photo by
Minna Turunen

# Did the reindeer eat all the shrubs? Mimicking Arctic big grazers in CLM

Heidrun Matthes, Adrien Damseaux, Jussi T. Eronen, Sari Stark, Gabriela Schaepman-Strub, Sirpa Rasmus, Bruce C. Forbes, Tim Horstkotte, Johan Olofsson, J. Otto Habeck

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- research within the framework of project CHARTER (Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity)
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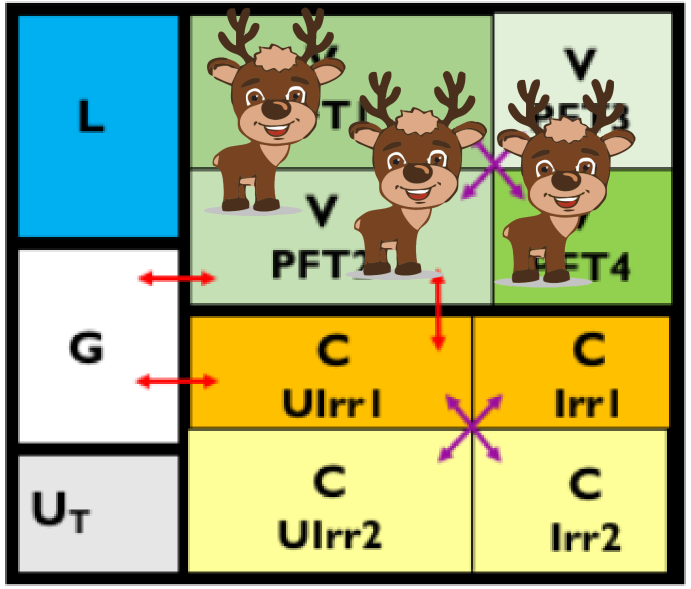

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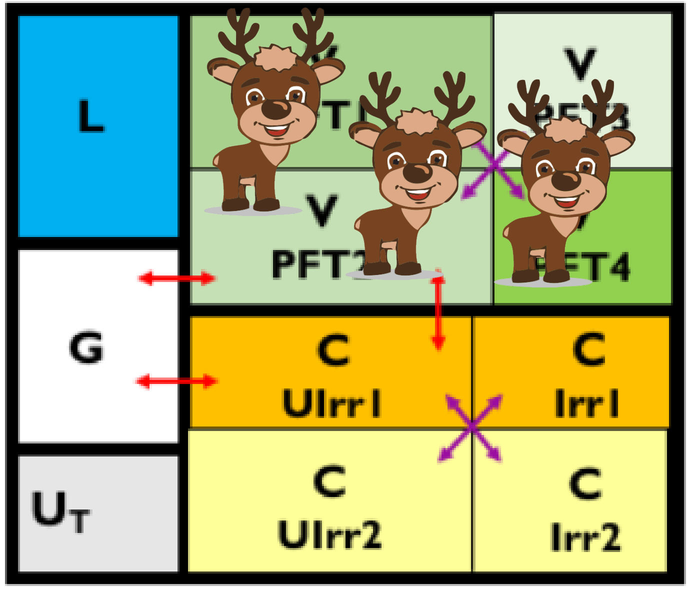
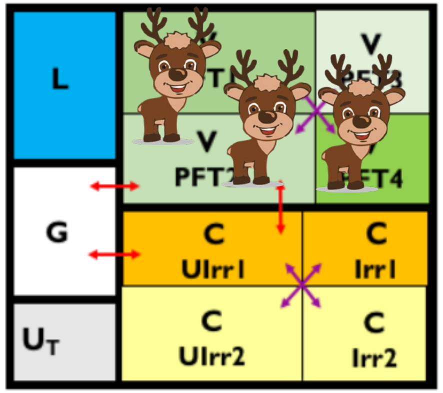



What this talk is about:
feasibility of mimicking big grazers
plausibility of the approaches

What this talk is not about:
model results – hopefully
coming soon, but not done yet

# Reindeer in the Arctic



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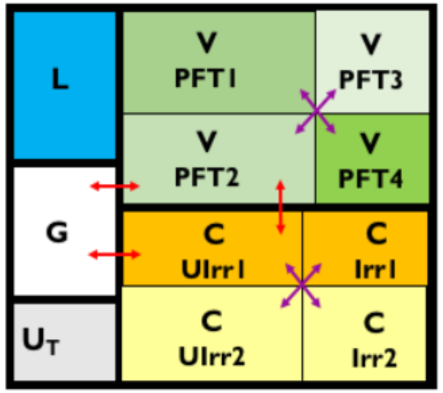

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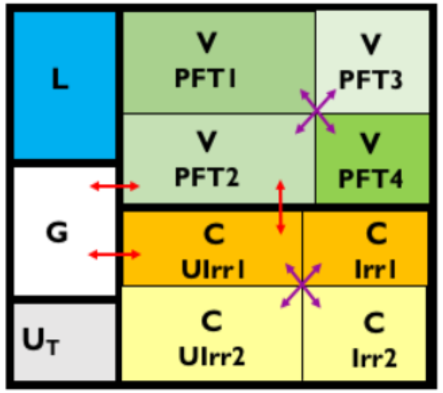


**impacts of large herbivores on the Arctic environment**

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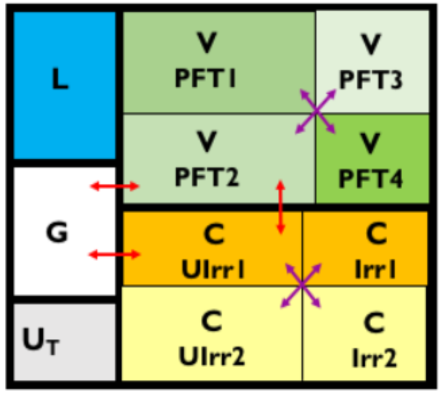


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**animal behaviour**

- browsing
- grazing
- Effects on wild animals?
- defecating
- trampling

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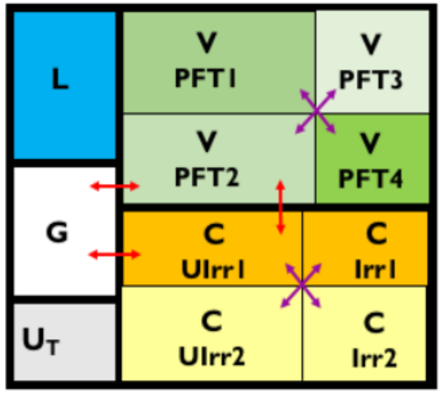


