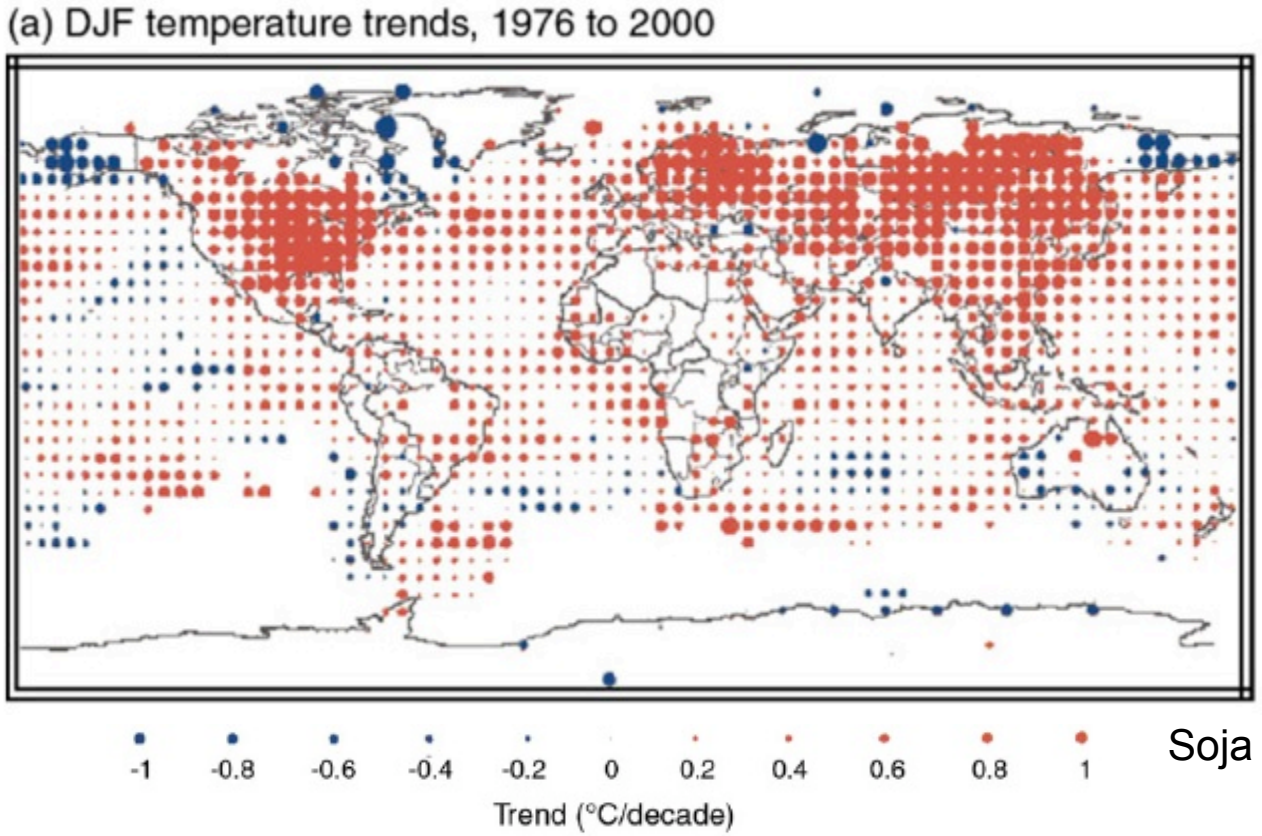
Does future climate increase turnover of soil organic matter and biomass production in southern Siberia?

Bernd Zeller, D. Derrien, D. Achat, M.R. Bakker, L. Briand, P. Nikitich, T. Raudina, O. Rusalimova, V. Tiertant, P. Barsukov

Introduction

Most probable climate change scenarios for southern Siberia predict a raise in temperature and an increase of precipitations, namely as snow (Gordov et al., 2010, Bulygina et al., 2009,Groisman et al., 2006)

Temperature



Soja et al. 2007

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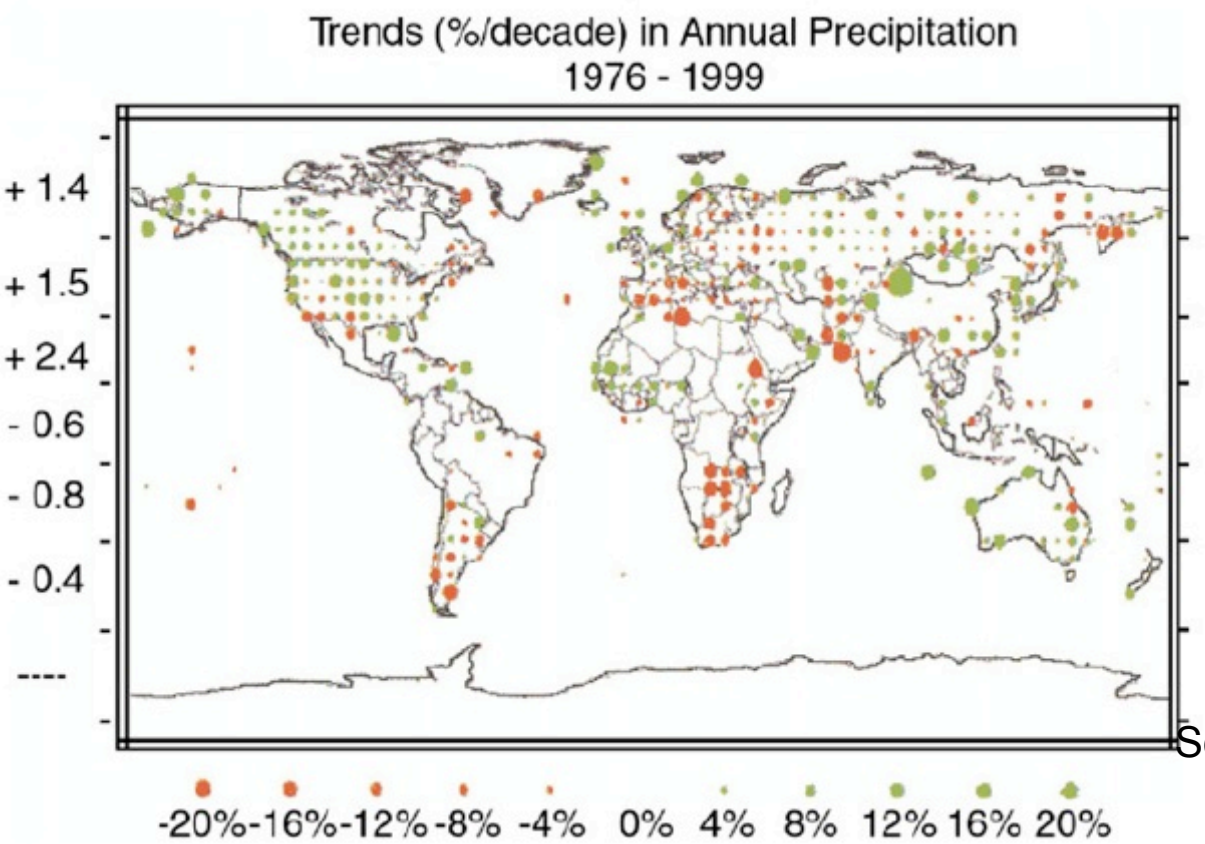
Precipitations



