The Arctic tundra: key drivers of the Carbon cycle under changing climate

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Global warming

Over the past 100 years, the global average temperature has increased by ~ **1.1°C,** compared to pre-industrial level.

(NASA Earth Observatory, 2022)

Arctic amplification

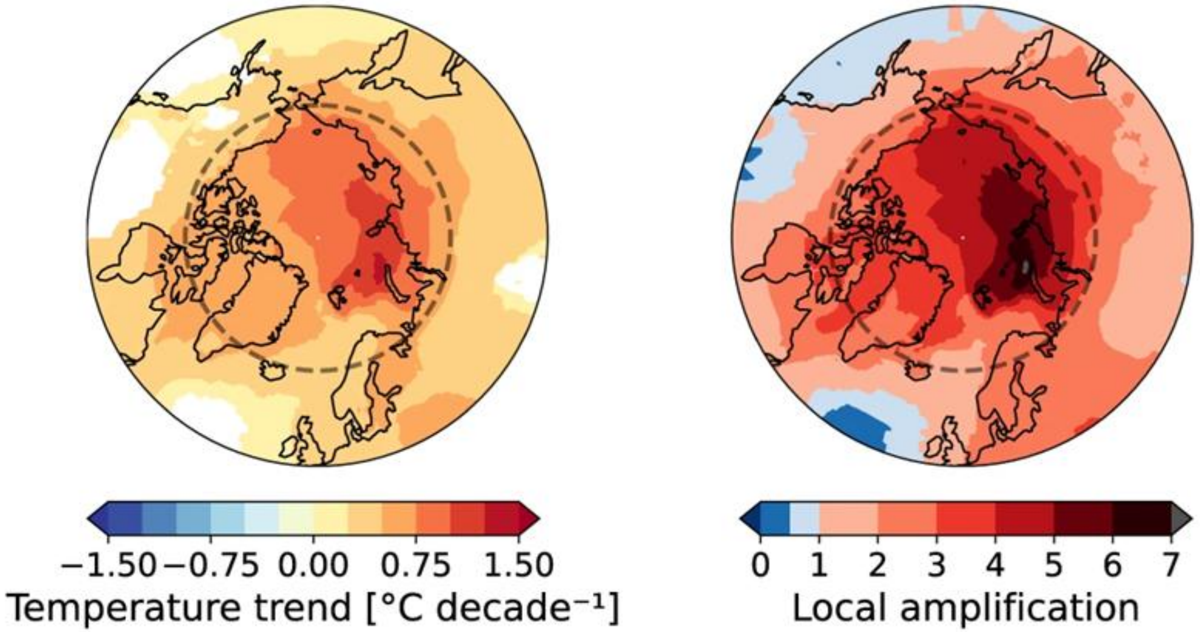
Consolidate phenomenon caused by multiple potential factors.
Arctic warming is **three times faster** than global warming.

(Arctic Monitoring and Assessment Programme - AMAP, 2021)

Most significant warming was recorded in the region between **Svalbard** and **Franz Joseph Land**;

- Winter T° increasing over 3.5°C
- Spring T° by more than 2.5°C

(Przybylak & Wyszyński, 2020)

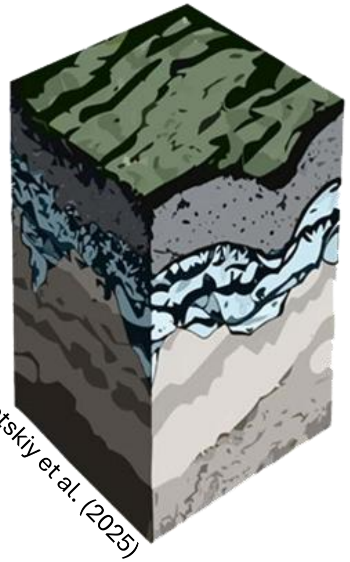


Rantanen et al. (2022)

