Agroenvironmental Performances of BIOCHAR Application in the Mineral and Organic Fertilization Strategies of a Maize–Ryegrass Forage System in Po Valley And mitigation of GHG emissions in field and stable

Regione Lombardia

PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI

Fondo Europeo Agricolo per lo Sviluppo Rurale: l'Europa investe nelle zone rurali

Fondazione Minoprio

crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

2017-2019: Infochar PSR Project
2020-2022: N-Control PSR Project
2020-2022: Agri Hub POR FESR Project

Massimo Valagussa, agronomist

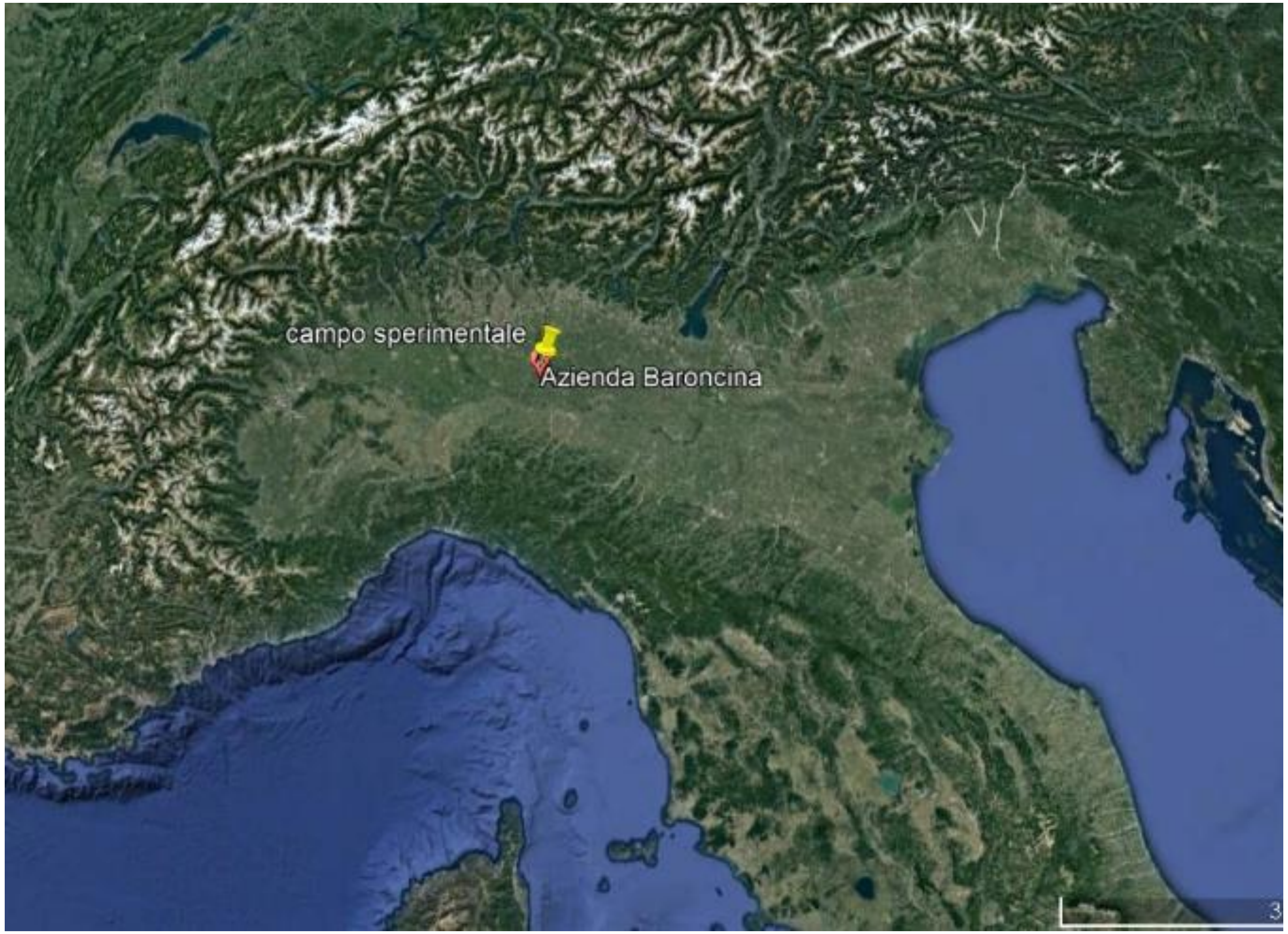
Project referents:
A. Tosca (Minoprio Foundation); C. Scotti, L. Borelli (CREA ZA Lodi); A. Lagomarsino, C. Becagli (CREA AA Firenze)

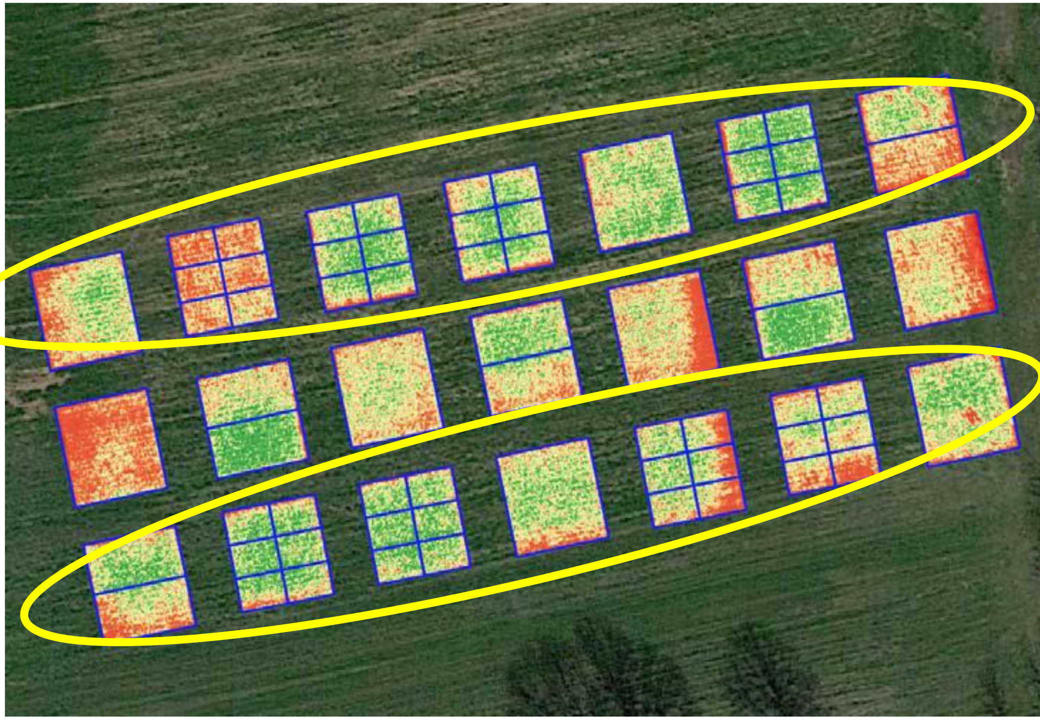
AGRI HUB

PLACE HOLDER

DEMONSTRATION FIELD SYSTEM

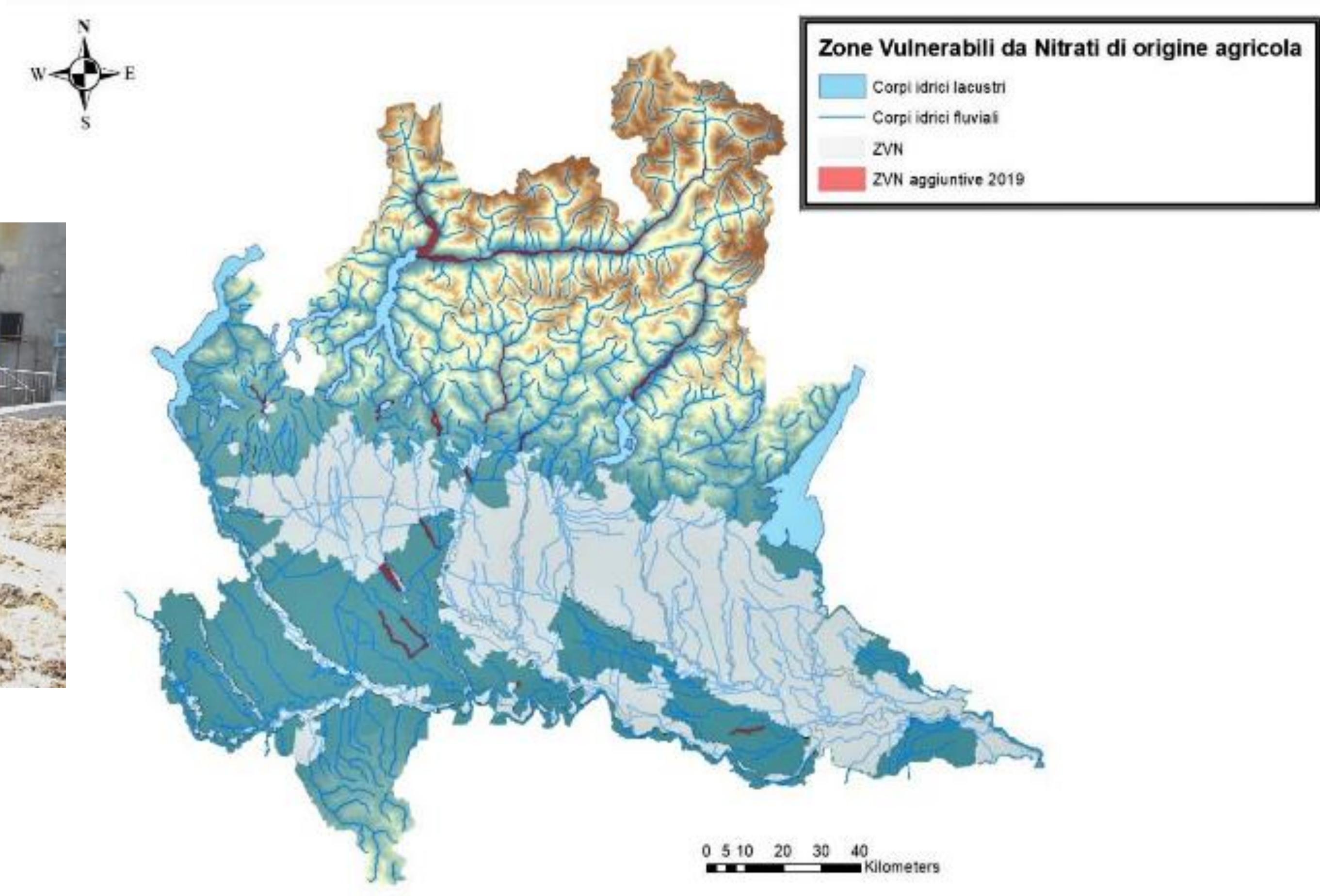
Lodi, Po Valley, Italy; 451702500 N–92904300 E; 81.5 m asl)





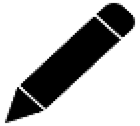
2019, Drone Survey: NDRE Index

- intensive dairy cattle farming region: increase of bovine effluents
- nitrate vulnerable zones: operational restrictions



BIOCHAR AND SOIL FERTILITY

Application of biochar in soil may influence:



- *carbon stock*
- *color (albedo)*
- *bulk density*
- *total porosity and water retention*
- *soil acidification*
- *cation and anion exchange capacity*
- *fertiliser efficiency*
- *organic matter mineralization*
- *soil life (microorganism)*
- *organic and inorganic pollution*
- *GHGs emission and nutrient leaching*
- *crop yelds*

Depending on:

- *feedstock use to produce biochar*
- *process (temperature and time)*

BIOCHAR PROPERTIES

- *soil properties*
- *mode of biochar use (rates, with what)*
- *climatic conditions*
- *type of crops*
- *………………..*

HOW AND WHERE BIOCHAR IS USED

Demonstration Field (Cascina Baroncina CREA-ZALodi) : Silage maize in rotation with Italina rye-grass

- Soil type: sandy loam soil, sub-acid pH, K and P low level, moderate in TOC

- biochar application
  - **Btq**: biochar
  - **Bchi**: biochar with mineral fertilisation
  - **Bdig**: biochar with digestate
  - **Bref**: biochar with bovine slurry

  Avalilable N provided to Maize: **170 Kg/ha** (+ 80 P and 180 K in mineral fertilisation)

- Control
  - **Cchi:** mineral fertilisation (urea + PK)
  - **Cdig**: digestate
  - **Cref**: bovine slurry
  - **Nconc**: no fertilisation

  Avalilable N provided to Maize: 170 Kg/ha (+ 80 P and 180 K in mineral fertilisation)

- biochar types
  - **BG**: biochar from gassification process - GLM SRL (MN)
  - **BP**: biochar from pyrolysis - Ecco Soluzioni SRL (CO)

- biochar application rates
  - **D1: 10 t ha^{-1} dm.**
  - **D2: 20 t ha^{-1} dm**
  - **D3: 40 t ha^{-1} dm**

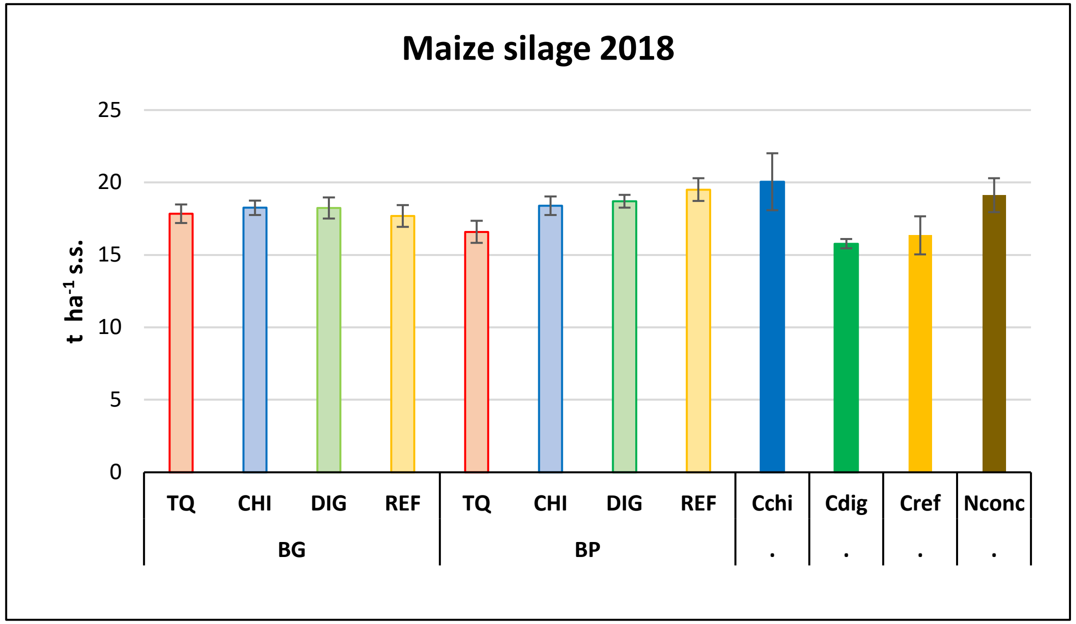
NOTE
Biochar application just at the first year
Chemical, Digestate and Slurry: every years at Maize sowing