Soja et al. 2007

Introduction

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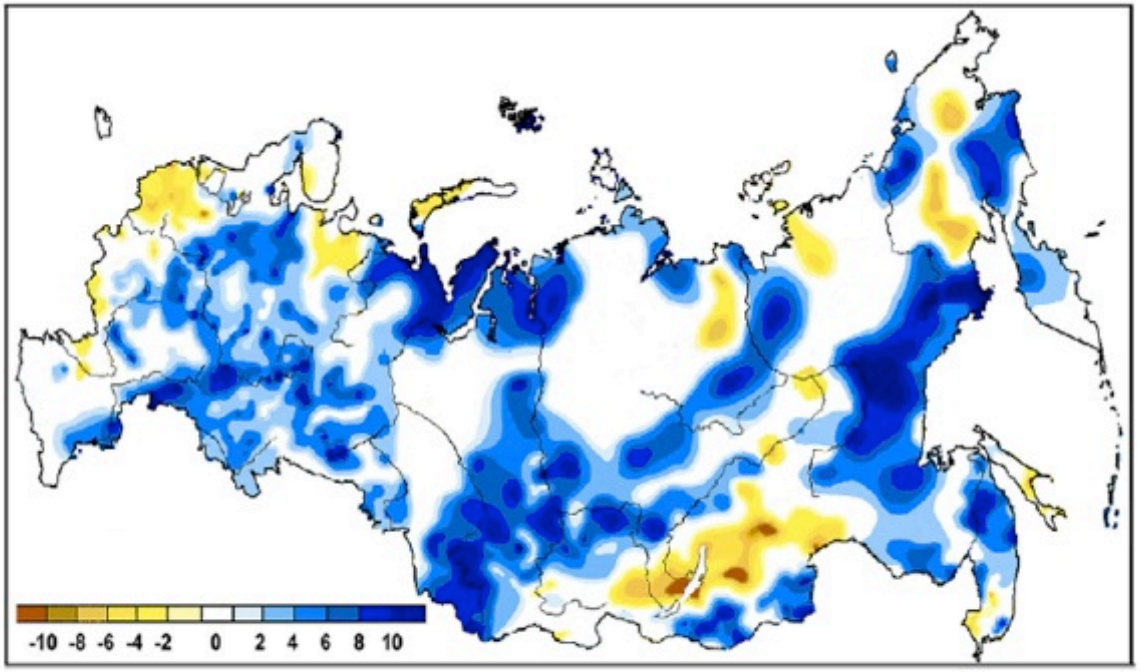
Snow cover

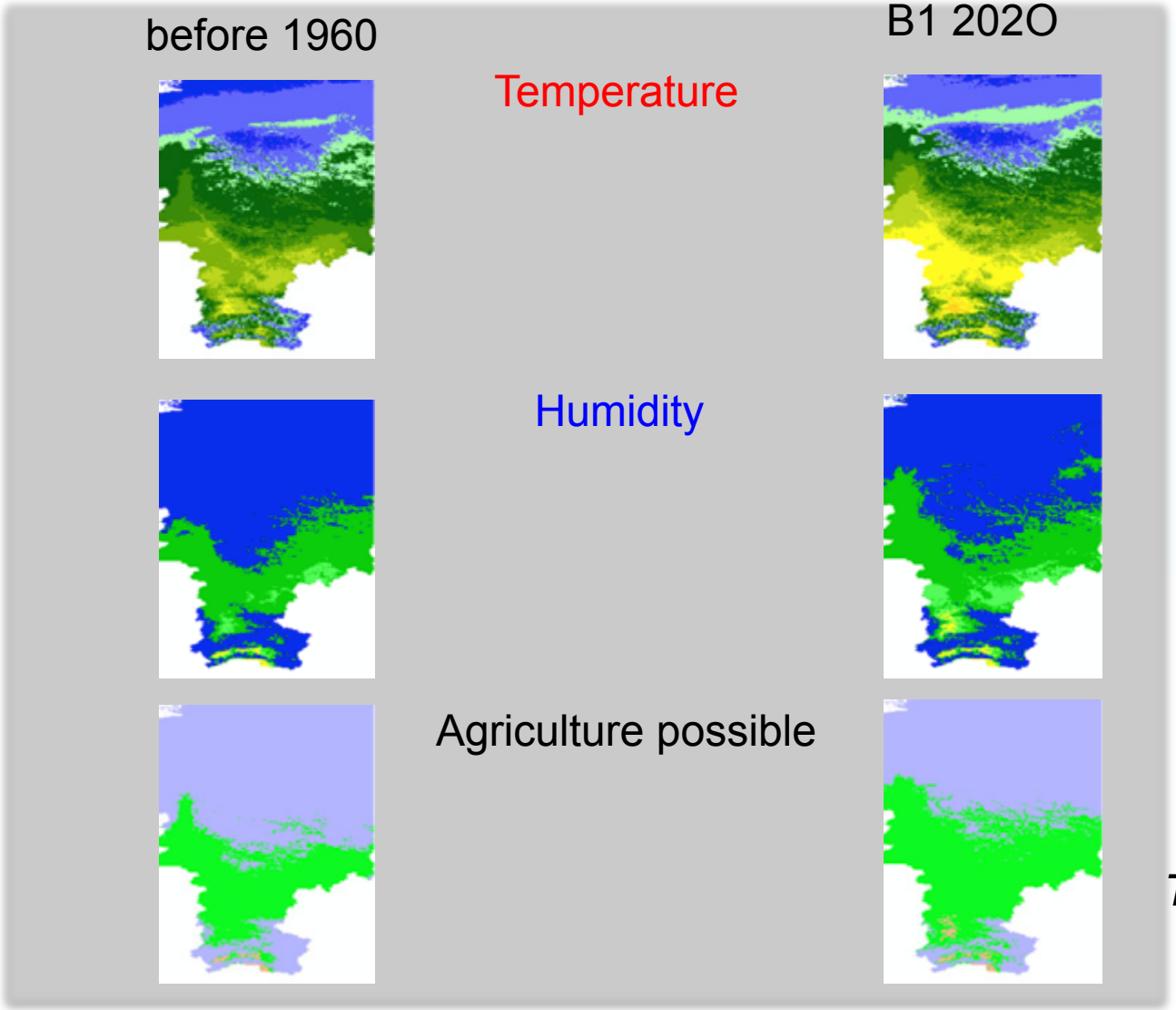


Bulygina et al. 2009

Figure 3. Spatial distribution of linear trend coefficients (days/10 yr; 1%–5% significance level) showing the number of days with snow cover exceeding 20 cm for 1966–2007.