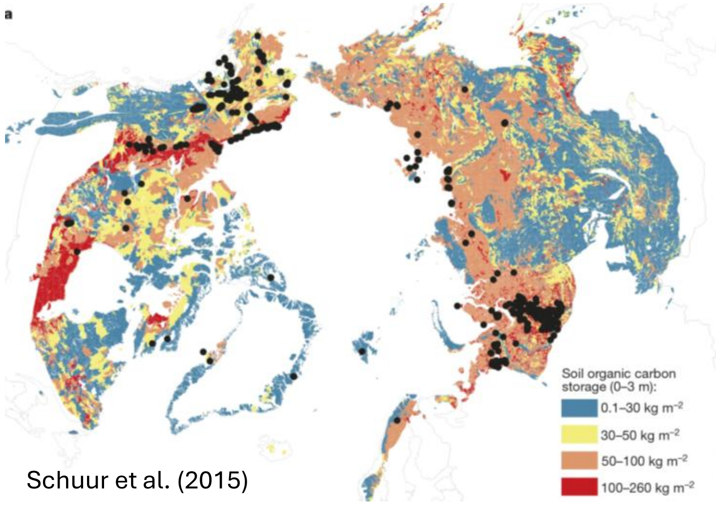
Permafrost

Perennially frozen ground

→ Account for approximately **50%** of the estimated **global belowground organic carbon (C) pool.**
(Tarnocai et al., 2009)



Streletskiy et al. (2025)



Schuur et al. (2015)

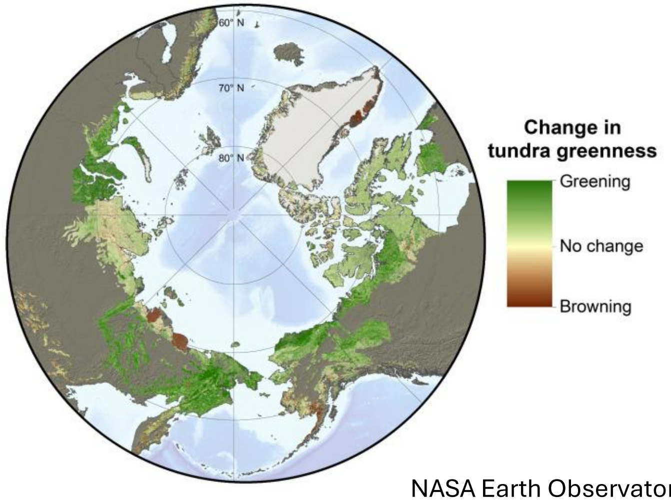
International Permafrost Association (1998)

One quarter (25%) of the **Northern Hemisphere** and **17%** of the **Earth's exposed land surface** is underlain by **permafrost.**
(Biskaborn et al., 2019)

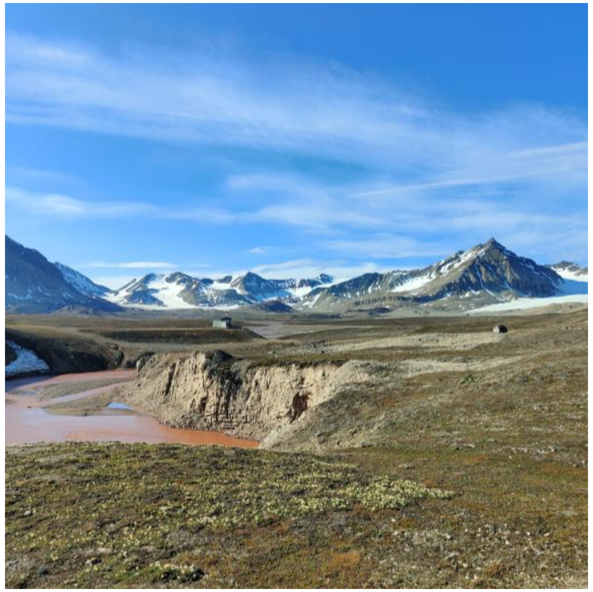
Permafrost thawing ⇒ Acceleration of **microbial breakdown** of **organic C** ⇒ Release of **GHG** (CO_2, CH_4) ⇒ **Role of Arctic in C cycle? What's the climate feedback?**

