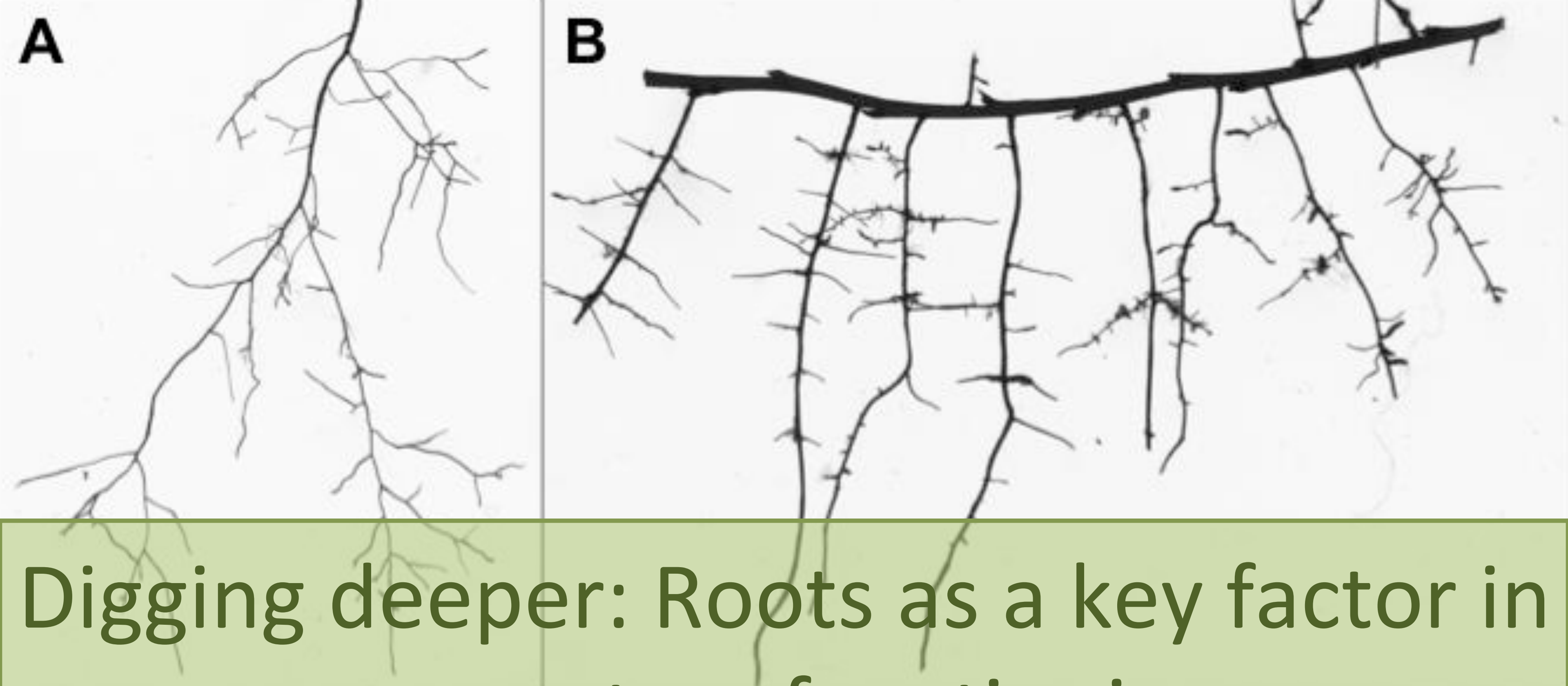


Digging deeper: Roots as a key factor in ecosystem functioning

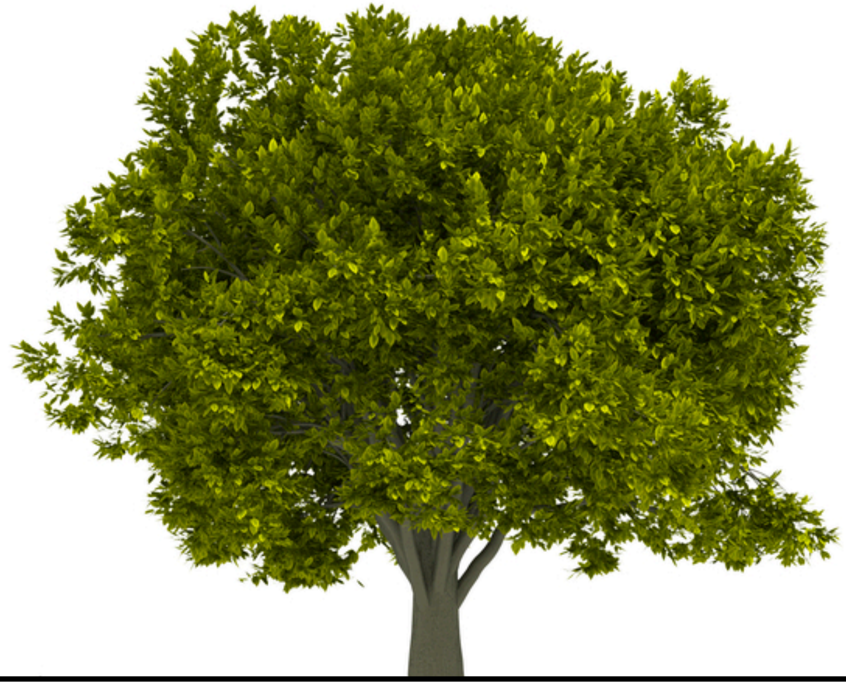
Ann Milbau

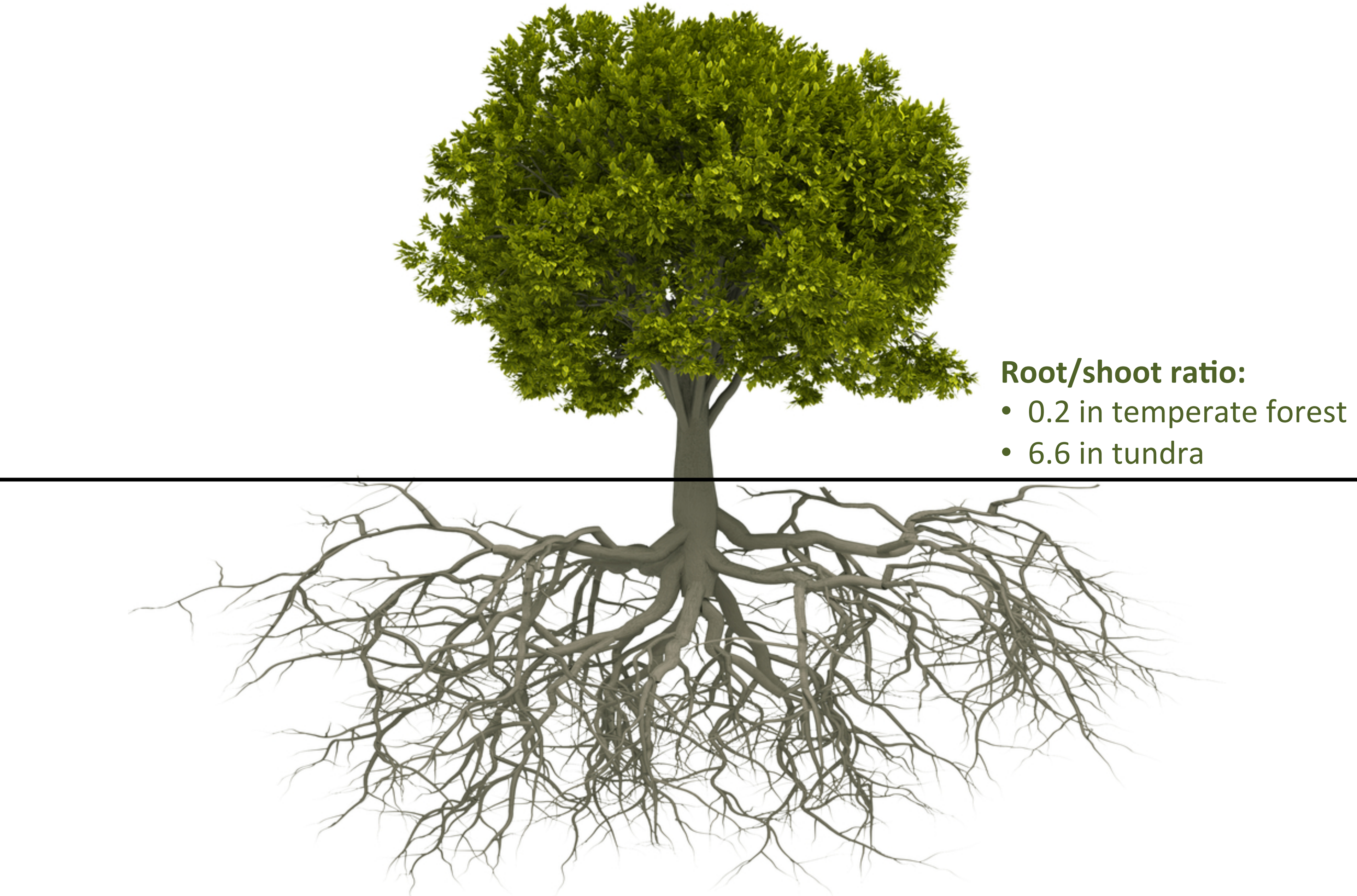
Climate Impacts Research Centre
Umeå University, Sweden