Introduction

Positive effects of climate change for agricultural land use, increase of suitable surface (example Krasnojarsk region)

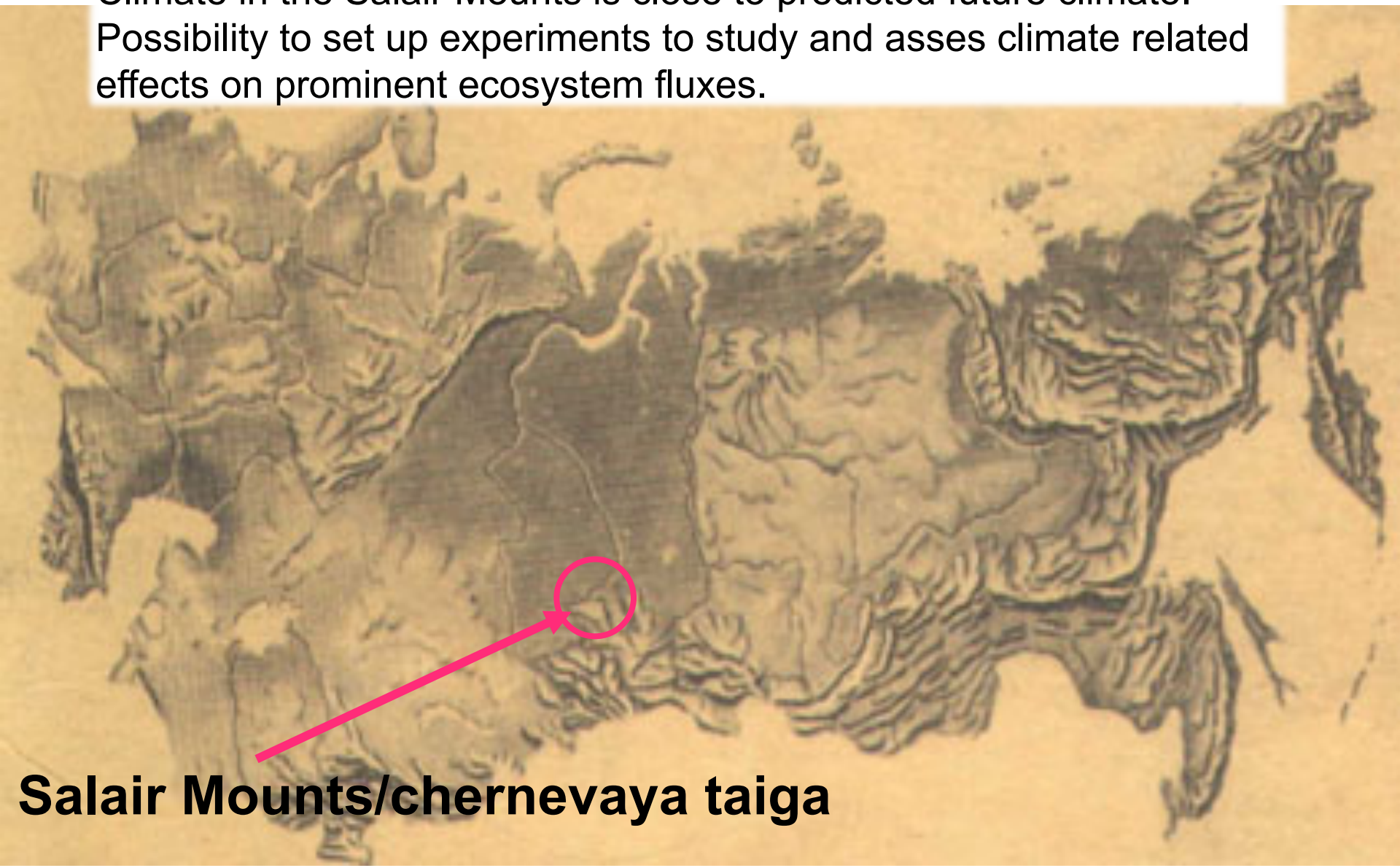


Kray de Krasnojarsk

Tchebakova et al., 2011

Introduction

Climate in the Salair Mounts is close to predicted future climate.
Possibility to set up experiments to study and asses climate related effects on prominent ecosystem fluxes.



Salair Mounts/chernevaya taiga

Introduction

Lessons from the Salair Mounts:
1. Snow height > 2.5 m prevent soils from freezing or limit depth of soil freezing.
2. Giant herb developpement indicate that resources (nutrients, water, light) are unlimited during the growing season (May to August).
3. Rapid litter decomposition and N turnover

Snow height > 2.5m


Herbs > 1.5 to 3.5 m

Hypothesis :
Increase of snow height (see IPCC scenario)

→ *Soils are not frozen, or less frozen*

→ *Microbes/Fungi are active during winter*

→ ***efficient recycling/turnover of nutrients, high productivity***

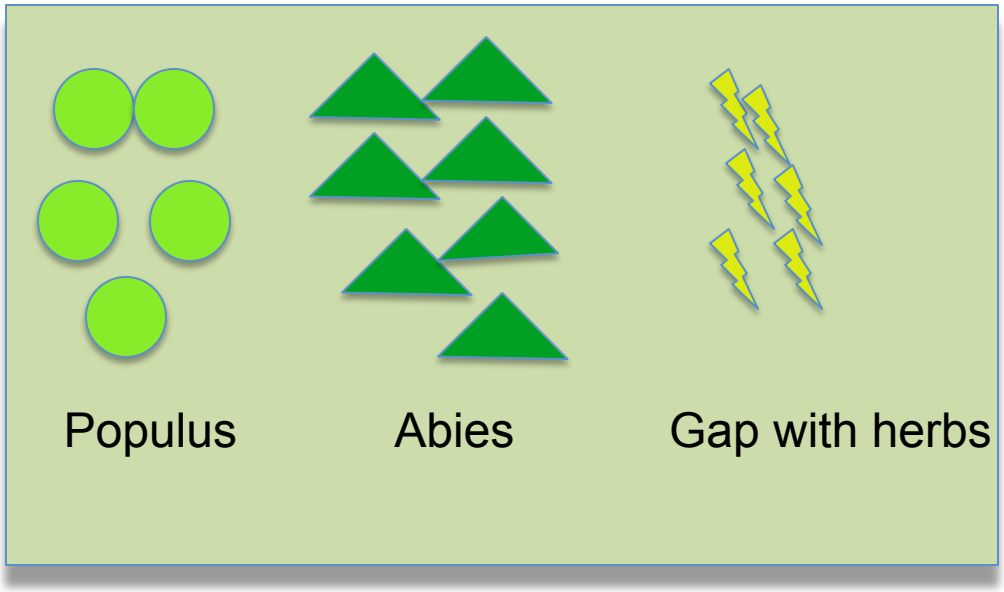
Courtesy to Kolja Lashchinskiy

Preliminary Pilot study, Blackish Taiga, Salair Mounts

Experimental approach(es):

1. *In situ* - Set up of a litter decomposition experiment with ^{15}N labelled Populus litter to study the turnover of litter N in relation to the vegetation type (Populus, Abies, gap with herbs).

2. *Ex situ* - P cycling/turnover in relation to vegetation cover and soil depths; indicator for nutrient cycling processes.



Preliminary Pilot study, Blackish Taiga, Salair Mounts

Aim of the litter decomposition experiments is to study the process of C, N, P mineralisation and turnover with respect to the vegetation type

Fate of litter-N in the soil-plant system

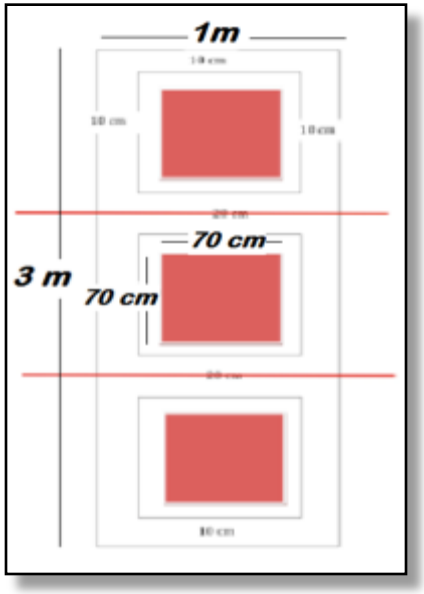
Characterize the stocks and the dynamics of different P fractions

Identify and characterize the functional diversity of decomposing microbes/fungi and their activity during the winter period

Material & Methods

In situ - Set up of a litter decomposition experiment with ^{15}N labelled Populus litter to study the turnover of litter N in relation to the vegetation type (Populus, Abies, gap with herbs).

