Supplementary Material

# Composition of rock powder and soil

The grain size of the rock powder was determined through Sympatec Helos KFMagic laser granulometry coupled to a Quixel wet dispersing unit (Figure 1).

Ein Bild, das Text, Diagramm, Reihe, Steigung enthält.

Automatisch generierte Beschreibung

Figure 1: Grain size distribution of the base soil and applied rock flour.

The chemical composition of basanite was analyzed using X-ray fluorescence (XRF) at the Mineralogical Institute, University Hamburg, while the mineralogical composition was determined by Qmineral using X-ray diffraction (XRD). The chemical and mineralogical composition of the rock powder is presented in Table 1. According to the modal mineralogical QAPF classification for volcanic rocks (Streckeisen, 1980) or the TAS classification (Le Bas et al., 1986), this rock powder can be classified as a basanite.

Table 1: *Main elements, trace elements, mineral composition and the grain size distribution of the basanite “Eifelgold” (bdl = below detection limit).*

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Main Elements | |  | Trace Elements | |  | Mineralogy | |  | Grain size distribution | |
| Element | wt% |  | Element | ppm |  | Mineral | wt% |  | Aperture µm | wt% |
| SiO2 | 43.86 |  | As | bdl |  | Clinopyroxene | 44.4 |  | 300 | 0 |
| TiO2 | 2.79 |  | Ba | 1026 |  | Plagioclase | 15.5 |  | 250 | 0.13 |
| Al2O3 | 14.15 |  | Bi | bdl |  | Nepheline | 11.2 |  | 210 | 0.17 |
| Fe2O3 | 11.28 |  | Ce | 104 |  | Leucite | 9.9 |  | 180 | 0.14 |
| MnO | 0.18 |  | Co | 51 |  | Olivine | 6.3 |  | 150 | 0.26 |
| MgO | 8.21 |  | Cr | 53 |  | 2:1 layer silicates | 5.1 |  | 120 | 1.2 |
| CaO | 11.63 |  | Cu | 66 |  |  | 100 | 2.87 |
| Na2O | 3.26 |  | Ga | 17 |  | Hematite | 3.1 |  | 86 | 4.17 |
| K2O | 3.35 |  | La | 52 |  | Spinel-type minerals | 1.9 |  | 74 | 5.67 |
| P2O5 | 0.6 |  | Nb | 52 |  |  | 62 | 8.13 |
| SO3 | bdl |  | Nd | 28 |  | Apatite | 1.1 |  | 52 | 8.89 |
| LOI | 0.44 |  | Ni | 124 |  | Analcime | 0.9 |  | 44 | 8.5 |
| Sum | 99.74 |  | Pb | 5 |  | Quartz | 0.7 |  | 36 | 9.63 |
|  |  |  | Rb | 86 |  |  |  |  | 30 | 7.86 |
|  |  |  | Sc | 22 |  |  |  |  | 26 | 5.5 |
|  |  |  | Sr | 882 |  |  |  |  | 22 | 5.64 |
|  |  |  | Th | 8 |  |  |  |  | 18 | 5.72 |
|  |  |  | U | 3 |  |  |  |  | 0.5 | 25.52 |
|  |  |  | V | 302 |  |  |  |  |  |  |
|  |  |  | Y | 24 |  |  |  |  |  |  |
|  |  |  | Zn | 90 |  |  |  |  |  |  |
|  |  |  | Zr | 271 |  |  |  |  |  |  |