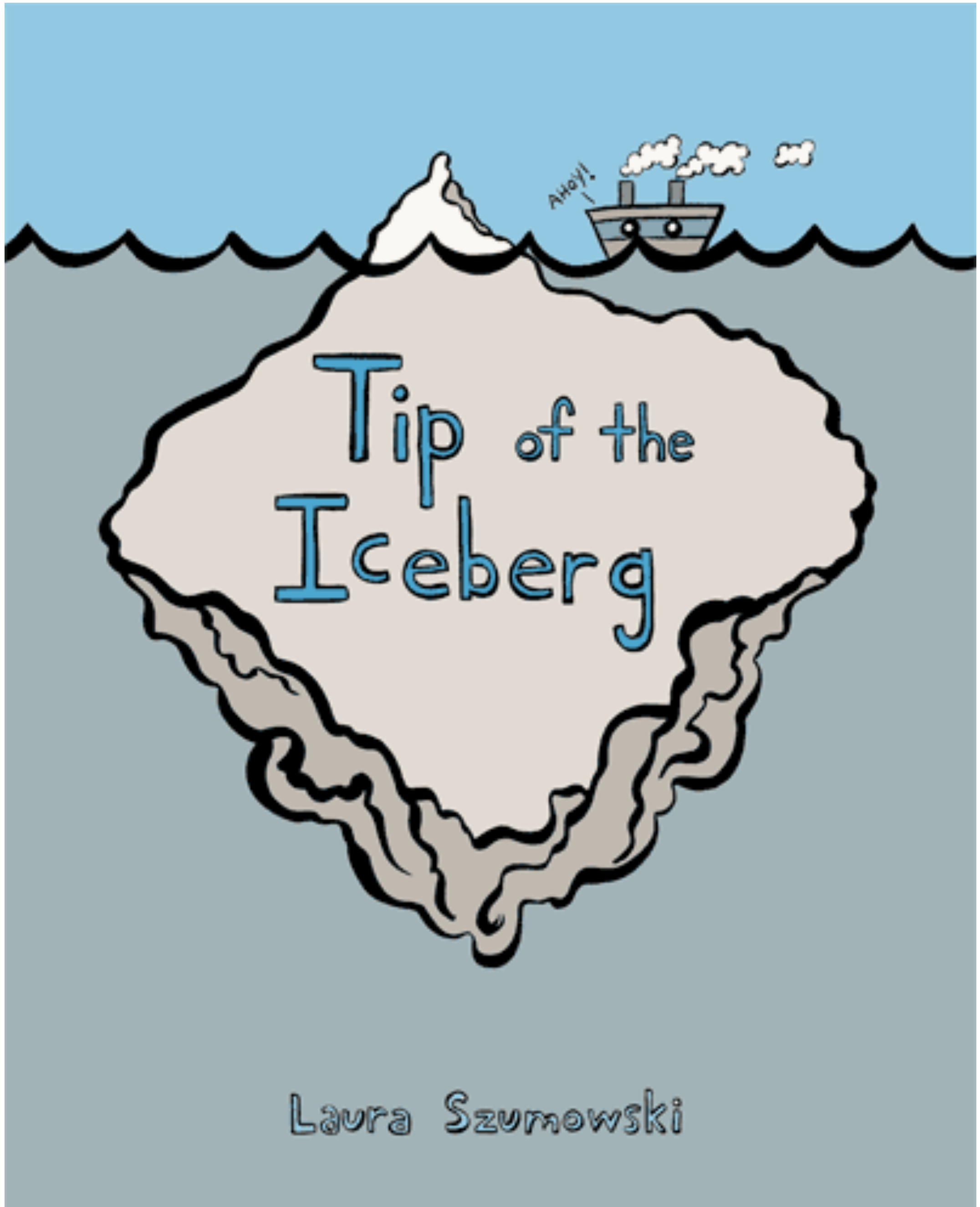
OVERVIEW

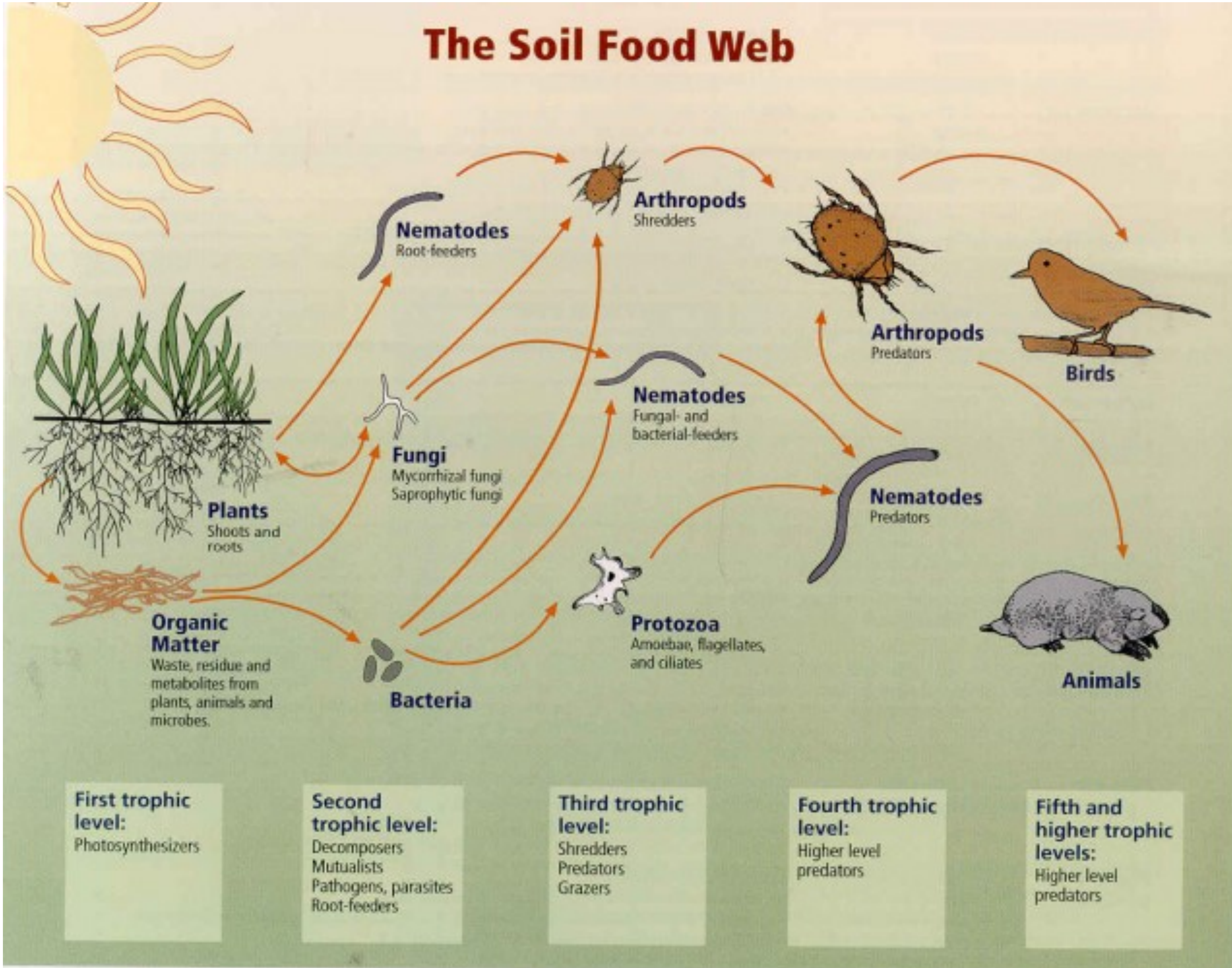
1. The importance of (fine) roots
2. Study on belowground phenology
3. Roots in a melting permafrost mire
4. Plans for the future