Production of ^{15}N labelled litter (in situ)



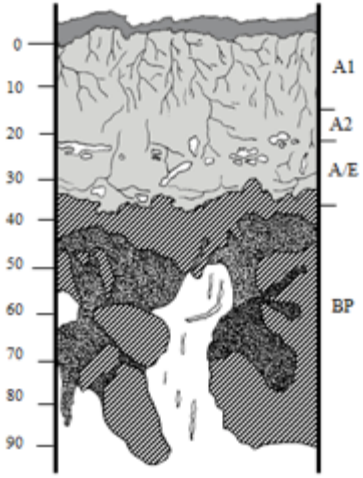
Set up of the litter decomposition & C/N turnover experiment at a representative field site in the Salair Mounts (nearby Barnaul)

Material & Methods

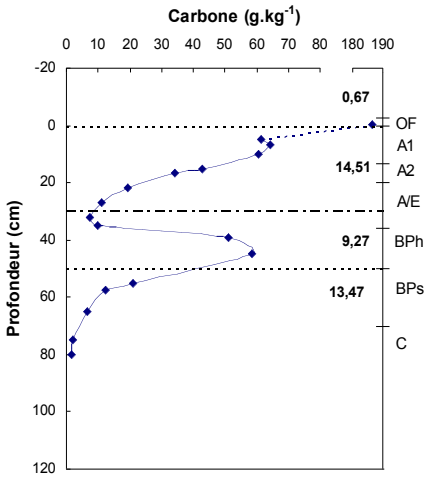
***Ex situ* -** P cycling/turnover in relation to vegetation cover and soil depths; indicator for nutrient cycling processes

Collection of representative litter, forest floor and soil samples(each vegetation type, per horizon)

Diagnostic horizons

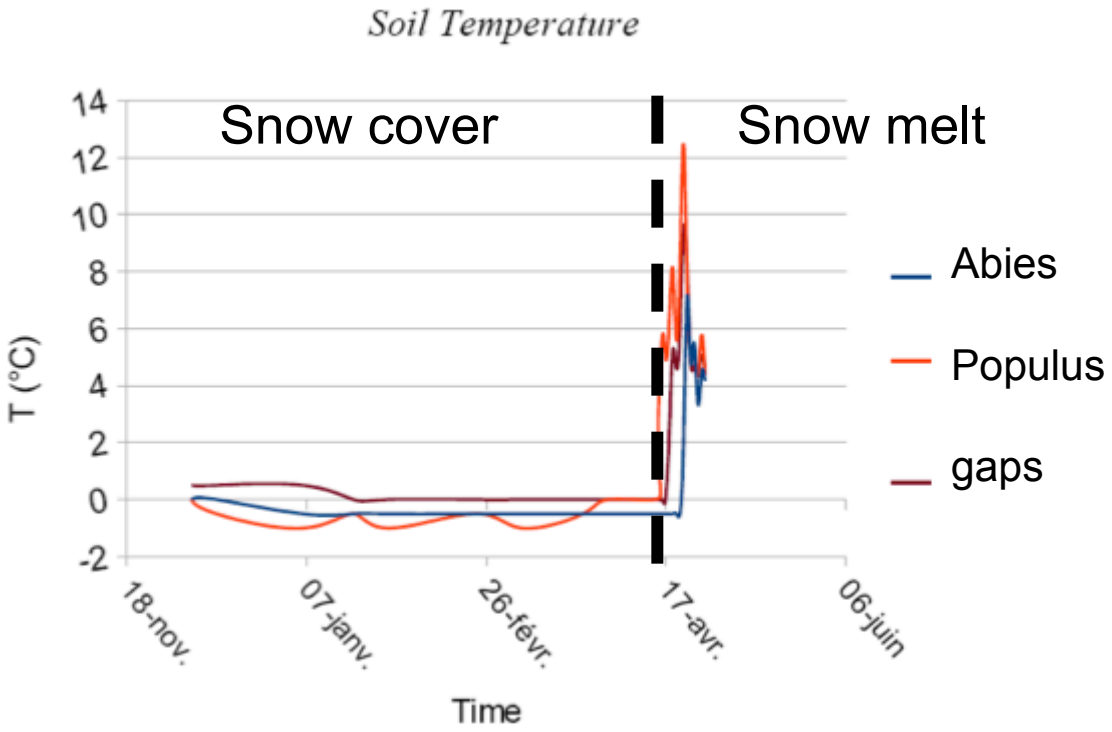


Root system



Vertical profiles (example C)

Results



Abies: soil temperture below 0°C
Populus: soil temperture below 0°C, variable
Gap: soil temperature around 0°C, soil not frozen,

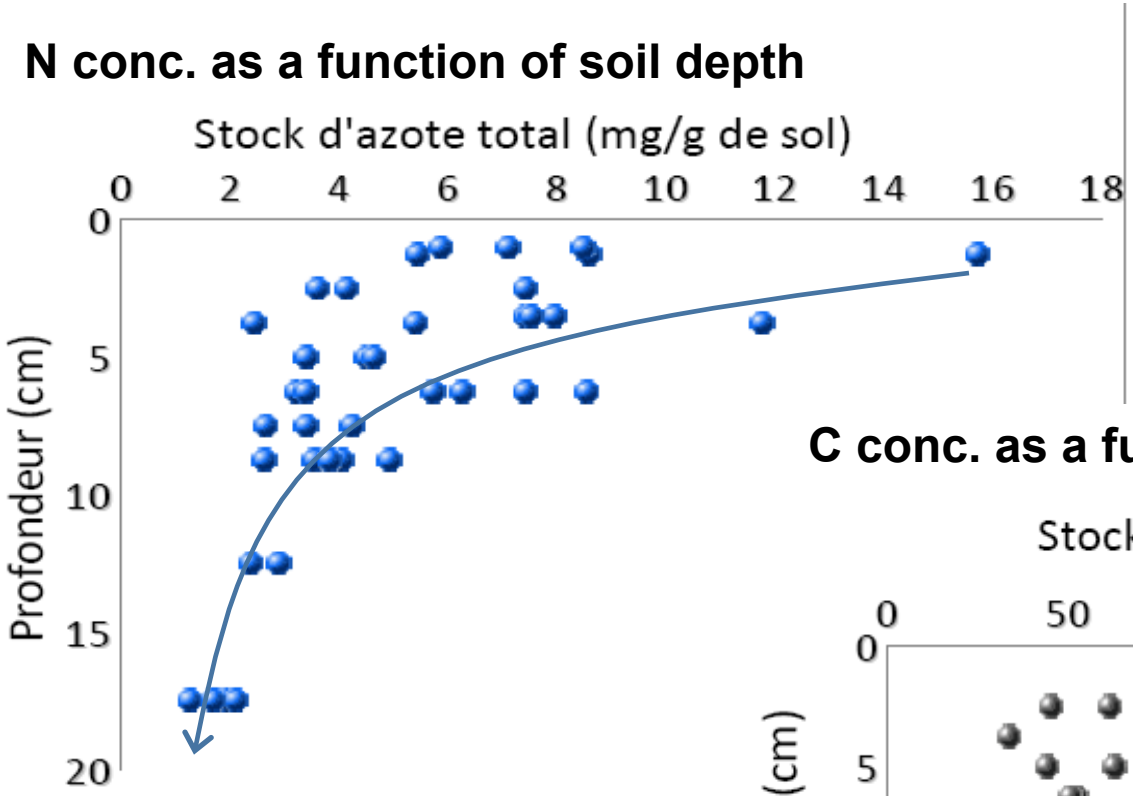
→ **biological activity possible, minor effect of the vegetation cover**

→ Snow melt, steep increase in soil temperature within a few days, increase of biological activity and onset of the vegetation period. Soil not frozen, no time lag between biological activity of the trees and the soil.