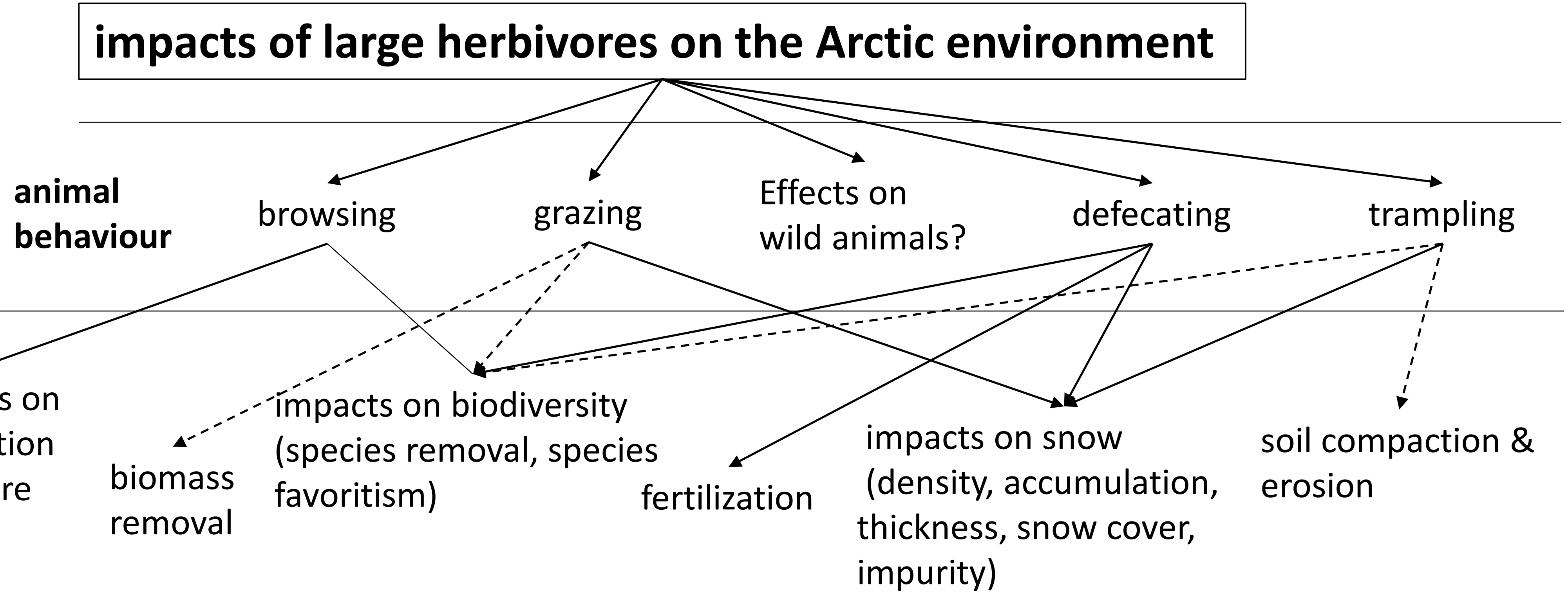

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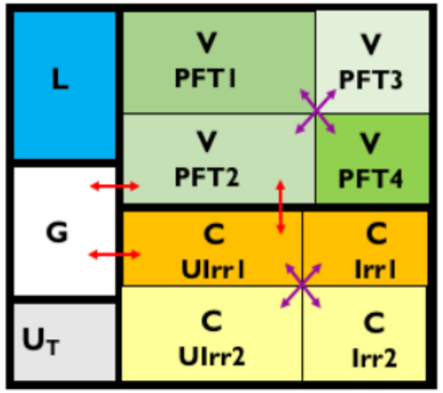



**impacts of large herbivores on the Arctic environment**

**animal behaviour**

browsing

grazing

Effects on wild animals?

defecating

trampling

**environ-mental impact**

impacts on vegetation structure

biomass removal

impacts on biodiversity (species removal, species favoritism)

fertilization

impacts on snow (density, accumulation, thickness, snow cover, impurity)

soil compaction & erosion

**translation into model parameters**

biogeophysical & biogeochemical
- pft distribution
- background albedo
- carbon cycling
- 

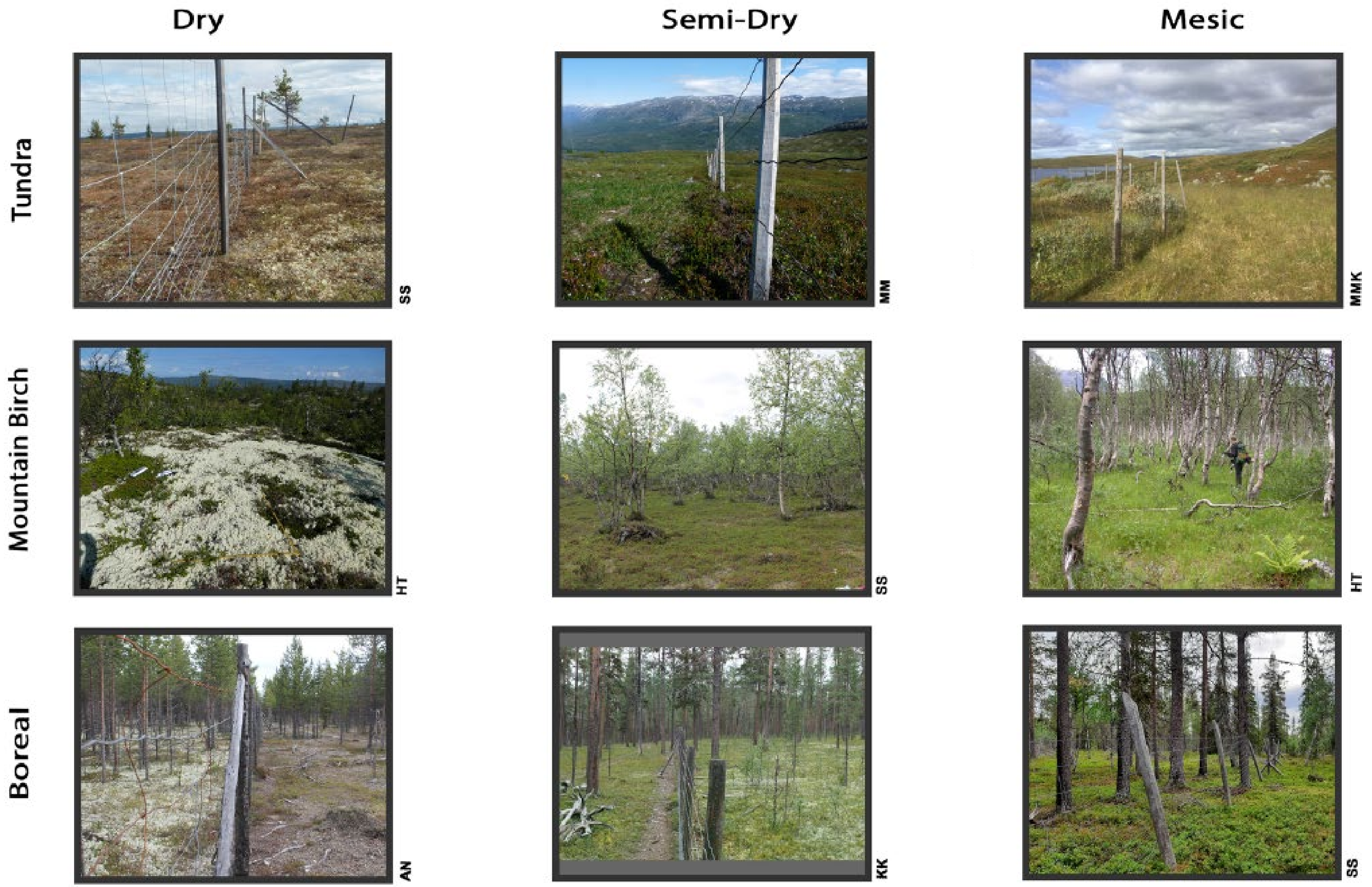
snow
- snow compaction
- snow optical properties
- 

