

Soil organic matter data

When using these data, please cite:

Mainka, M.; Bakker, L.; Maier, A.; Ruethers, J.; Bakke Westergaard, K.; Fior, S.; Frossard, A.; Griepentrog, M.; Van de Broek, M.; Wilken, F, Dötterl, S.; Alexander, J.; Magnabosco, C. (2025): Arctic Greening Database. v0.1. GFZ Data Services.
<https://doi.org/10.5880/fidgeo.2025.074>

Introduction

In this data sheet all measured soil organic matter variables per soil plot depth increment, soil pit horizon and bioplot are shown. These data entail the sample id, plot id, site id, total carbon, total nitrogen, dissolved organic carbon, dissolved nitrogen, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, F^{14}C , F^{14}C standard deviation, ^{14}C age, ^{14}C age standard deviation, $\Delta^{14}\text{C}$, NO_3^- , NH_4^+ , resin-extractable P, organic NaHCO_3 -extractable P, inorganic NaHCO_3 -extractable P, total NaHCO_3 -extractable P, organic NaOH -extractable P, inorganic NaOH -extractable P, total NaOH -extractable P, HCl -extractable P, total Hedley-extractable organic P, total Hedley-extractable inorganic P, total Hedley-extractable P.

Table 1. General information

project_name	ETH+ Arctic Greening
creation_date	2024-12-03
last_modification_date	2025-03-05
sampling_period	2022-07-09 – 2023-08-09
creator	Annina Maier
contact_1	annina.maier@usys.ethz.ch
contact_2	sdoetterl@usys.ethz.ch
number_samples	489
processing_status	ongoing
upload_status	ongoing

Table 2. Variable overview

variable	explanation	unit
plot_id	plot_id of a respective observation	-
sample_id	sample_id of a respective observation	-
TC_pct	Total carbon concentration of the bulk soil	%
TC_pct_predicted	Indication if the TC value in the TC column was measured (No) or predicted (Yes) using a DRIFT spectroscopy calibrated model. For details see soil spectroscopy metadata	-
TN_pct	Total nitrogen concentration of the bulk soil	%
TN_pct_predicted	Indication if the TN value in the TN column was measured (No) or predicted (Yes) using a DRIFT spectroscopy calibrated model. For details see soil spectroscopy metadata	-

TCTN_ratio	The ratio between TC and TN	-
DOC	Dissolved organic carbon concentration of the bulk soil	mg kg ⁻¹
DN	Dissolved nitrogen concentration of the bulk soil	mg kg ⁻¹
d13C	The ¹³ C/ ¹² C ratio of a sample relative to the ¹³ C/ ¹² C ratio of Vienna Pee Dee Belemnite (VPDB)	‰
d15N	The ¹⁵ N/ ¹⁴ N ratio of a sample relative to the ¹⁵ N/ ¹⁴ N ratio of atmospheric nitrogen (N ₂)	‰
d15N_predicted	Indication if the ¹⁵ N/ ¹⁴ N ratio of a sample in the d15N column was observed or predicted using a DRIFT spectroscopy calibrated model. For details see soil spectroscopy metadata	-
F14C	Fraction ¹⁴ C of the bulk soil	-
F14C_sd_rel	Relative standard deviation of fraction ¹⁴ C of the bulk soil	%
Delta_14C	The per mil deviation from ¹⁴ C/ ¹² C ratio of oxalic acid in 1950 (Stuiver and Polach, 1977) of the bulk soil	‰
age_14C	¹⁴ C Libby age, calculated using a Libby halflife of 5568 years	a
age_14C_sd	Standard deviation of the ¹⁴ C Libby age	a
NO3	Nitrate concentration of the bulk soil	mg kg ⁻¹
NH4	Ammonium concentration of the bulk soil	mg kg ⁻¹
resin_Pi_tot	Resin-extractable, inorganic P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaHCO3_Po	NaHCO ₃ -extractable, organic P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaHCO3_Pi	NaHCO ₃ -extractable, inorganic P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaHCO3_P_tot	Total NaHCO ₃ -extractable P (Σ organic- and inorganic NaHCO ₃ -extractable P) of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaOH_Po	NaOH-extractable, organic P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaOH_Pi	NaOH-extractable, inorganic P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
NaOH_P_tot	Total NaOH-extractable P (Σ organic- and inorganic NaOH-extractable P) of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
HCl_P_tot	HCl-extractable P of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
Hedleysum_Po_tot	Total extractable organic P (Σ NaHCO ₃ - and NaOH- organic extractable P) of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
Hedleysum_Pi_tot	Total extractable inorganic P (Σ Resin-, NaHCO ₃ - and NaOH-inorganic extractable P) of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹
Hedleysum_P_tot	Total extractable P (Σ Resin-, NaHCO ₃ -, NaOH- and HCl-extractable P) of the bulk soil, measured as part of the sequential Hedley P extraction	mg P kg ⁻¹