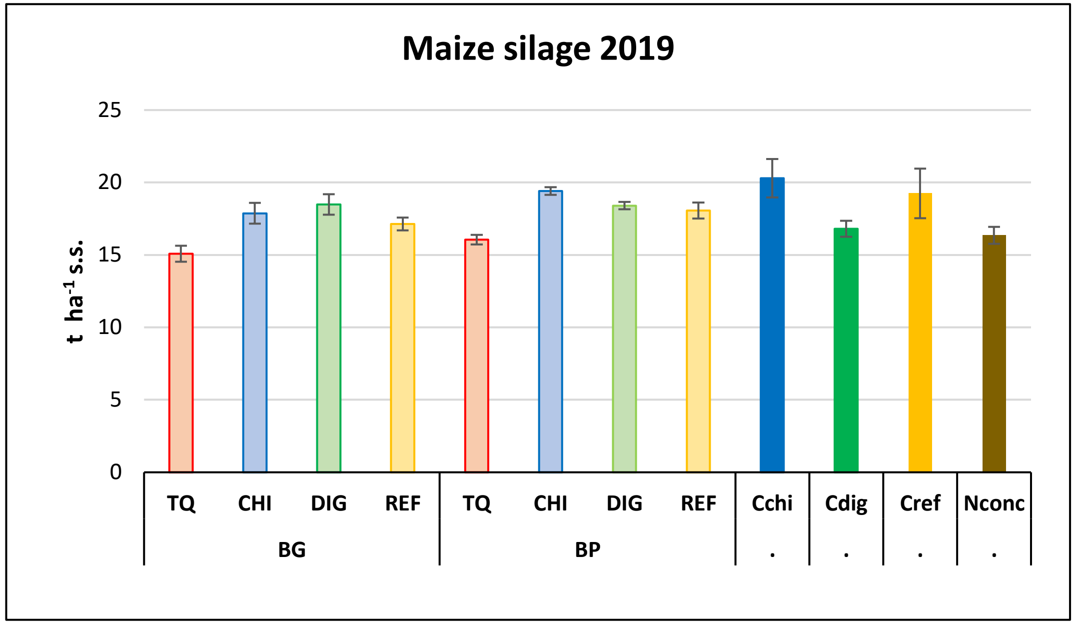
MAIN BIOCHAR PROPERTIES

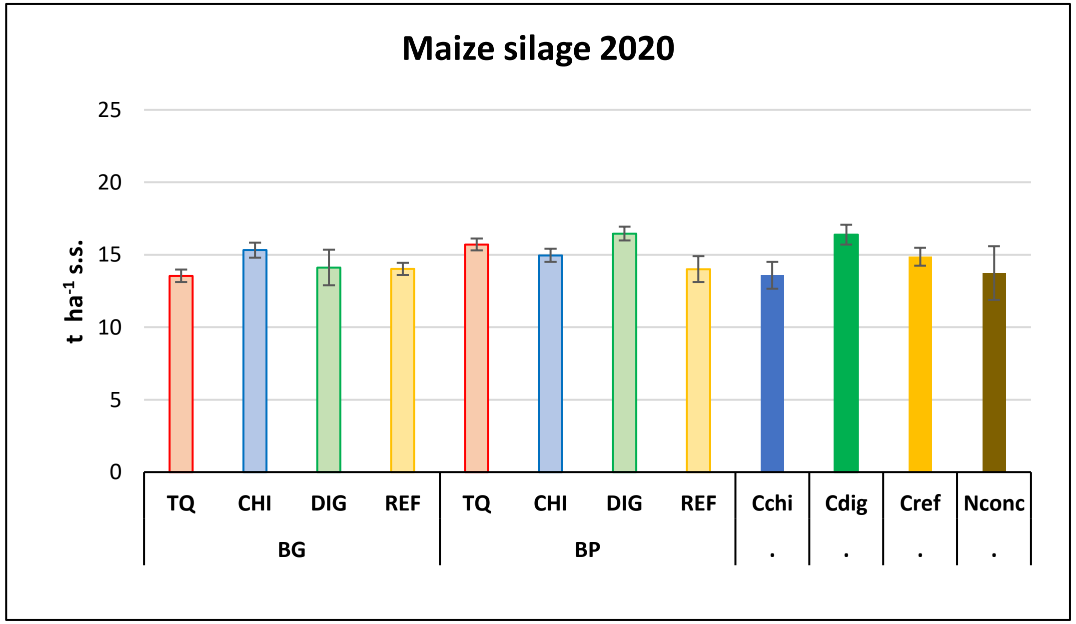
PARAMETER	BIOCHAR G	BIOCHAR P	STANDARD
Water content (% m/m)	67,6	68,3	EN 13040
pH	9,9	9,2	EN 13037
Electrical conductivity (dS/m)	73	6	EN 13038
Total Carbon (% dm)	77,9	77,9	D.Lgs 7276:16 (Dumas)
Organic Carbon (% dm)	76,8	77,6	D.Lgs 7276:16 (Dumas)
Molar ratio H:Corg	<0,1	0,1	D.Lgs 7276:16 (Dumas)
Stable Carbon (% C. org)	87,1	91,9	H_2O_2 oxidation (BQM)
Ash 550°C (% dm)	17,06	6,26	EN 13039
Total Nitrogen (% dm)	0,16	0,20	EN 13654-2
Total Phosphorus (% dm)	0,26	0,05	EN 13650
Total Potassium (% dm)	1,03	0,27	EN 13650
Water soluble Potassium (mg/L fm)	1363	19	EN 13652