# Composition of (rock-enhanced) biochars

Table 2: *An overview over the basic physio-chemical composition of RE-biochar (10BaW-P, 50BaW-P and 10BaS-P) and PyC (W-P and S-P) from Meyer zu Drewer et al. (2025).*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | 10BaW-P | 50BaW-P | 10BaS-P | W-P | S-P |
|  |
| Basic Characterisation |  |  |  |  |  |  |
| Mass conversion | % | 28.0 | 59.5 | 32.7 | 21.8 | 24.4 |
| Rock Content | wt% | 31.0 | 79.9 | 31.0 | 0.0 | 0.0 |
| Biochar content | wt% | 69.0 | 20.1 | 69.0 | 100.0 | 100.0 |
| Total Ash Content | wt% | 38.4 | 82.1 | 45.2 | 10.8 | 20.4 |
| Biochar Ash content | wt% | 7.4 | 2.2 | 14.2 | 10.8 | 20.4 |
| C | wt% | 58.0 | 17.0 | 51.6 | 85.1 | 73.4 |
| Corg | wt% | 57.5 | 17.0 | 50.7 | 84.3 | 72.9 |
| Total IC | wt% | 0.5 | <0.1 | 0.9 | 0.8 | 0.5 |
| Carbonate CO2 | wt% | 1.8 | <0.4 | 3.4 | 2.8 | 2.0 |
| H | wt% | 0.8 | 0.5 | 0.9 | 1.4 | 1.1 |
| N | wt% | 0.7 | 0.2 | 0.7 | 1.1 | 1.0 |
| S | wt% | 0.1 | 0.0 | 0.2 | 0.1 | 0.3 |
| H/Corg Molar ratio |  | 0.2 | 0.4 | 0.2 | 0.2 | 0.2 |
| CaOeq. | wt% | 8.5 | 10.1 | 11.5 | 6.8 | 8.1 |
| pH |  | 8.6 | 9.2 | 11.2 | 8.5 | 10.3 |
| BET | m² g-1 | 36.8 | 5.8 | 33.0 | 197.0 | 200.0 |
| EC | mS cm-1 @5 bar | 6.7 | 0.6 | 17.0 | 8.0 | 25.0 |
| Main Elements as Oxides |  |  | | | | | |
| SiO2 | wt% | 13.8 | 35.1 | 19.1 | 0.2 | 0.4 |
| Al2O3 | wt% | 4.4 | 11.3 | 4.4 | 0.0 | 0.1 |
| Fe2O3 | wt% | 3.5 | 9.0 | 3.5 | 0.0 | 0.1 |
| MnO | wt% | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| MgO | wt% | 2.8 | 6.6 | 2.9 | 0.4 | 0.8 |
| CaO | wt% | 6.9 | 10.3 | 5.8 | 4.9 | 9.2 |
| Na2O | wt% | 1.0 | 2.6 | 1.2 | 0.0 | 0.1 |
| K2O | wt% | 1.9 | 2.9 | 4.1 | 1.3 | 2.4 |
| P2O5 | wt% | 0.8 | 0.7 | 1.2 | 0.9 | 1.6 |
| SO3 | wt% | *n.a.* | *n.a.* | *n.a.* | 0.4 | 0.7 |

# Soil analyses

The soil was sieved to < 2 mm. Various soil parameters were analyzed, including total carbon (Ctot) and total nitrogen (Ntot) using an elemental analyzer (vario MAX cube, Elementar Analysensysteme GmbH, Langenselbold, Germany), as well as total inorganic carbon (TIC) using a TOC analyzer (soli TOC® cube, Elementar Analysensysteme GmbH, Langenselbold, Germany). The organic carbon (Corg) content was calculated by the difference between Ctot and TIC. To determine the pH and electrical conductivity (EC) of the soil, 2 x 10 g of air-dried soil were weighed into centrifuge tubes. One tube was treated with 25 ml of 0.01 M CaCl2 solution, while the other tube was treated with deionized water (DI). After one hour of horizontal shaking and one hour of resting, the samples were stirred, and the pH was measured in both treatments using an MP230 pH meter (Mettler Toledo). The EC was measured in the DI treatment using a WTW conductivity meter (Cond 330i).

The effective cation exchange capacity (CECeff) was analysed following the DIN EN ISO 14240-1:2011-09 (Deutsche Institut für Normung e. V., 2011) determined from 5 g soil dry weight equivalent. To determine exchangeable cations (K+, Na+, Ca2+, Mg2+), the soil was washed five times with 1 M NH4Cl solution removing the exchangeable cations from their absorbers. The collected extract, including the exchangeable cations, was measured using flame atomic absorption spectrometry (AA280FS, Varian, Palo Alto, Californien, USA). To determine CECeff, 1 M KCl solution was used and the extract was measured using photometry (DR5000, Hach Lange, Loveland, Colorado, USA). The results were corrected by using blank solutions.