soil
- soil porosity
- soil color
- organic matter content
- 

# Reindeer in the Arctic

- Quantifying these impacts is usually attempted using exclosure sites

- specific impacts found in studies like this are variable

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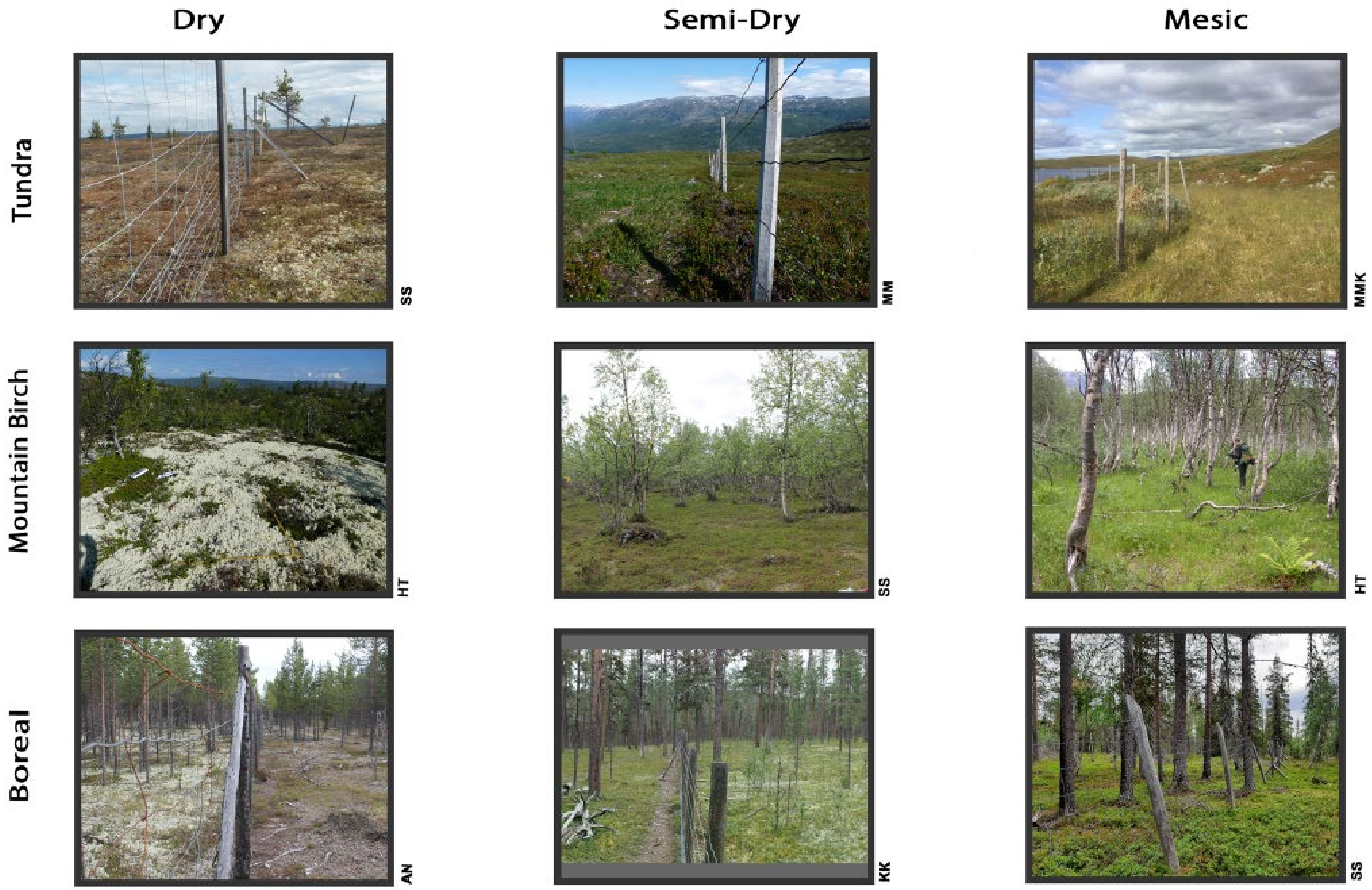
- However, a number of effects seem to be common: exclosure sites have
    - more shrubs
    - more lichen
    - thicker organic soil layers (with similar carbon storage)
    - lower snow density (higher snow depth with the same swe)

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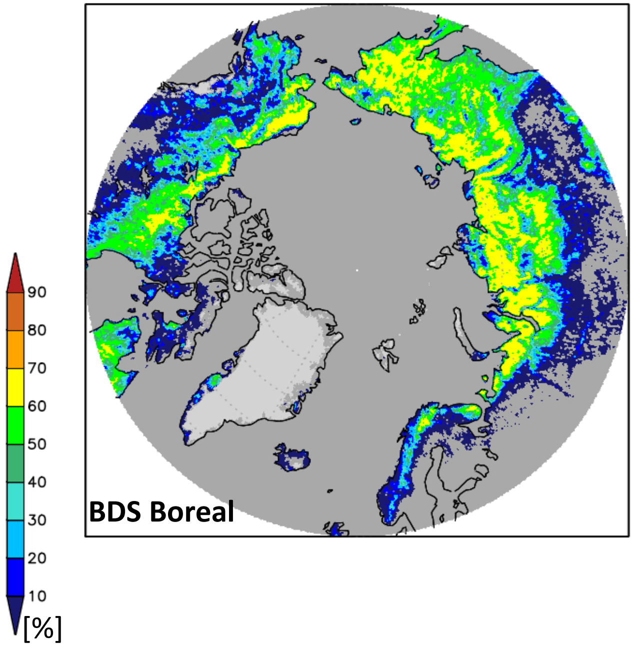
# increase of shrubs

- across studies, deciduous shrubs increased in exclosure sites by 15% (+- quite some margin!)

CTSM standard



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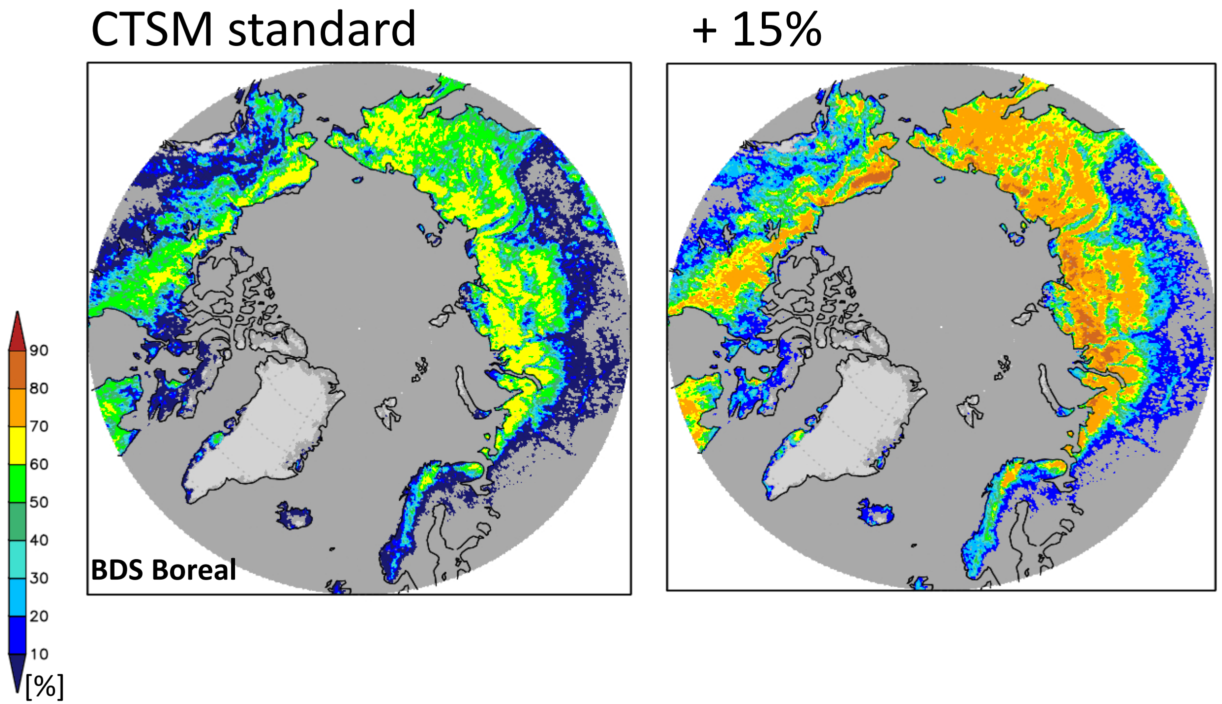