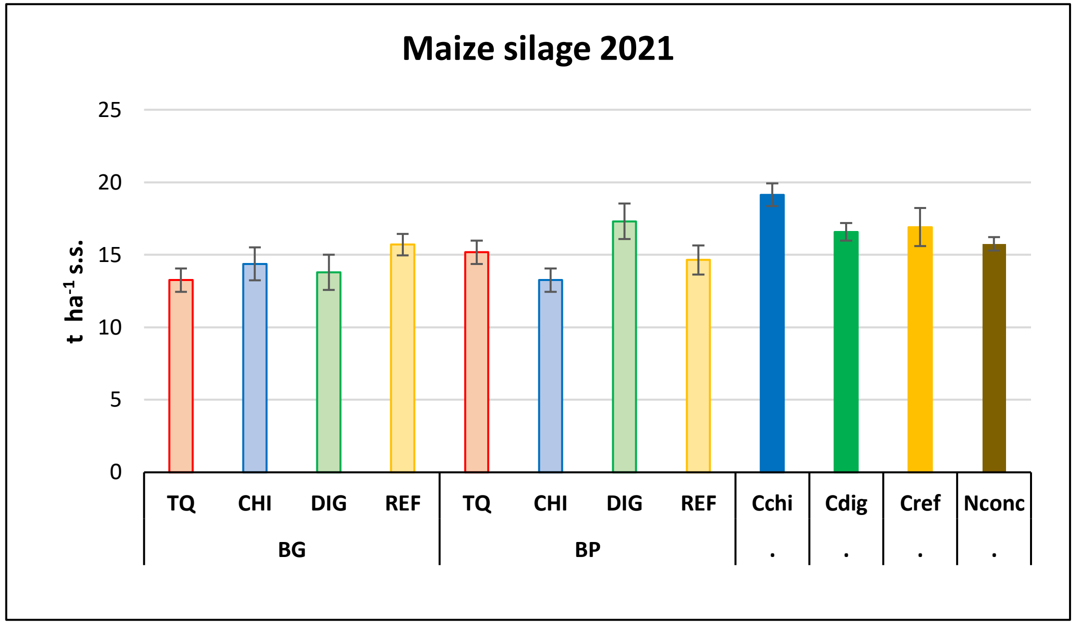
Feedstock: wood from local forests

Maize silage yeld 2018-2021

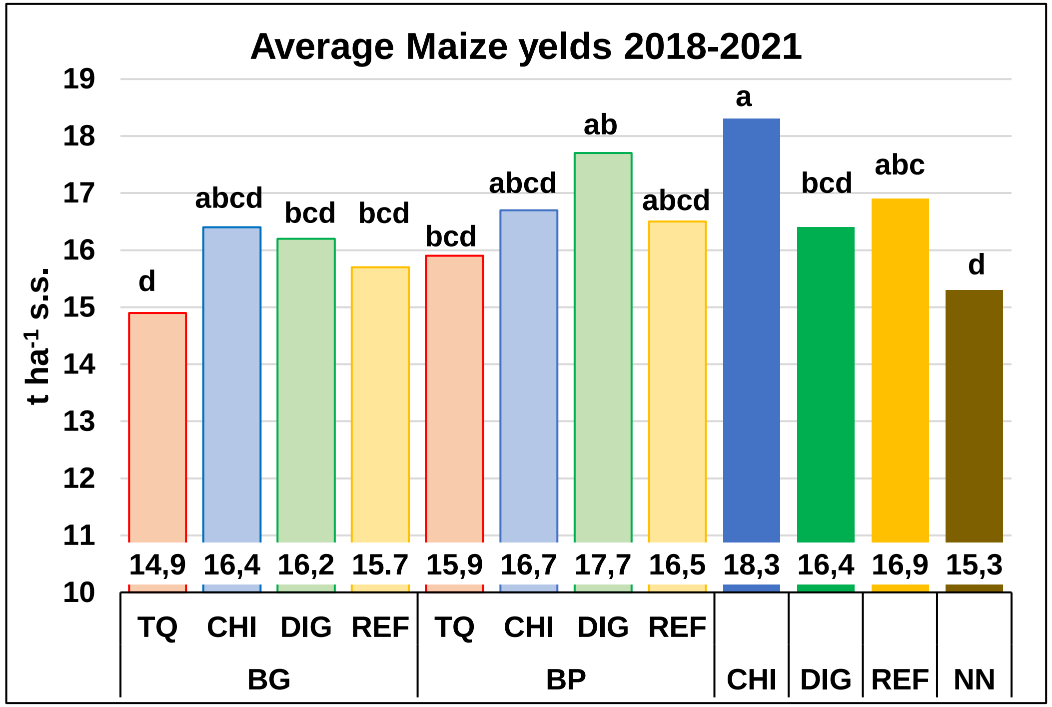


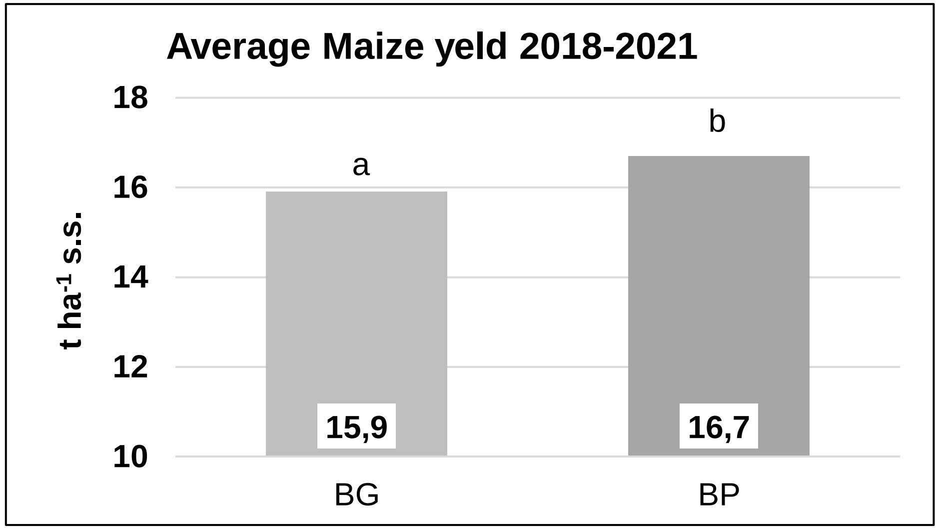




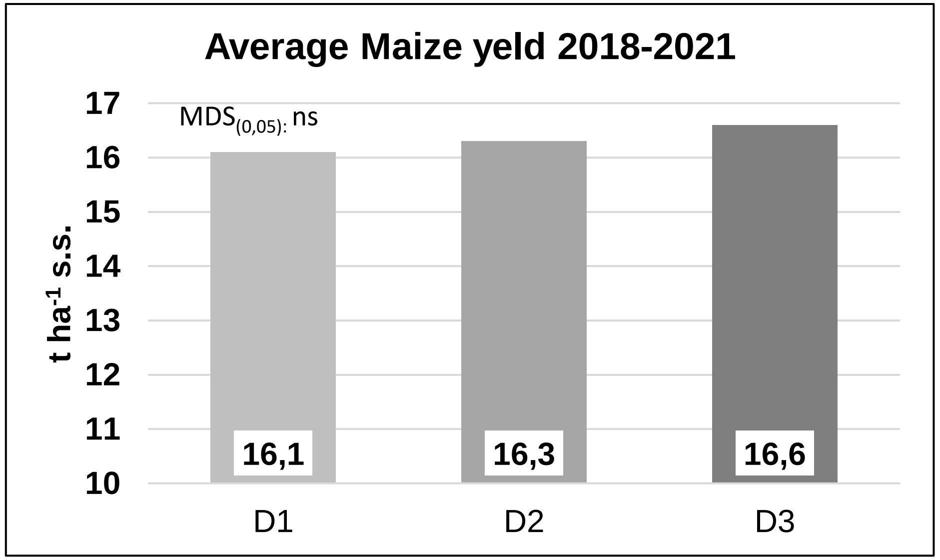


Maize silage yeld 2018-2021

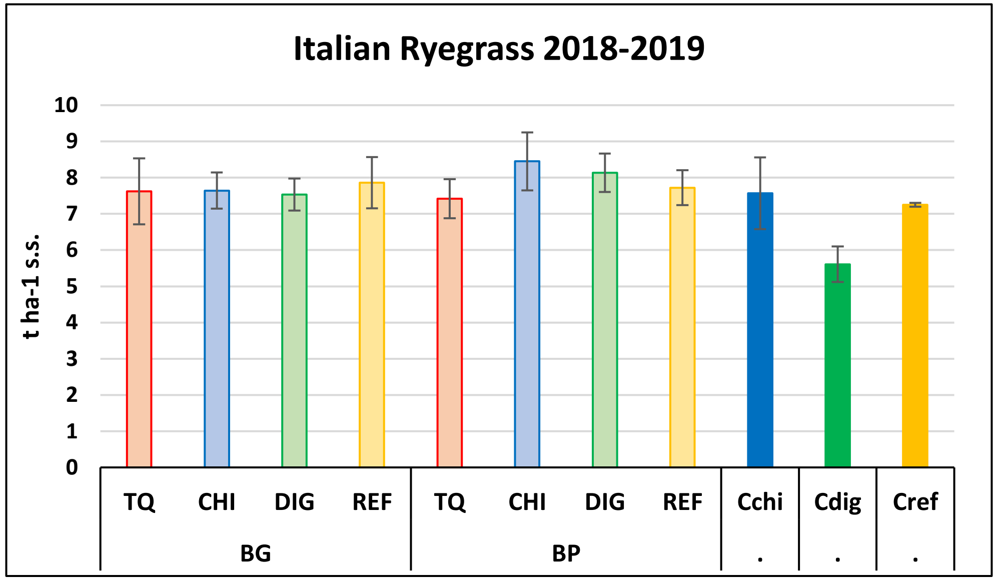


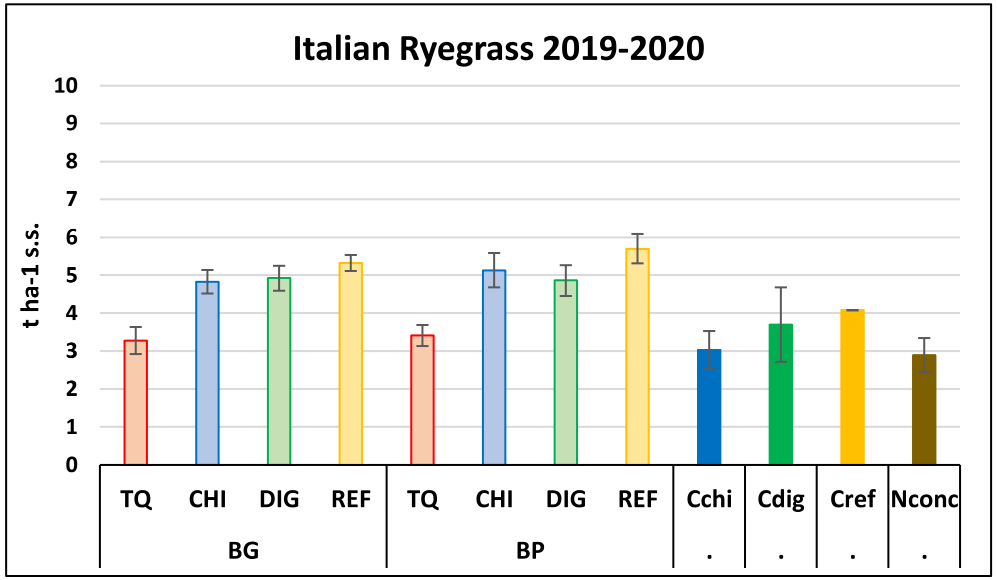


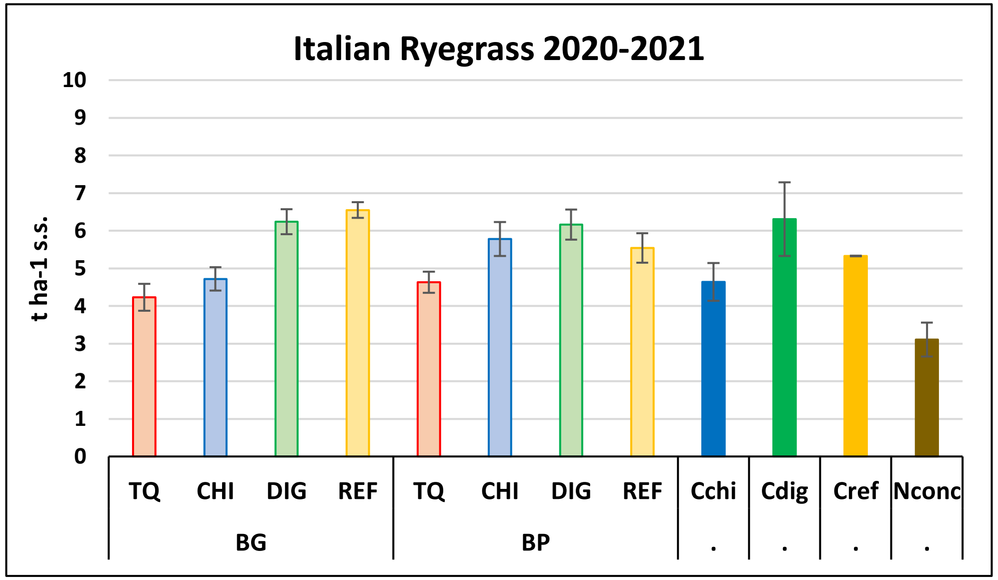
Average Maize yelds 2018-2021

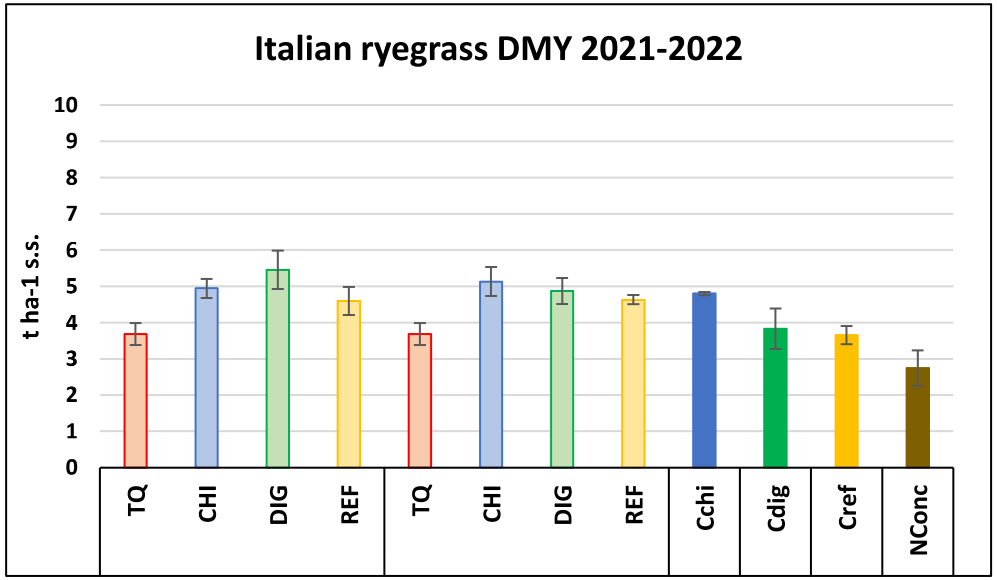


Italian Ryegrass yeld 2019-2021



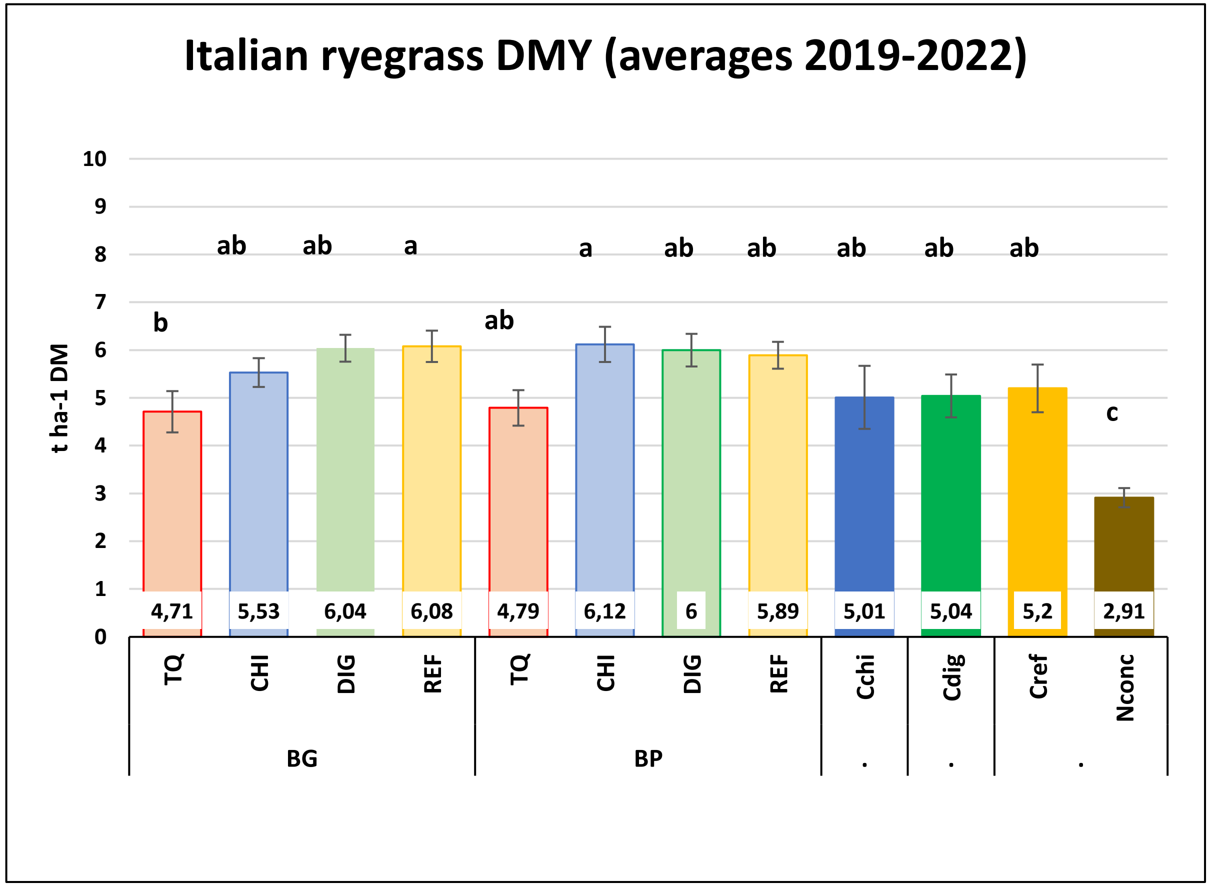


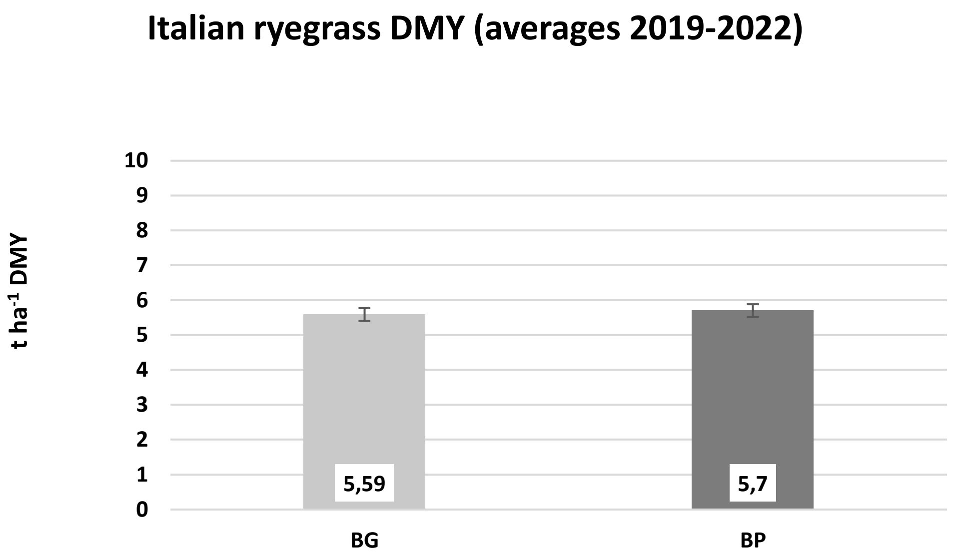