The water content of the soil samples was determined by weighing the difference between air-dried soil and dried soil (at 105 °C until constant weight). For water holding capacity (WHC), 3 x 20 g of air-dried soil was each weighed in a funnel and rewetted using 100 ml of deionized water. The funnel was then covered with aluminium foil and left undisturbed. After 24 hours, the moist soil and funnel were weighed, followed by drying at 105°C until constant weight. The WHC was calculated as the difference between the weight of the moist soil and the weight of the soil after drying at 105 °C. The grain size distribution was determined according to DIN ISO 11277 (Deutsche Institut für Normung e. V., 2002). Soil samples were freed from organic matter by treatment with 30% H2O2. After dispersion with sodium pyrophosphate (Na4P2O7 **·** 10 (H2O)), the sand fraction (63 μm ‑ 2000 μm) was assessed with a vibratory sieve shaker (Retsch GmbH, Haan, Germany). The proportions of silt and clay were analyzed based on the Köhn-pipette fractionation method using a Sedimat 4-12 (Umwelt-Geräte-Technik GmbH, Muencheberg, Germany, Figure 1). All measurements were conducted using triplicate samples (except for WHC).

# Calculation of C-sinks

The PyC-sink was calculated using the following equation:

|  |  |
| --- | --- |
|  | Eq. 1 |

Taking the Corg or all (RE-)biochars as *Corg(RE-)biochar* (%), the ash fraction of (RE-)biochars as *(RE-)biocharashfraction*(%), and the molar mass of CO2 *MCO2* (44.01 g mol-1) and C *MC* (12.01 g mol-1).

The IC-sink generated from alkalinity release of rock powder was determined by

|  |  |
| --- | --- |
|  | Eq. 2 |

Using the fraction of rock *Rockfraction* (%)in the (RE-)biochar and the CDR potential of our basanite rock CDRBasanite (0.370 kg CO2 per t rock). CDRbasanite was calculated after Renforth (2019) as:

|  |  |
| --- | --- |
|  | Eq. 3 |

With the molar mass of CO2 *MCO2* (44.01 g mol-1), of CaO MCaO (56.08 g mol-1), of MgO MMgO (40.30 g mol-1), of Na2O MNa2O (61.98 g mol-1), of K2O MK2O (94.2 g mol-1), of SO3 MSO3 (80.06 g mol-1), and P2O5 MP2O5 (141.94 g mol-1). The coefficients consider the relative contribution of each oxide and are set to 1 for α, β, ε, θ, set to -1 for γ, and set to -2 for δ. The factor for accounting the CO2 loss due to re-equilibration in rivers and the ocean is set to 0.85 mol for η. The IC-sink based on carbonate minerals in RE-biochars is determined by

|  |  |
| --- | --- |
|  | Eq. 4 |

Using the factions of *Rockfraction* (%)in (RE-)biocharsand particulate inorganic carbon (PIC) of rock *PICrock* (%), the fraction of RE-biochar *RE-biocharfraction* (%), PIC in RE-biochar *PICRE-biochar* (%) and the fraction of biochar (BC) in RE-biochar *BCfraction* (%), the molar mass of CO2 *MCO2* (44.01 g mol-1) and C *MC* (12.01 g mol-1), and the molar ratio of CO2 to monovalent cation sequestration (0.85 according to Renforth, 2019).

The IC-sink for biochar the equation is the following

|  |  |
| --- | --- |
|  | Eq. 5 |

With the fraction of biochar *Biocharfraction* (%), PIC in biochar *PICbiochar* (%), the molar mass of CO2 *MCO2* (44.01 g mol-1) and C *MC* (12.01 g mol-1), and the molar ratio of CO2 to monovalent cation sequestration (0.85 according to Renforth, 2019).

# Laboratory conditions and sampling intervals

The conditions of pCO2 (Figure 2) and temperature (Figure 3) were monitored during the experiment.