Arctic Greening

The increase in **tundra greenness** across the Arctic over the past four decades is partially attributed to **enhanced vegetation growth**, driven by **warmer** and **longer summers** (Elmendorf et al., 2012)



NASA Earth Observatory (2021)



Bayelva river, Ny-Ålesund - Svalbard Island
Photo by Carlotta Volterrani, 2024

Alteration in **carbon** and **nitrogen** (N) cycles across the **atmosphere-biosphere continuum**, leading to **increased ecosystem complexity** driven by fine-scale ecological interactions and climate change.

Complex interractions between vegetation and soil processes

Objectives

- Asses the sensitivity of **dominant tundra species** to variations in climatic drivers;
- Examine the impact of **biological drivers** (e.g., herbivores) on **ecosystem functioning** and the **interactions** between soil microorganisms and vegetation communities;
- Explore shifts in **C and N allocation strategies** between **plants** and **soil** in response to vegetation composition changes, including shrubs, sedges, mosses, and lichens;

ARCTIC STATION NY-ÅLESUND 79°N SVALBARD ISLANDS NORWAY DIRIGIBILE ITALIA

Methodologies

Species photosynthetic efficiency and spectral reflectance with change of:

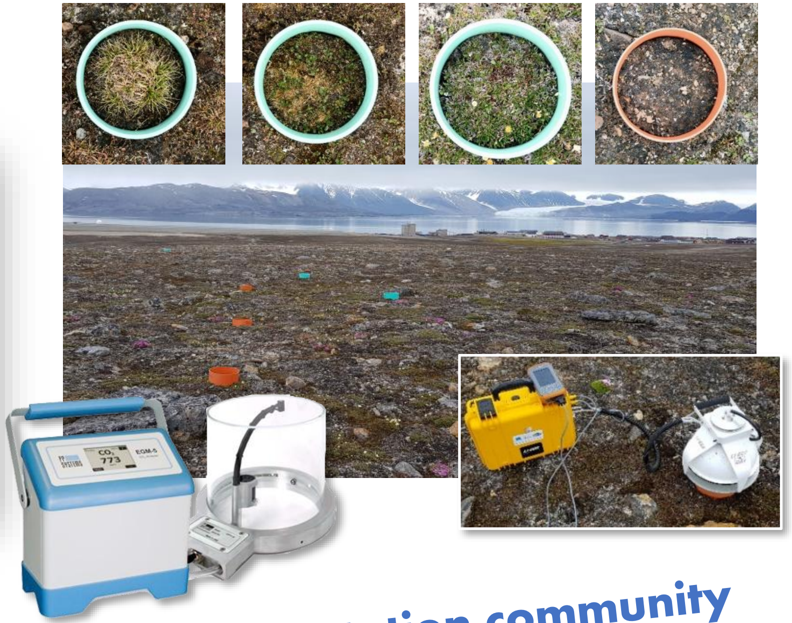
- **Light**
- **CO_2**
- **Temperature**
- **Nutrients**

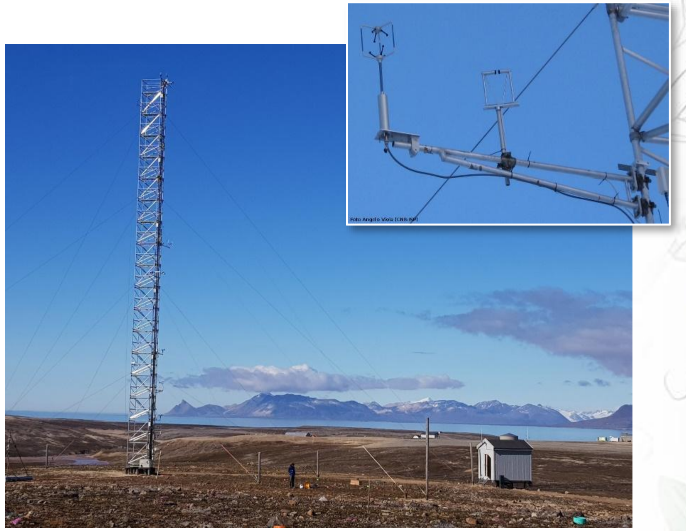
Carbon and Nitrogen assimilation and allocation in relation to vegetation community and grazing pressure:

- **CO_2 flux measurements**
- **^{13}C pulse labelling**
- **^{15}N pulse labelling**

Carbon balance with eddy covariance

- **Continuous**
- **High-time resolution**
- **Non-specific**
- **Interannual variability**



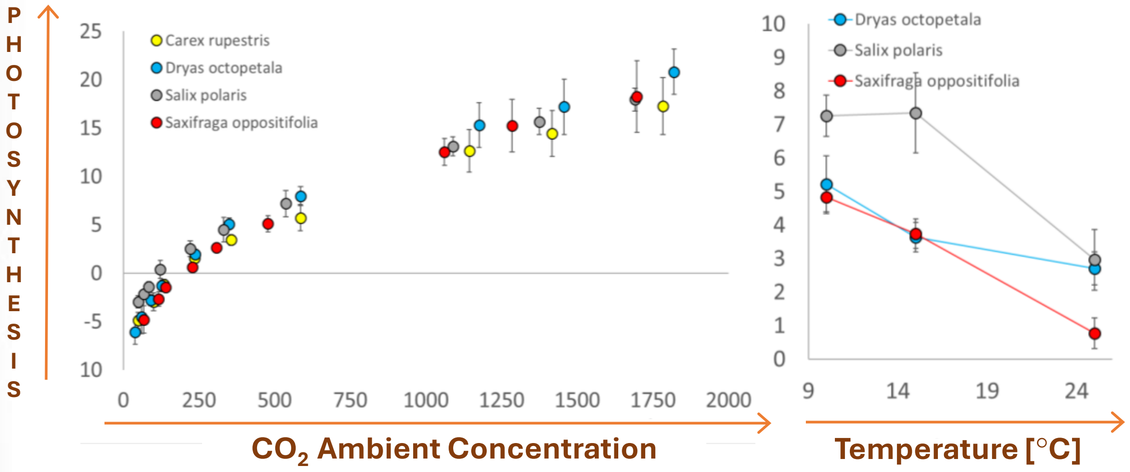


LEAF scale

Polar Biol (2016) 39:1581–1596
DOI 10.1007/s00300-015-1883-9
CrossMark
ORIGINAL PAPER

The interaction of biotic and abiotic factors at multiple spatial scales affects the variability of CO_2 fluxes in polar environments

N. Cannone[1,2] · A. Augusti[2] · F. Malfasi[1] · E. Pallozzi[2] · C. Calfapietra[2,4] · E. Brugnoli[3]



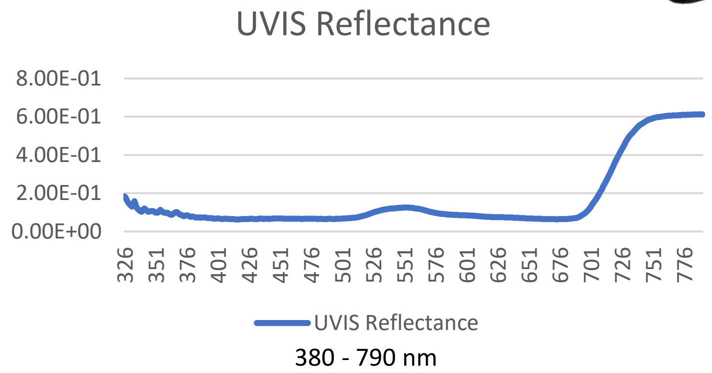
Different responses among species to light intensity