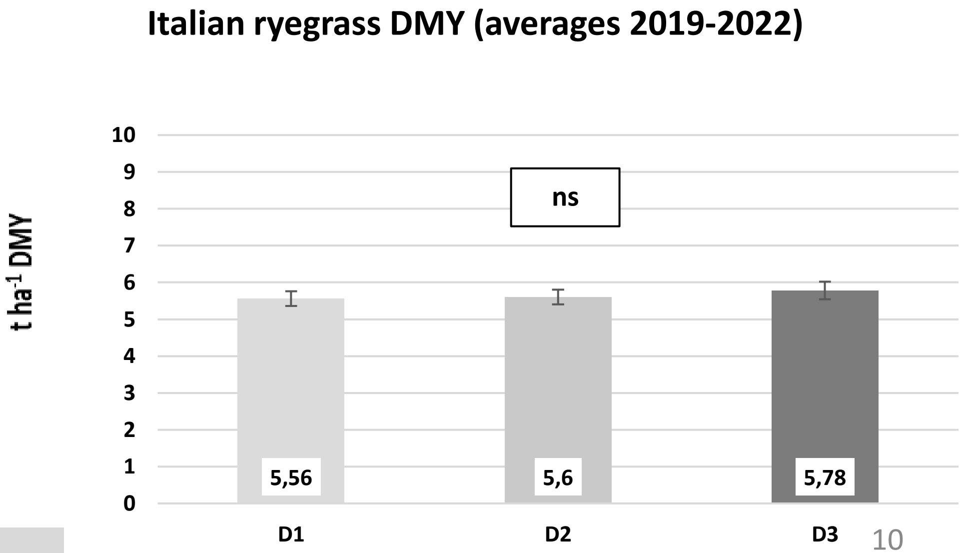


Crop not fertilized

Italian Ryegrass yeld 2019-2022

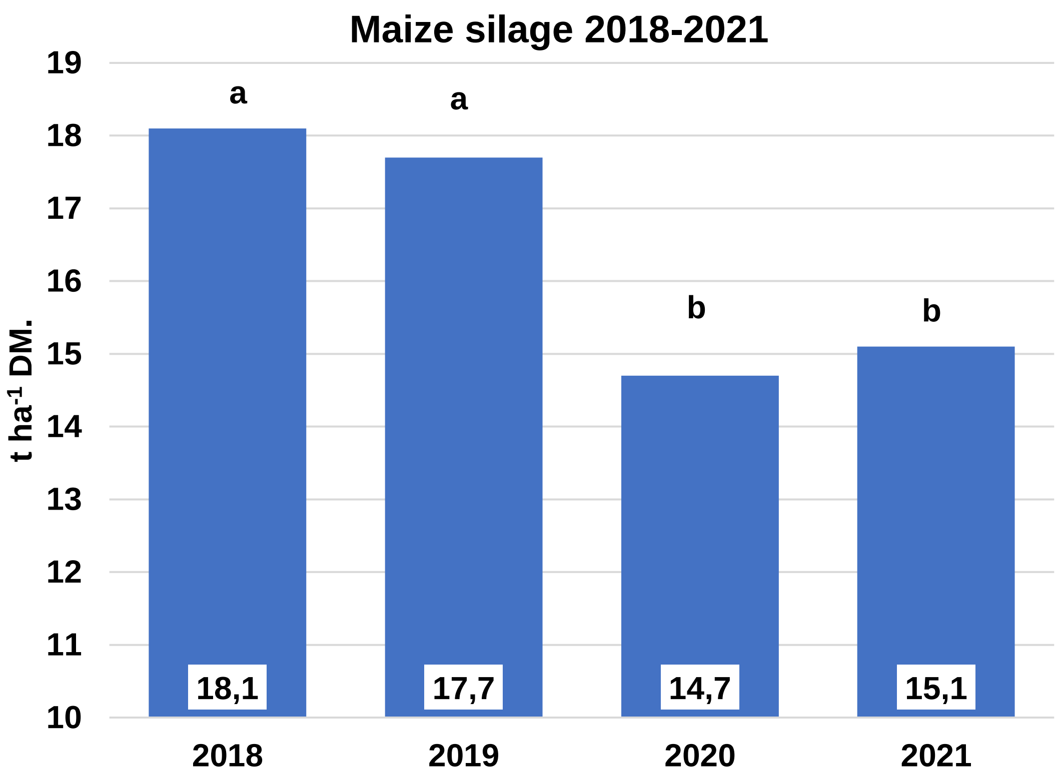


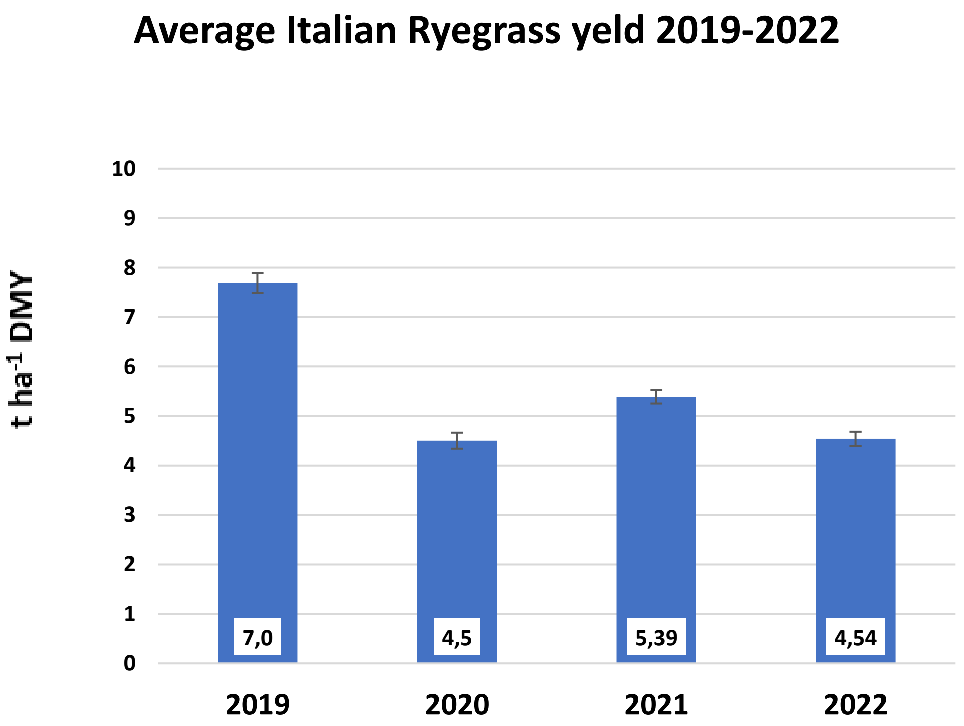




Crop not fertilized

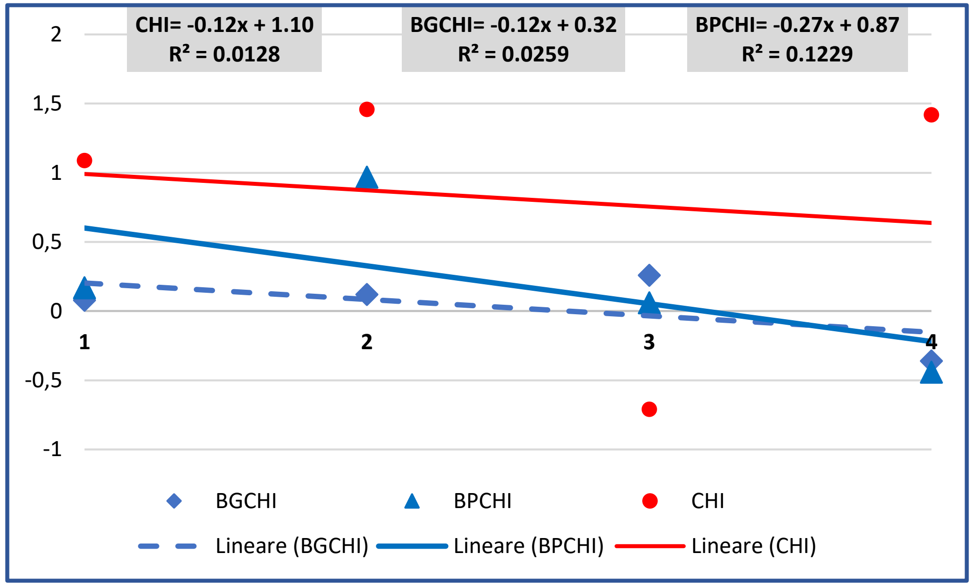
Average yeld 2018-2022



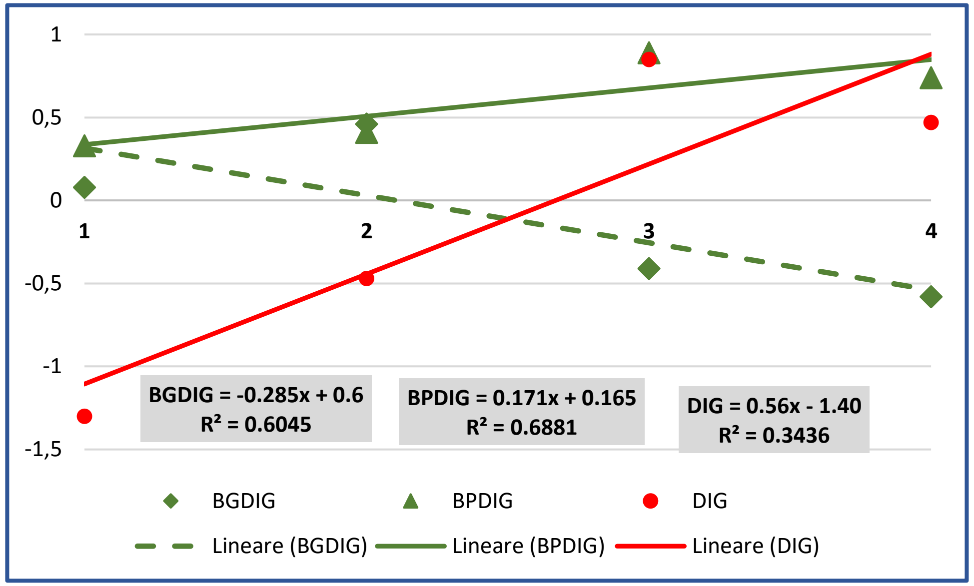


Maize silage yeld 2018-2021: standardized data of different treatments

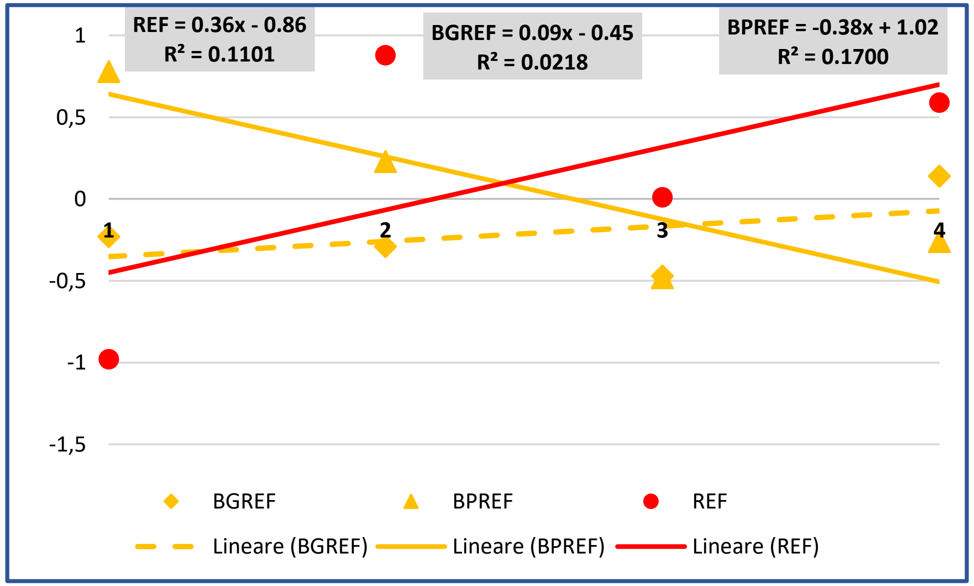
Biochar vs mineral fertilisation



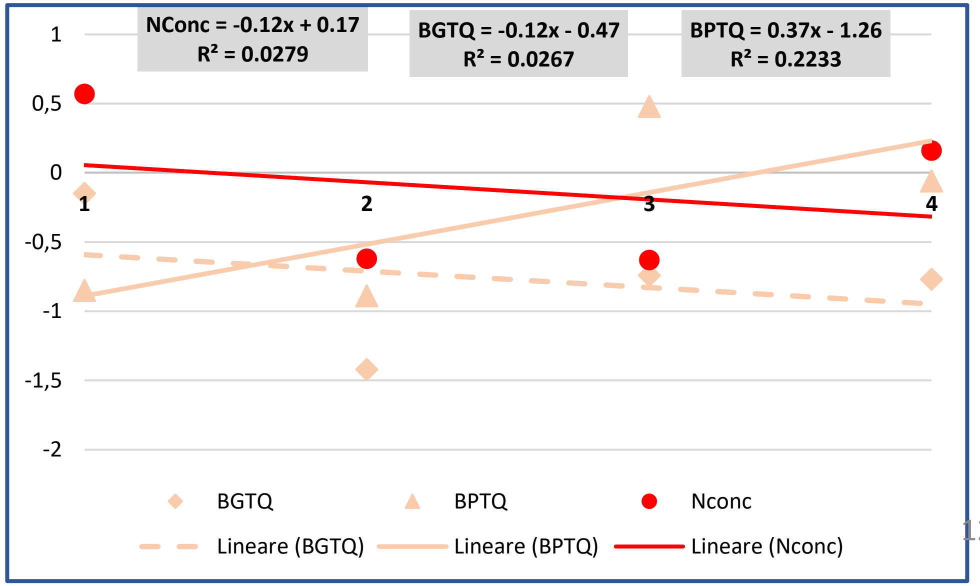
Biochar vs digestate



Biochar vs bovine slurry