A graph of a line and a line

Description automatically generated with medium confidence

Figure 2: *Calculated mean atmospheric CO2 levels in the box based on DIC and pH, under the assumption that sample waters and atmosphere are in equilibrium. The pCO2 was lower than the supplied gas concentration, because the box gloves are not entirely gastight, watering and sampling operations required to transfer materials into and out of the box, and irrigation water may have equilibrated to some extent with the surrounding waters when refilling and transferring to the boxes. Whiskers indicate the standard deviation.*

A graph of a graph showing the growth of a number of years

Description automatically generated with medium confidence

Figure 3: *Development of room temperature during the experiment. Gaps indicate missing data records. Shaded areas indicate the sampling intervals increasing over time.*

# Detailed leachate analyses

DIC was sampled without filtration and inside the incubator and analysed with a Picarro G2131-I cavity ring-down spectrometer coupled with an AutoMate FX preparation device. Samples for alkalinity and major ion chromatography were filtered through a 0.45 µm polyethersulfone (PES) syringe filter and measured within 48 h to minimise sample alteration by precipitation of potentially supersaturated minerals. Samples for dissolved organic carbon (DOC) were filtered through muffled glassfiber filters with ~0.45 µm mesh size (Whatman GF/F). All samples were stored dark and cool until analysis.

Total alkalinity (TA) was measured through automated titration to pH 4.3 (Metrohm Titrando, using 0.02 N HCl), following the method described by Dickson (1981). The titrator was calibrated against two in-house standards with an accepted error below 1%. Major cations (Na+, K+, Ca2+, and Mg2+) and anions (Cl- and SO42-) were determined using ion chromatography (Metrohm 881 Compact IC Pro system), with an acceptable error rate of less than 5%. The measurement of dissolved silica (DSi) was conducted utilizing the molybdate blue colorimetric method, following the procedure outlined by Hansen and Koroleff (1999). The coefficients of variation for all the measured samples were on average 0.6 ± 0.8%. DOC was measured using a Shimadzu TOC-VCSH Analyzer, equipped with a non-dispersive infrared sensor, employing high temperature combustion.

# Calculation of PyC-sink decay

We calculated a conservative estimation for the remaining Corg fraction from PyC over time (Cremain) from the most recent approach by the Global Biochar C-Sink (2024) for PyC with a H/Corg ratio of < 0.40:

|  |  |
| --- | --- |
|  | Eq. 6 |

Where mPyC is the mass of PyC, CPyC the carbon content of PyC, and *t* the elapsed time in years. We assume the same behaviour of decay of PyMiCCS materials, as the H/OC ratios are also below 0.4.

# Calculations of element fluxes, weathering rates and TA production rates

**Element fluxes**: The weekly flux of element x (Fx) per interval i is calculated by

|  |  |
| --- | --- |
|  | Eq. 7 |

With cx as the concentration of element x, Qrain as volume of irrigation water gathered per interval and ti the number of weeks per interval. To calculate the total flux over 27 weeks of experiment all fluxes were summed:

|  |  |
| --- | --- |
|  | Eq. 8 |

**Weathering rates**: Weathering of basanite rock in a soil can be determined from the instantaneous release rate of TA (Amann et al., 2022) and we derived the weathering rate WR [mol m-2 s-1] using the following equation:

|  |  |
| --- | --- |
|  | Eq. 9 |

where Qrain [L] is the leachate volume from the column per sampling interval ti, cTA [mol L-1] is the phreeqC calculated TAcalc at ti, ATSA [m2] is the total surface area of rock in the column, and [s] is the residence time of the solution occupying the column pore space. The total surface area is simply:

|  |  |
| --- | --- |
|  | Eq. 10 |

where mrock [g] is the mass of rock and ASSA [m2 g-1] is the specific surface area of 3.0 m2 g-1 (determined by Meyer zu Drewer, 2025).

The pore space of the columns was approximated to be about 171 mL by using the column dimensions, the average filling of material per column (17.4 cm), and an average porosity of 0.4 (in line with calculations from Amann et al., 2022). At a watering amount of 75.75 mL per week, this pore space would be filled in about 2.3 weeks. This equates to a residence time of roughly 16 days (1.365 x 106 s). This assumption neglects gravitational flow, however, changes in in the range of 7-20 days do not significantly affect the WR. Calculations used net TAcalc values, meaning no log WR could be calculated for treatments with a negative TAcalc flux. Additionally, weathering rates were applied to all columns using a normalized value for total surface area, regardless of amendment type.