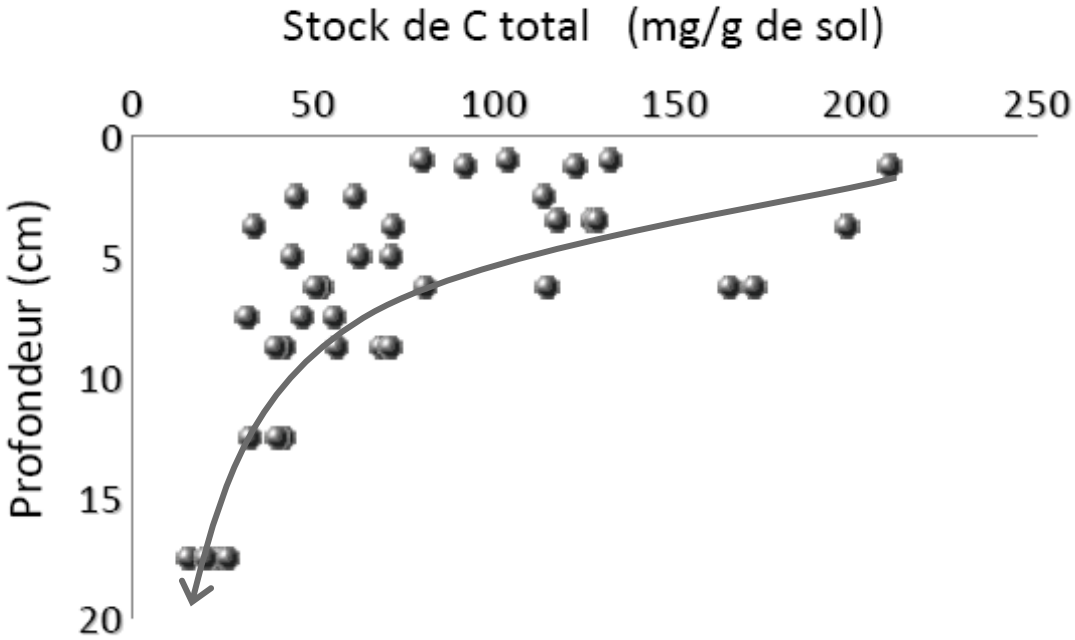
Hypothesis confirmed; high snow cover allows to maintain a biological activity during winter.

Results

N conc. as a function of soil depth



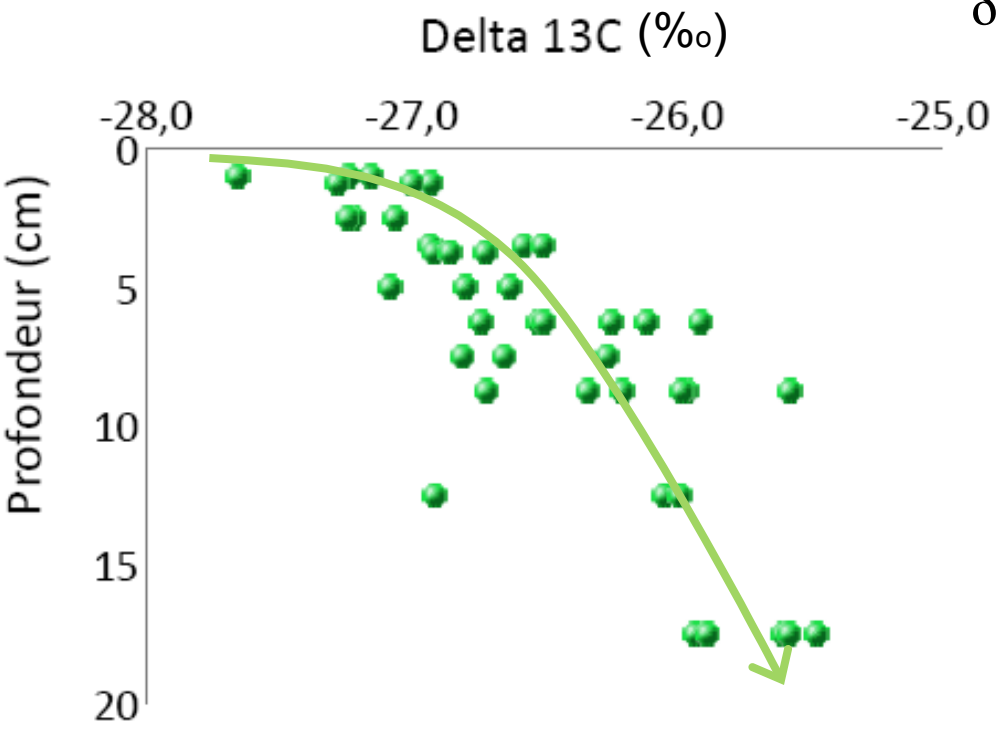
C conc. as a function of soil depth



Decrease of C and N concentration along the soil profile.
No significant effect of the vegetation cover.

Results

$\delta^{13}C$ as a function of soil depth



$$\delta^{13}C = \left(\frac{^{13}C/^{12}C_{\text{échantillon}}}{^{13}C/^{12}C_{\text{standard}}} - 1\right) * 1000$$

→^{13}C is used as an indicator of the origin of the SOM (plant vs. microbes) and provide deeper insight into the process of C stabilization.