Methods

Sample processing

TC and TN, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, ^{14}C analyses were carried out with 30 °C dried and powder-milled (Mixer Mill MM 200, Retsch GmbH Haan, Germany) soil samples. NO_3^- , NH_4^+ , Hedley P extraction analyses were carried out with fresh, sieved soil samples (< 2 mm).

Sample analysis

Total C and N

Aliquots from the 30 °C dried, milled, bulk soil samples were analyzed for their organic carbon (OC) and N content using a CN analyzer (Vario MAX cube, Elementar, Langenselbold, Germany). Soils with a pH $\geq$ 6.3 were measured a second time following carbonate removal, to accurately measure organic carbon contents. This was done according to (Walthert et al., 2010) by applying hydrochloric acid (HCl) fumigation.

Dissolved organic C, dissolved N, nitrate, ammonium and resin-extractable phosphorus (DOC, DN, NO_3^- , NH_4^+ , resin-P)

6 g of sieved frozen soil was added to a tube with 30 ml of 1M KCl, the sample was shaken on a horizontal shaker for 1 h. Then the sample was centrifuged at 3000 rpm for 10 min, afterward the supernatant was filtered using a syringe and transferred into a new tube. Then the sample was acidified with a drop of 37 % HCl. For DOC extracts were diluted 1:20, for DN extracts were measured in an undiluted way. For NO_3^- and NH_4^+ measurements an aliquot of undiluted sample was taken. Samples for DOC and DN were measured on a C, N elemental analyzer, with samples stored at -20 ° C prior to measurement.

For NO_3^- and NH_4^+ either 130 μl or 10 μl respectively of indicated sample were pipetted into one respective microplate each, on top of which a volume of 40 μl (NH_4^+) or 80 μl (NO_3^-) of a corresponding colour reagent was added. These plates were then covered with lids and incubated in an oven/incubator at 45 ° C for 1 h (NO_3^-) or left at room temperature for 1h (NH_4^+). After incubation, the plates are read on a plate reader with a respective NH_4^+ or NO_3^- method.

Sequential phosphorus extraction (modified Hedley P extraction (Hedley et al., 1982))

For resin-extractable phosphorus (P), 2-5 g of soil (organic vs. mineral horizons) were added into a centrifuge tube with 30 ml of MQ and 2-3 (mineral vs. organic horizons) conditioned resin strips. These tubes were then shaken overnight (16 h). The day after the resins are removed and added into fresh tubes to which 20 ml of 0.5 M HCl is added, left open for an hour, then closed and shaken for 2 h. The resins are then removed again and the solution is measured for resin-extractable inorganic P (P_i) on a spectrophotometer (Varian 50 Scan UV-Visible Spectrophotometer).

The leftover soil suspensions from the previous step is centrifuged, the supernatant discarded and the tubes filled with 30 ml of 0.5M NaHCO_3 . The tubes are then vortexed and shaken overnight (16 h). The day after the soil suspension is centrifuged at 25'000 g for 10 min, the supernatant decanted into a new tube and the leftover soil kept in the old tube. The decanted solution is measured for NaOH-extractable inorganic P (P_i) on a spectrophotometer and later

measured on ICP-OES to determine total P (P_{tot}). Organic-extractable P is determined by subtracting P_i from P_{tot} .