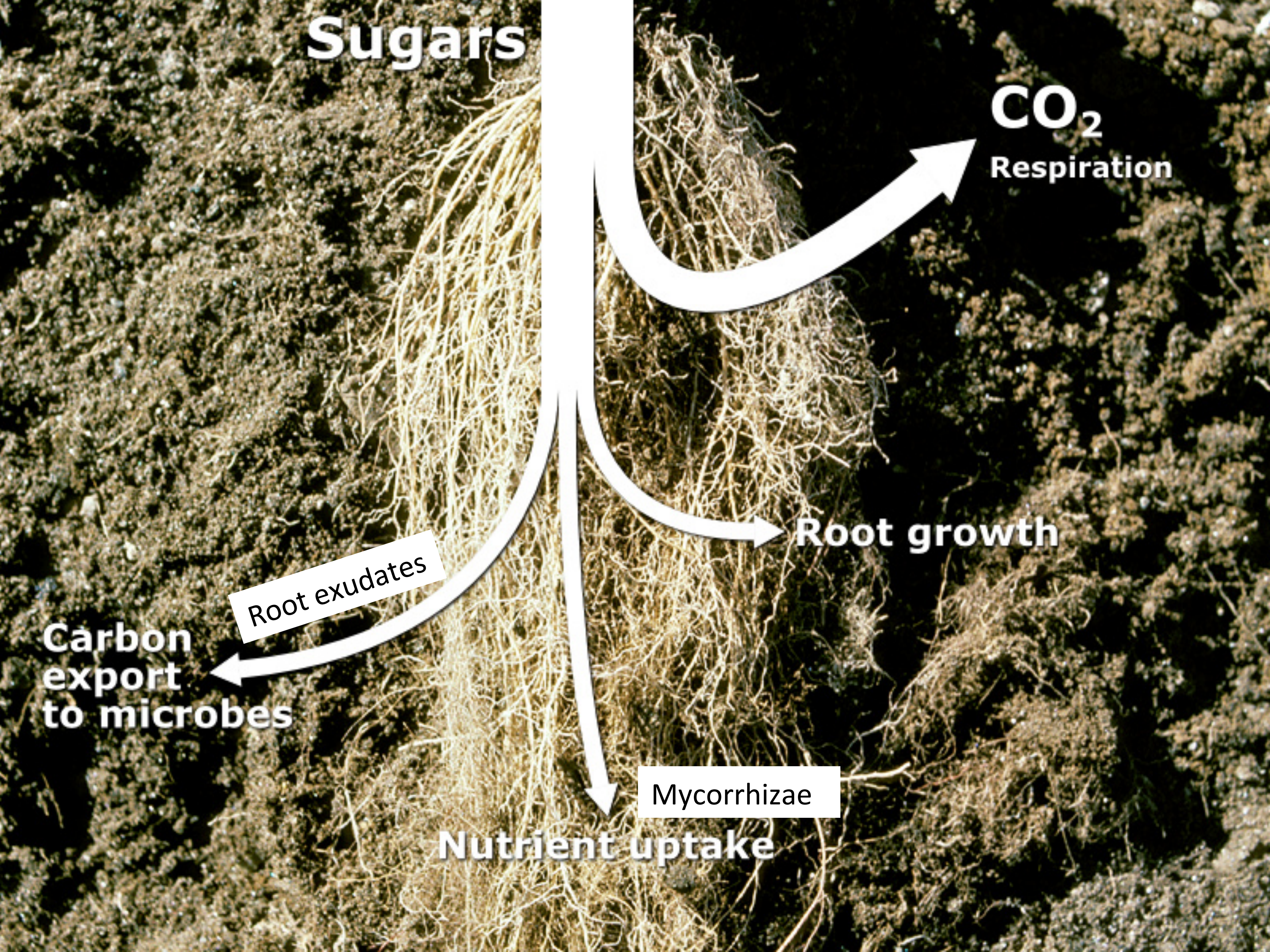
1. The importance of (fine) roots

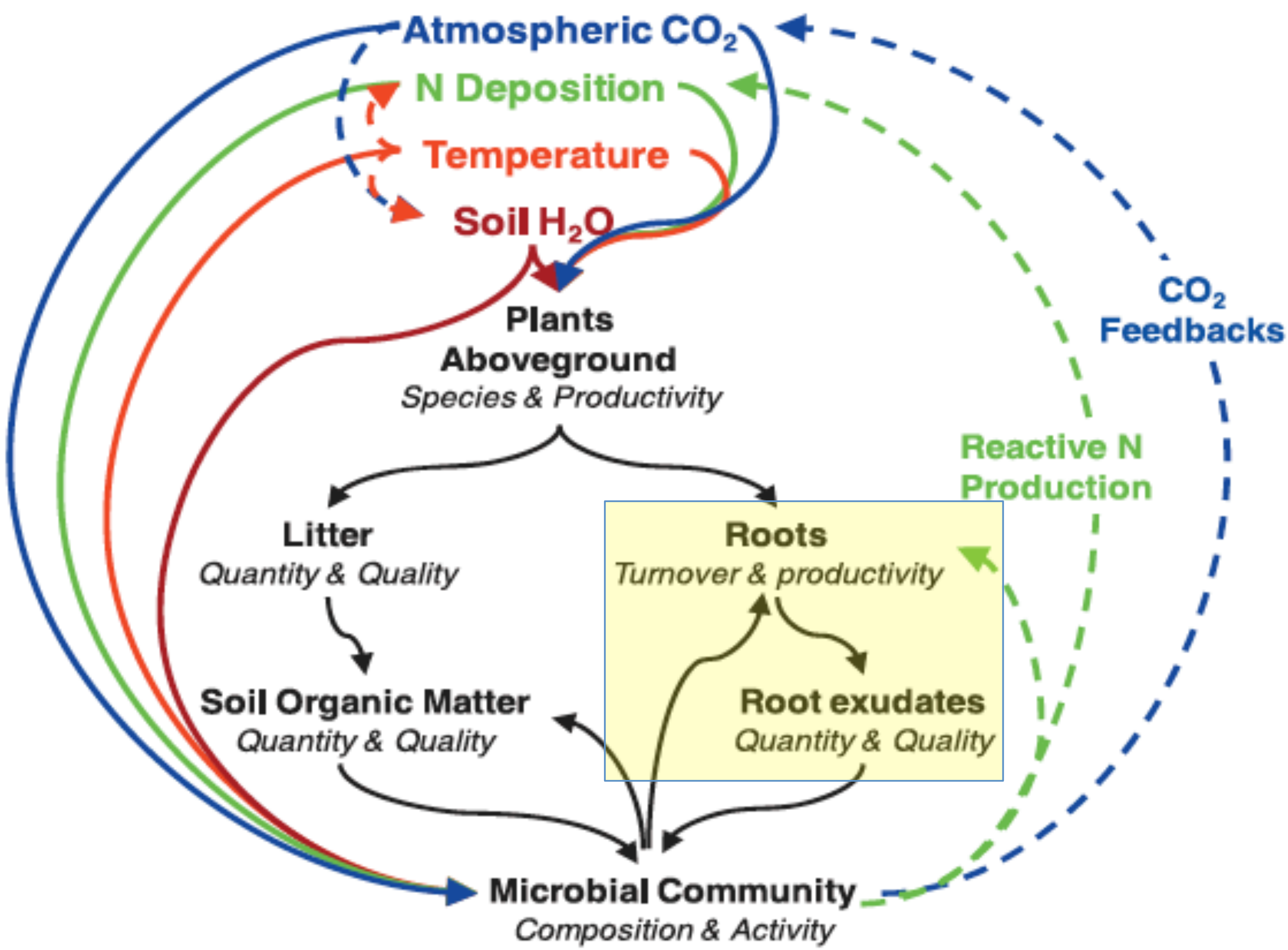



Root/shoot ratio:
• 0.2 in temperate forest
• 6.6 in tundra


AHOY!
Tip of the Iceberg
Laura Szumowski


The Soil Food Web
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Plants
Shoots and roots
Fungi
Mycorrhizal fungi
Saprophytic fungi
Nematodes
Fungal- and bacterial-feeders
Nematodes
Predators
Organic Matter
Waste, residue and metabolites from plants, animals and microbes.
Bacteria
Protozoa
Amoebae, flagellates, and ciliates
Animals
First trophic level:
Photosynthesizers
Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders
Third trophic level:
Shredders
Predators
Grazers
Fourth trophic level:
Higher level predators
Fifth and higher trophic levels:
Higher level predators

