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SOIL CARBON DEVELOPMENT IN THE RECENTLY DEGLACIATED FORELAND OF MIDTRE LOVÉNBREEN, SPITSBERGEN

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Introduction

Global warming leads to rapid retreat of glaciers in the high Arctic, exposing new land. Soil organic carbon (SOC) accumulation in the proglacial environment started soon after microorganisms and plants have settled down. Studies in glacier forelands mostly focused on consequent changes in soil, plants, and microorganisms after glacier recession. However, the quantity and rate of SOC accumulation over the glacier foreland are affected not only by time but also by several environmental factors. Furthermore, proglacial land is dynamically reworked by runoff activity of glacier streams. Therefore, we aim to understand the distribution pattern of SOC and to produce a map of SOC stock in the foreland of the Midtre Lovénbreen, Spitsbergen, Norway (79°N, 12°W) taking into account age of soil since deglaciation and environmental factors such as microtopography, runoff activity, etc.

Materials and Methods

- Sampling sites selection: Stratified sampling with a consideration of X, Y coordinates, runoff, age, slope, and wind among 300 sites of Moreau (2005)

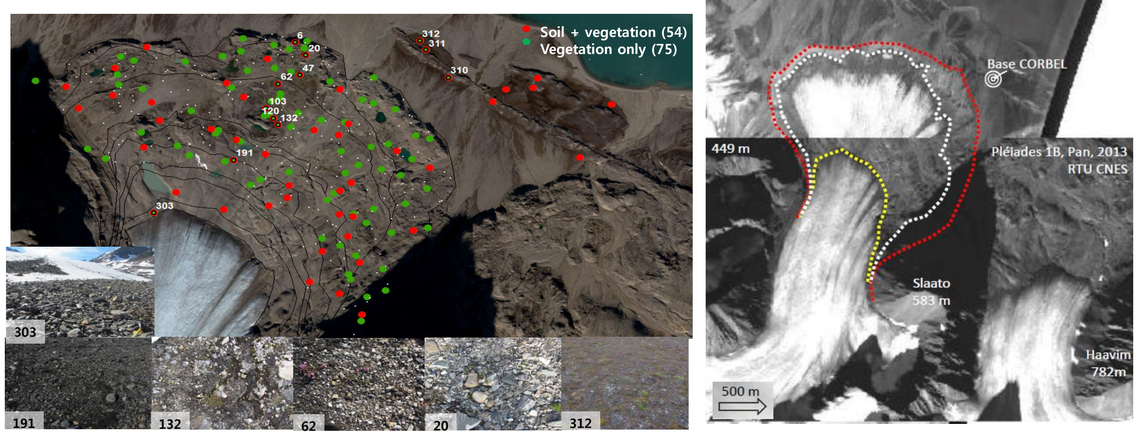


Fig. 1. Distribution of study plots and glacier retreat in the glacier foreland of Midtre Lovénbreen, Brøgger Peninsula, Svalbard (79°N, 12°W)

