Conifer wood biochar as amendment for agricultural soils in South-Tirol: impact on greenhouse gases emissions and soil carbon stocks

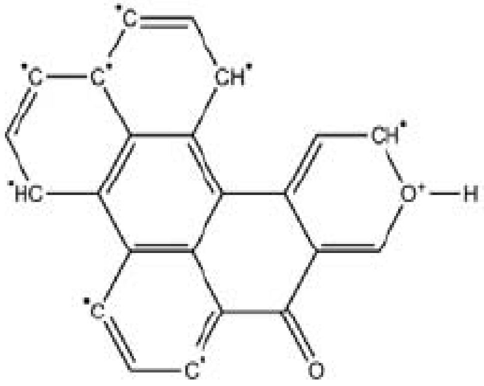
I. Criscuoli, M. Ventura, B. Glaser, K. Wiedner, P. Panzacchi,
C. Ceccon, M. Petrillo, D. Zanotelli, C. Andreotti, G. Tonon

EGU General Assembly 2020 – sharing geoscience online

Europäischer Fonds für regionale Entwicklung
Fondo europeo di sviluppo regionale
EUROPEAN UNION
AUTONOME PROVINZ BOZEN SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO ALTO ADIGE

Biochar

BIOCHAR IS
CHARCOAL APPLIED
TO AGRICULTURAL FIELDS
IN ORDER TO IMPROVE
ECOSYTEM SERVICES



IT IS A CARBONACEOUS MATERIAL
WITH STABLE CHEMICAL STRUCTURE → PROPOSED AS A STRATEGY FOR CLIMATE CHANGE MITIGATION

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Wood-Up project

Optimization of WOOD gasification chain in South-Tirol to produce bioenergy and other high-value green products to enhance soil fertility and mitigate climate change

Funded by

efre · fesr Südtirol · Alto Adige
Europäischer Fonds für regionale Entwicklung
Fondo europeo di sviluppo regionale
FESR1028

EUROPEAN UNION

AUTONOME PROVINZ BOZEN SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO ALTO ADIGE

Partners

unibz Freie Universität Bozen / Libera Università di Bolzano / Università Liedia de Bulsan

LAIMBURG Versuchszentrum Laimburg / Centro di Sperimentazione Laimburg / Laimburg Research Centre

IDM SÜDTIROL ALTO ADIGE

MARTIN-LUTHER UNIVERSITÄT HALLE-WITTENBERG

LCAworks

Framework and objectives of the project

unibz Freie Universität Bozen Libera Università di Bolzano Università Liedia de Bulsan

FRAMEWORK

1 Million m^3 $year^{-1}$ biomass for energy in South Tyrol → > 40 gasification plants of small-medium size → **~ 1500 t $year^{-1}$ biochar produced in South-Tirol** → Disposal as non-dangerous waste: 140 €/ton

OBJECTIVES

- State of the art of gasification in South Tyrol
- Optimisation of the gasification chain in South Tyrol
- Characterization of biochar produced in South Tyrol
- Before-energy-use of woody biomass for food and pharmaceutical purposes
- Agronomical impact of biochar use in vineyards and apple orchards
- Biochar impact on soil water and nutrients
- Impact on GHG soil emissions and soil C stocks