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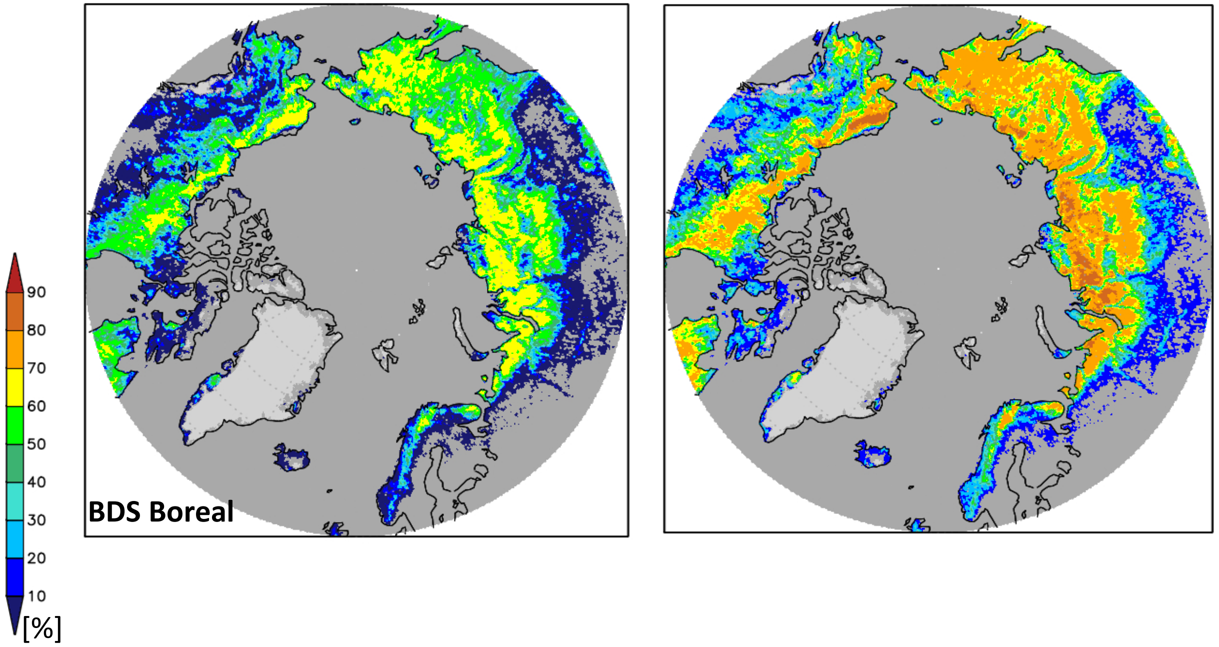


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- but for pfts to add up correctly, we need to decrease other pfts
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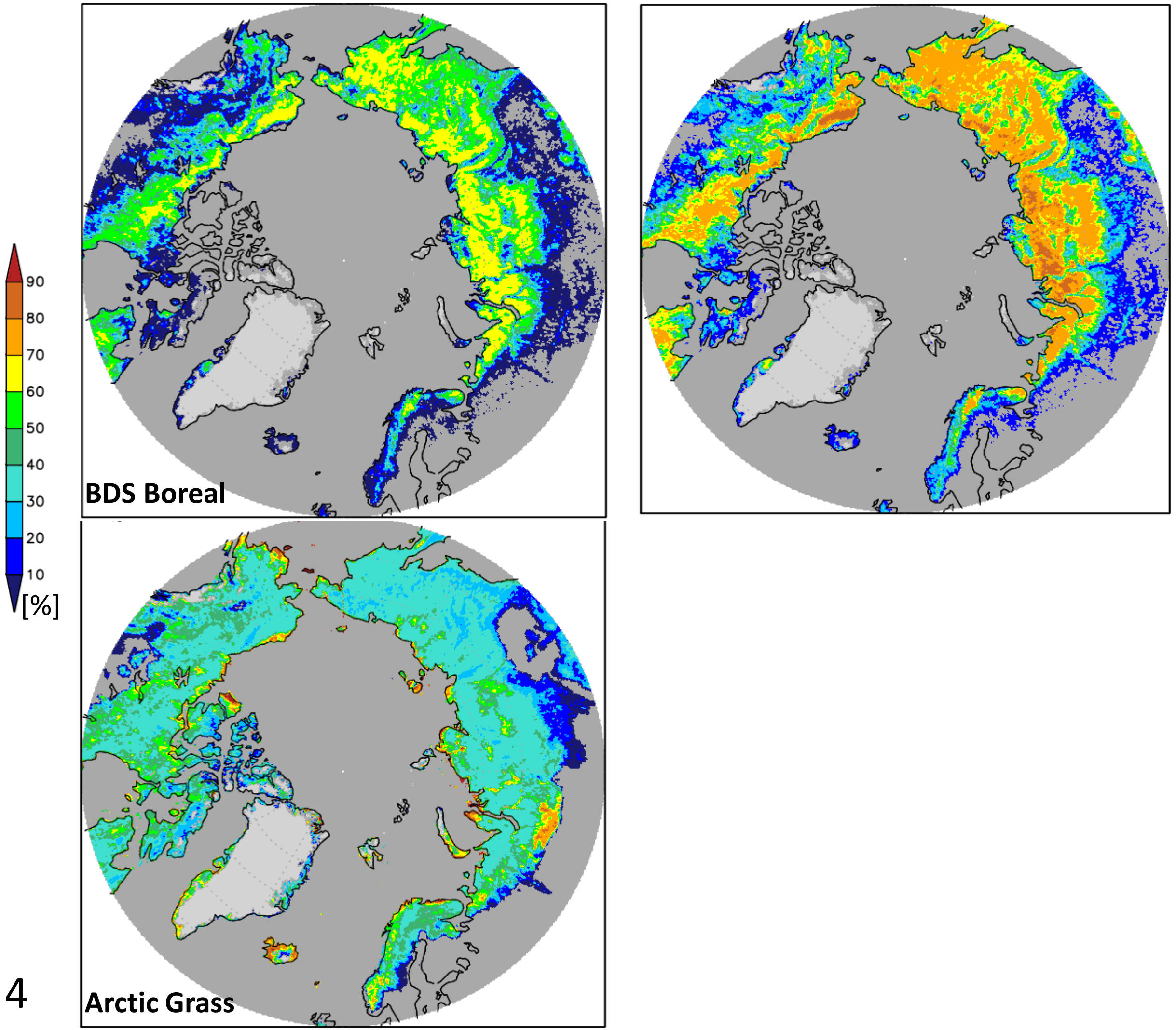