**Alkalinity production rates**: The net production rate of TA (TAprod) per mass of soil amendment per week was based on the released TA following equation:

|  |  |
| --- | --- |
|  | Eq. 11 |

where Qrain [L] is the leachate volume from the column per sampling interval ti, cTA [mol L-1] is the phreeqC calculated TAcalc at ti, massamendment is the mass [g] of the according soil amendment, and intervalweek is the number of weeks since the last sampling event.

# Details for extrapolation scenarios

*Table 3: The fit parameters of the minimum scenario of extrapolation.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fit type: exponential model, f(x) = a \* exp-b\*x | |  |  |  |
|  |  |  |  |  |
| low pCO2 | Model fit for total alkalinity | | | |
| Column Configuration | a | b | r2 | RMSE |
| 10BaW-P | 20651.22 | -0.03 | 0.89 | 0.07 |
| 50BaW-P | 13890.63 | -0.02 | 0.74 | 0.08 |
| 10BaS-P | 23874.95 | -0.04 | 0.93 | 0.06 |
| W-P + Ba | 16711.39 | -0.03 | 0.78 | 0.08 |
| S-P + Ba | 20063.58 | -0.03 | 0.88 | 0.07 |
| W-P | 19764.01 | -0.04 | 0.81 | 0.11 |
| S-P | 21804.71 | -0.04 | 0.88 | 0.08 |
| Ba | 15104.78 | -0.02 | 0.79 | 0.07 |
| Control soil | 15737.33 | -0.03 | 0.95 | 0.04 |
|  |  |  |  |  |
| high pCO2 |  |  |  |  |
| Column Configuration | a | b | r2 | RMSE |
| 10BaW-P | 17081.32 | -0.02 | 0.96 | 0.02 |
| 50BaW-P | 17426.55 | -0.02 | 0.78 | 0.07 |
| 10BaS-P | 28127.79 | -0.04 | 0.99 | 0.02 |
| W-P + Ba | 23000.39 | -0.04 | 0.96 | 0.04 |
| S-P + Ba | 28293.52 | -0.04 | 0.94 | 0.06 |
| W-P | 29892.08 | -0.05 | 0.91 | 0.09 |
| S-P | 29245.85 | -0.05 | 0.96 | 0.06 |
| Ba | 14707.56 | -0.01 | 0.25 | 0.09 |
| Control soil | 22342.36 | -0.03 | 0.93 | 0.06 |

Ein Bild, das Text, Screenshot, Reihe, Diagramm enthält.

KI-generierte Inhalte können fehlerhaft sein.

Figure 4: Concept of C-sinks based on experimental data extrapolated over 20 years according to a minimum, medium and maximum possible scenario.

# Results of anions and DSi

The anions Cl- and SO42- show a continuous decline from 8.6 and 2.1 to 0 mmol L-1, respectively, ending with values near or below the detection limit, while the pattern of NO3- leaching is inconsistent ranging from 0.8 to 0 mmol L-1. DSi values range from 1.4 to 0.1 mmol L-1 and show a decreasing trend (Figure 5).



Figure 5: Time *series data of the experiment - development of major anions and dissolved silica (DSi).* *Time series data of anions and dissolved silica (DSi) of leachates from the column experiment with application of rock-enhanced (RE) biochar, equivalent co-application of biochar and rock powder, application of biochar of rock powder to an oxisol. The concentrations of Cl- under a) low pCO2 and b) high pCO2, NO3 under c) low and d) high pCO2, SO42- under e) low and f) high pCO2, and DSi under g) low and h) high pCO2 are shown. Whiskers indicate the standard deviation.*

# Decay of Corg in PyC



Figure 6: The *remaining fraction of Corg in wood and straw PyC based on Global C-Sink et al.*(2024)*.*

# C-sinks in the experiment



Figure 7: The total net C-sinks at the start and end of the experiments at a) low and b) high pCO2. Note, that the IC-sink is 0 at the start of the experiment because it increases with the weathering over time.