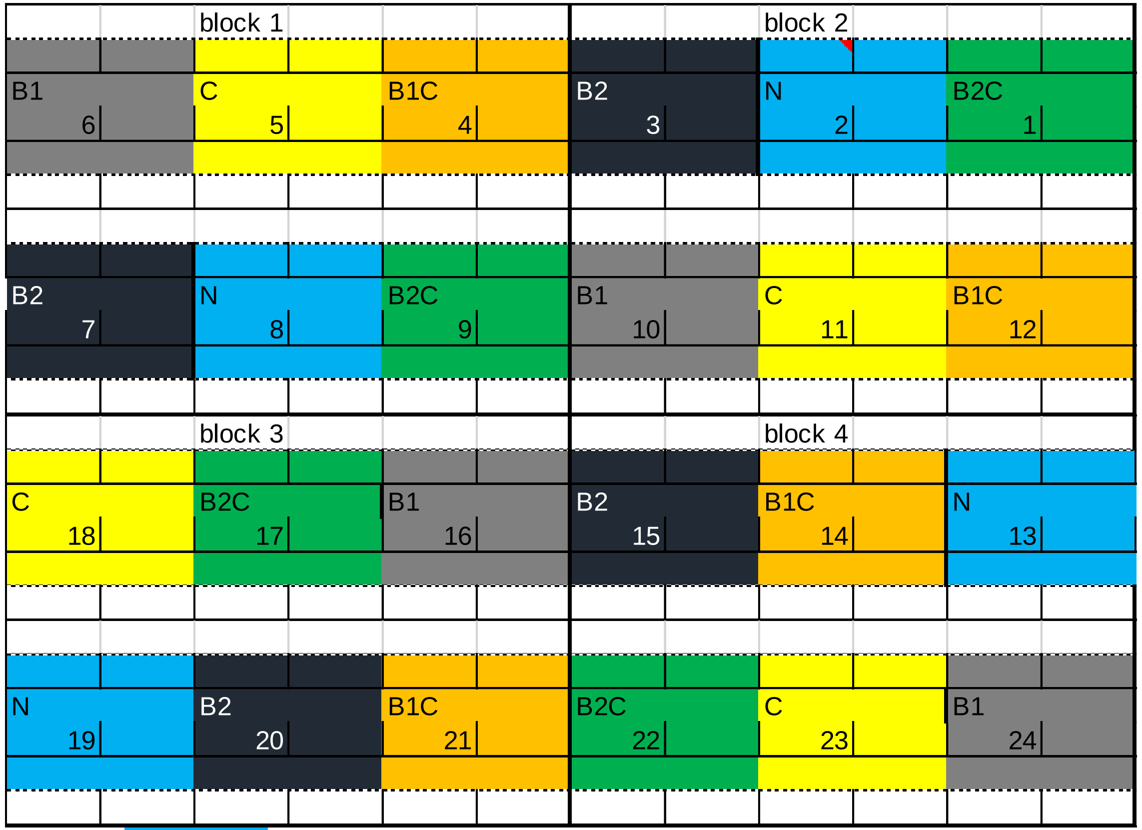
Focus of this presentation

1. STABILITY OF WOOD BIOCHAR IN AGRICULTURAL SOILS OF SOUTH-TIROL

2. IMPACT OF BIOCHAR ON GREENHOUSE GASES (GHG) EMISSIONS FROM AGRICULTURAL SOILS IN SOUTH-TIROL

unibz
Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Field experiment



N	control
C	compost (45 t/ha)
B1	biochar 25 t/ha
B2	biochar 50 t/ha
B1C	biochar 25 t/ha + compost
B2C	biochar 50 t/ha + compost

Vineyard (Müller Thurgau) near Merano, South-Tirol, Northern Italy

1. Biochar stability in soil

SOIL SAMPLING:
T0 (before biochar distribution)
T1 (3 weeks after biochar distribution)
T2 (1 year after biochar distribution)
T3 (2 years after biochar distribution)

2 samples per plot: 48 sampling points until 20 cm depth

Assessment of:
- C_{org} (%)
- Bulk density (ρ)

BIOCHAR STABILITY ESTIMATE THROUGH 2 ANALYTICAL TECHNIQUES:

1. ^{13}C Isotopic mass balance
2. Benzene polycarboxylic acids (BPCA) analysis (Busch and Glaser 2015)

1.1 Isotopic mass balance

$$f = \frac{(\delta^{13}C_{tot} - \delta^{13}C_{SOM})}{(\delta^{13}C_{biochar} - \delta^{13}C_{SOM})}$$