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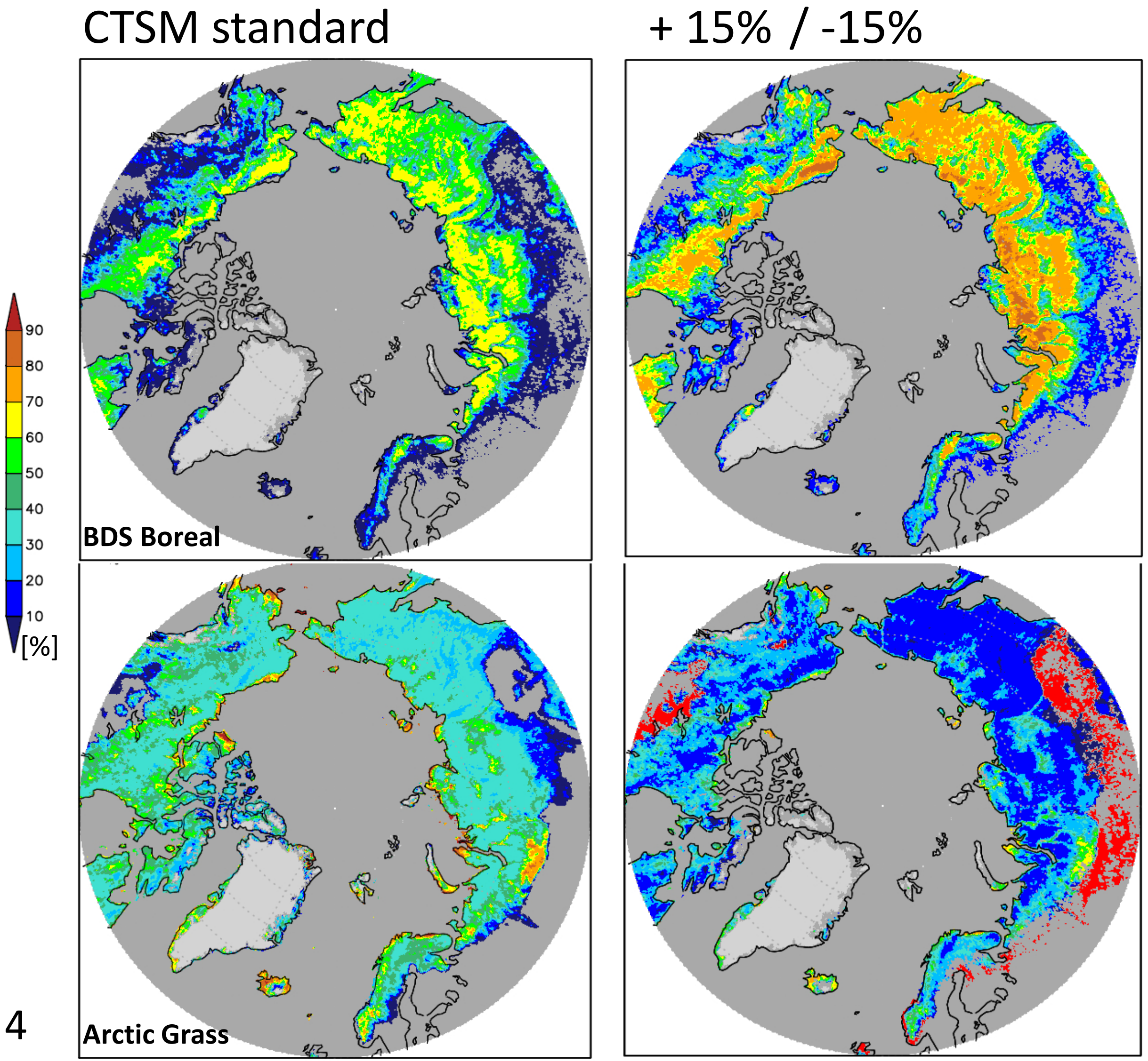


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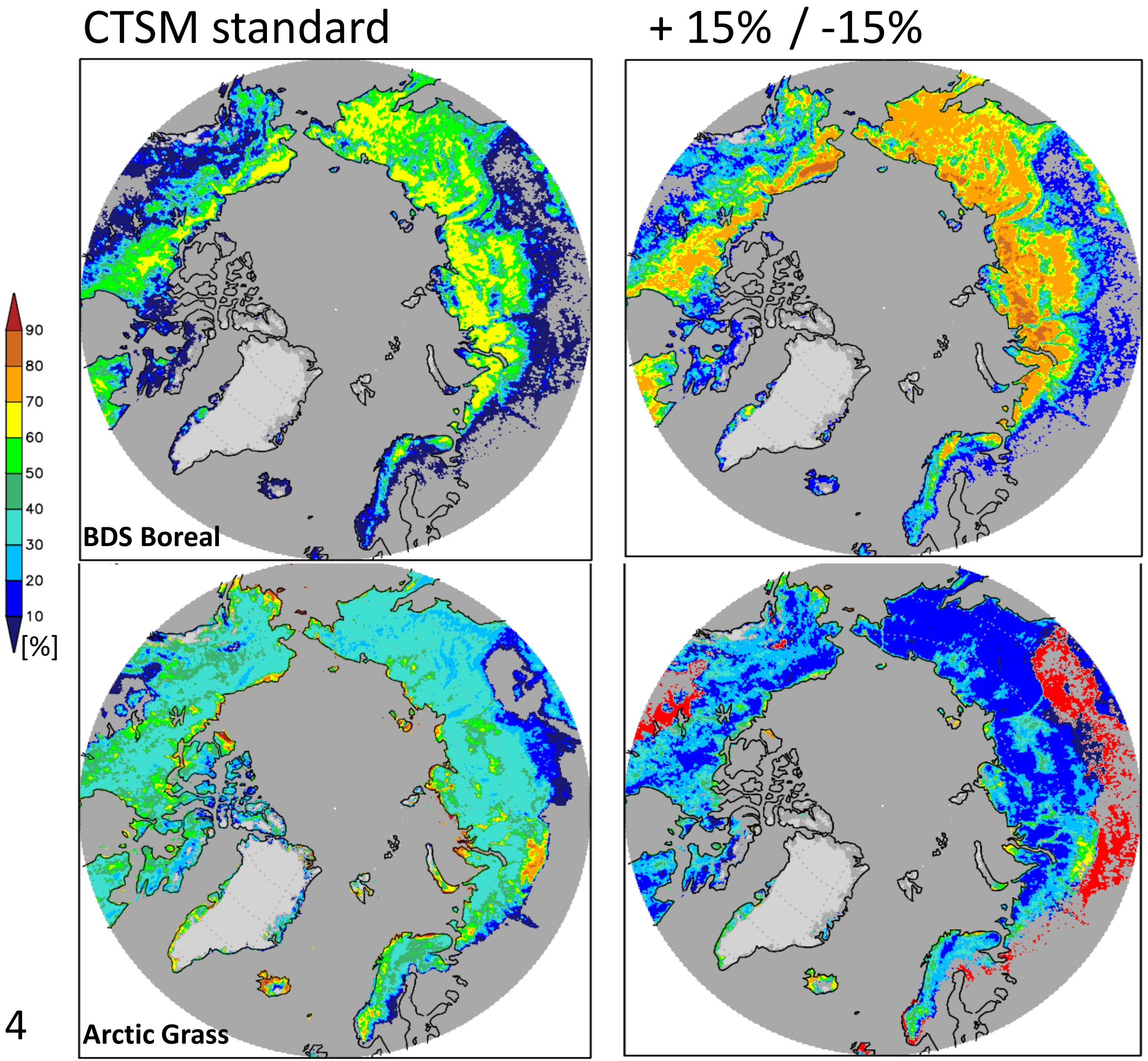


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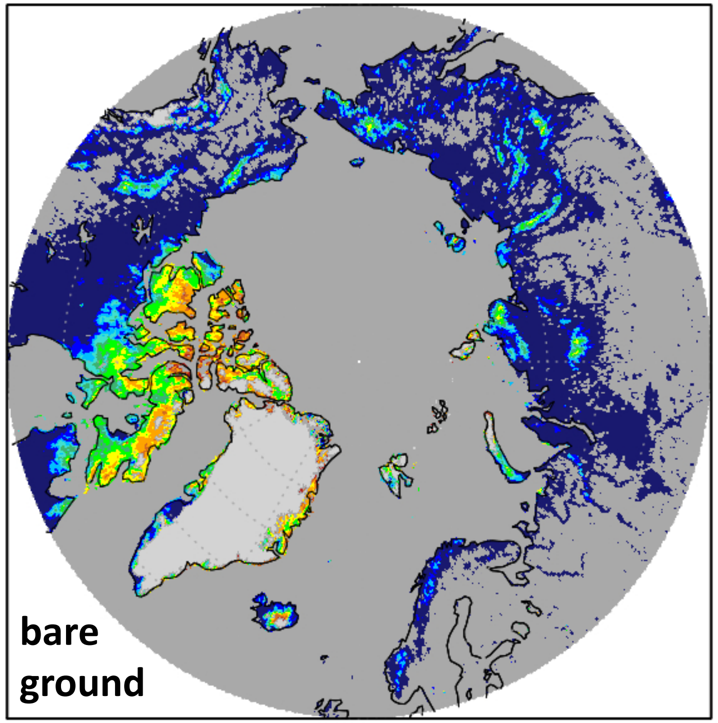
- part of that can be considered by changing C3 grasses
- everywhere else, the increase in shrubs is decreased so there is no reduction of forest