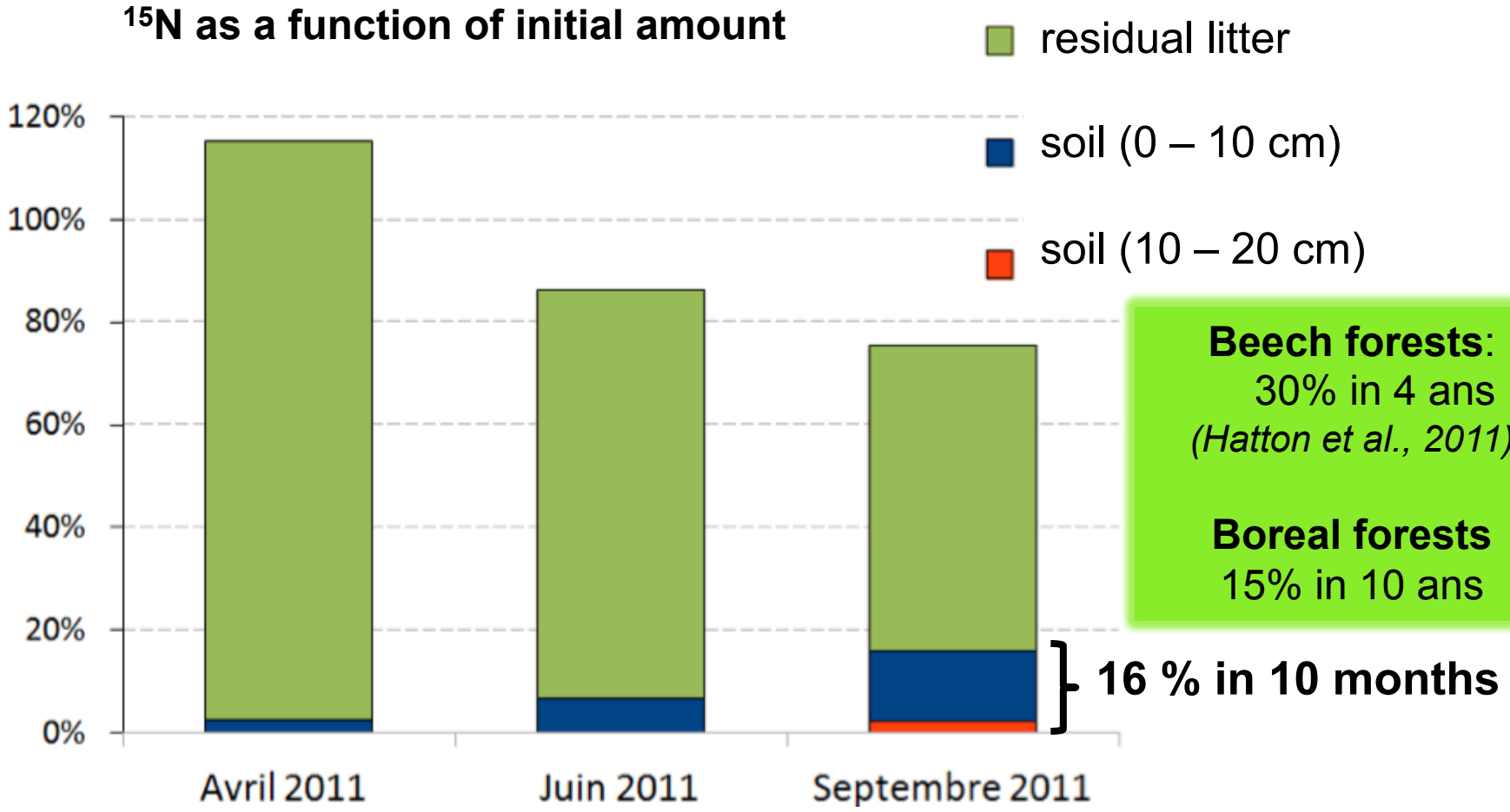
Microbes : -28 à -25 ‰
Plants : -30 à -27 ‰

$\delta^{13}C$ increase with soil depth, indicates that C is more and more processed by microbes.

Results

Gap (herbs)

Transfer of litter ^{15}N into the topsoil



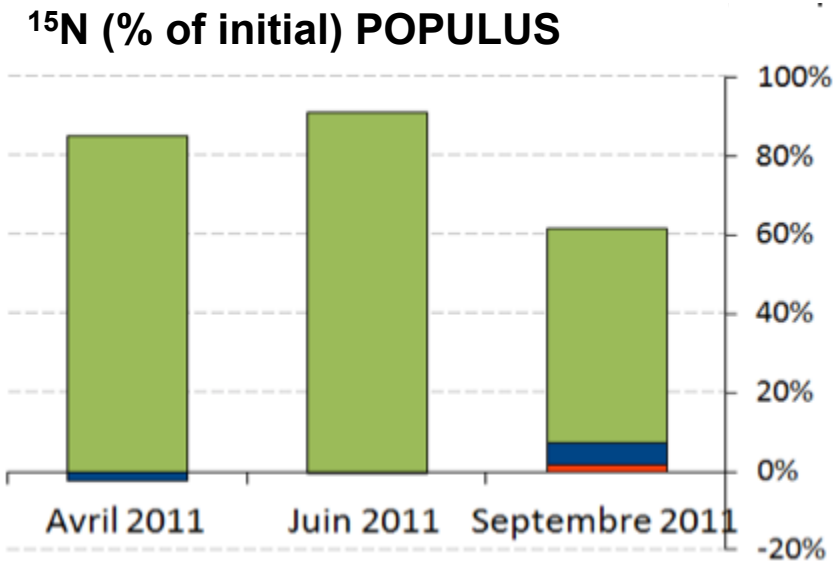
Beech forests:
30% in 4 ans
(Hatton et al., 2011)

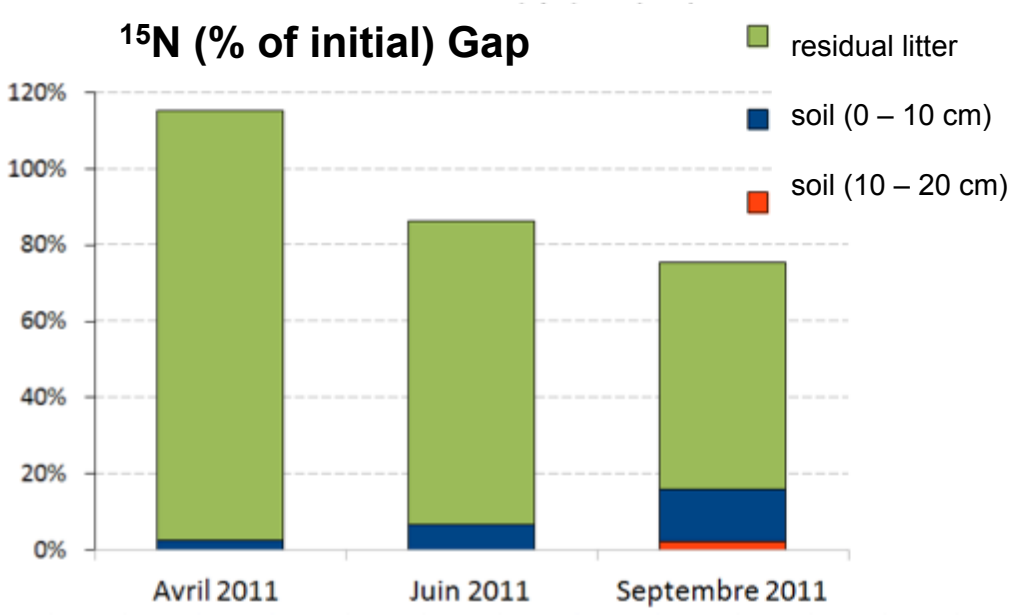
Boreal forests
15% in 10 ans

Transfer of litter N into the soil by the soil fauna, but not by earthworms. Uptake by the vegetation?

Results

^{15}N budgets (soil)