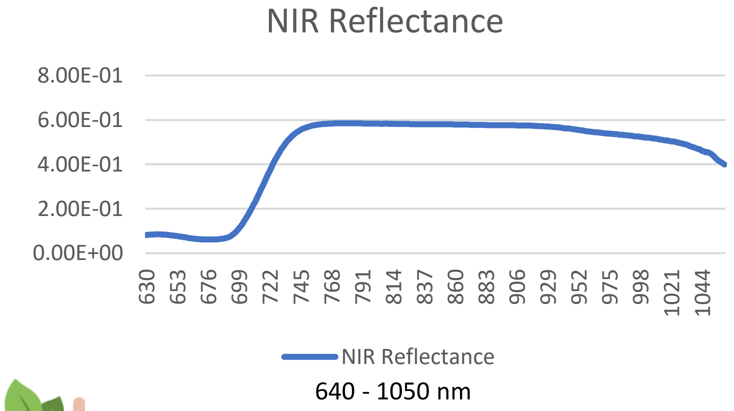
Different species dominant in Brøgger peninsula are similarly sensitive to increase in CO_2 concentration. However, they demonstrate different sensitivity to short-term increase in ambient temperature.

Creation of reflectance database measurements

Based on:

- Different species
- Location
- Treatment





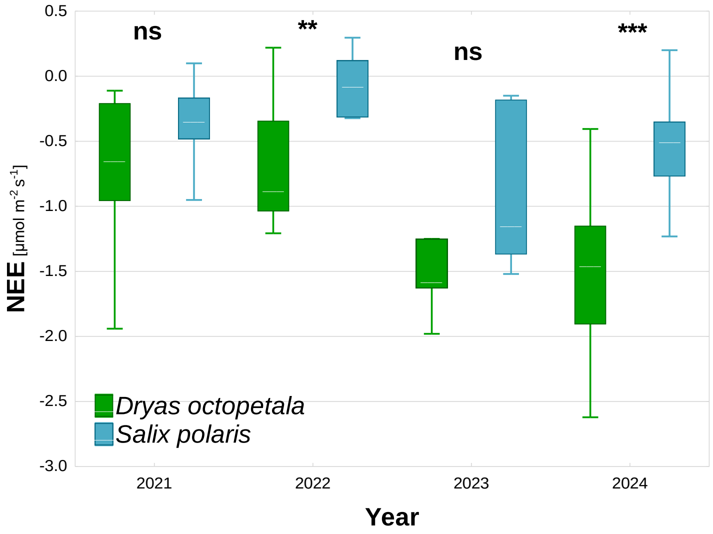
Non-destructive measurements

COMMUNITY scale

Carbon fluxes across dominant plant communities

Monitoring activity

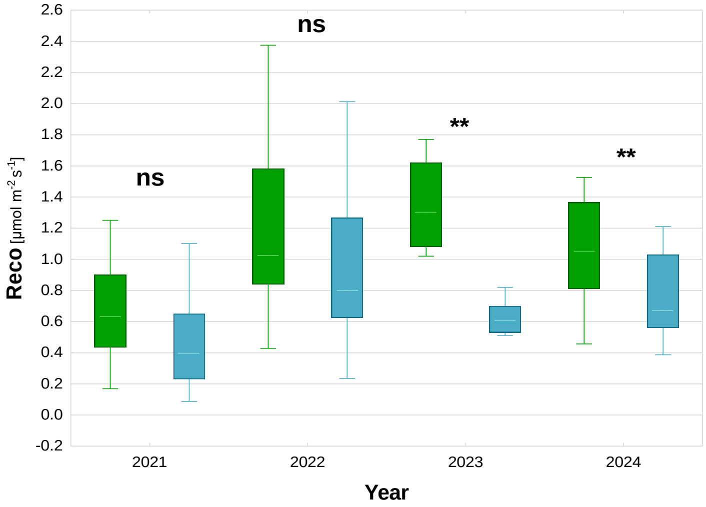
- Started in 2021;
- Selection of two dominant species (*Dryas octopetala* L. and *Salix polaris* Wahlenb);
- Measurements of Net Ecosystem Exchange (NEE) and Ecosystem Respiration (Reco) , coupled with enviroment parameters (T_{soil} °, EC and Soil Water Content)