# increase of lichen abundance

- there is no lichen representation in CTSM yet
- tundra is represented as a mix of bare ground and grass



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| | Dry | | Saturated | |
|---|---|---|---|---|
| Color Class | vis | nir | vis | nir |
| 11 | 0.24 | 0.37 | 0.13 | 0.26 |
| 12 | 0.23 | 0.35 | 0.12 | 0.24 |
| 13 | 0.22 | 0.33 | 0.11 | 0.22 |
| 14 | 0.20 | 0.31 | 0.10 | 0.20 |
| 15 | 0.18 | 0.29 | 0.09 | 0.18 |
| 16 | 0.16 | 0.27 | 0.08 | 0.16 |
| 17 | 0.14 | 0.25 | 0.07 | 0.14 |
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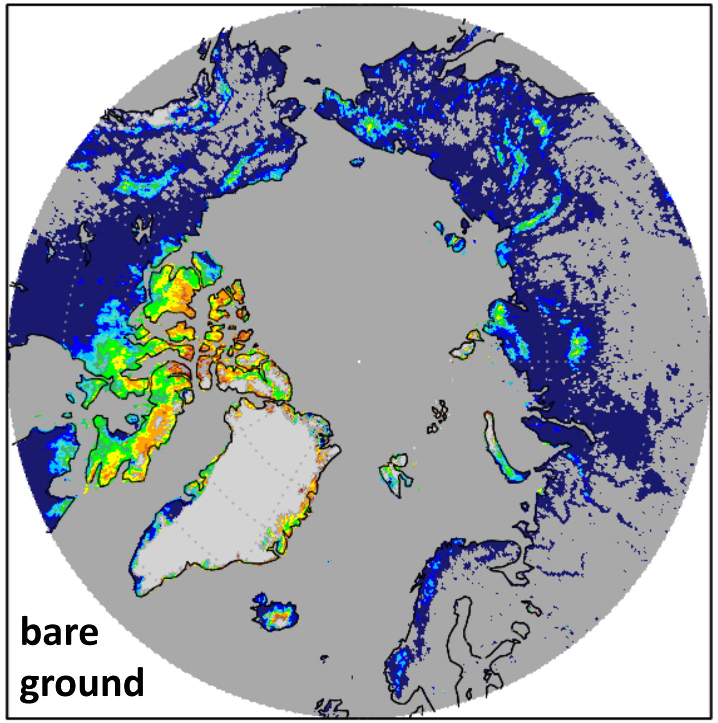
CLM Technical Note, https://escomp.github.io/ctsm-docs/versions/master/html/tech_note



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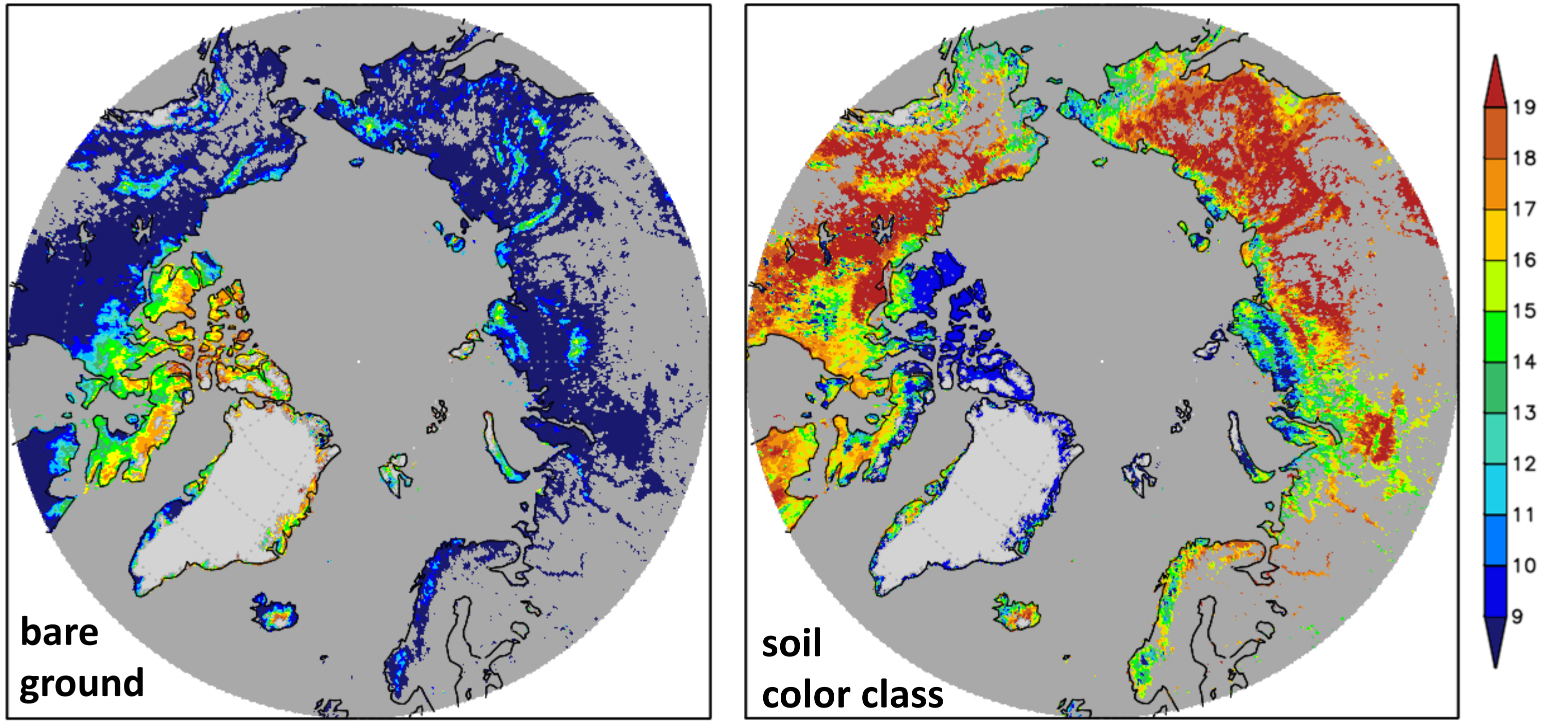
- we shift soil color class of all grid cells with bare ground by 1

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- possible approaches:
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$$\Delta z_i^{n+1} = \Delta z_i^n \left(1 + C_{R,i}\Delta t\right) \Rightarrow \Delta z_i^{n+1} = \Delta z_i^n \left(1 + \alpha \cdot C_{R,i}\Delta t\right)$$

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  2. decrease snow density by modifying the density of freshly fallen snow