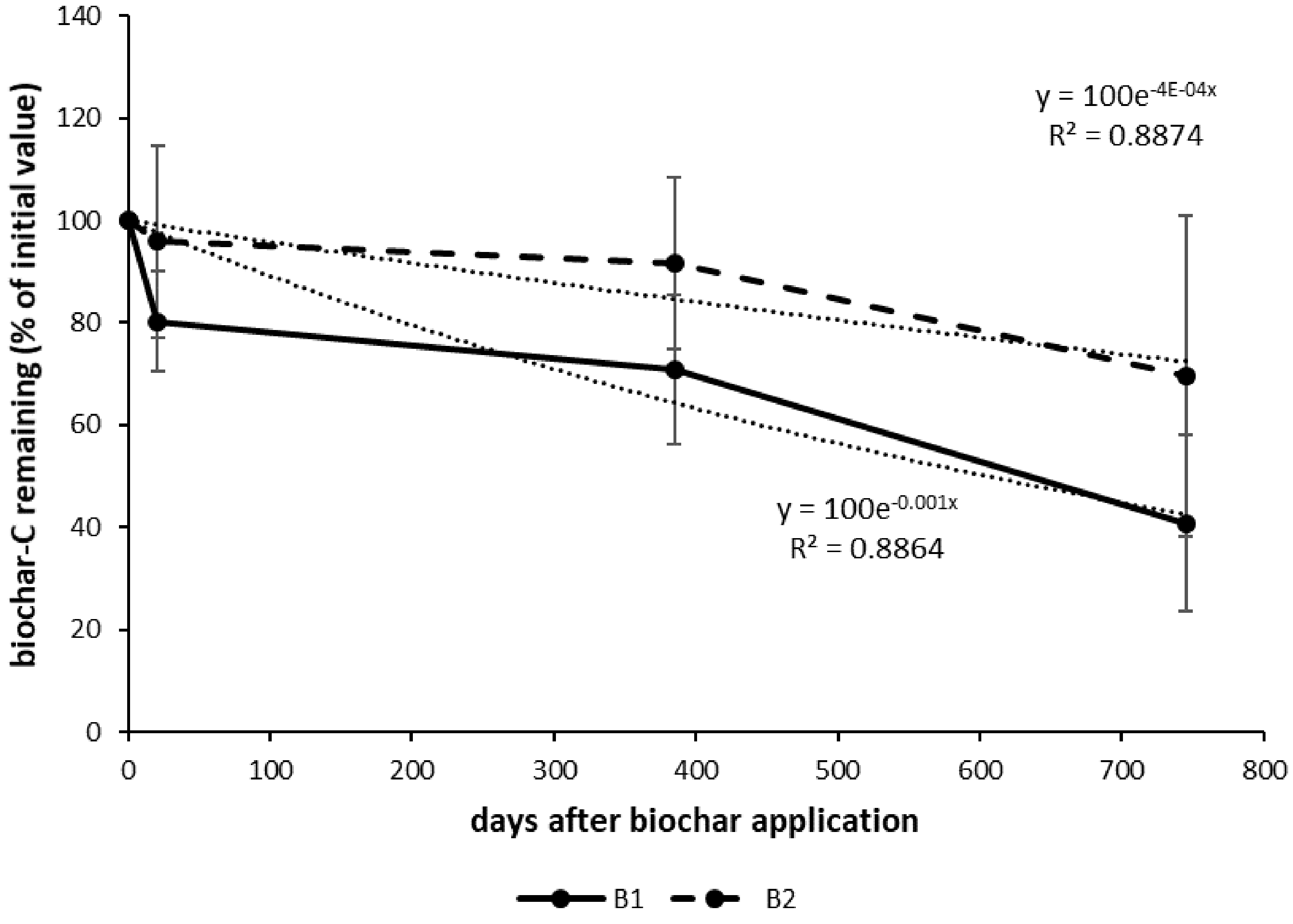
$\delta^{13}C_{biochar}$ = -24.81‰

$\delta^{13}C_{SOM}$ = isotopic signature before amendments (T0)

$\delta^{13}C_{tot}$ = isotopic signature after amendments (T1, T2, T3)

Biochar–C [t ha^{-1}] = $f \times C_{org}$[%]/100 × ρ [g cm^{-3}] × 20 [cm] × 100 unibz Freie Universität Bozen Libera Università di Bolzano Università Liedia de Bulsan

1.1 Isotopic mass balance results



Single-exponential decay model:

$$Biochar\text{-}C_t = biochar\text{-}C_0^{-kt}$$

Biochar application rate (t ha^{-1})	Biochar-C application rate (t ha^{-1})	Annual decay rate (%)	Mean Residence Time (MRT, y)
25	15.9	36.5	2.7
50	31.9	14.6	6.8

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

1.2 BPCA method

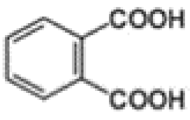
MARTIN-LUTHER-UNIVERSITÄT
HALLE-WITTENBERG

Fakultät Naturwissenschaften III
Institut für Agrar- und Ernährungswissen-
schaften
FG Bodenbiogeochemie

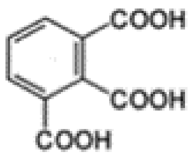
Bruno Glaser

Katja Wiedner

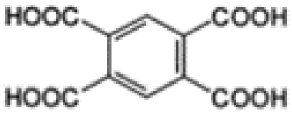
Assessment of Benzene Polycarboxylic Acids (BPCA):
molecular markers of black carbon