- *D. octopetala* acts as stronger sink for C in confront to *S. polaris* as suggested by more negative NEE, due to higher green area and biomass of Dryas compared with Salix

Higher sequestration of C

- Despite higher R_{eco} values registered in Dryas plots, although the differences with Salix were not always significant.



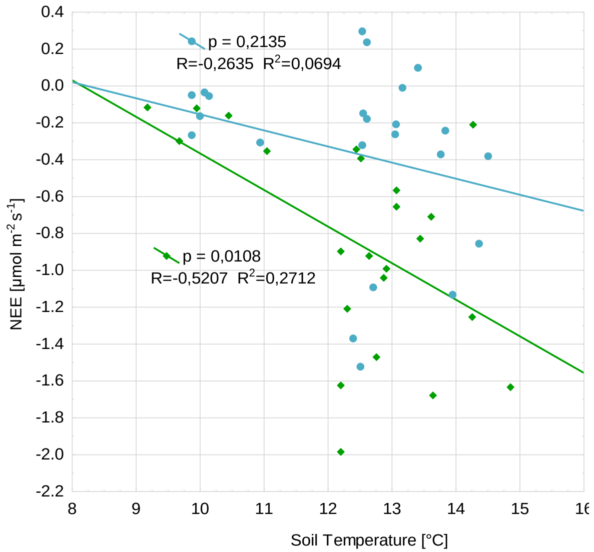
Consiglio Nazionale delle Ricerche

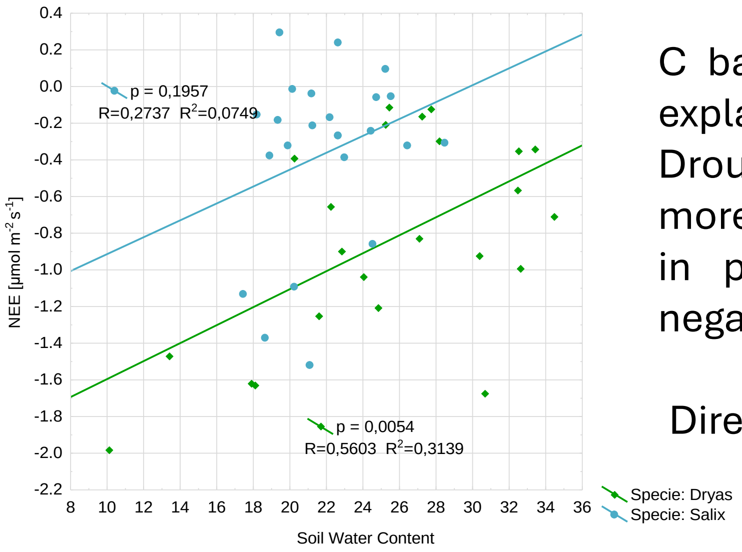
CNR IRET Conference Rome, February 18th-19th, 2025