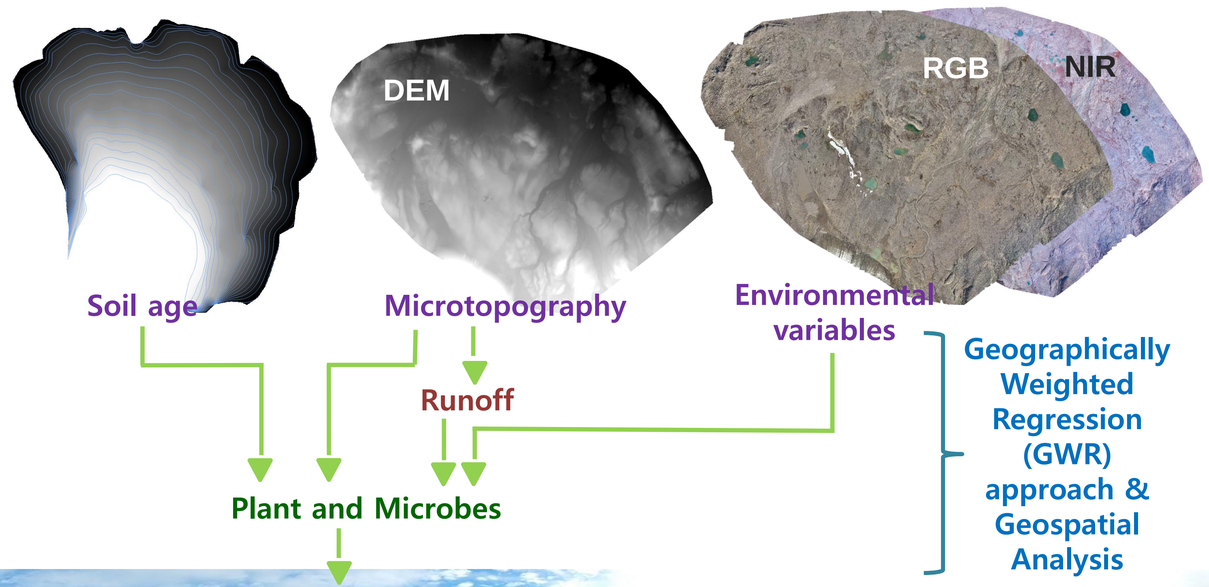
- Soil sampling: 54 sites; vegetation survey: 129 sites in 2014
- Soil sampling depth: 0-5, 5-10, 10-20, 20-30 cm
- SOC content: combustion at 950 °C after acid washing
- Bulk density estimation from soil texture (SPAW software; Saxton & Rawls, 2006)
- SOC_{FE}: SOC content (Mg C/Mg soil) x ρ_{FE} (Mg soil/m^3 soil) x depth (m)
- SOC_{hybrid}: SOC content (Mg C/Mg soil) x ρ_{hybrid} (Mg soil/m^3 soil) x depth (m)
  - ρ_{FE}: Mass of the fine earth (< 2 mm)/volume of the fine earth in the sample
  - ρ_{hybrid}: Mass of the fine earth (< 2 mm) in the sample/volume of the entire core
- Density-size based fractionation: Sodium polytungstate solution density (1.6 g/cm^3)
  - FLF: less than density 1.6 g/cm^3
  - HF: sand size fraction (SF) > 53 um and silt and clay size fraction (SCF) < 53 um

Soil age: aerial photographs

- Environmental variables from remote sensing data (Pleiades August 2013)
- NIR and RGB photographs: obtained by drone (PM16) flights in 2016
- Mosaicking & DEM production by Pix4D
- Topographic attributes acquisition from DEM (3.5-5 cm resolution)

Research Approaches

Factors affecting SOC distribution in the glacier foreland



Results

Table 1. Pearson correlation matrix between measured variables

	Gravel	Sand	Clay	SOC_{FE}	SOC_{hy}	SOC_{con}	BC	Li	Bryo	VP	TotCov	Freq
Sand	0.50											
Clay	-0.52	-0.82										
SOC_{FE}	-0.52	-0.61	0.78									
SOC_{hy}	-0.58	-0.63	0.81	0.99								
SOC_{con}	-0.50	-0.47	0.53	0.81	0.79							
BC	-0.19	-0.22	0.20	0.31	0.26	0.53						
Li	-0.47	-0.20	0.29	0.48	0.49	0.42	0.21					
Bryo	-0.26	-0.25	0.31	0.43	0.39	0.50	0.73	0.50				
VP	-0.25	-0.23	0.28	0.36	0.32	0.48	0.87	0.33	0.86			
TotCov	-0.26	-0.25	0.27	0.39	0.35	0.57	0.97	0.37	0.84	0.95		
Freq	-0.57	-0.43	0.54	0.59	0.59	0.62	0.52	0.42	0.52	0.58	0.59	
Year	0.04	-0.26	0.08	-0.19	-0.15	-0.38	-0.04	-0.18	-0.10	-0.01	-0.05	-0.27

Gravel: gravel to soil ratio; SOC_{con}: SOC content for 0-5 cm depth; Sand: proportion of sand; Clay: proportion of clay; SOC_{FE}: SOC stock of fine earth (< 2 mm); SOC_{hy}: SOC stock calculated by a hybrid method; BC: coverage of black crust; Li: coverage of lichen; Bryo: coverage of bryophyte; VP: coverage of vascular plant; TotCov: the sum of coverage of black crust, lichen, bryophyte, and vascular plant; Freq: sum of each plant frequency; Year: year at deglaciation

- SOC stock down to 30 cm depth ranged from 1.5 to 15.4 Mg/ha in the glacier foreland of Midtre Lovénbreen.
- The proportion of gravel to soil was a very important parameter to determine the amount of SOC stock (Table 1).
- SOC content among 5-10, 10-20, and 20-30 cm did not differ, and bulk density through all depths did not vary either. Thus, SOC stock was closely related to the SOC content of the top soil (0-5 cm) (Table 1).
- Among several vegetation related parameters, the sum of vascular plants' frequency showed the highest correlation with the SOC content of top soil and SOC stock (Fig. 2).
- The active and intermittent runoff sites showed significantly lower SOC content compared to no runoff sites (Fig. 3). Glacier/snow meltwater would have washed out previously established vegetation and accumulated SOC.