The leftover soil from the previous step is filled with 30 ml 0.25 NaOH + 0.05 M EDTA, vortexed and shaken overnight (16 h). The day after the soil suspension is centrifuged at 25'000 g for 10 min, the supernatant decanted into a new tube and the leftover soil kept in the old tube. The decanted solution is measured for NaOH-extractable inorganic P (P_i) on a spectrophotometer and later measured on ICP-OES to determine total P (P_{tot}). Organic-extractable P is determined by subtracting P_i from P_{tot} .

The leftover soil from the previous step is filled with 30 ml 1 M HCl, vortexed and shaken overnight (16 h). The day after the soil suspension is centrifuged at 25'000 g for 10 min, the supernatant decanted into a new tube. The decanted solution is measured for HCl-extractable, total P on a spectrophotometer.

Stable isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$)

Approximately 5 or 20 mg (organic vs. mineral soil horizons respectively), of 30 °C dried, milled soil samples were weighed in to tin capsules and placed into the IRMS.

Radiocarbon (^{14}C)

Between 2 - 32 mg of 30 °C dried, milled bulk soil material, corresponding to ca. 300 ug C, were transferred into 0.025 ml tin capsules. Prior to measurement with the EA-AMS, samples were acidified to remove carbonates. ^{14}C analyses were conducted using an elemental analyzer coupled to a gas-ion-source equipped accelerator mass spectrometer (EA-AMS) at the Laboratory of Ion Beam Physics (LIP) at ETH Zurich (Haghipour et al., 2019; Welte et al., 2018). Results of the ^{14}C analysis are reported as fraction modern ($F^{14}\text{C}$) according to Reimer et al. 2004, with values > 1 defined as modern, as conventional radiocarbon age (a), calculated with a Libby halflife of 5568 years and as $\Delta^{14}\text{C}$, which is the per mil deviation from $^{14}\text{C}/^{12}\text{C}$ ratio of oxalic acid in 1950 (Stuiver and Polach, 1977).

References

- Haghipour, N., Ausin, B., Usman, M. O., Ishikawa, N., Wacker, L., Welte, C., Ueda, K., & Eglinton, T. I. (2019). Compound-specific radiocarbon analysis by elemental analyzer–accelerator mass spectrometry: Precision and limitations. *Analytical Chemistry*, 91 (3), 2042–2049. <https://doi.org/10.1021/acs.analchem.8b04491>
- Hedley, M. J., Stewart, J. W. B., & Chauhan, B. S. (1982). Changes in Inorganic and Organic Soil Phosphorus Fractions Induced by Cultivation Practices and by Laboratory Incubations. *Soil Science Society of America Journal*, 46 (5), 970–976. <https://doi.org/10.2136/sssaj1982.03615995004600050017x>
- Reimer, P. J., Brown, T., and Reimer, R. (2004). Discussion: Reporting and calibration of post-bomb ^{14}C data (UCRL-JRNL-207168). Livermore.
- Stuiver, M. & Polach, H. Reporting of ^{14}C data. *Radiocarbon* 19, 355–363 (1977). <https://doi.org/10.1017/S0033822200003672>
- Walthert, L., Graf, U., Kammer, A., Luster, J., Pezzotta, D., Zimmermann, S., and Hagedorn, F. (2010). Determination of organic and inorganic carbon, $\delta^{13}\text{C}$, and nitrogen in soils containing carbonates after acid fumigation with HCl, *J. Plant Nutr. Soil Sc.*, **173**, 207–216, <https://doi.org/10.1002/jpln.200900158>
- Welte, C., Hendriks, L., Wacker, L., Haghipour, N., Eglinton, T. I., Günther, D., & Synal, H.-A. (2018). Towards the limits: Analysis of microscale ^{14}C samples using EA-AMS. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 437, 66–74. <https://doi.org/10.1016/j.nimb.2018.09.046>