# Mapping of Permafrost Landforms and Soils

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## Abstract

Permafrost is defined as permanently frozen ground. Permafrost soils or landforms are sensitive to alterations in temperature. Climate change may affect permafrost water regime, active layer thickness, geomorphological features and soil processes; consequently, leading to the release of carbon, nitrogen and contaminants into rivers and the ocean.

The PhD project is part of the EU project Nunataryuk. One aim is to use high resolution remote sensing (RS) imagery in combination with ground truth data to map the geomorphological features, landcover and soils of coastal catchments in Northwest Canada. Further, RS data will be used as part in the modelling of the spatial distribution of soil organic carbon and nitrogen.

## Background

Arctic permafrost coasts are 34 % of the Earth's coastlines (e.g. Fritz et al. 2017, Lantuit et al. 2013). Recent studies show erosion rates of up to 25 m $yr^{-1}$ at specific locations (Lantuit et al. 2013). Environmental changes such as rising sea level and longer and warmer thawing seasons requires the research of processes and interconnections of parameters of arctic coastal systems (e.g. Fritz et al. 2017).

Investigations on Soil organic carbon is one relevant aspect, as the northern circumpolar permafrost region comprises more than 50 % of the reported global carbon pool below ground (Tarnocai et al. 2009). It is a total of 1300 Pg SOC of which 800 Pg are stored in perennially frozen soils and deposits (Hugelius et al. 2014).

Machine learning Digital Soil mapping methods are widely used for the spatial modelling of SOC in general, but less widespread for Arctic regions (e.g. Siewert 2018, Wagner 2017). Recent studies (Siewert 2018, Wagner 2017) show a successful applicability of the method Random Forest.

### Previous case study: Wagner (2017) Spatial modelling of soil organic carbon stocks in permafrost affected soils in West Greenland.

**Data/ Methods:**

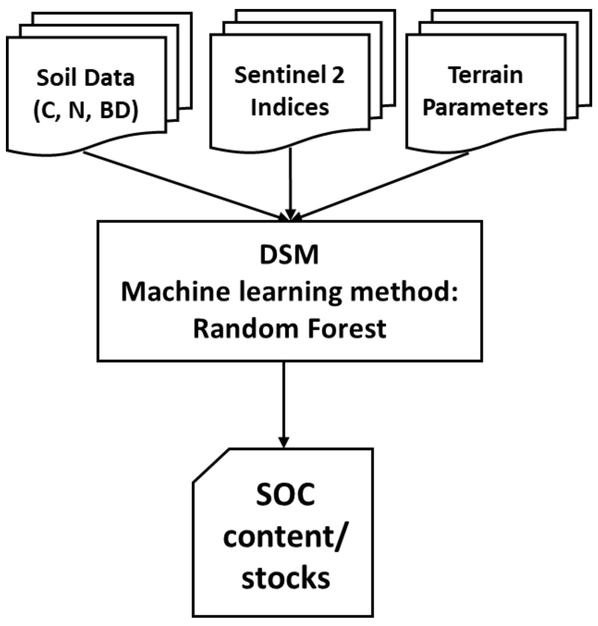



Fig 1: Simplified workflow of Data and method (Wagner 2017).

- Random Forest (machine learning method) was applied for two climatic different research areas in West-Greenland (ice margin and coast) for modelling the distribution on SOC stocks.
- Terrain parameters derived from DEM (e.g. slope, aspect, eastness, northness, profile curvature, plan curvature, flow direction, flow accumulation, flow path length, LS-factor, TWI, valley depth) and Indices derived from Sentinel 2 (e.g. NDVI, NDWI, NDSI, BSI, NDMI, NDSI) were used as covariates for spatial prediction and to understand the drivers for SOC distribution.