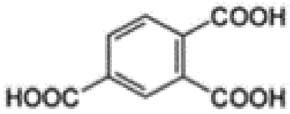
phthalic acid



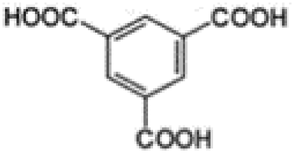
hemimellitic acid



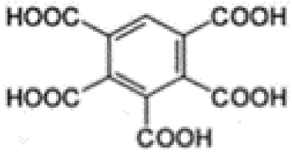
pyromellitic acid



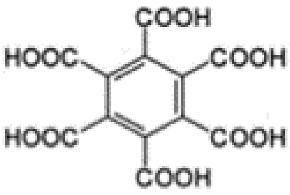
trimellitic acid



trimesic acid



benzenepentacarboxylic acid

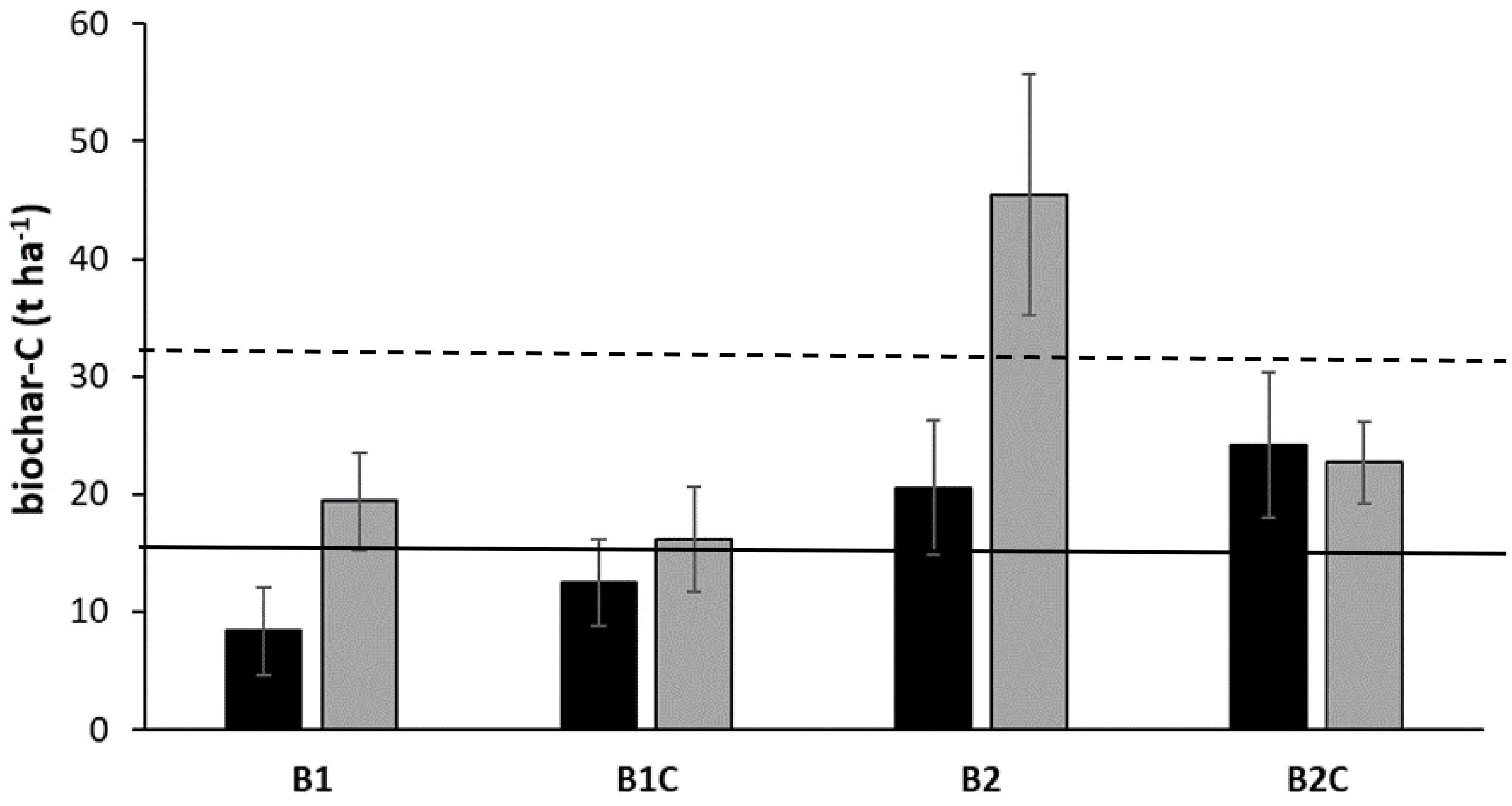


mellitic acid

Biochar–C [t ha^{-1}] = C_{BPCA} [g kg^{-1}] × biochar factor x ρ [g cm^{-3}] × 20 [cm] × 10