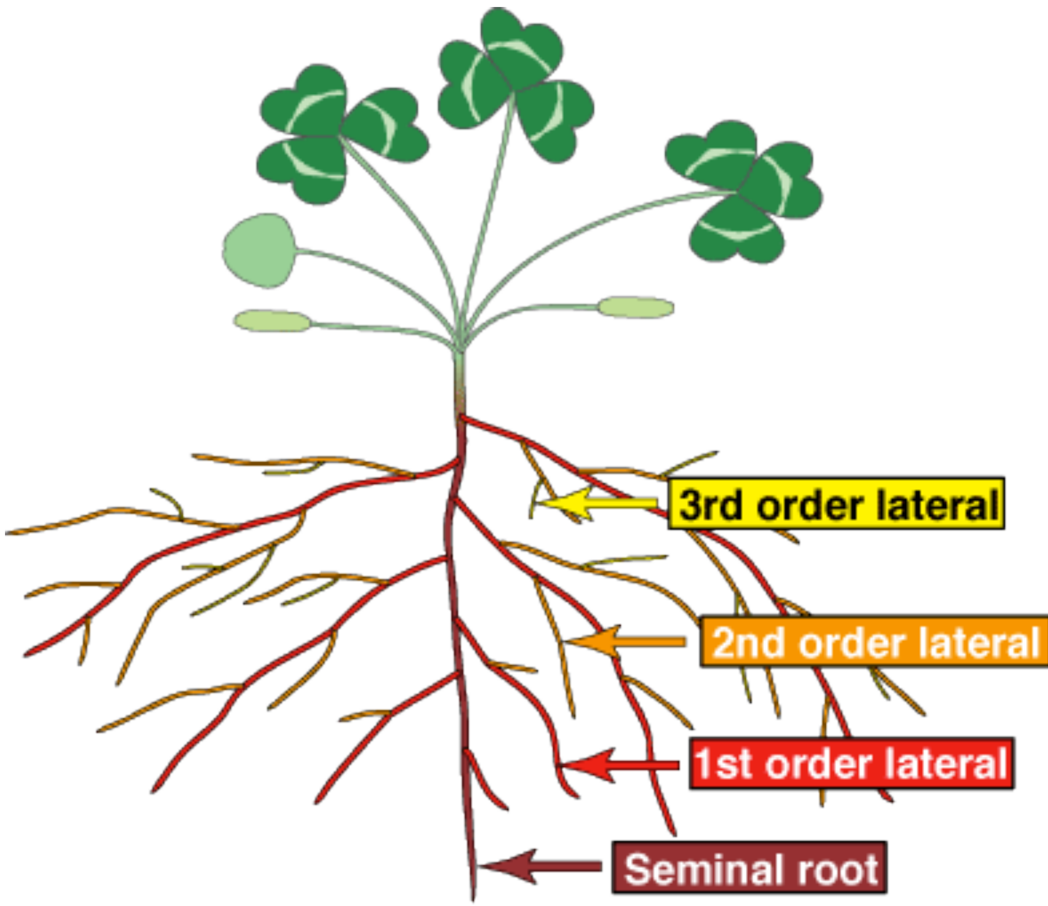

Sugars
CO_2
Respiration
Root growth
Root exudates
Carbon export to microbes
Mycorrhizae
Nutrient uptake



Global change feedbacks mediated by belowground processes

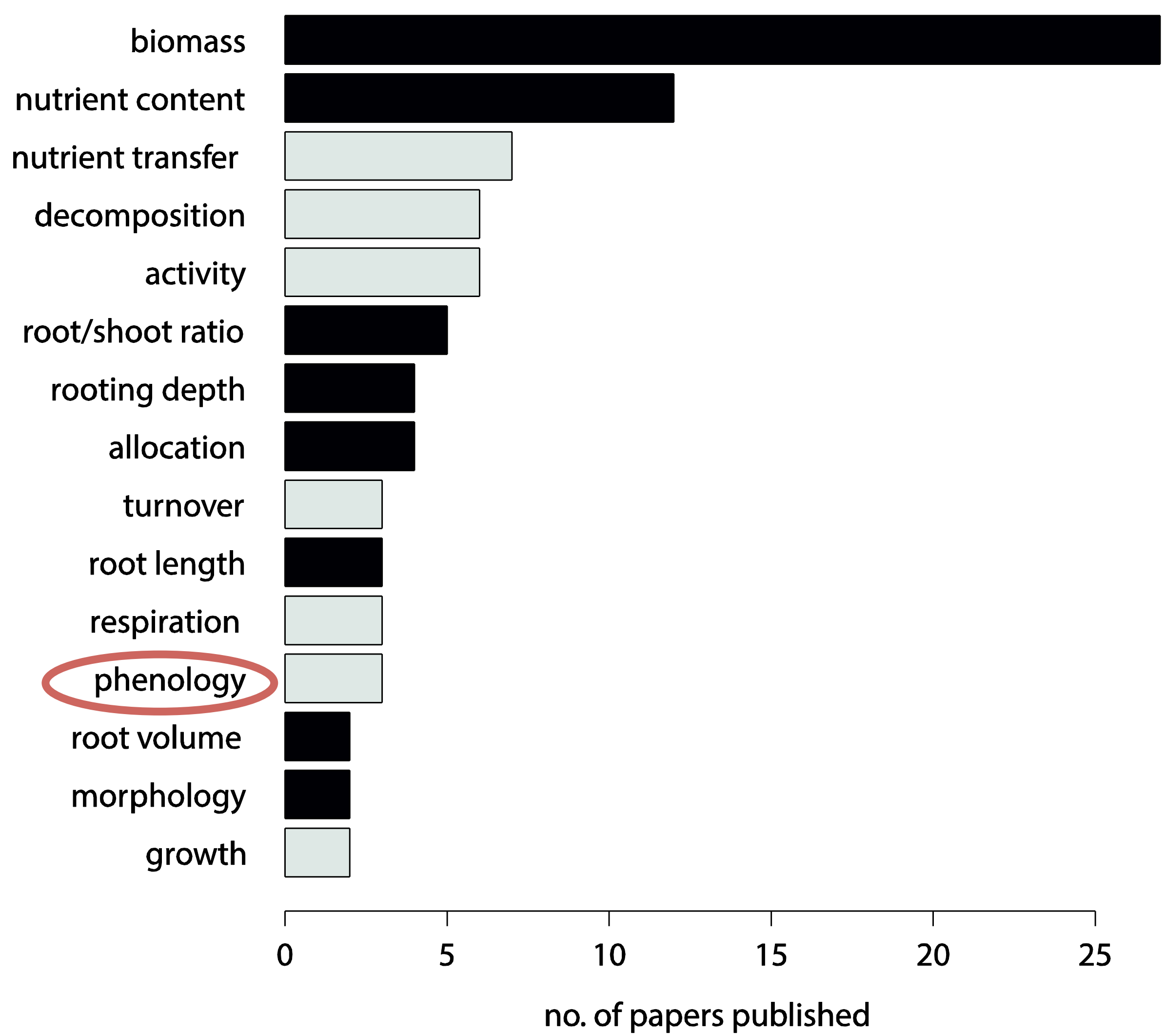
Derived from Pendall *et al.* 2008

Not all roots are the same!



- Coarse *vs.* fine roots (< 2 mm in diameter)
- Very fine (< 0.5 mm) *vs.* fine roots
- Position on the branching root system (e.g. Pregitzer 2002)
- However, knowledge on form and function still at its beginning

Root research in arctic ecosystems



Blume-Werry et al., manuscript

2. Study on belowground phenology

Coupling of Above- and Belowground Phenology Along an Altitudinal Gradient in Subarctic Sweden

Rationale:

- Climate warming prolongs the growing season in arctic regions (Barichivich et al. 2013)
- Start, peak and end of the (aboveground) growing season are used to model vegetation influences on biogeochemical cycles (Fatichi et al. 2014)