**Result(s):**

- At the ice margin, dry climate and low precipitation leads to a limited availability of water. Therefore, parameters in the context of water content (TWI) and terrain position are the major predictors. Since water availability is connected with plant growth, the NDVI plays an important role as well.
- In contrast the coast possesses higher precipitation due to the climate, which leads to the dominance of redistribution processes of soil material. Important factors are LS-factor and flow path length. However parameters related to the surface structure and vegetation cover such as NDMI, northness and NDSI dominate in the upper depth increments.
- An average of 12 kg $m^{-2}$ SOC is stored at the coast and an average of 8 kg $m^{-2}$ SOC at the ice margin in the upper 25 cm.
- Results fit in framework of local studies and show under-/overestimation of largescale studies

—> Machine learning methods are successfully applicable

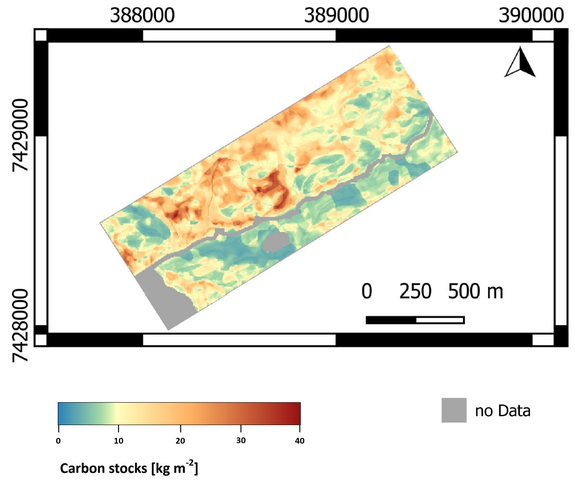



Fig 2: Modelled soil organic carbon stocks for 0-25 cm depth for the research area near the coast (Wagner 2017).

## New research area

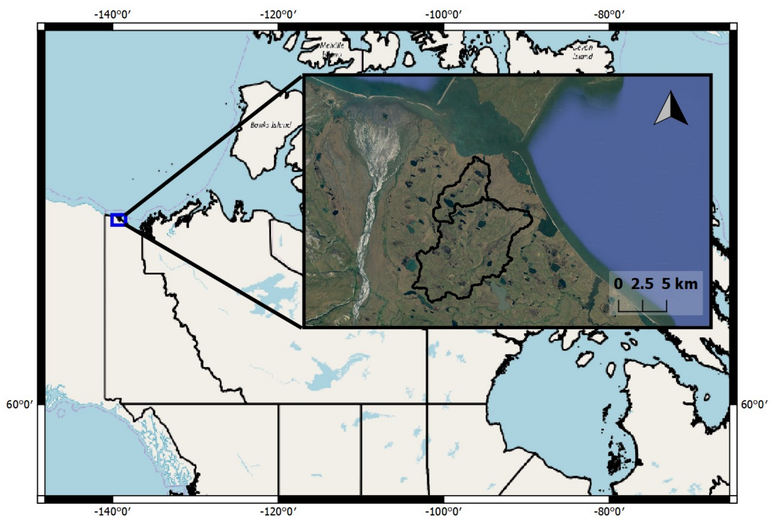



Fig 3: Overview of the research areas of the Expedition 2018.

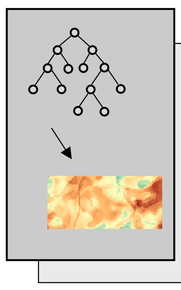
The research area is located south of Herschel Island on the Yukon Coastal Plain. The two catchments lie within the Laurentide Ice Sheet limit and the sediments consist mainly of glacial and glacial-marine deposits.

Landforms along the southern Beaufort Sea comprise mainly erosional coastal landforms (60%). Although deltas are usually considered as accumulative landforms, high retreat reates occur. Along the eastern Yukon coast, retreat rates of 0.5 m $yr^{-1}$ arise (Harper 1990).

## Data and methods (planned)

Mapping of landforms and landcover using high resolution RS data (e.g. Worldview-3, Sentinel 1, 2)

Mapping of soils and soil properties (texture, content of different nutrients, contaminants, SOC and nitrogen) and estimation of potential thaw impacts (field and laboratory)



Using machine learning DSM methods to model the spatial distribution of SOC, incorporating variables derived from RS data (e.g. indices)

## Objectives

⇒ Information on SOC, nitrogen, nutrients and contaminants stored in permafrost soils and their remobilization potential

⇒ local to pan-Arctic scaling of links between periglacial landforms, vulnerability to thaw and lateral fluxes of sediments, organic matter, major nutrients and contaminants from land to sea

⇒ Modelling the spatial distribution of SOC and improve the understanding of different drivers determining the distribution, local studies for linking processes and drivers

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