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

1.2 BPCA results



T1: just after biochar distribution

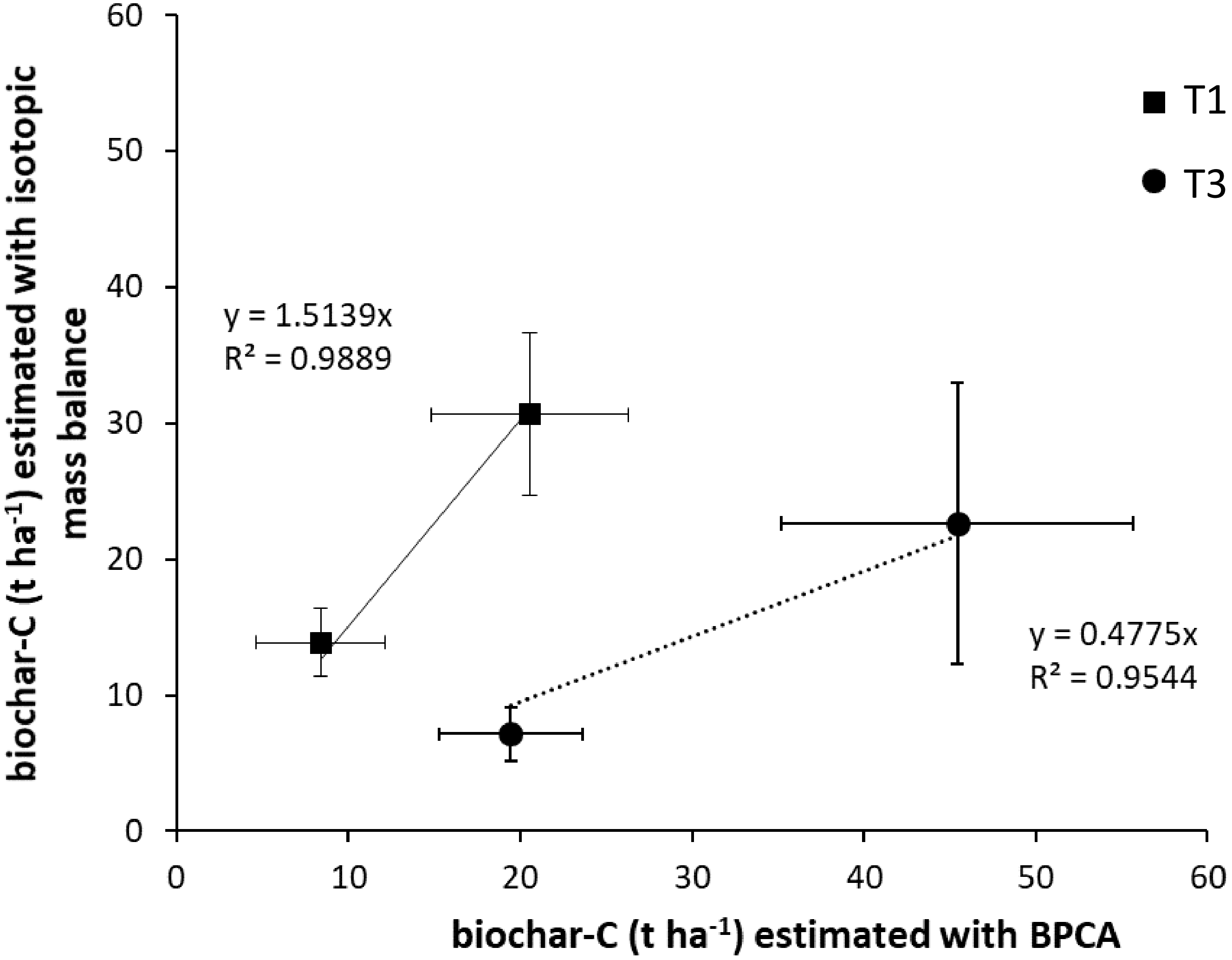
T3: 2 years after biochar distribution

B2= 31.9 t biochar-C ha^{-1}

B1= 15.9 t biochar-C ha^{-1}

→ THE INCREASE OVER TIME IS NOT STATISTICALLY SIGNIFICANT, RESULTS MIGHT BE LINKED TO THE HETEROGENEITY OF BIOCHAR CONCENTRATION IN THE SOIL

1.3 Methods comparison



T1: 3 weeks after biochar application, BPCA method estimate < isotopic mass balance *and* the estimate of isotopic mass balance is very close to the dose applied

T3: 2 years after biochar application, BPCA method estimate > isotopic mass balance

2. Impact of biochar on soil GHG emissions - methods

PICARRO

CRDS Analyzer

Carbon and Water Cycle Measurements

$N_2O + CH_4 + CO_2$

2. Impact of biochar on soil GHG emissions - methods

- Experimental duration: August 2017 - December 2019

- Campaign frequency: monthly for 2 days

- Experimental design:

  - 6 chambers remotely controlled with a Multiplexer
  - measurements duration: 10 min
  - measurements replicated on 3 plots for each soil treatment + 24 hours on 1 replicate for each soil treatment

- Monitoring of environmental parameters:
  - soil humidity
  - soil temperature

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

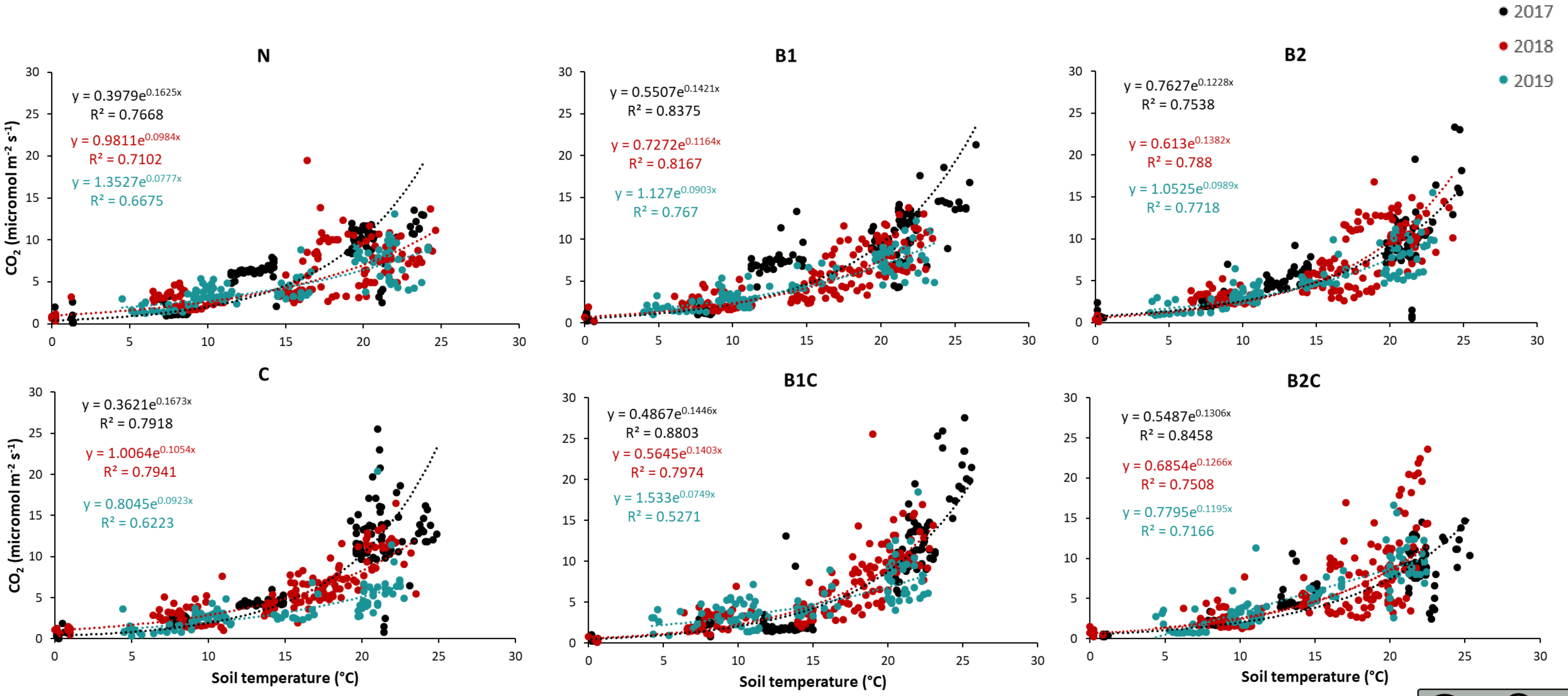
2. Impact of biochar on soil GHG emissions - data analysis