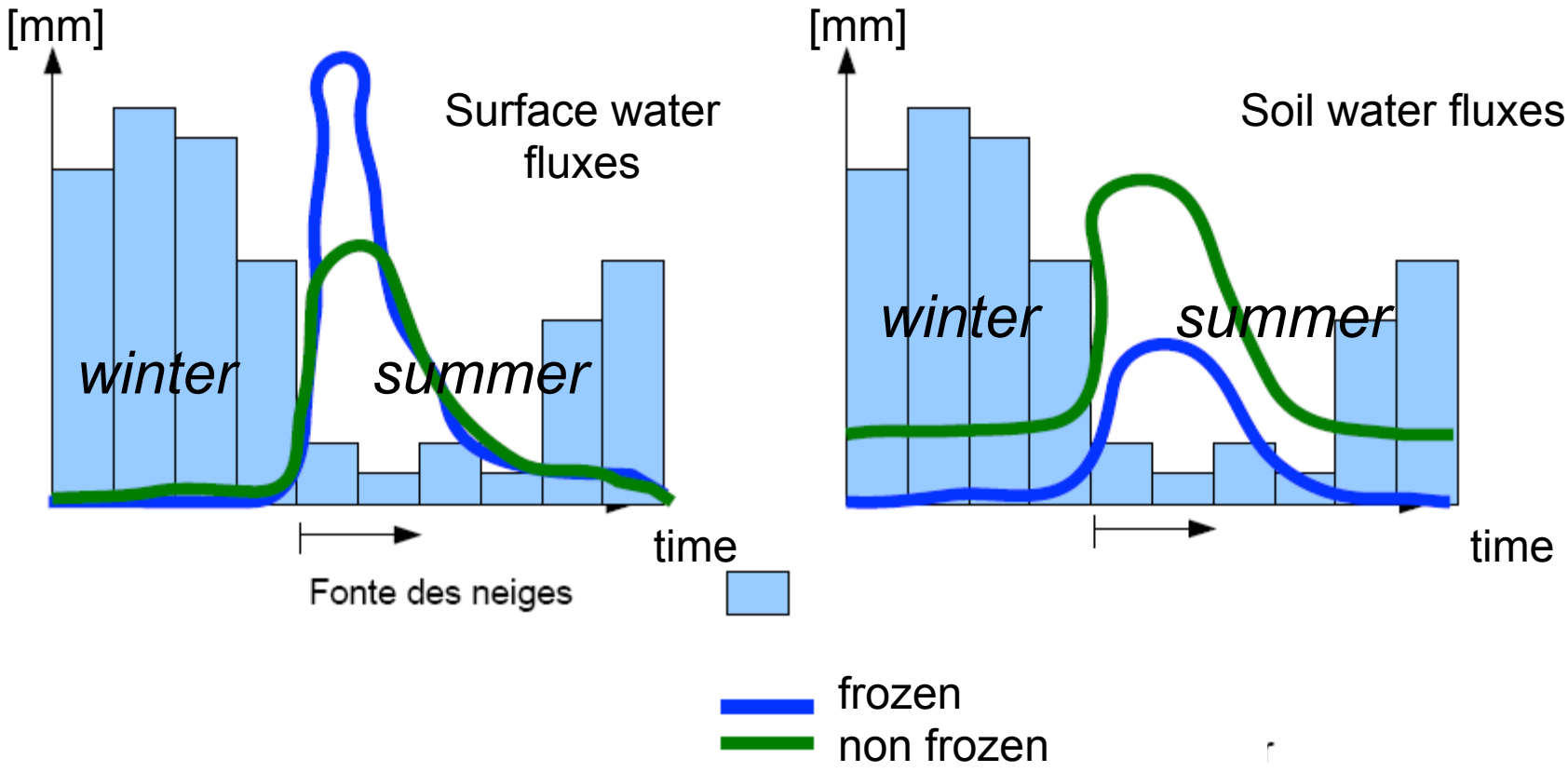


Faster incorporation of litter ^{15}N into the mineral soil in gaps with herbs as vegetation compared to Populus and Abies spots

Budgets are not complete, incorporation into the plants and the trees is missing, also losses as DON or nitrate.

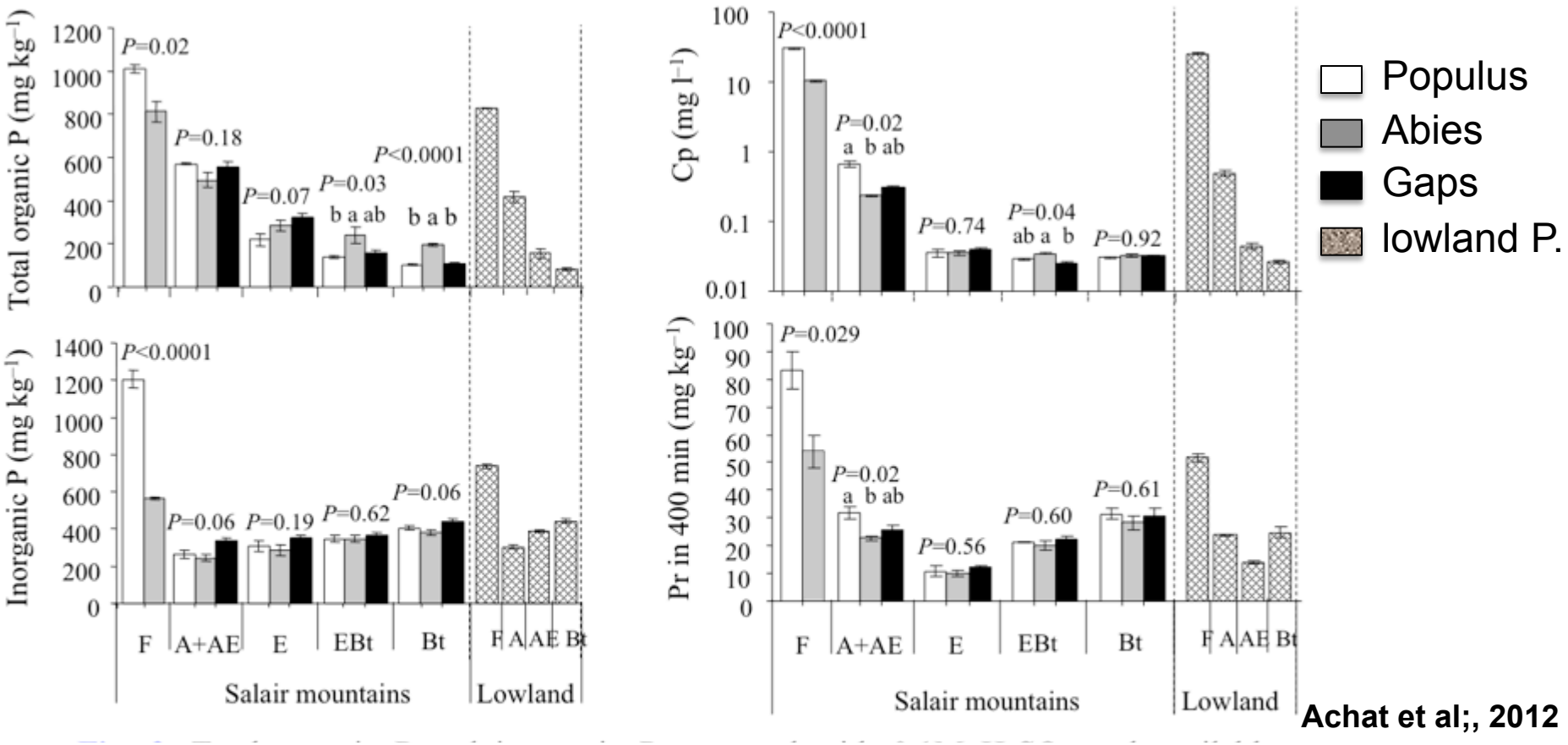
Results

Simulation of soil water fluxes of frozen and non frozen soils



Non frozen soils have less surface runoff during snowmelt, better infiltration and thus higher soil water reserves than frozen soils.

Results



Achat et al;, 2012

Total P (720–890 mg kg^{-1} in the surface mineral soils) is high compared to other forest soils in the world (mean of 30 forest soils = 557 mg kg^{-1}).

Species effect on the stock of total organic P and inorganic P in the forest floor (Abies > others).