The total C-sink achieved after 27 weeks of experimentation ranged between 1.25 (50BaW-P) to 31.2 t CO2 ha-1 (W-P) for amendments containing PyC or RE-biochar (Table 4). The differences between low and high pCO2 environments were negligible and were only impacted by the change of possible IC-sink related to pCO2. The lowest C-sinks occurred in single basanite applications (-0.10 to 0.01 t CO2 ha-1).

Table 4: The total C-sinks of each amendment in our experiment after 27 weeks of experiment. The C-sink includes the PyC-sink and the IC-sink with all biogenic and geogenic cations depending on pCO2 environment. The lowest and highest values are indicated with bold letters.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Amendment | C-sink potential |  | PyC-sink |  | IC-sink of observed flux | | |  | Total observed C-Sink | | |
|  |  |  |  |  | low CO2 |  | high CO2 |  | low CO2 |  | high CO2 |
|  | t CO2, application rate 12 t ha-1 |  | t CO2 after 27 weeks, application rate 12 t ha-1 |  | t CO2 after 27 weeks, application rate 12 t ha-1 | | |  | t CO2 after 27 weeks, application rate 12 t ha-1 | | |
| 10BaW-P | 18.82 |  | 14.54 |  | 0.14 |  | 0.10 |  | 14.68 |  | 14.64 |
| 50BaW-P | 5.02 |  | 1.26 |  | 0.09 |  | 0.01 |  | 1.34 |  | 1.26 |
| 10BaS-P | 16.75 |  | 11.08 |  | 0.26 |  | 0.23 |  | 11.35 |  | 11.32 |
| W-P + Ba | 20.83 |  | 15.53 |  | 0.13 |  | 0.13 |  | 15.65 |  | 15.66 |
| S-P + Ba | 18.31 |  | 11.61 |  | 0.20 |  | 0.22 |  | 11.81 |  | 11.83 |
| W-P | 37.09 |  | 30.90 |  | 0.31 |  | 0.24 |  | **31.21** |  | 31.14 |
| S-P | 32.08 |  | 23.11 |  | 0.38 |  | 0.42 |  | 23.49 |  | 23.53 |
| Ba | 4.40 |  | - |  | 0.01 |  | **-0.10** |  | 0.01 |  | **-0.10** |

During the experiment, the planned simulated rain of 1600 mm year-1 could not be maintained in all soil columns due to waterlogging, which directly influenced the IC-sink. Figure 8 shows the different IC-sinks under the observed and planned water fluxes. Under the planned water flux, the IC-sinks would have delivered higher and positive IC-sinks for Ba and a lower range of potential IC-sinks from biochar and RE-biochar amendments.