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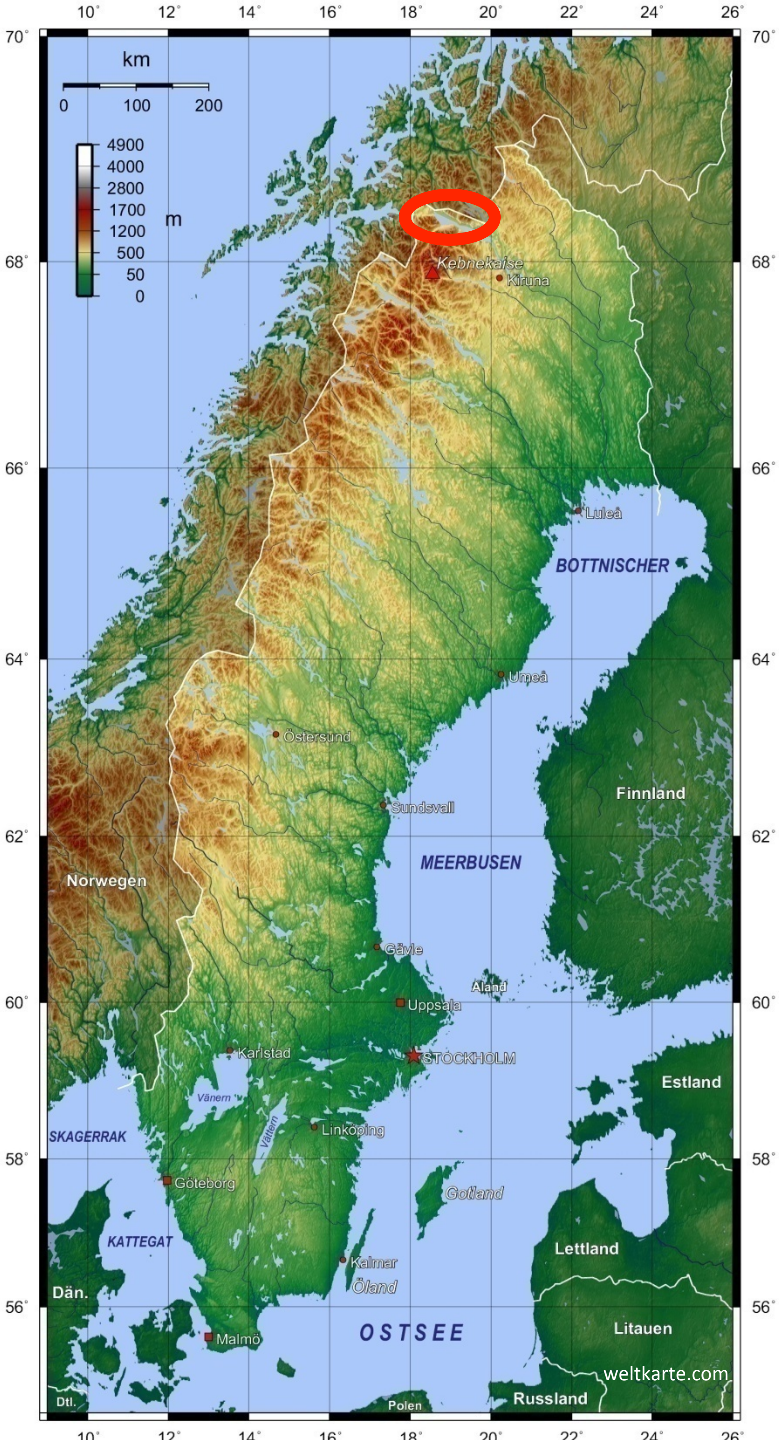
- Start, peak and end of the (aboveground) growing season are used to model vegetation influences on biogeochemical cycles (Fatichi et al. 2014)
- However, over 80% of the plant biomass in the Arctic consists of roots!
- Is aboveground phenology a good measure for overall plant phenology? Are root and shoot phenology tightly coupled?



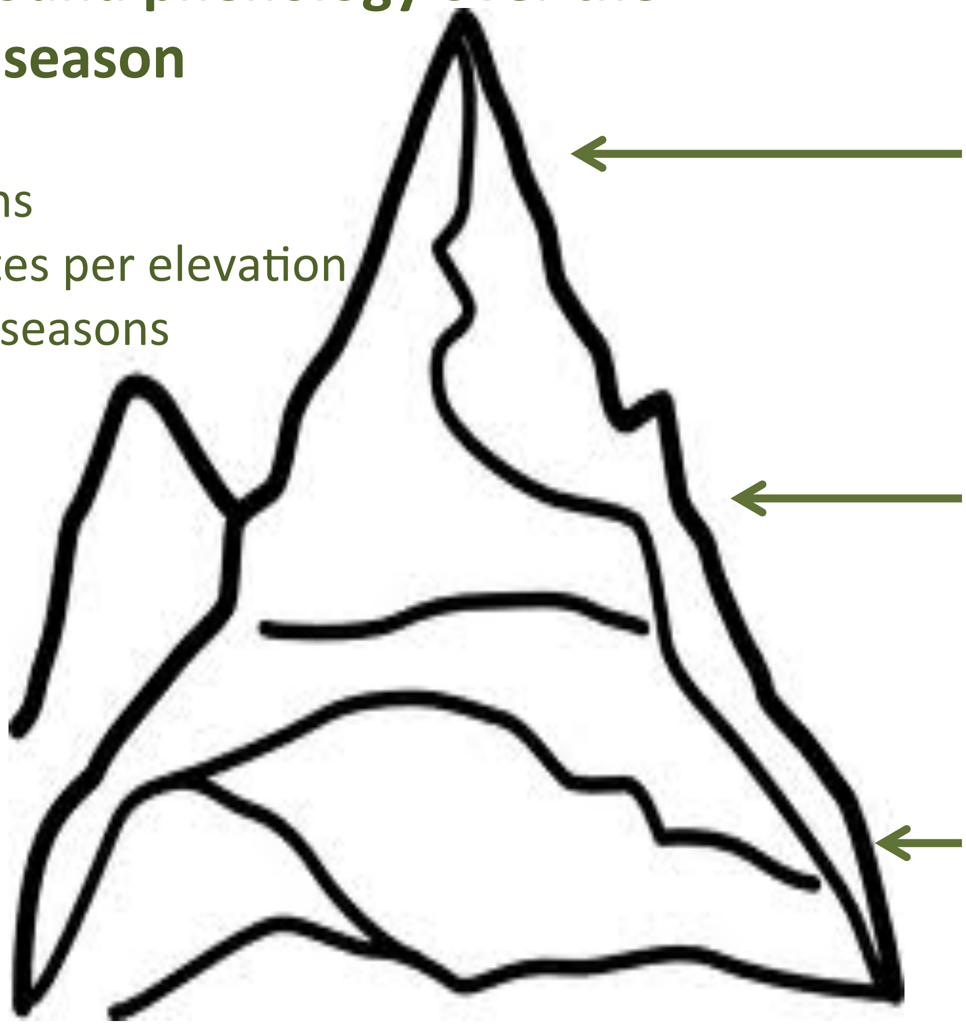
Study site

- Abisko, northern Sweden
- 68°21'N, 18°49'E
- 200 km north of the Arctic Circle

Methods

Bi-weekly measurements of above- and belowground phenology over the growing season

3 elevations
10 replicates per elevation
2 growing seasons



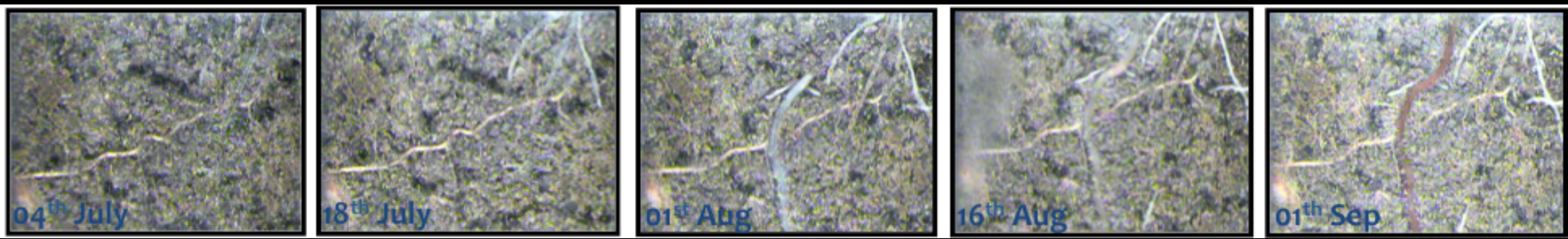
High-alpine tundra, 1100 m a.s.l.

Low-alpine tundra, 800 m asl

Sub-alpine birch forest, 500 m a.s.l.

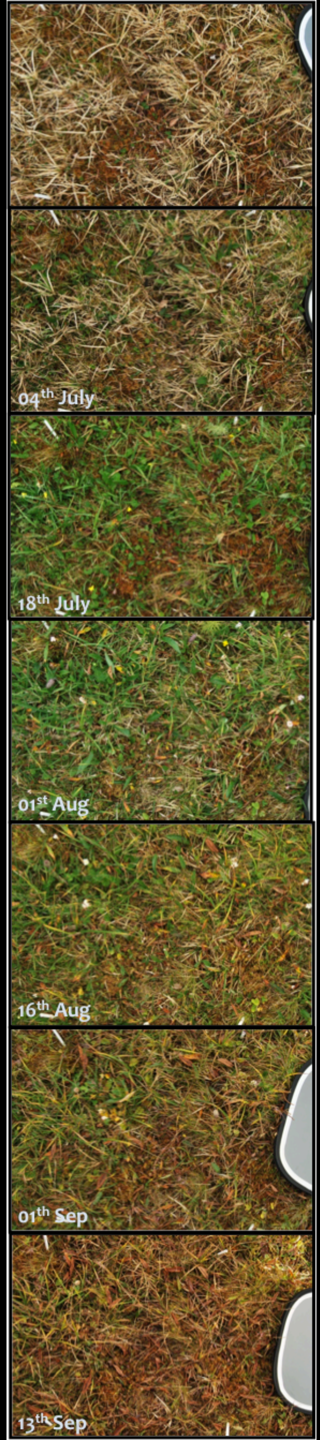
Minirhizotron
Tube
45°
Soil
Surface
1 m
1 m
Johnson *et al.* 2001
Jack
Wolfskin