CNR IRET

Preliminary results • Paper in preparation

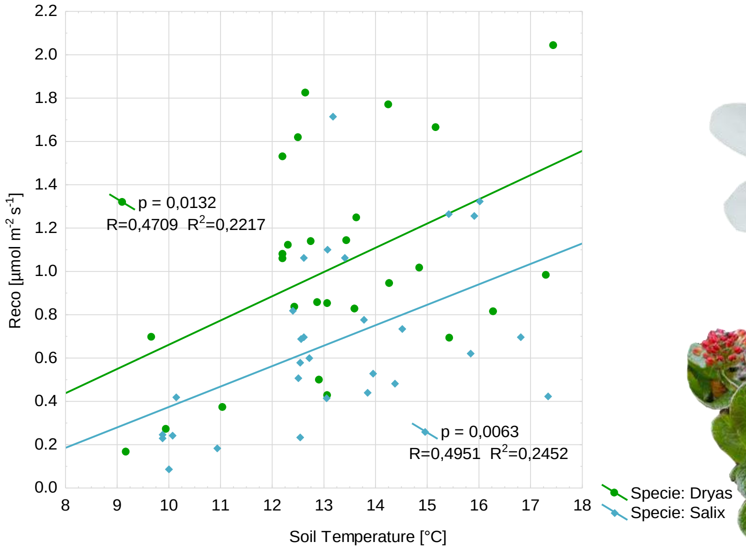
Multi-year study on carbon fluxes





C balance variation in Dryas is best explained by SWC variation. Drought-adapted Dryas assimilates more C at lower SWC. Future increase in precipitation and cloudiness will negatively impact this plant community

Direct relationship between **Dryas** and **Soil Water content**



- Positive relationship of Ecosystem respiration with soil temperature suggest **negative impact** of warming on C balance on both communities;
- Salix shows stronger correlation between Reco and soil temperature than Dryas.

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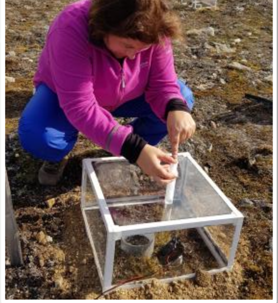
CNR IRET Conference

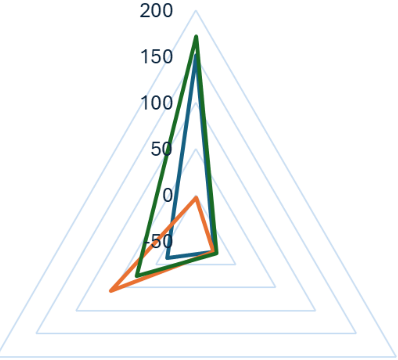
Rome, February 18th-19th, 2025

COMMUNITY scale

Soil-plant interactions through C and N allocation strategies

^{13}C pulse-labelling experiment





^{15}N pulse-labelling experiment

Assess the role of herbivores and hence to envisage the future contribution of them in tundra contribution to C cycle by studying:

- nutrient interactions (C and N) associated to primary producer composition and physiology;
- effects of reindeer grazing on the functioning of the primary players and on CO2 fluxes.

Ca' Foscari University of Venice

National Doctoral Degree Programme in Polar Sciences

Curriculum: Biology, Ecology & Biodiversity

PhD project: **Herbivore impacts on Carbon and Nitrogen relationship in High Arctic tundra**