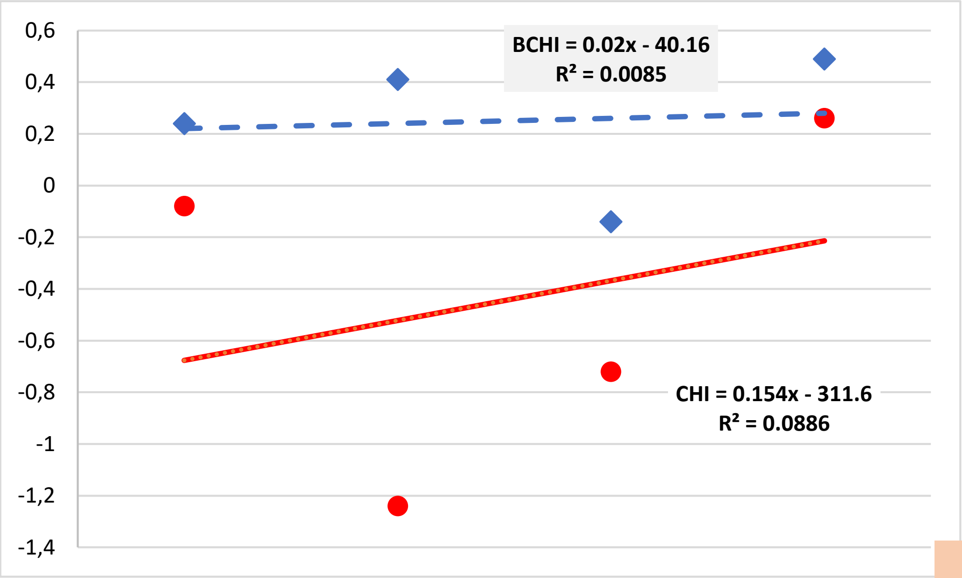


Biochar vs no fertilisation

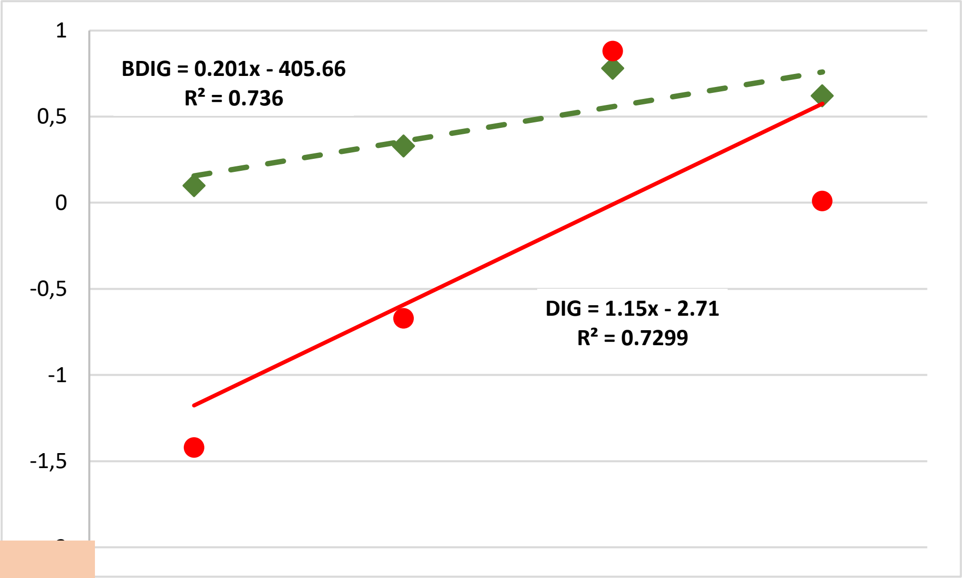


Italian ryegrass yeld 2018-2021: standardized data of different treatments

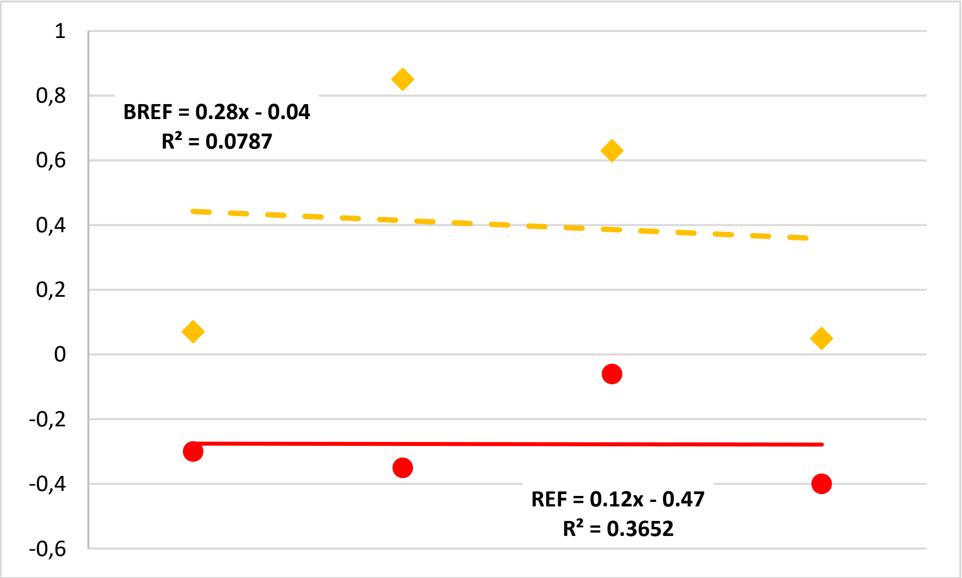
Biochar vs mineral fertilisation



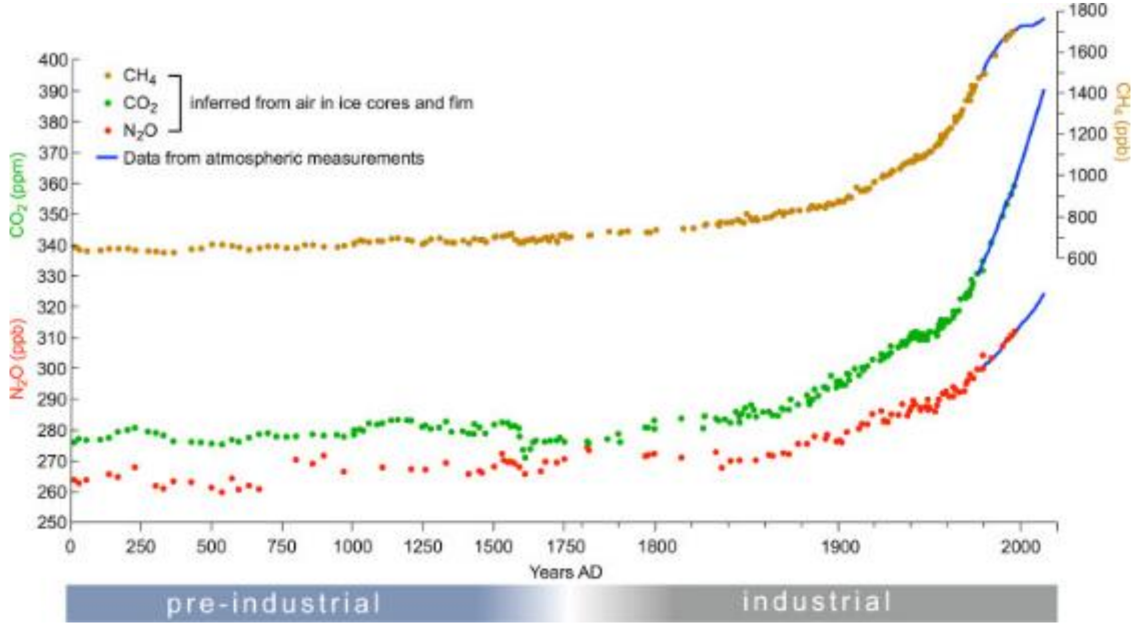
Biochar vs digestate



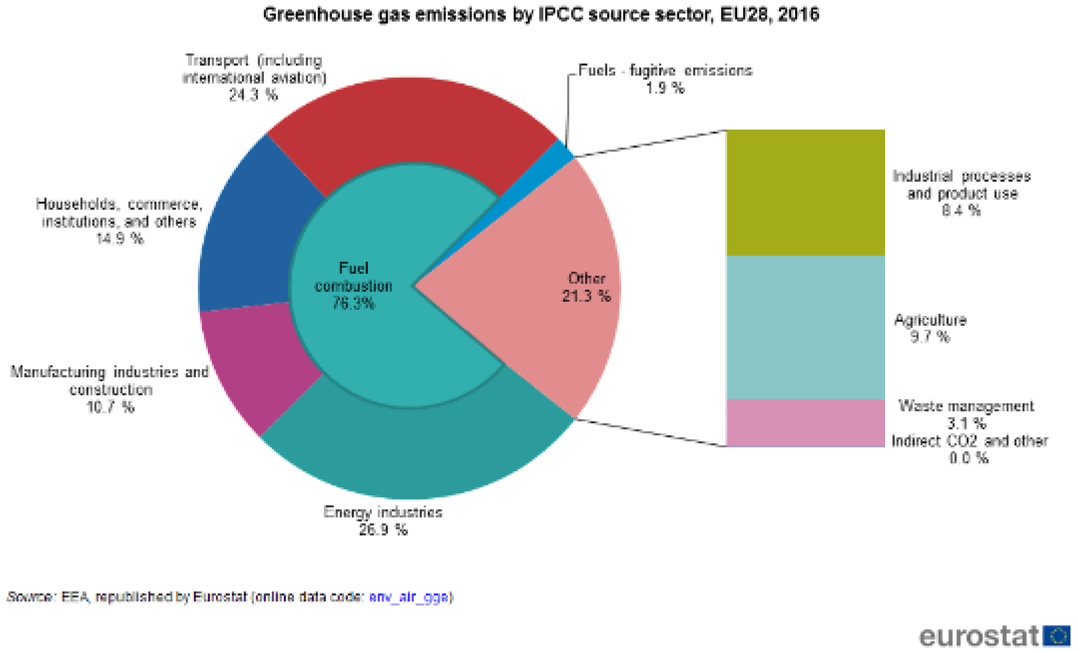
Biochar vs bovine slurry

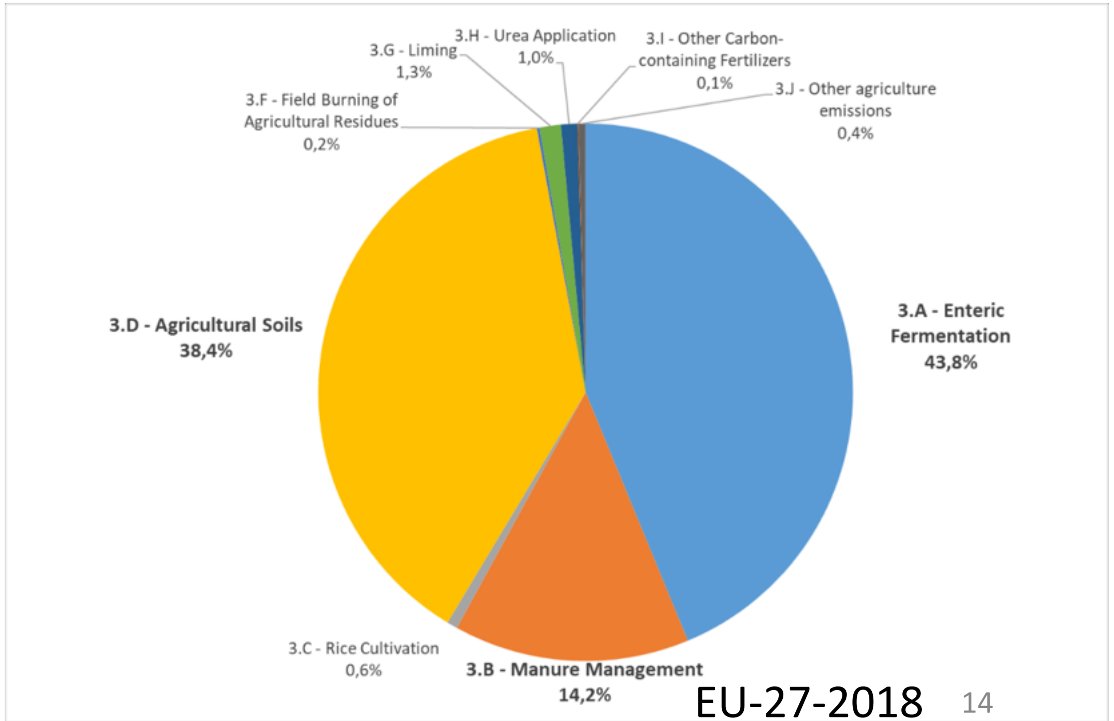


GREENHOUSE GAS EMISSION (GHGs)



Engel, 2018. Reference Module in Earth Systems and Environmental Sciences, 2018.