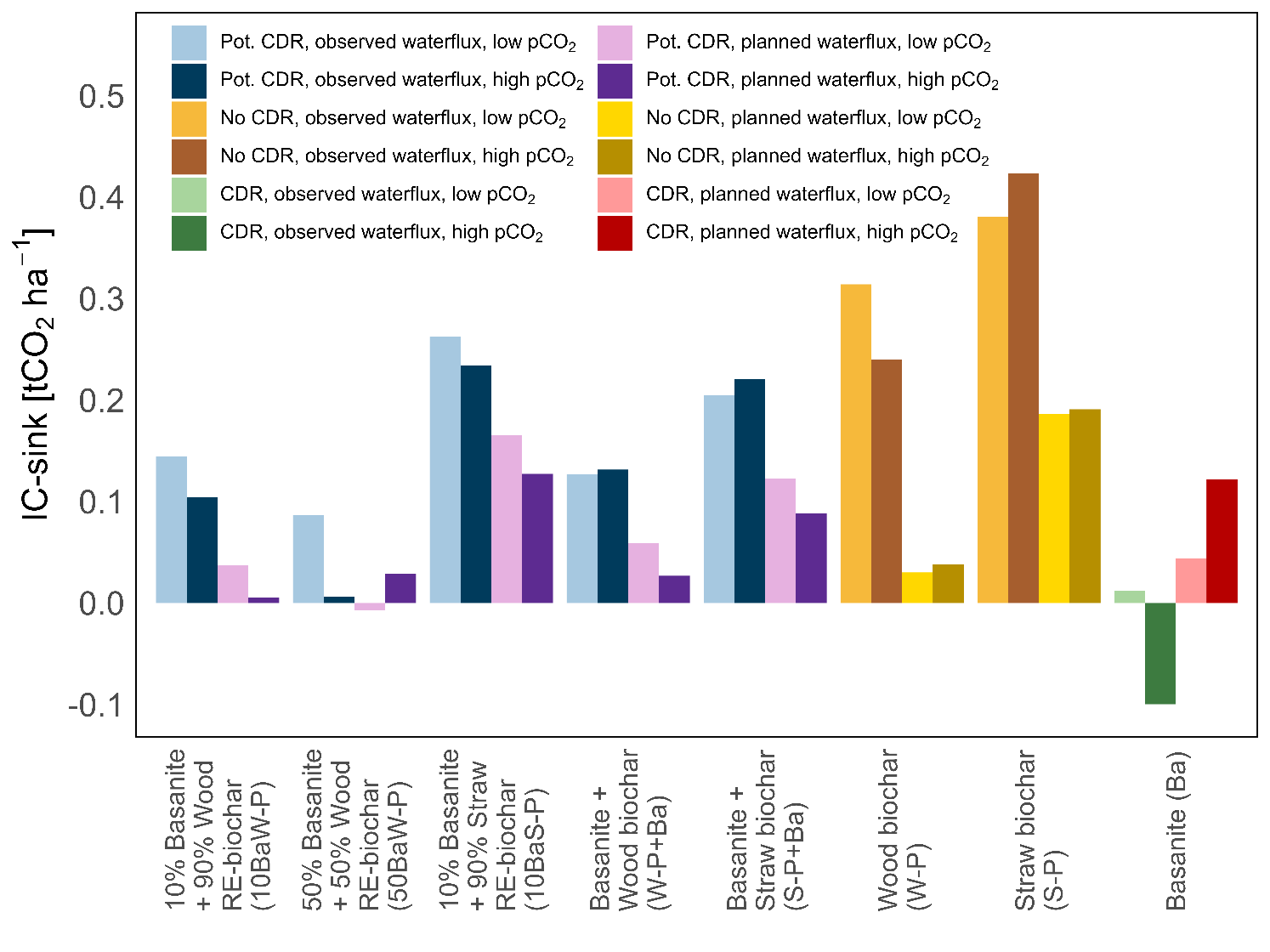


Figure 8: Comparison of average inorganic carbon (IC)-sinks and resulting carbon dioxide removal (CDR) calculated from total alkalinity concentrations and water flux. The planned water flux of 1600 mm year-1 was not achieved in all soil columns due to waterlogging. The observed, lower water flux impacted the IC-sink and led to a lower IC-sink from rock powder. When considering the planned water flux, most amendments have positive weathering fluxes and create a positive IC-sink which means a CO2 sequestration. CDR refers to IC-sink based on geogenic cations, “no CDR” refers to IC-sink, from biogenic (= biochar derived) cations. If the IC-sink originates from both geogenic and biogenic cations, it is referred to here as a “potential CDR”.

# Saturation index



Figure 9: Saturation index of calcite in the sampled leachate water under a) low and b) high pCO2. Data calculated with PhreeqC based on major ion content, DIC and pH. Whiskers indicate standard deviations.

# Weathering rates based on soil column leachates



Figure 10: Time series of the net weathering rates based on the leachate water of the soil columns experiment with application of rock-enhanced (RE) biochar, equivalent co-application of biochar and rock powder and application of rock powder to an Oxisol under a) low and b) high pCO2. It is important to note, that these weathering rates are not equal to in-situ mineral weathering in the soil. Whiskers indicate the standard deviation.

# CDR contribution of experiment data

Table 5: The theoretical contribution of the IC-sink from Basanite amendments from the experiment to the total IC-sink after 20 years under ideal hydrological conditions.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | low pCO2 | high pCO2 |
|  |  | t CO2 ha-1 | |
| IC-sink from experiment (27 weeks) |  | 0.04 | 0.12 |
| IC- sink after 20 years (1040 weeks) |  | 0.46 | 0.98 |
| Contribution of experiment to the total IC-sink |  | 9.2% | 12.4% |

# DOC leaching



Figure 11: Extrapolated DOC leaching over 20 years based on the medium scenario. Positive values indicate DOC leaching while negative values display a retention of DOC in the soil. All values are normalized to a 12t ha-1 application rate of amendment.