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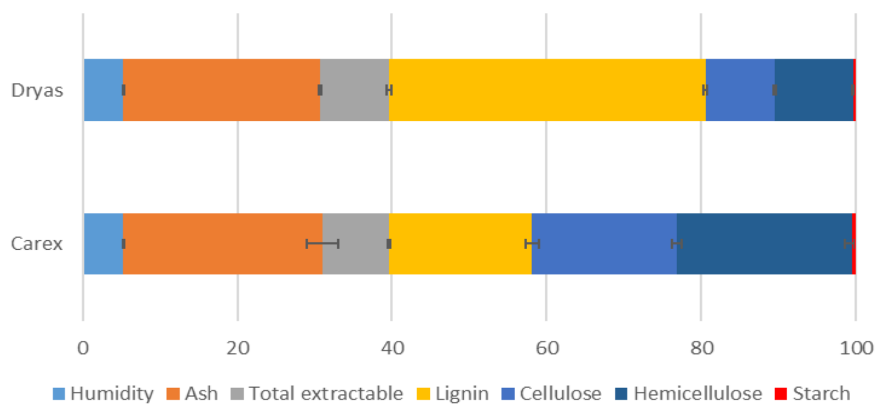
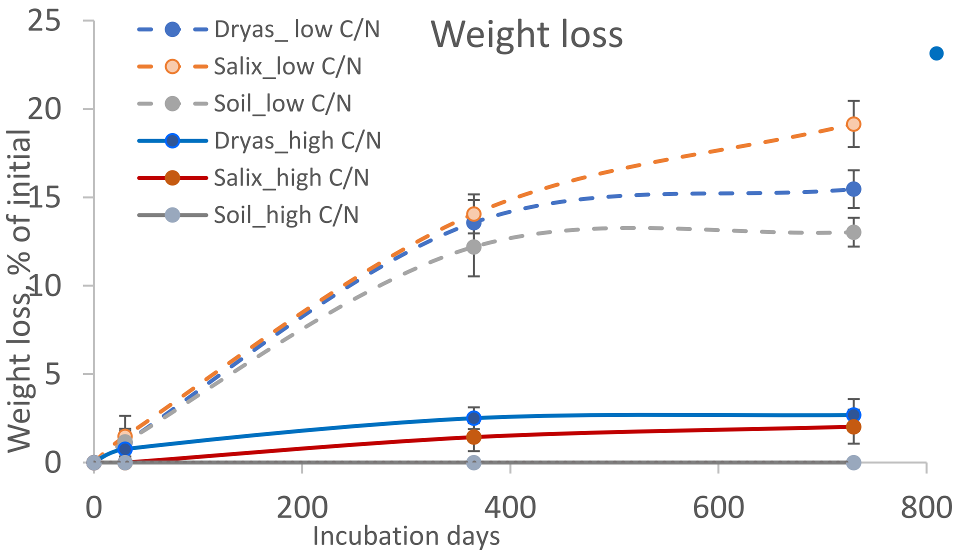
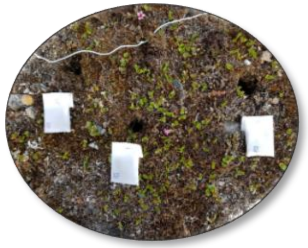
Microbial activity



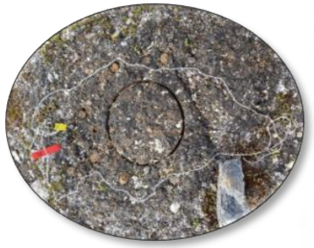


Two different plants communities and bare soil



Salix polaris

Dryas octopetala



Bare soil

- Microbial community of bare soil is not capable to decompose recalcitrant litter
- The growth of vegetation (Arctic greening) will impact on soil microbial activity

⇓

Causes of change:
Shift in microbial community?
Expression of dormant genes?

This research was supported by the Research Council of Norway, projects:

- ***2018*** *- Contribution of Vegetation and Soil components to Carbon cycle in Arctic environment in relationship to climate change (VegSoCA)*
- ***2021*** *- Effects of big herbivores on the functioning of decomposers and primary producers in High Arctic tundra (GrazeAct)*

Svalbard Integrated Arctic Earth Observing System - Knowledge Centre (SIOS-KC)

SIOS
SVALBARD INTEGRATED ARCTIC EARTH OBSERVING SYSTEM

SVALBARD SCIENCE FORUM

For 2025 summer field campaign, we will receive funds from ***Arctic Field Grant (AFG)*** *– Funding for Fieldwork in Svalbard from the Research Council of Norway, project:*

- *Beyond Soil: exploring microbial dynamics and carbon cycling in Arctic Tundra soils*

This grant will fund two Arctic expedition in late June – early July and in the end of August

Research group

Dr. Angela Augusti
Senior researcher
Leader of Ny-Ålesund Terrestrial Flagship

Dr. Olga Gavrichkova
Senior researcher

Dr. Emanuele Pallozzi
Senior technologist

Dr. Federica D’Alò
Post-doc researcher

Thank you!