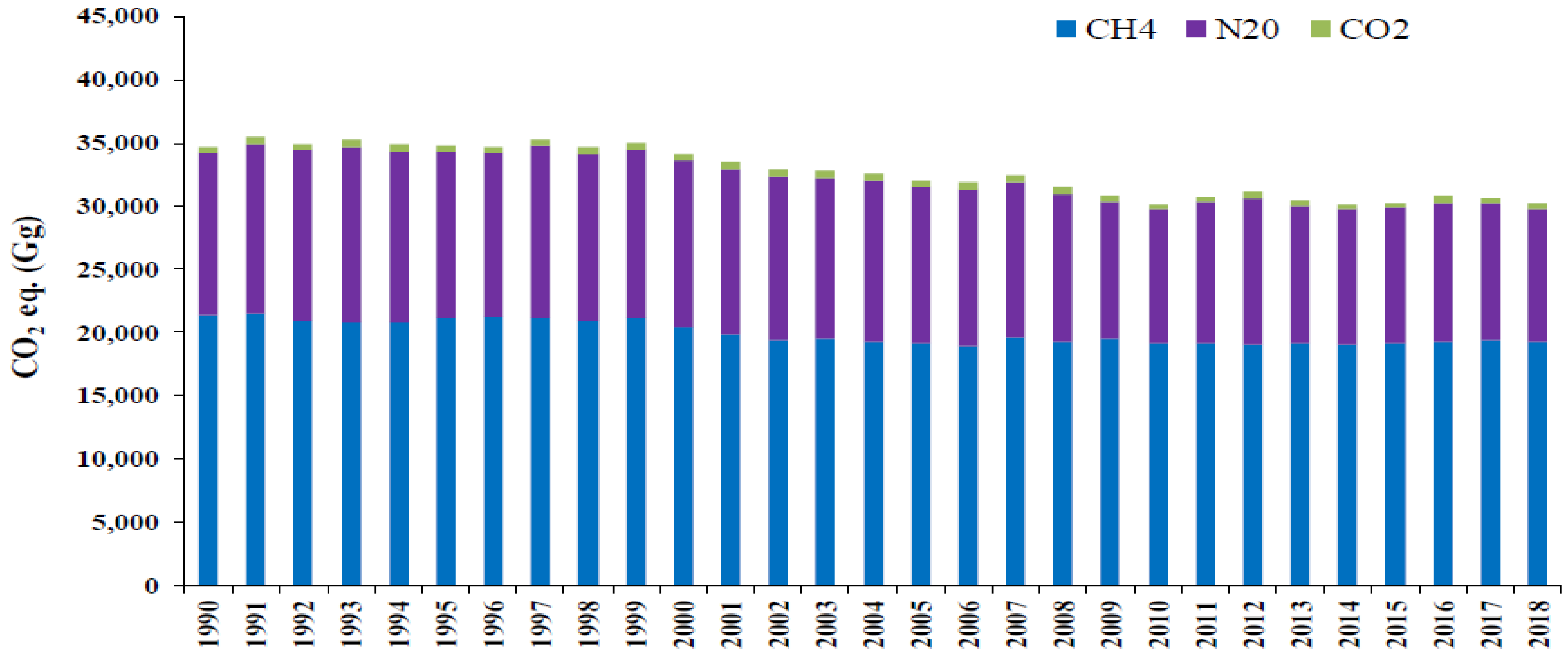




EU-27-2018

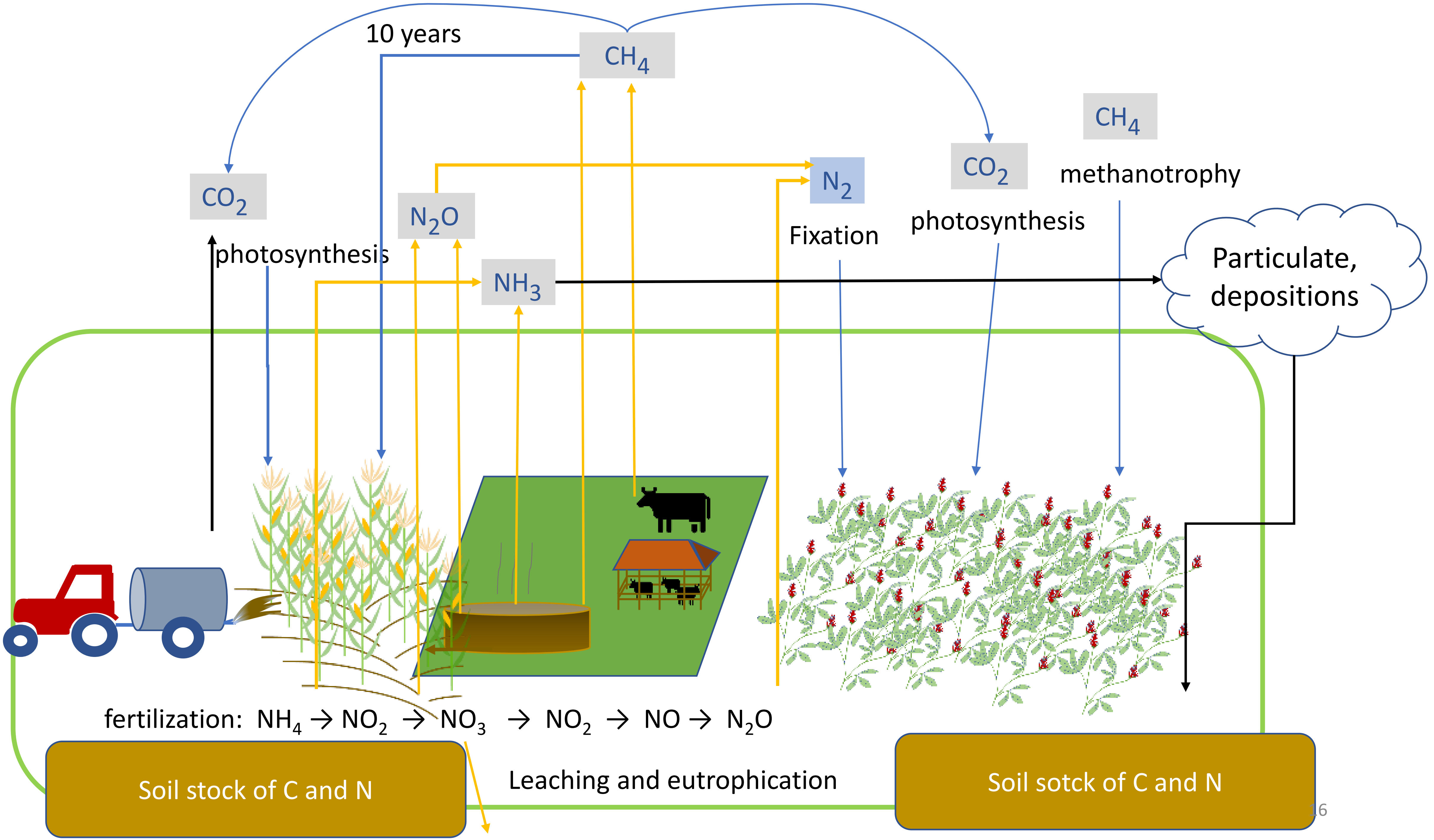
GREENHOUSE GAS EMISSION IN ITALY

CO_2 equivalents = $CO_2 + 34*CH_4 + 298*N_2O$



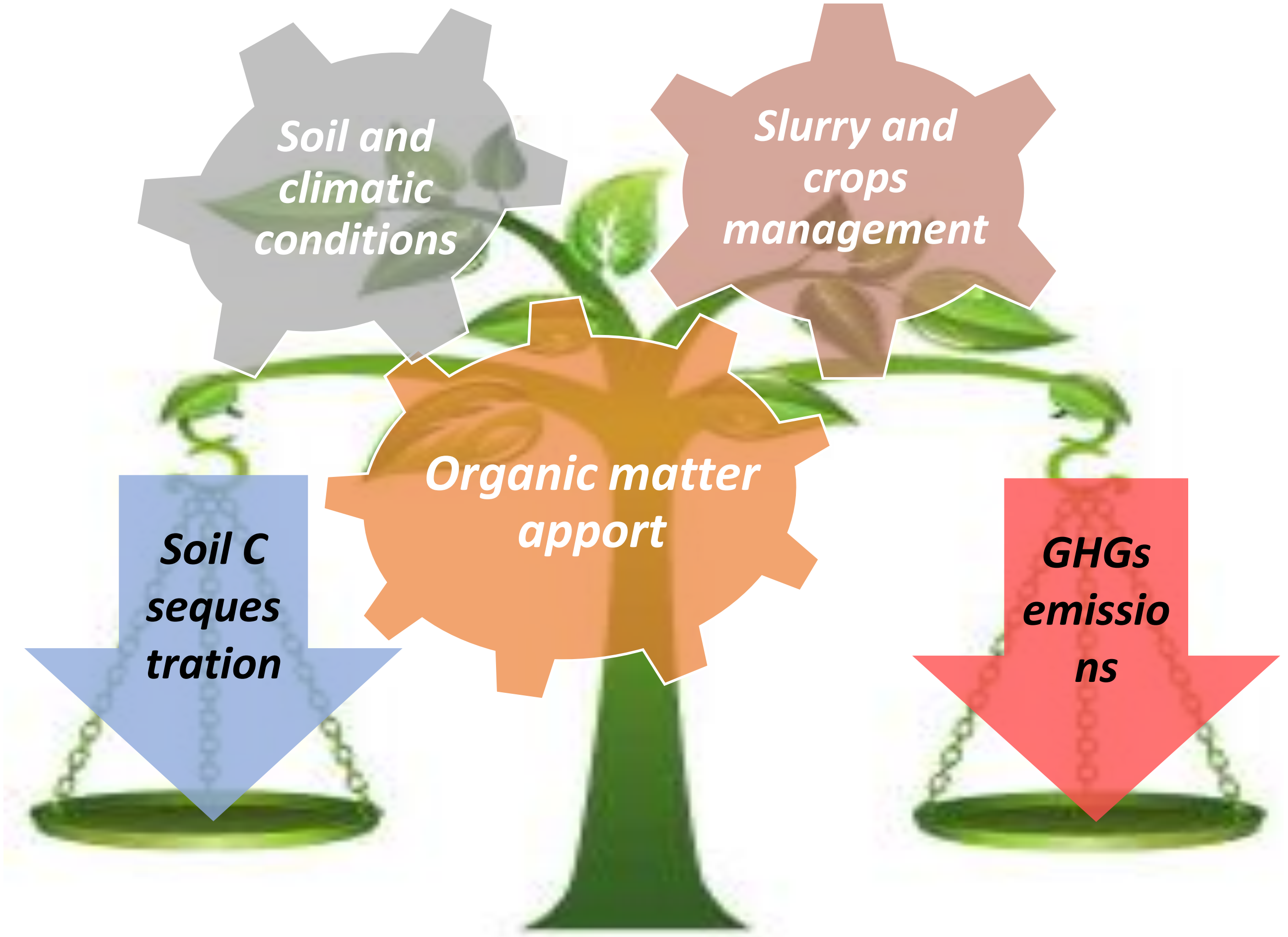
ISPRA 2020

reduction of the number of animals, agricultural surfaces and fertilizers

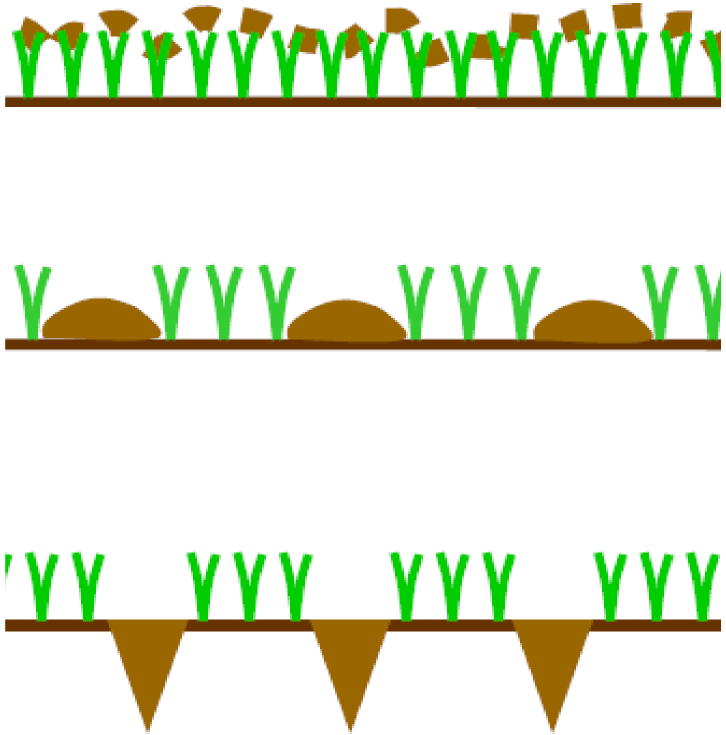


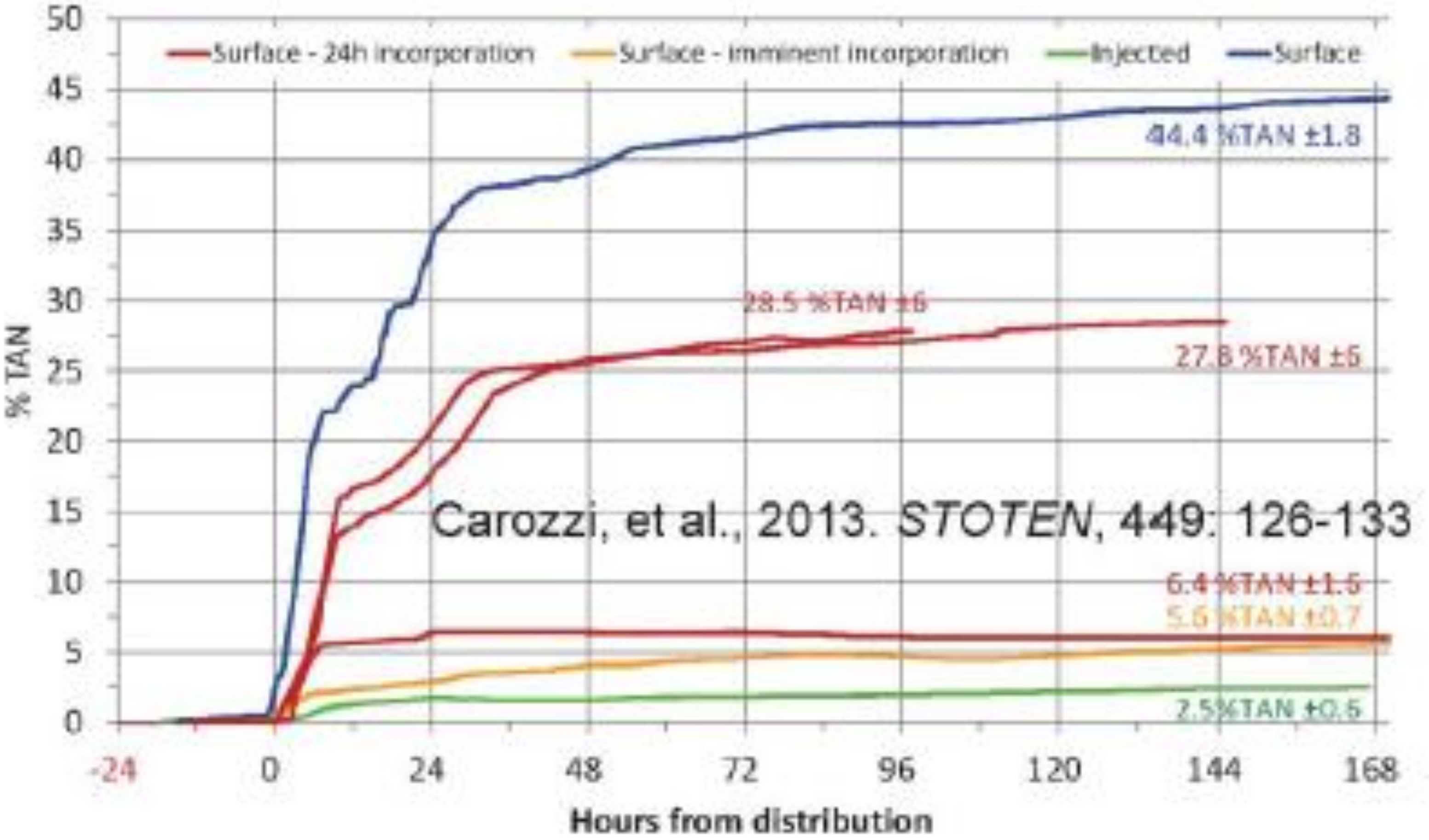
10 years
CH4
CO2
CH4
methanotrophy
CO2
N2O
N2
Fixation
photosynthesis
photosynthesis
NH3
Particulate,
depositions
fertilization: NH4 → NO2 → NO3 → NO2 → NO → N2O
Soil stock of C and N
Leaching and eutrophication
Soil sotck of C and N