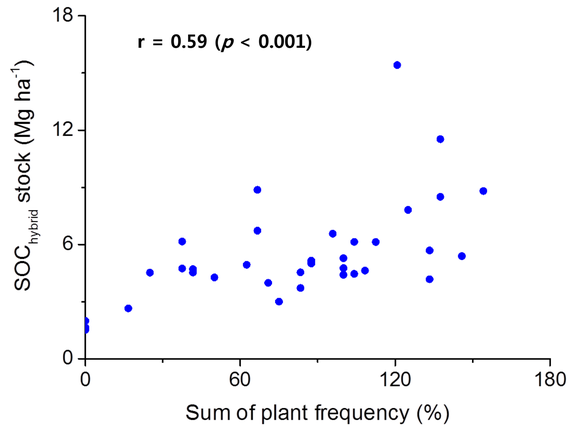


Fig. 2. A scatter plot with the sum of plant frequency and SOC_{hybrid} stock

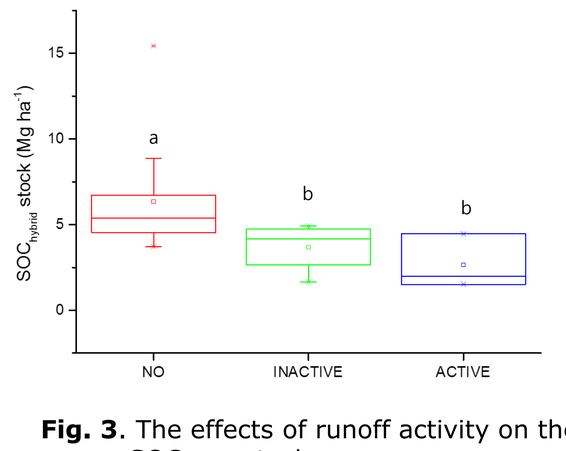


Fig. 3. The effects of runoff activity on the SOC_{hybrid} stock

Table 2. The average value of soil fractions and major elements content in the top soil

	FLF (%)	SF (%)	SCF (%)	TP	K	Ca	Mg	Na
Mean	1.1	63.5	35.4	0.31	10.4	8.3	4.1	389
Std Dev	0.6	15.6	15.7	0.11	3.0	3.9	1.7	361

Unit for the element content: mg g^{-1}

Table 3. Pearson correlation matrix between parameters in top soil (0-5 cm)

	Sand	SOC_{con}	FLF	SF	SCF	TP	K	Ca	Mg	Na	BC	TotCov
SOC_{con}	-0.32											
FLF	0.26	0.40										
SF	0.86	-0.44	0.18									
SCF	-0.86	0.42	-0.22	-1.00								
TP	-0.16	0.16	-0.14	-0.25	0.25							
K	-0.38	0.12	-0.30	-0.45	0.46	0.28						
Ca	-0.09	-0.15	-0.02	-0.02	0.02	0.27	0.14					
Mg	0.01	-0.15	-0.09	0.04	-0.04	0.24	0.36	0.44				
Na	-0.06	-0.03	0.08	-0.01	0.00	-0.34	0.30	0.42	0.34			
BC	-0.13	0.56	0.45	-0.12	0.10	-0.07	-0.18	-0.13	-0.19	-0.11		
TotCov	-0.14	0.60	0.39	-0.16	0.14	-0.08	-0.16	-0.17	-0.24	-0.13	0.97	
Year	-0.37	-0.42	-0.30	-0.28	0.29	0.10	0.19	0.15	0.22	-0.12	-0.19	-0.22

Sand: proportion of sand; SOC_{con}: SOC content for 0-5 cm depth; FLF: free light fraction; SF: sand size fraction; SCF: silt and clay size fraction; TP: total phosphorus content; Ca: calcium content; Mg: magnesium content; Na: sodium content; BC: coverage of black crust; TotCov: the sum of coverage of black crust, lichen, bryophyte, and vascular plant; Year: year at deglaciation

- The proportion of FLF was very low as 1.1 % on average, and that of SF was similar to the sand percentage in soil (Table 2, 3).
- The proportion of FLF was correlated with the top SOC content and BC. The total amount of major elements was not related to the soil age (Table 3).
- We are currently analyze the relationship between SOC stock and environmental variables acquired from DEM and remote sensing data in-depth as a next step.
- Understanding the relationship between SOC concentration and environmental parameters allows for viewing the ecosystem development in an overall perspective.

Acknowledgements

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