BIOCHAR IMPACT ON SENSITIVTY OF GHG FLUXES TO SOIL TEMPERATURE AND BASAL EMISSIONS

- Relation between GHG fluxes and soil temperature:
  - for each treatment
  - for each year of experiment
- Linearization of exponential relations
- Comparison of the regression lines parameters:
  - Slopes (*b*): sensitivity of fluxes to soil temperature
  - Intercepts (R_0): basal emission
- Statistical tests: ANCOVA and Tukey test applied to orthogonal comparisons:
  - N vs. B1 and B2
  - C vs. B1C and B2C

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

2. CO_2 fluxes and soil temperature - results



Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

2. CO_2 fluxes and soil temperature - results

2017	b		R_0	
N	0.1625	a	0.3979	a
B1	0.1421	a	0.5507	a
B2	0.1228	a	0.7627	a

2018	b		R_0	
N	0.0984	b	0.9811	
B1	0.1164	b	0.7272	
B2	0.1382	a	0.613	

2019	b		R_0	
N	0.0777	b	1.3527	
B1	0.0903	ab	1.127	
B2	0.0989	a	1.0525	

2017	b		R_0	
C	0.1673	a	0.3621	
B1C	0.1446	a	0.4867	
B2C	0.1306	b	0.5487	

2018	b		R_0	
C	0.1054	a	1.0064	a
B1C	0.1403	a	0.5645	b
B2C	0.1266	a	0.6854	ab

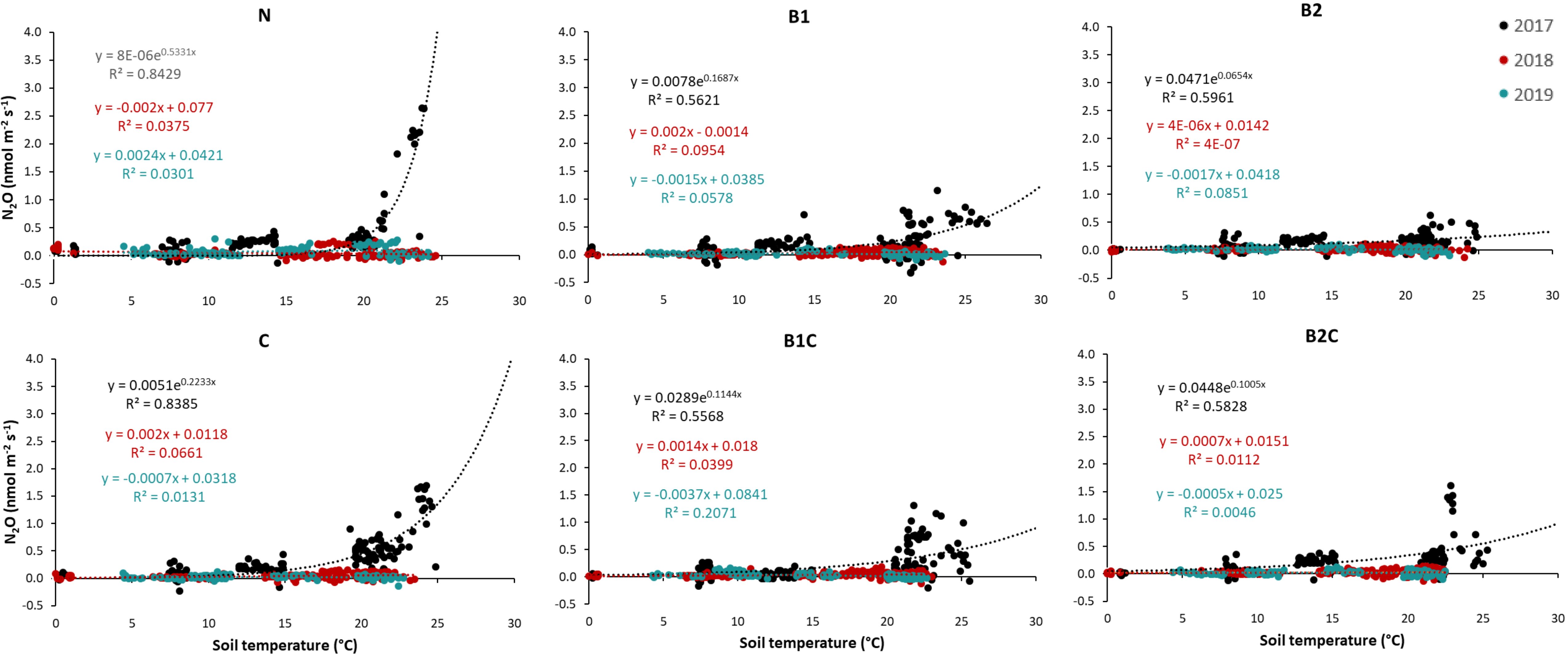
2019	b		R_0	
C	0.0923	b	0.8045	
B1C	0.0749	b	1.533	
B2C	0.1195	a	0.7795	

Biochar reduces the sensitivity to temperature of CO_2 fluxes in comparison to soils amended only with compost

Biochar increases the sensitivity to temperature in comparison to control soils and **reduces R_0** in comparison to soils amended only with compost

Biochar increases the sensitivity to temperature in comparison to control soils and soils amended only with compost