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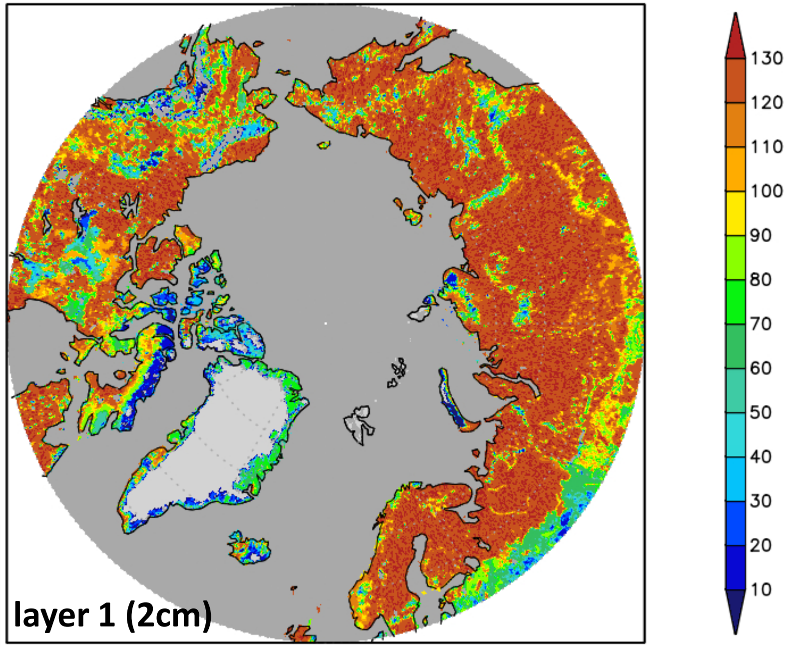


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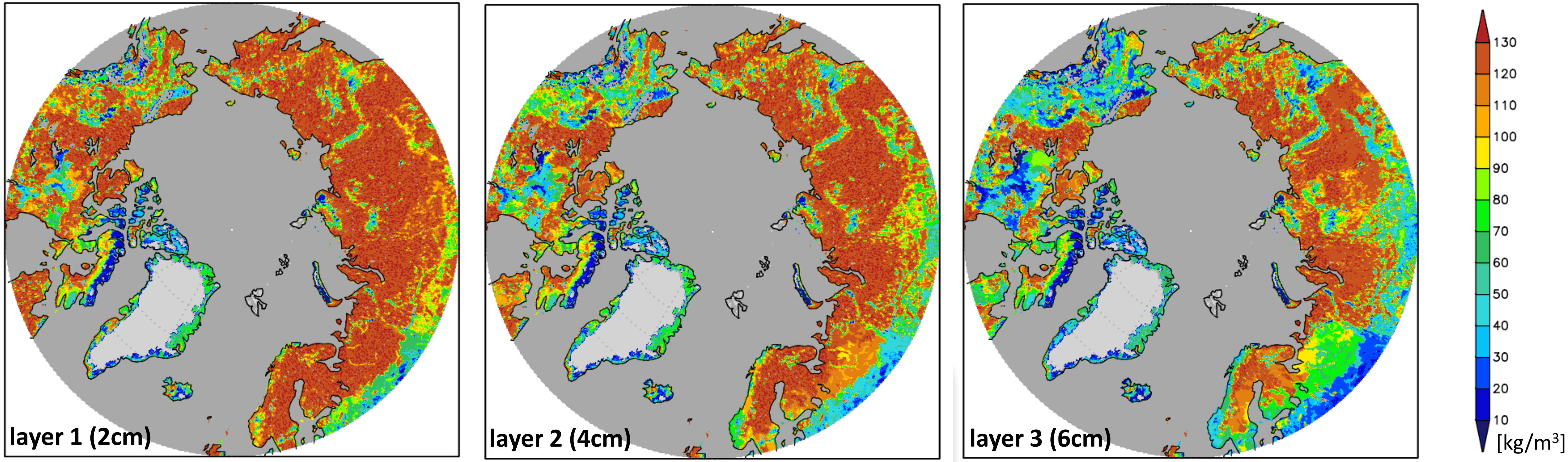
    2. “move” the organic matter content of the deeper soil layer to the top layers -> keeps the overall carbon storage similar where there is room for the additional organic matter



organic matter density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# conclusions

parameters usable for mimicking the impact of big grazers in the environment:

- shrub abundance ✓
- lichen abundance ( ✓ )
- thickness of organic soil layers (with similar carbon storage) ✗
- snow density (different snow depth with the same swe) ✗

photo by Bruce C Forbes

# conclusions

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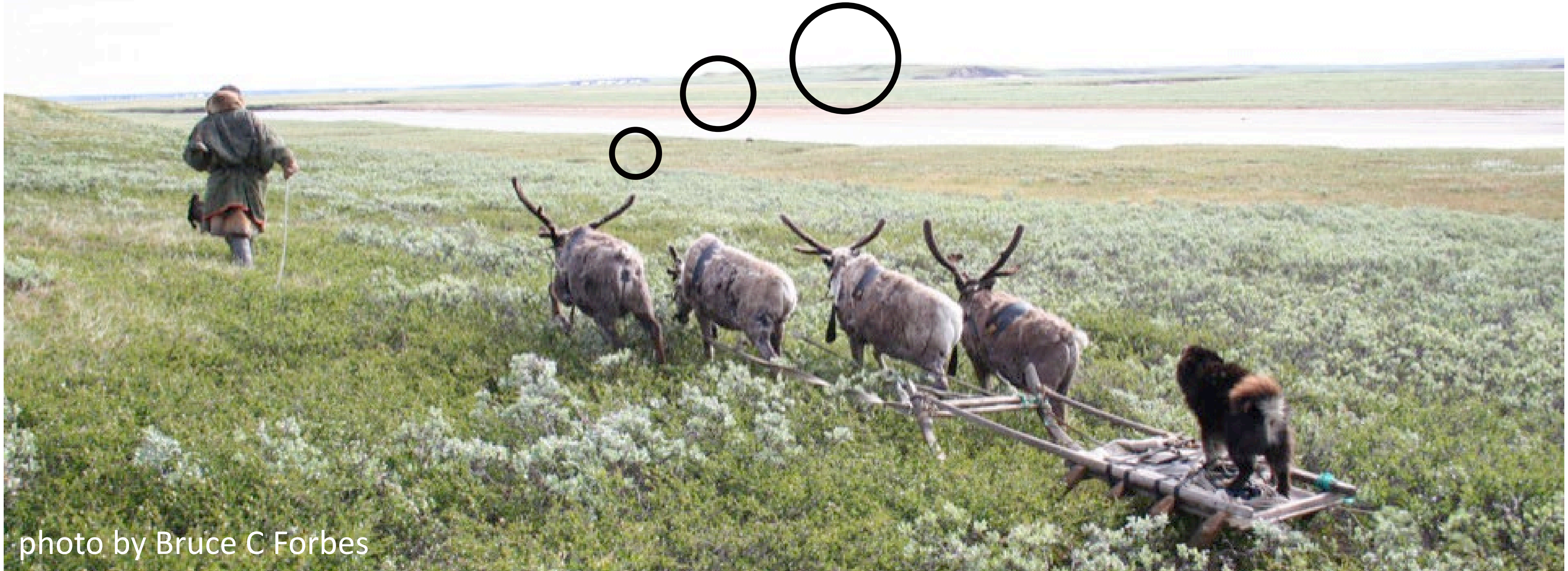