SLURRY APPLICATION NOT ONLY POSITIVE



DIFFERENT APPLICATION OF SLURRY AND GHGs EMISSION

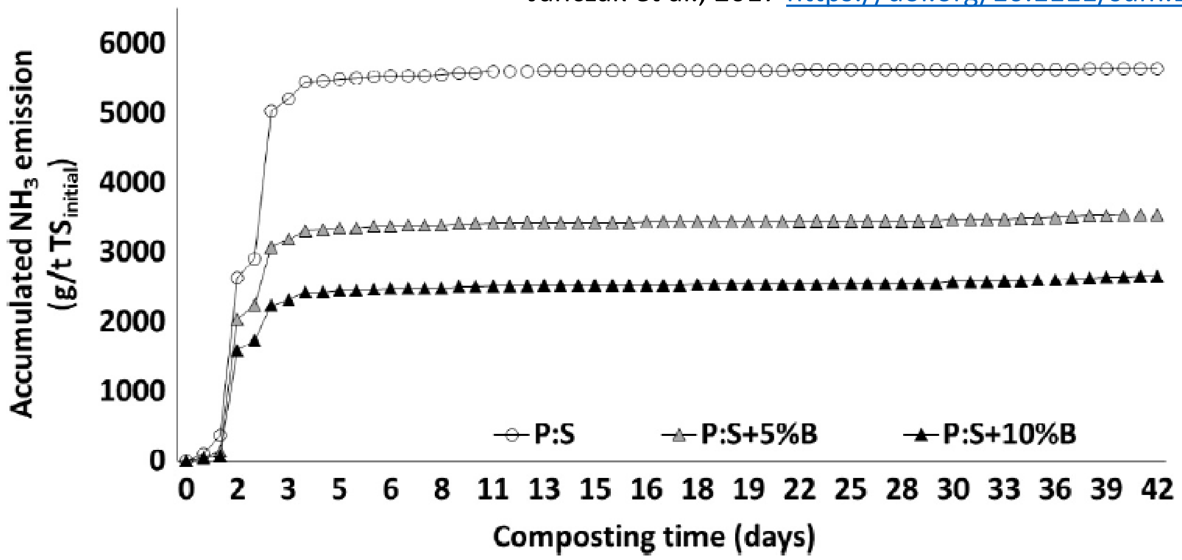


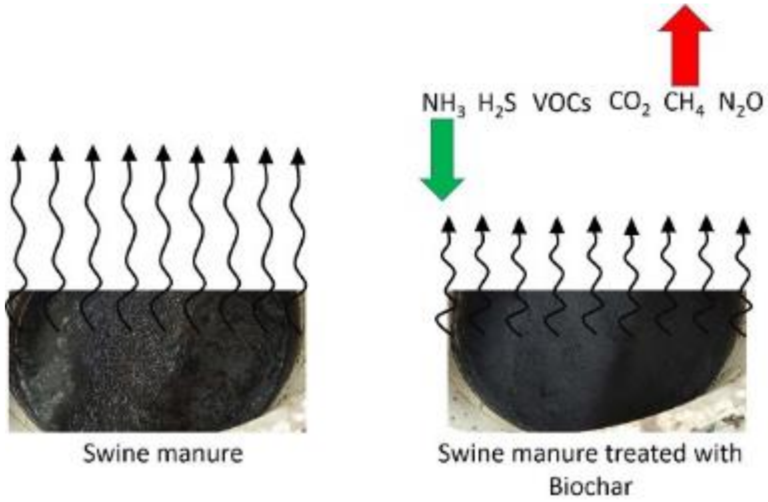


https://doi.org/10.1016/j.scitotenv.2012.12.082

GREENHOUSE GAS EMISSION AND BIOCHAR

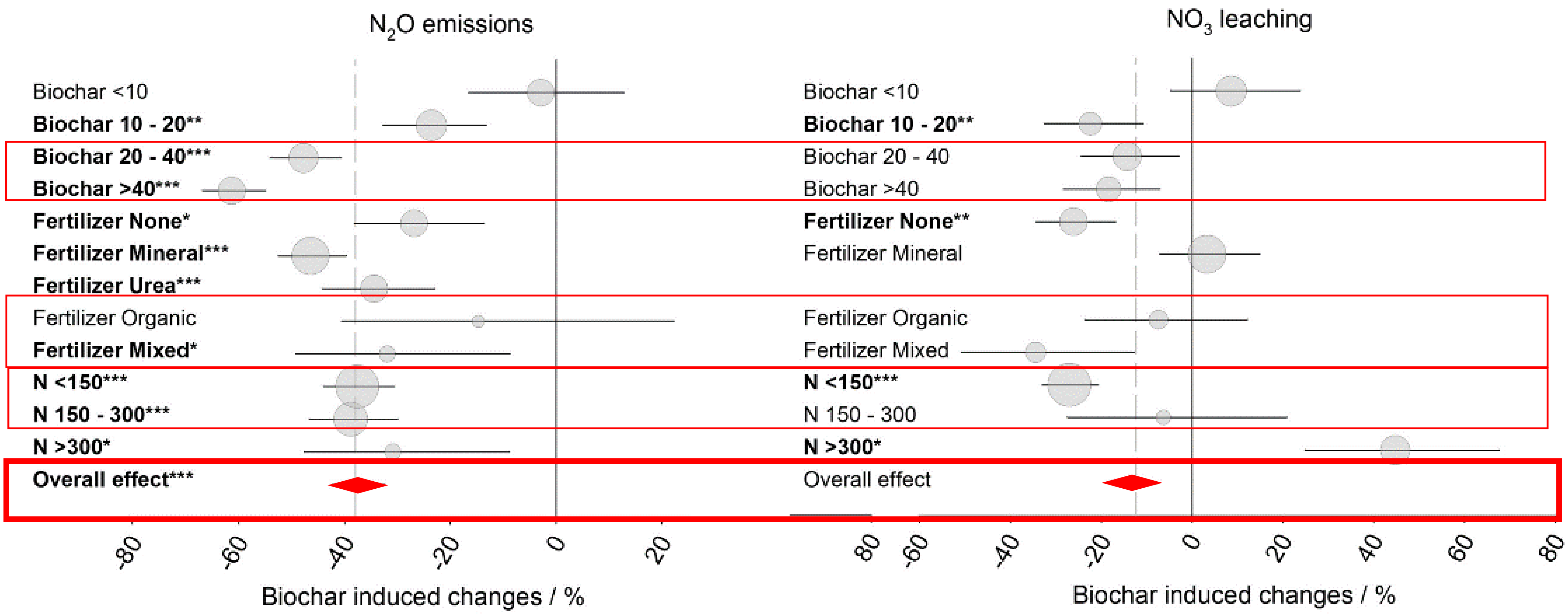
Schmidt, 2014 www.biochar-journal.org/en/ct/29
Maurer et al., 2017 https://doi.org/10.3390/su9060929
Janczak et al., 2017 https://doi.org/10.1111/sum.12465





Techniques to prevent emissions during storage:
- ✓ Reducing storage time
- ✓ Covering manure (semi-permeable or impermeable covers)
- ✓ Mechanical aeration
- ✓ Acidification
- ✓ Solid-liquid separation
- ✓ Anaerobic degestion
- ✓ Composting

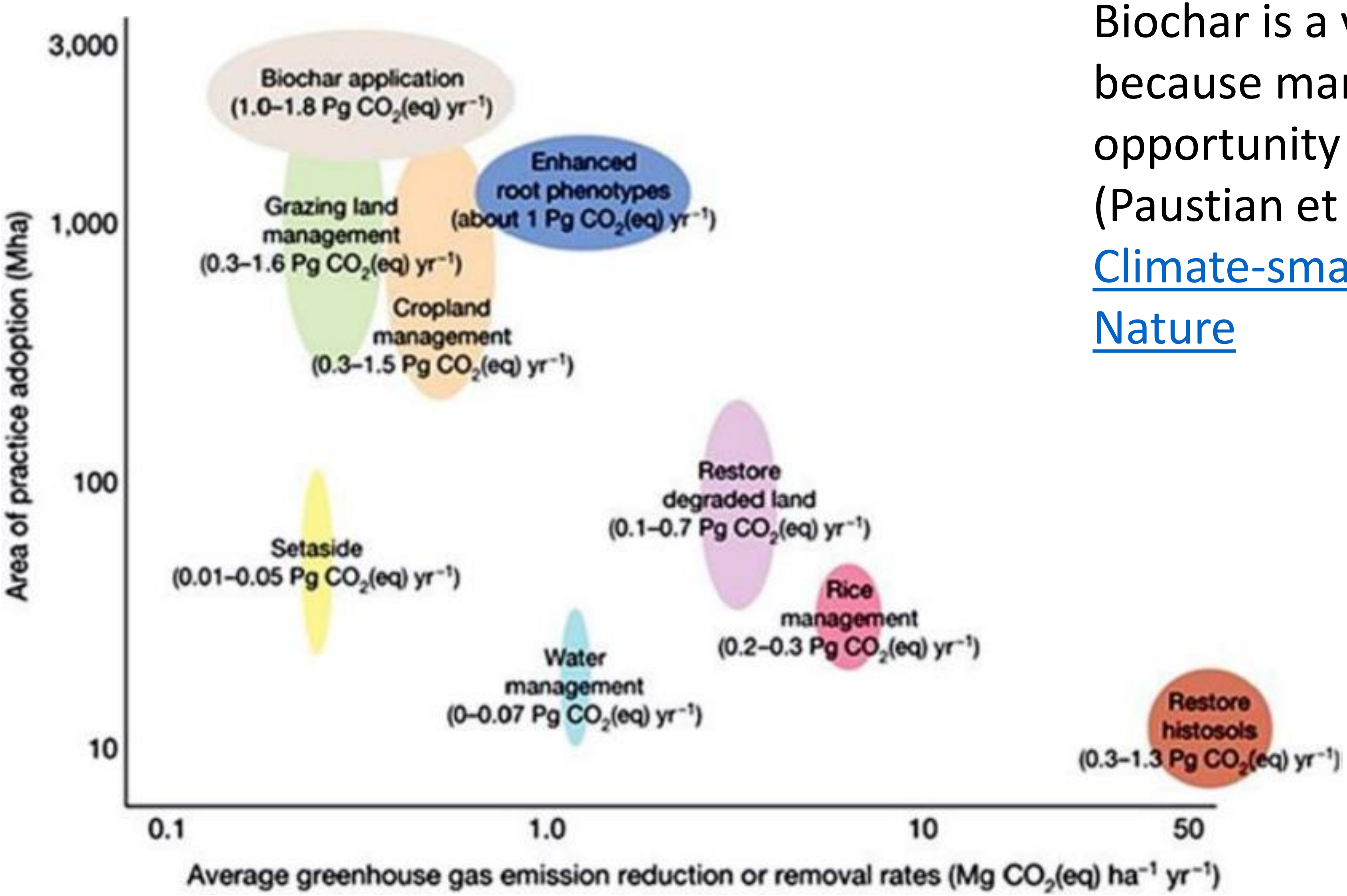
BIOCHAR APPLICATION TO SOIL REDUCE OF 38% GHGs EMISSION AND ALSO REDUCE OF 18% NO3 LEACHING



Biochar rate application [Mg ha^{-1}], kind of fertilizer [kg ha^{-1}]

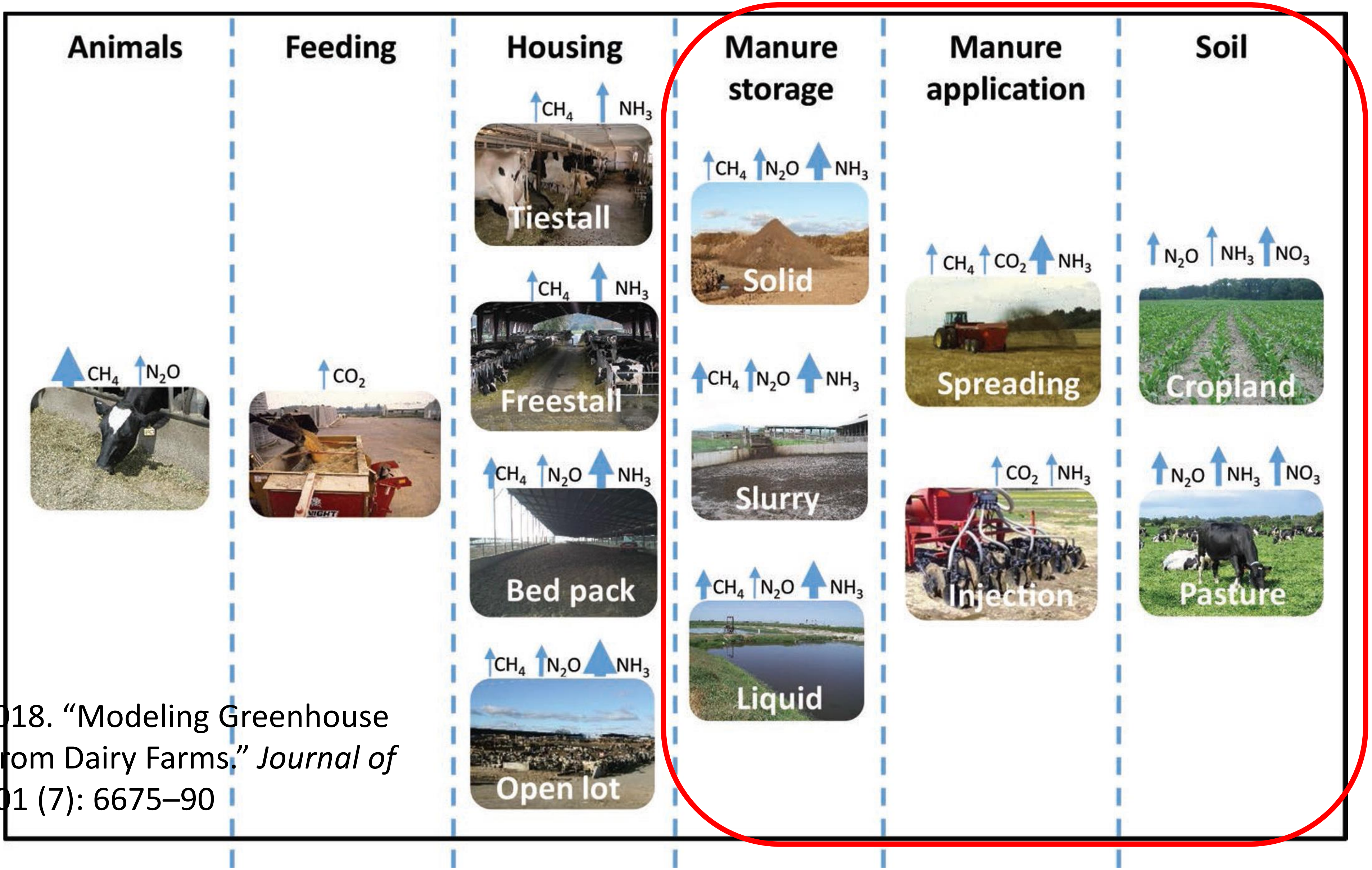
Borchard et al., 2019. https://doi.org/10.1016/j.scitotenv.2018.10.060

BIOCHAR USE FOR GHGs EMISSION REDUCTION AND FOR INCREASING OF CARBON STOCK IN SOIL



Biochar is a valid solution because many opportunity of application (Paustian et al., 2016) [Climate-smart soils | Nature]

GREENHOUSE GAS EMISSION: PROJECT FOCUS



Rotz, C. Alan. 2018. “Modeling Greenhouse Gas Emissions from Dairy Farms.” *Journal of Dairy Science* 101 (7): 6675–90

GREENHOUSE GAS EMISSIONS
FIELD MEASUREMENT METHODS

first 24 hours after application:
measurement of CO_2, CH_4, N_2O and NH_3 with static chambers and determination with portable FTIR instrumentation (GASMET DX 4040)

during the crop development:
measurement of CO_2, CH_4 and N_2O with static chambers and gas chromatographic determination (SHIMADZU 2014) in the 2018 and 2021 growing seasons (17 samplings per year)