Species effect on available soluble inorganic P (Cp) and diffusive P (Abies > others)

Results

Stocks of C, N, P in the entire forest floor + mineral soil profile

	Site of the Salair mountains, unfrozen during winter			Lowland site, frozen during winter
	P. tremula	*A. Siberica*	*Forest gap*	*P. tremula*
Total C (Mg ha)	108±6 ***a***	117±13 ***a***	113±6 ***a***	138±3 ***a***
Total N (Mg ha)	12.4±0.6 ***a***	11.7±0.8 ***a***	11.3±0.4 ***a***	10.8±0.1 ***a***
Total P (kg ha)	9810±424 ***a***	8560±354 ***ab***	9147±100 ***a***	7417±109 ***b***
Available P ions in one week (kg ha)	1078±74 ***a***	902±57 ***ab***	923±78 ***ab***	736±54 **b**

Achat et al;, 2012

- The soils from the Salair mounts exhibit high contents in total C, N and P. 47–56% of total P in the surface mineral soils consists of organic P, what shows that decomposition processes potentially play a significant role in P availability.
- P is relatively well available as ionic P. In addition, there was an accumulation of available P ions in the sub soils. Deep root systems would lead to substantial amounts of available P for the trees and the potential enhance growth and C sequestration due to climate change could *a priori* not be P-limited.

Conclusions

Lessons learned form the case study in the Salair mounts:

snow cover prevents soils from freezing during winter. The vegetation has no effect or minor effects soil temperature during winter, but increase in soil temperature is faster in gaps compared to forests.

Litter decomposition and N turnover depends on vegetation cover, at least during the first year. Incorporation of litter N into the soil profile is shallow and slow.

Phosphorus stocks are rather high compared to other forests in the world. P forms in the soil differ according to the vegetation cover, hence most marked in the forest floor.

Need to dig deeper = ERANET RUS Project

A-West-CC (ERANET RUS funded project)

The Agro-potential of Western Siberia Territories in a Changing Climate

Snow manipulation experiments as a mean to asses effects on:

Working packages

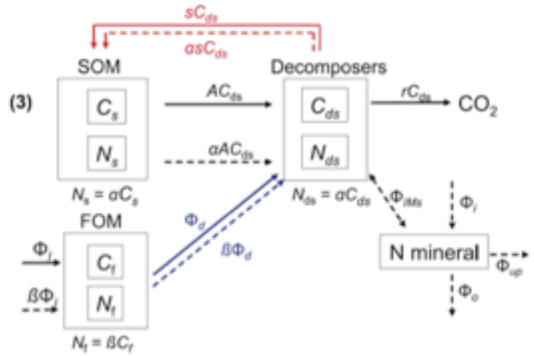
WP1: soil pedoclimate and plant water sources

WP2: Dynamics of P and litter derived N (using isotope tracing)

WP3: Decomposer community structure and activity

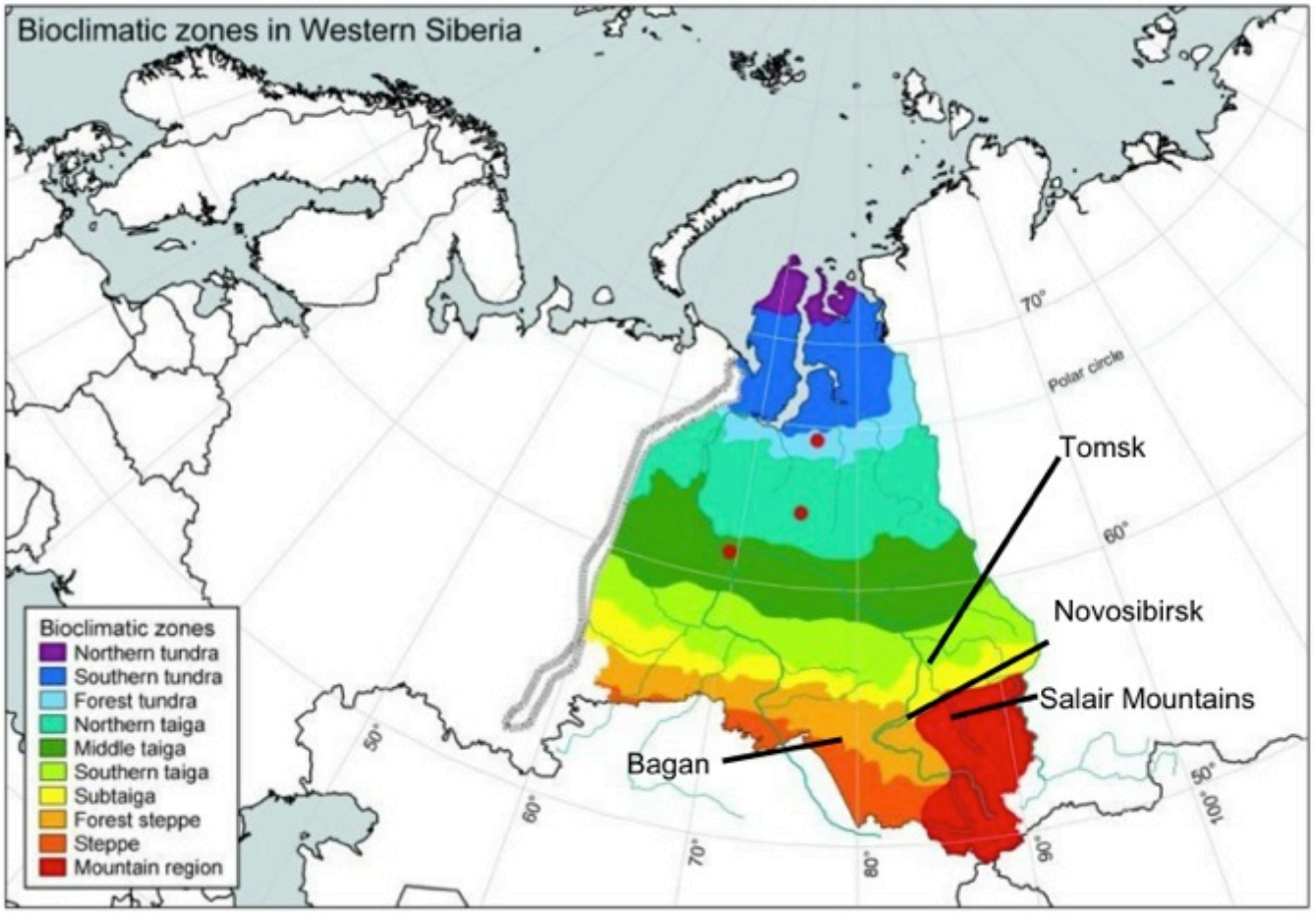
WP4: Modeling of soil processes

WP5: Carbon and nutrients balance - recommendation for sustainable agricultural management

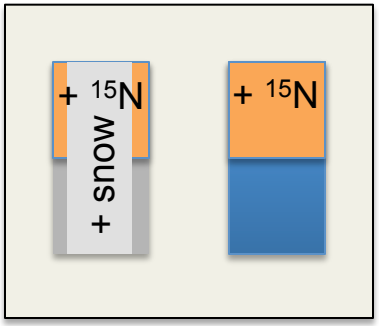


A-West-CC (ERANET RUS funded project)

North south transect covering different vegetation zones
Land use: forest, meadows and agriculture
Two PhD projects starting in 2012
Interdisciplinary research teams



A-West-CC (ERANET RUS funded project)



Design of the snow manipulation and tracer experiment. (Start in 2012).

- Two representative vegetation types (Populus forest, meadows - cultivated land)
- N – S climatic transect

- Measurements (combination of continuous and events)

Interdisciplinary approach (soil – plant system)

Modelling of C and N turnover, agricultural growth and yield model.

Opportunity to link this project with others.

Thanks for your attention!

Any questions ?