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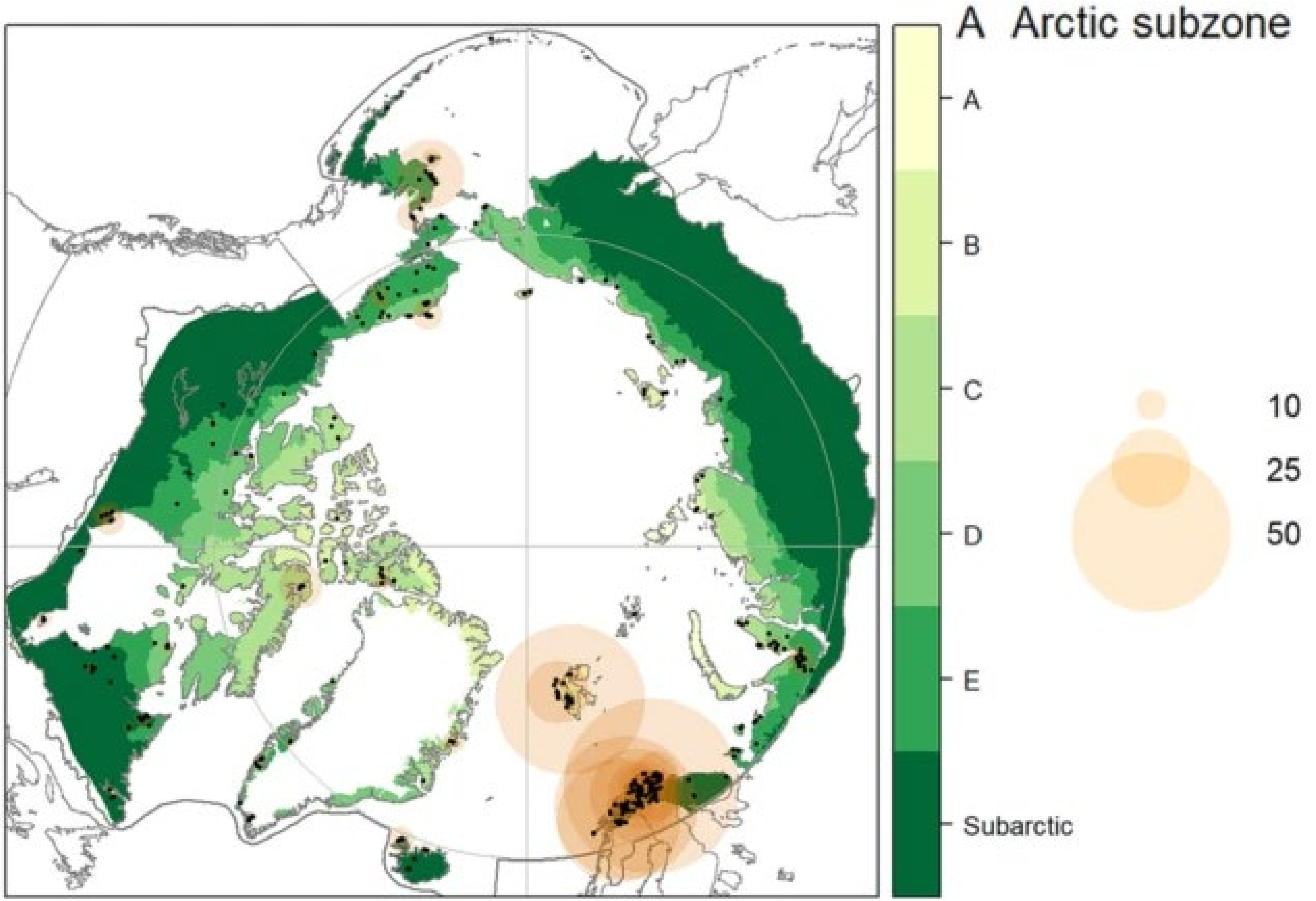
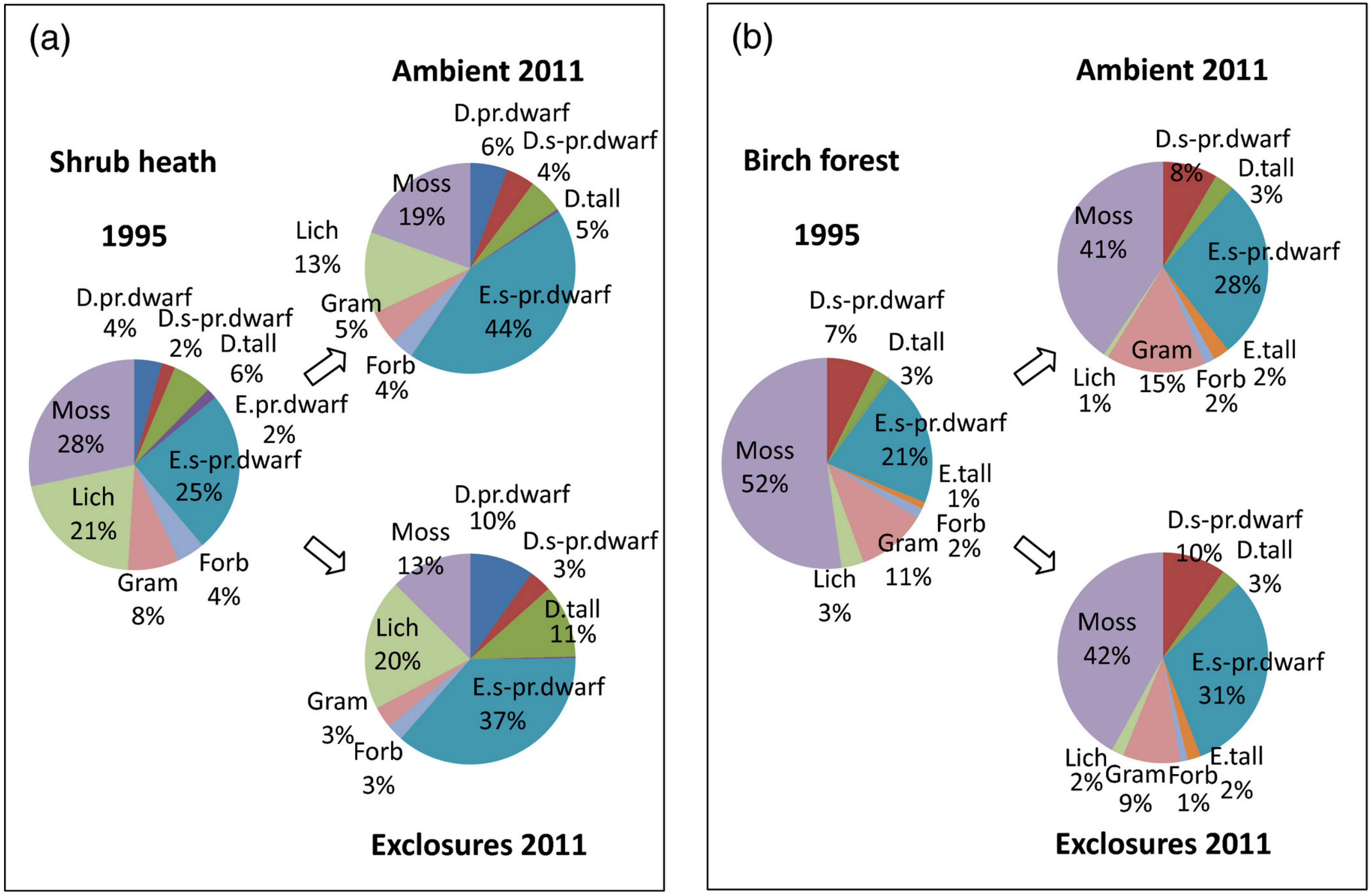
# Coming up with parameters – exclosure sites




Soininen, E. M., Barrio, I. C., Bjørkås, R., Björnsdóttir, K., Ehrich, D., Hopping, K., ... & Speed, J. D. (2021). Location of studies and evidence of effects of herbivory on Arctic vegetation: a systematic map. *Environmental Evidence*, *10*(1), 1-21.

# Coming up with parameters – example for pfts




Vowles, T., Gunnarsson, B., Molau, U., Hickler, T., Klemedtsson, L., & Björk, R. G. (2017). Expansion of deciduous tall shrubs but not evergreen dwarf shrubs inhibited by reindeer in Scandes mountain range. *Journal of Ecology*, *105*(6), 1547-1561.