

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### Background

There is still a debate if the Kobresia biome on the Tibetan Plateau is human induced or climate driven. Grazing enclosure experiments show a fast replacement of Cyperaceae by Poaceae. This points to a zoo-anthropogenic influenced plant composition. We aimed to find a biomarker to distinguish between different grasses and herbs dominating under different condition.

### Why Suberin and Cutin?

Suberin and cutin signatures are used as biomarkers for determining soil organic matter (SOM) sources. Previous studies succeeded in differentiating between closely related tree species, e.g. fir (*Abies alba*), spruce (*Picea abies*) and Douglas fir (*Pseudotsuga menziesii*) (Spielvogel 2010). However, signatures of different grasses and herbs have not been analyzed in detail, and it is unknown if they are identifiable in soil.

### Suberin and cutin...

- ... are ubiquitous in plants.
- ... are important components of hydrophobic layers in plant cell walls.
- ... play an important role as barriers controlling gas-, water-, and nutrient transport in plants.
- ... are characteristic for roots (suberin) and leaves (cutin), respectively.

**Fig 2: Schematic of exopolymer cutin and suberin location in plants, (a) cutin deposition in leaves (EW = epicuticular waxes, C = cuticle, CW = cuticular layer) (b) suberin deposition in roots (ML = middle lamella, PM = primary wall, SW = secondary wall, PM = plasma membrane, Cy = cytoplasm, V = Vascular)**

### Method

Samples (5-20 g, depending on carbon content)

1. Extraction (double deionized water) → water soluble polar compounds
2. Extraction CH<sub>2</sub>Cl<sub>2</sub>/MeOH → 'tree lipids'

**Alkaline hydrolysis:** Teflon-lined bombs 100 °C / 3 h (1 M methanolic KOH) → Addition of internal recovery standard

**Filtration, Residue:** washed (x 3) CH<sub>2</sub>Cl<sub>2</sub>, MeOH → Extraction of acidic lipids

**Acidified to pH 1 (6 M HCl)** → Remove solvents

**Rotary evaporation:** Re-dissolved in double deionized H<sub>2</sub>O

**Liquid-liquid extraction (CH<sub>2</sub>Cl<sub>2</sub>)** → Monomers → Silylation → Analyses with GC-MS

### Material

- Plant and soil material from grazing enclosures (*Kobresia* dominated grasslands) in a montane (near Xinghai) and an alpine (north of Lhasa) area
- 20 x 20 m fences inside Yak pastures, fenced 1997 (Reting) and 2002 (Xinghai).
- Monitoring of plant community composition inside enclosures and adjacent grazed area indicate changes in vegetation structure after fencing
- Identification of characteristic plants for both treatments
- Analysis of root and sprout samples from indicator plants: among others *Kobresia pygmaea* (Cyperaceae, grazed), *Leymus* (Poaceae, ungrazed)
- Analysis of soil samples taken inside and outside the grazing excluding fences

**Fig 5: Distribution area of Kobresia pygmaea and study sites**

**Fig 6: Leymus and Kobresia pygmaea**

### Results and Discussion

**Fig 7: Chromatograms of Kobresia (Cyperaceae) and Leymus (Poaceae) – sprouts and roots**

- Chromatograms of plant materials show clear differences between grass species
- Signatures of roots and shoots are also different
- The suberin signature of *Kobresia* roots is characterized by several long-chain fatty acids > 26 C-atoms that are missing in *Leymus* roots

**Soil grazed plot – Kobresia dominated (5-15 cm)** vs **Soil fenced plot – Poaceae dominated (5-15 cm)**

**Fig 8: Chromatograms of soils sampled inside and outside of the grazing excluding fence (montane area).**

- Depth increment 0.5 cm (= dense root layer) mirrors pattern from pure plant roots
- Fatty acid signature of soils from areas of different altitude but similar vegetation did not differ
- The long-chain fatty acids signature typical for *Kobresia* roots, can still be identified seven years after fencing, however, decreased distinctly
- Di-carboxylic acids seemed to have longer turnover times than ω-Hydroxy fatty acids

### Conclusion

Hydrolysable aliphatic lipids derived from suberin and cutin are well suitable to distinguish between different grasses and herbs indicating diverse grazing pressure. Cutin and Suberin are compounds with a high diagnostic value for vegetation history of grasslands due to the preservation of species specific long-chain aliphatic lipids.

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