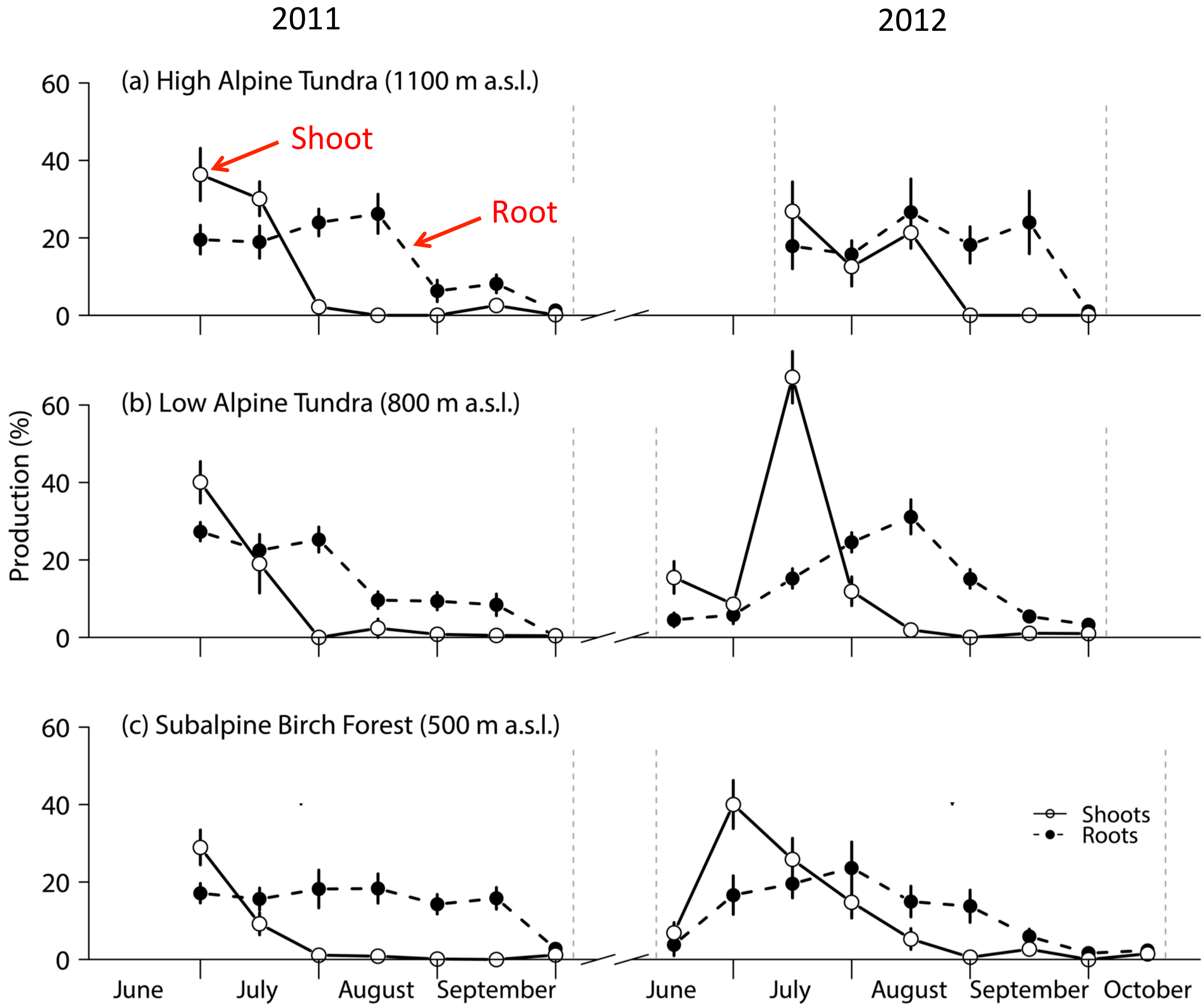
Belowground phenology




Nikon

Aboveground phenology





2011
2012
(a) High Alpine Tundra (1100 m a.s.l.)
Shoot
Root
(b) Low Alpine Tundra (800 m a.s.l.)
(c) Subalpine Birch Forest (500 m a.s.l.)
Production (%)
60
40
20
0
Shoots
Roots
June
July
August
September
October

Completion of the growing season above- and belowground

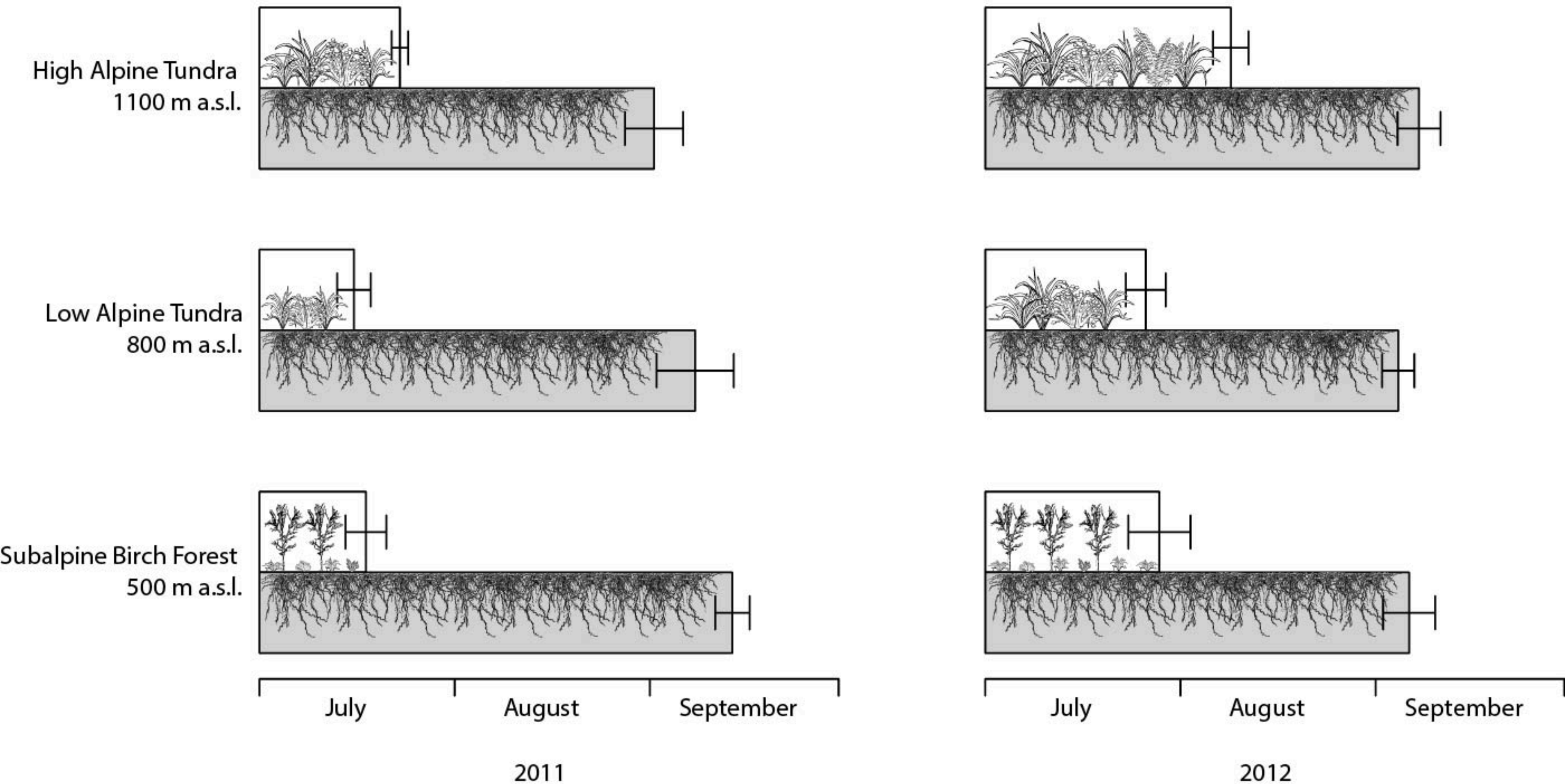


Fig. 2 Completion of the growing season above- and belowground. White and grey bars show when 90% of the yearly aboveground cover and fine root growth were exceeded, respectively, after beginning of measurements, in high alpine tundra (at 1100 m a.s.l., n=10), in low alpine tundra (at 800 m a.s.l., n=10) and in subalpine birch forest (at 500 m a.s.l., n=9). Error bars are +/- SE.