# CDR potential for agricultural Oxisols

We assessed the area of Oxisols in the humid tropics by using the USDA Soil Class Map (USDA Soil Class Map, 2005) and selected data of oxisol area. Then, a raster of global land cover (GlobCover 2009 land cover map, ESA GlobCover 2009 Project, Arino et al., 2012) was used and only area with the classification of “Post-flooding or irrigated croplands (or aquatic)”, “Rainfed croplands”, “Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)” or “Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)” extracted and only considered where oxisols were present (extract by Mask). These steps were done in ArcGIS Pro 3.2.0 and a global area of agricultural Oxisols of 1.84 x 10-6 km² was determined. The area is displayed in Figure 10.

To determine the CDR potential on agricultural soils after 20 years and the required material for a single application they were multiplied with the area (data see table 5 in the manuscript):

|  |  |
| --- | --- |
|  | Eq. 12 |

Resulting in

and

.

Ein Bild, das Text, Karte enthält.

KI-generierte Inhalte können fehlerhaft sein.

Figure 12: Map of agricultural Oxisols. Note that for displaying purposes the outline of the polygons is drawn with 0.5 pt.

**References**

Arino, O., Ramos Perez, J. J., Kalogirou, V., Bontemps, S., Defourny, P., and Van Bogaert, E. (2012). Global Land Cover Map for 2009 (GlobCover 2009). 40 data points. doi: 10.1594/PANGAEA.787668

Deutsche Institut für Normung e. V. (2002). DIN ISO 11277:2002-08, Bodenbeschaffenheit - Bestimmung der Partikelgrößenverteilung in Mineralböden - Verfahren mittels Siebung und Sedimentation (ISO 11277:1998 + ISO 11277:1998 Corrigendum 1:2002). doi: 10.31030/1804005

Deutsche Institut für Normung e. V. (2011). DIN EN ISO 14240-1:2011-09, Bodenbeschaffenheit\_- Bestimmung der mikrobiellen Biomasse von Böden\_- Teil\_1: Substrat-induziertes Respirationsverfahren (ISO\_14240-1:1997); Deutsche Fassung EN\_ISO\_14240-1:2011. doi: 10.31030/1804005

Dickson, A. G. (1981). An exact definition of total alkalinity and a procedure for the estimation of alkalinity and total inorganic carbon from titration data. *Deep Sea Research Part A. Oceanographic Research Papers* 28, 609–623. doi: 10.1016/0198-0149(81)90121-7

Global Biochar C-Sink, Schmidt, H.-P., Kammann, C., and Hagemann, N. (2024). Certification of the carbon sink potential of biochar. Available at: http://carbon-standards.com

Hansen, H. P., and Koroleff, F. (1999). “Determination of nutrients,” in *Methods of Seawater Analysis*, (John Wiley & Sons, Ltd), 159–228. doi: 10.1002/9783527613984.ch10

Le Bas, M. J., Le Maitre, R. W., Streckeisen, A., Zanettin, B., and IUGS Subcommission on the Systematics of Igneous Rocks (1986). A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. *Journal of Petrology* 27, 745–750. doi: 10.1093/petrology/27.3.745

Meyer zu Drewer, J., Vorrath, M.-E., Amann, T., Hartmann, J., De la Rosa, J. M., Möllmer, J., et al. (2025). Combining Pyrogenic Carbon and Carbonating Minerals for enhanced Plant growth and Carbon Capture and Storage (PyMiCCS) Part I. *Frontiers in Climate*.

Renforth, P. (2019). The negative emission potential of alkaline materials. *Nat Commun* 10, 1401. doi: 10.1038/s41467-019-09475-5

Streckeisen, A. (1980). Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites and melilitic rocks IUGS Subcommission on the Systematics of Igneous Rocks. *Geol Rundsch* 69, 194–207. doi: 10.1007/BF01869032

USDA Soil Class Map (2005). USDA Soil Class Map. Updated September 2005. Overlay of Soil Climate and FAO Soil map of the world 1:5M. Reclassified as Soil Taxonomy Suborders.