2. N_2O fluxes and soil temperature - results



2. N_2O fluxes and soil temperature – results

2017	b		R_0	
N	0.5331	a	0.000008	
B1	0.1687	b	0.0078	
B2	0.0654	b	0.0471	

2018	b		R_0	
N	-0.002	b	0.077	
B1	0.002	a	-0.0014	
B2	0.000004	b	0.0142	

2019	b		R_0	
N	0.0024	a	0.0421	
B1	-0.0015	b	0.0385	
B2	-0.0017	b	0.0418	

2017	b		R_0	
C	0.2233	a	0.0051	
B1C	0.1144	b	0.0289	
B2C	0.0448	b	0.1005	

2018	b		R_0	
C	0.002	a	0.0118	a
B1C	0.0014	a	0.018	a
B2C	0.0007	a	0.0151	a

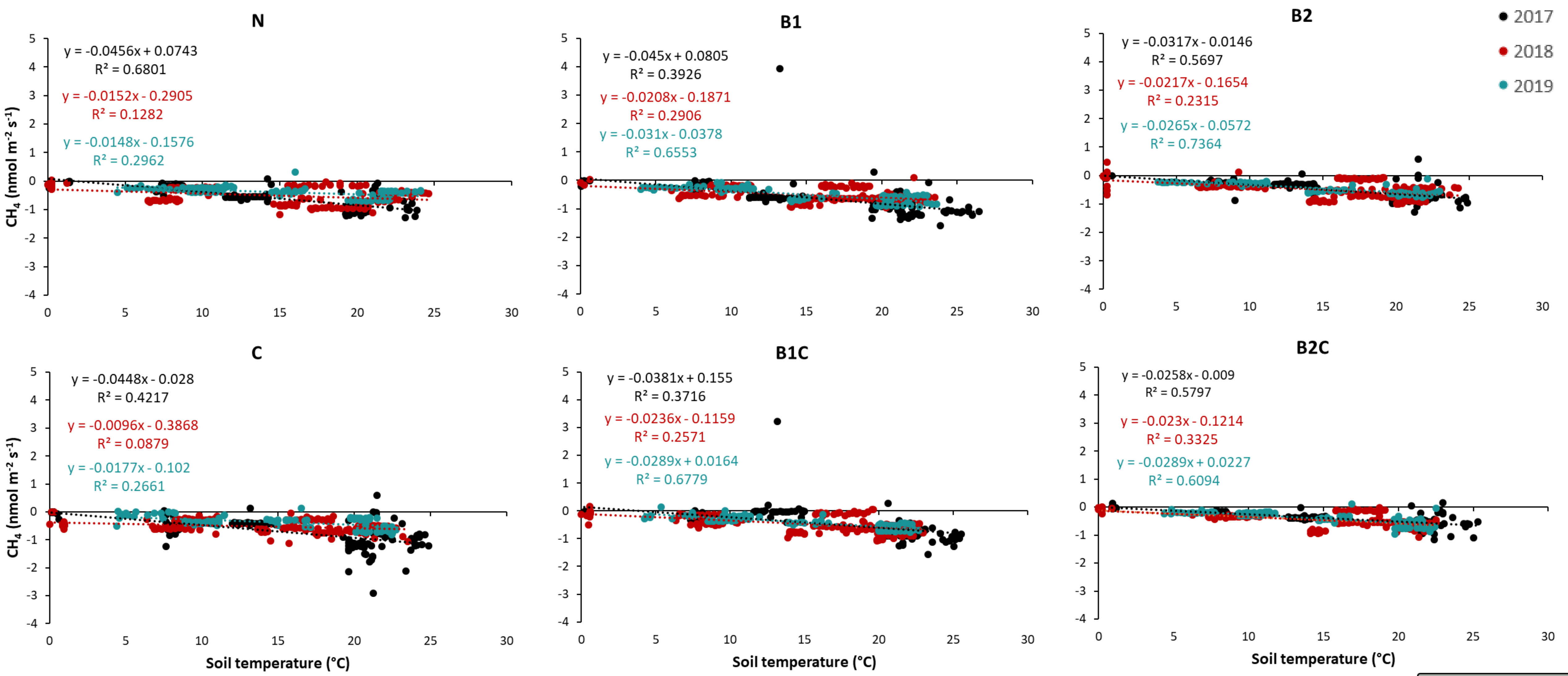
2019	b		R_0	
C	-0.0007	a	0.0318	
B1C	-0.0037	b	0.0841	
B2C	-0.0005	a	0.025	

Biochar reduces the sensitivity to temperature of N_2O fluxes in comparison to control and soils amended only with compost

Biochar tends to change the sign of the relation between temperature and N_2O fluxes in comparison to control

Biochar tends to change the sign of the relation between soil temperature and N_2O fluxes in comparison to control and **increases the sensitivity** in comparison to soils amended only with compost