Results and conclusions

- Shoot phenology severely underestimates the length of the total growing season in arctic regions
- Remotely sensed information cannot be used to infer the actual length of the growing season, nor root growth patterns
- We currently fail to measure phenological responses to a warming climate of *c.* 80% of the arctic biomass
- Prolonged root growth may change the timing when Arctic ecosystems shift from being C sinks to sources
- Seasonal root growth should be included in scenarios of how arctic ecosystems respond to climate warming

3. Roots in a melting permafrost mire

Root responses to melting permafrost in a peat mire

Climate warming in the Subarctic

-> thawing permafrost

-> increased active layer thickness

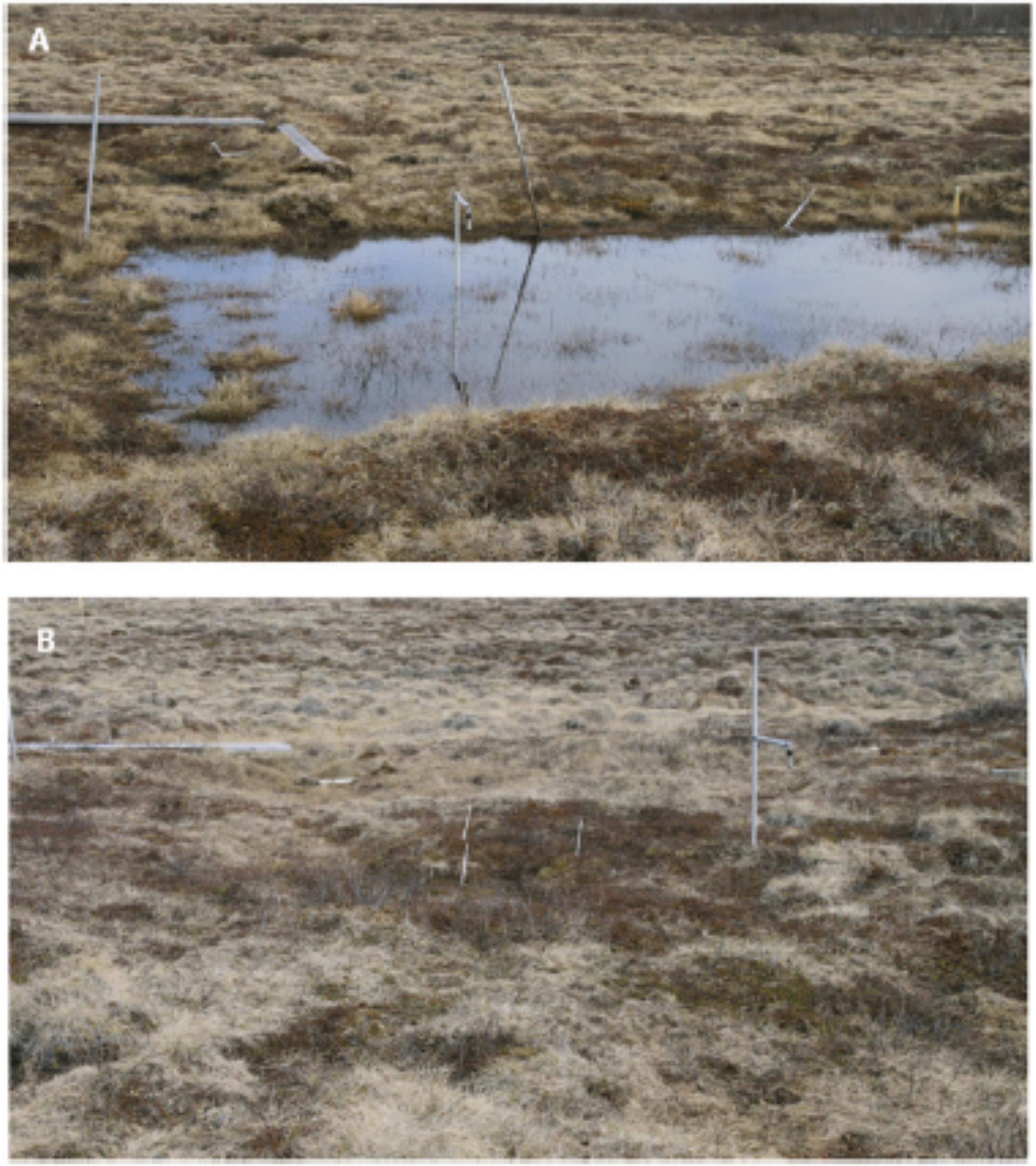
-> vegetation changes

- How will this affect root growth?
- Can roots benefit from new ‘deep’ nutrient sources?
- Will there be priming effects? (via root exudates)

Experimental set-up

- Storflaket peat mire
- 9 years of snow addition (warmer soil temperatures in winter)
- Treatments:
  - Control
  - Snow addition (= permafrost melting)
  - Deep fertilization: ^{15}N added at 50 cm depth

  (can plants take up deep nutrients when those are released due to permafrost degradation?)
- 6 replicates per treatment
- 3 minirhizotron tubes per plot (54 in total)

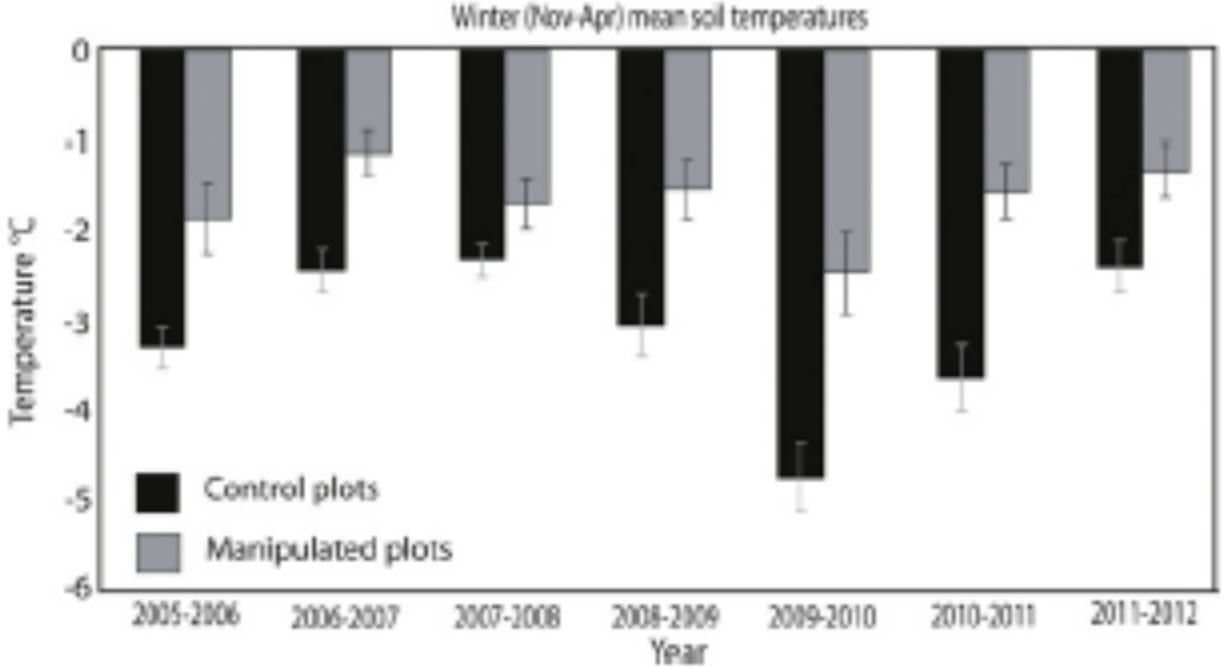


Snow fence

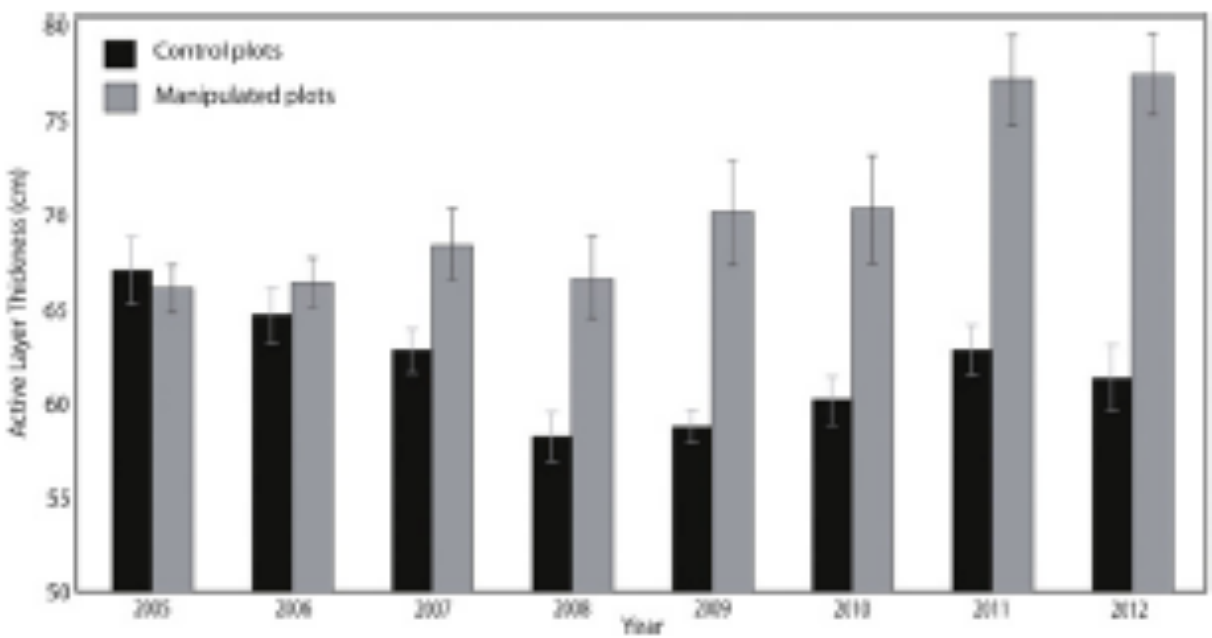
Control

Addition of NH_4NO_3 containing ^{15}N at 50 cm depth

Winter soil temperatures



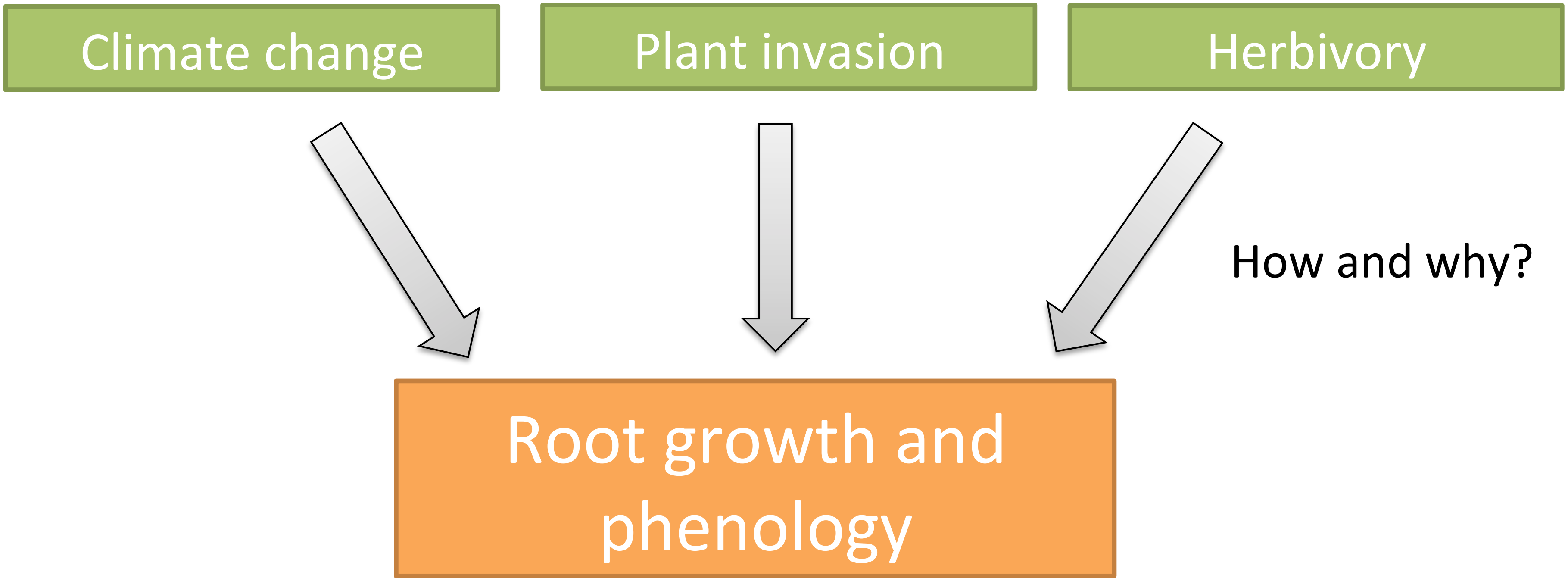
Active layer thickness

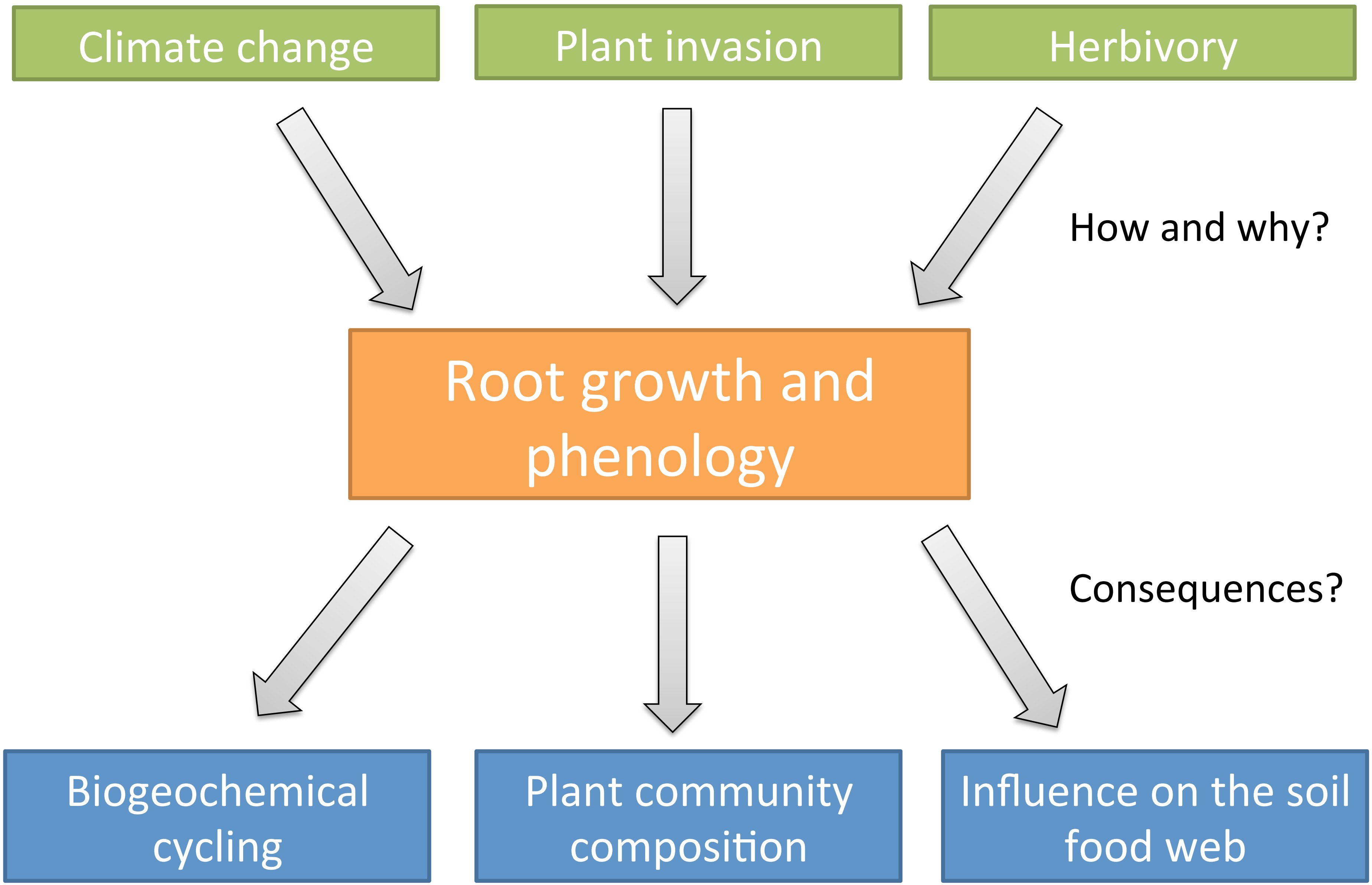


Johansson *et al.*
Env. Res. Lett. 2013

To be continued ….

4. Plans for the future


Climate change
Plant invasion
Herbivory
How and why?
Root growth and phenology


Climate change
Plant invasion
Herbivory
How and why?
Root growth and phenology
Consequences?
Biogeochemical cycling
Plant community composition
Influence on the soil food web


Thank you for your attention!