2. CH_4 fluxes and soil temperature - results



unibz Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

2. CH_4 fluxes and soil temperature – results

2017	b		R_0	
N	-0.0456	b	0.0743	
B1	-0.045	b	0.0805	
B2	-0.0317	a	-0.0146	

2018	b		R_0	
N	-0.0152	a	-0.2905	a
B1	-0.0208	a	-0.1871	a
B2	-0.0217	a	-0.1654	a

2019	b		R_0	
N	-0.0148	a	-0.1576	
B1	-0.031	b	-0.0378	
B2	-0.0265	b	-0.0572	

2017	b		R_0	
C	-0.0448	b	-0.028	
B1C	-0.0381	b	0.155	
B2C	-0.0258	a	-0.009	

2018	b		R_0	
C	-0.0096	a	-0.3868	
B1C	-0.0236	b	-0.1159	
B2C	-0.023	b	-0.1214	

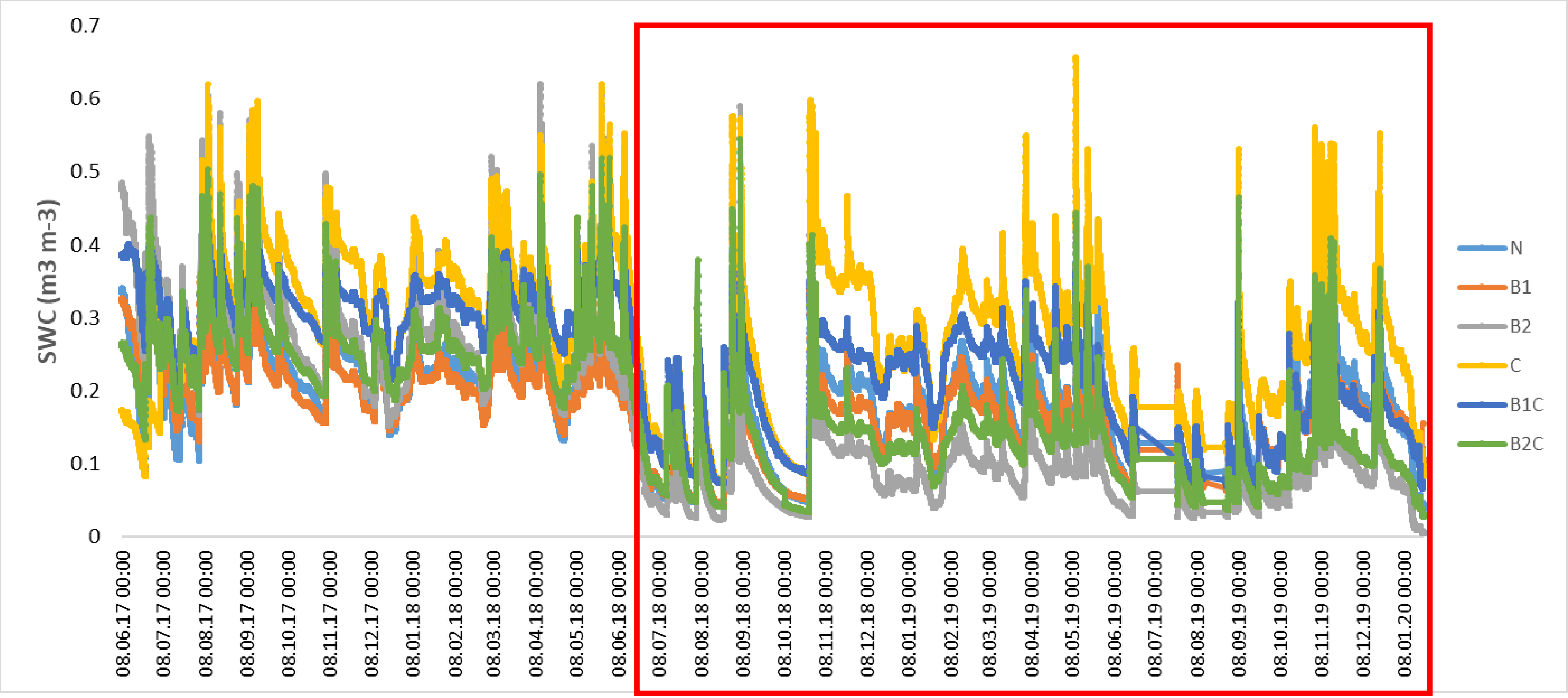
2019	b		R_0	
C	-0.0177	a	-0.102	
B1C	-0.0289	b	0.0164	
B2C	-0.0289	b	0.0227	

Biochar reduces the sensitivity to temperature of CH_4 fluxes compared to control soils and soils amended only with compost

Biochar increases the sensitivity to temperature of CH_4 fluxes compared to soils amended only with compost

Biochar increases the sensitivity to temperature of CH_4 fluxes compared to control and soils amended only with compost

2. Soil humidity - results



SOIL HUMIDITY REDUCTION COMPARED TO THE FIRST YEAR OF EXPERIMENT → POSSIBLE IMPACT ON GHG SOIL EMISSIONS

Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Conclusions

- ✓ The estimated **biochar residence time in soil (MRT)** is short but estimations are **uncertain**:
  - ✓ different results according to the specific method
  - ✓ further analysis are needed to confirm biochar stability in the **long term**

- ✓ **CO_2 and CH_4 emissions:**
  - ✓ 1st year since application: biochar **reduces** sensitivity to temperature
  - ✓ Following years: biochar **increases** sensitivity, mainly at **high application** rates

- ✓ **N_2O emissions:**
  - ✓ 1st year since application: biochar strongly **reduces** sensitivity to temperature
  - ✓ Following years : biochar **changes the sign** of the relation between fluxes and soil temperature compared to control soils. Impact on the magnitude of parameters is less clear, but less relevant because fluxes are very low

- ✓ These results are confirmed if biochar is applied together with **compost**
- ✓ Results suggests that the impact of biochar on GHG fluxes is influenced by **biochar aging**
- ✓ **Soil humidity** decreases after June 2018 → possible impact on GHG emissions → confounding effect with biochar aging


Thank you for your attention