GREENHOUSE GAS EMISSIONS
FIRST 24 HOURS

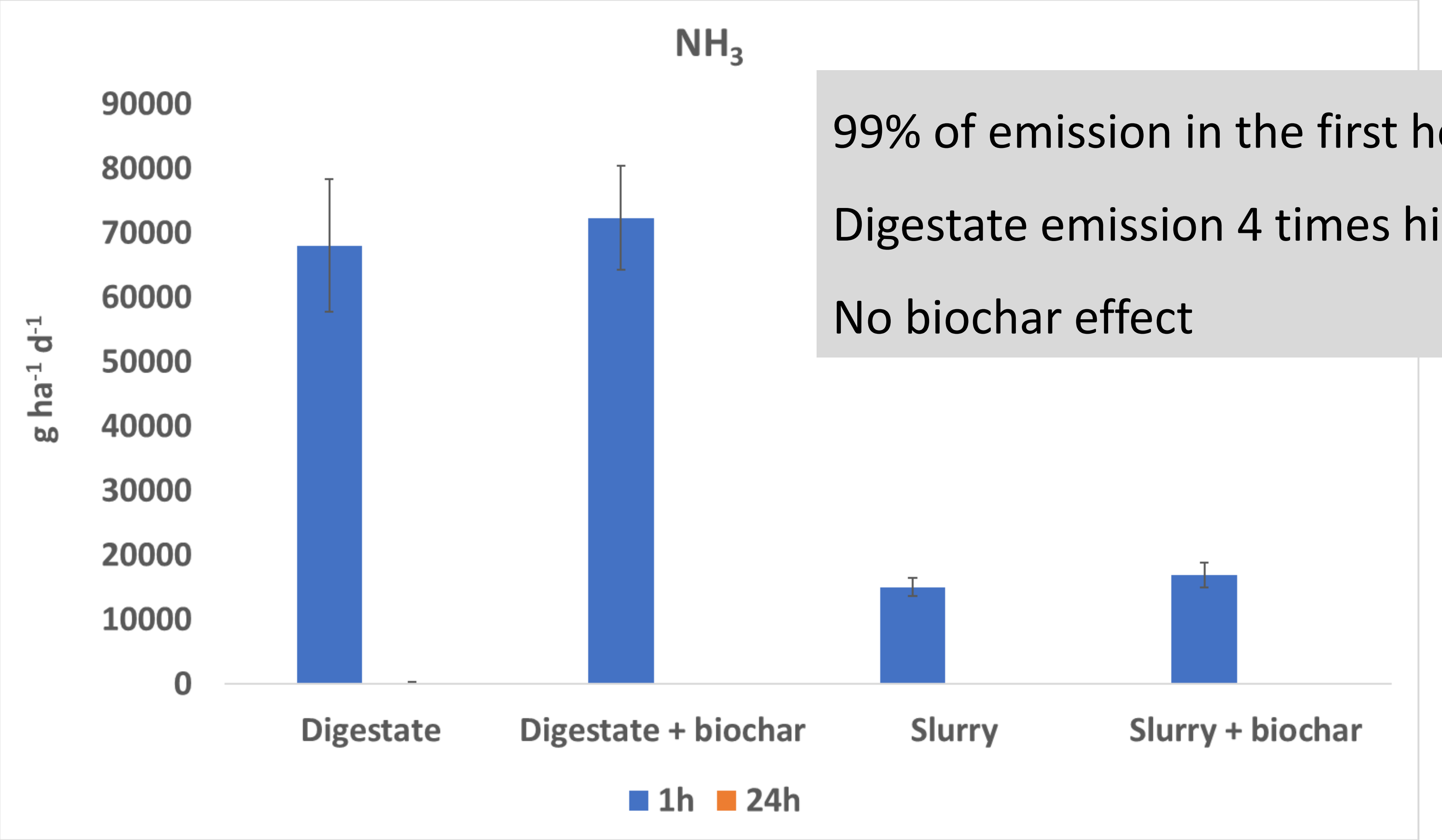
Digestate/slurry application

flow measurement in the first hour

soil tillage

flow measurement after 24 hours

GREENHOUSE GAS EMISSIONS
NH3 EMISSIONS

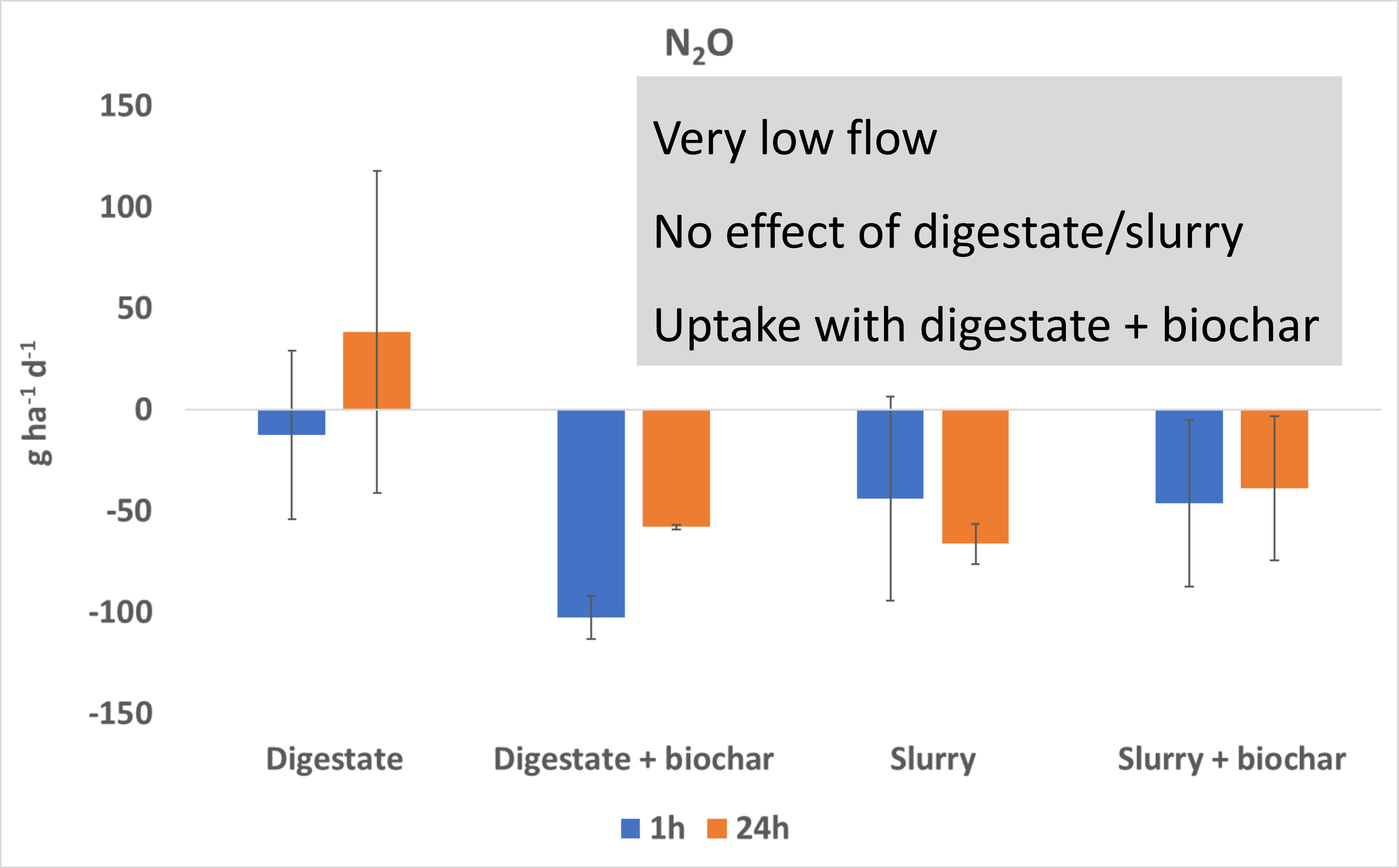


99% of emission in the first hour

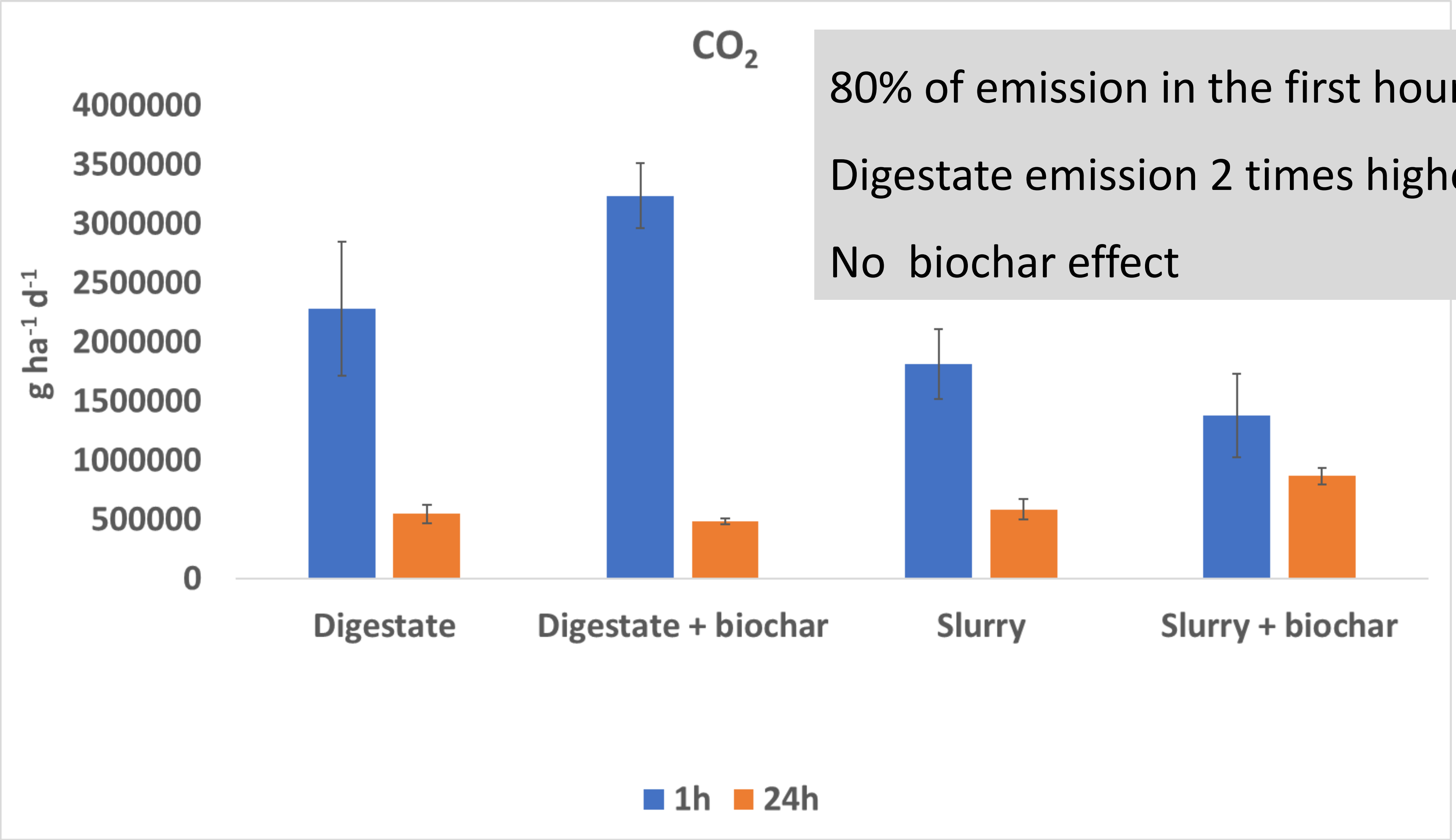
Digestate emission 4 times higher

No biochar effect

GREENHOUSE GAS EMISSIONS
N2O FLOW



GREENHOUSE GAS EMISSIONS
CO2 FLOW

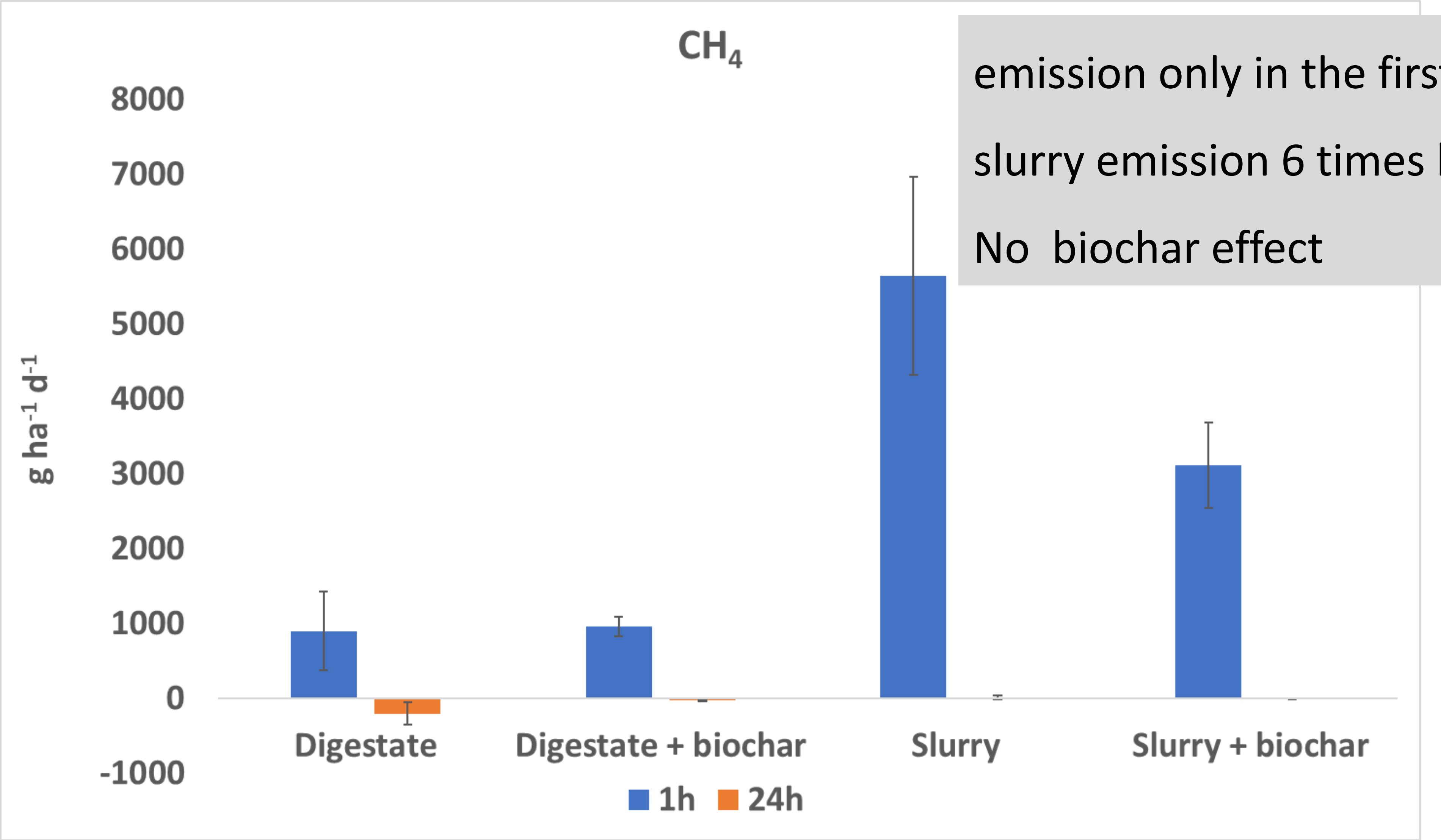


80% of emission in the first hour

Digestate emission 2 times higher

No biochar effect

GREENHOUSE GAS EMISSIONS
CH4 FLOW

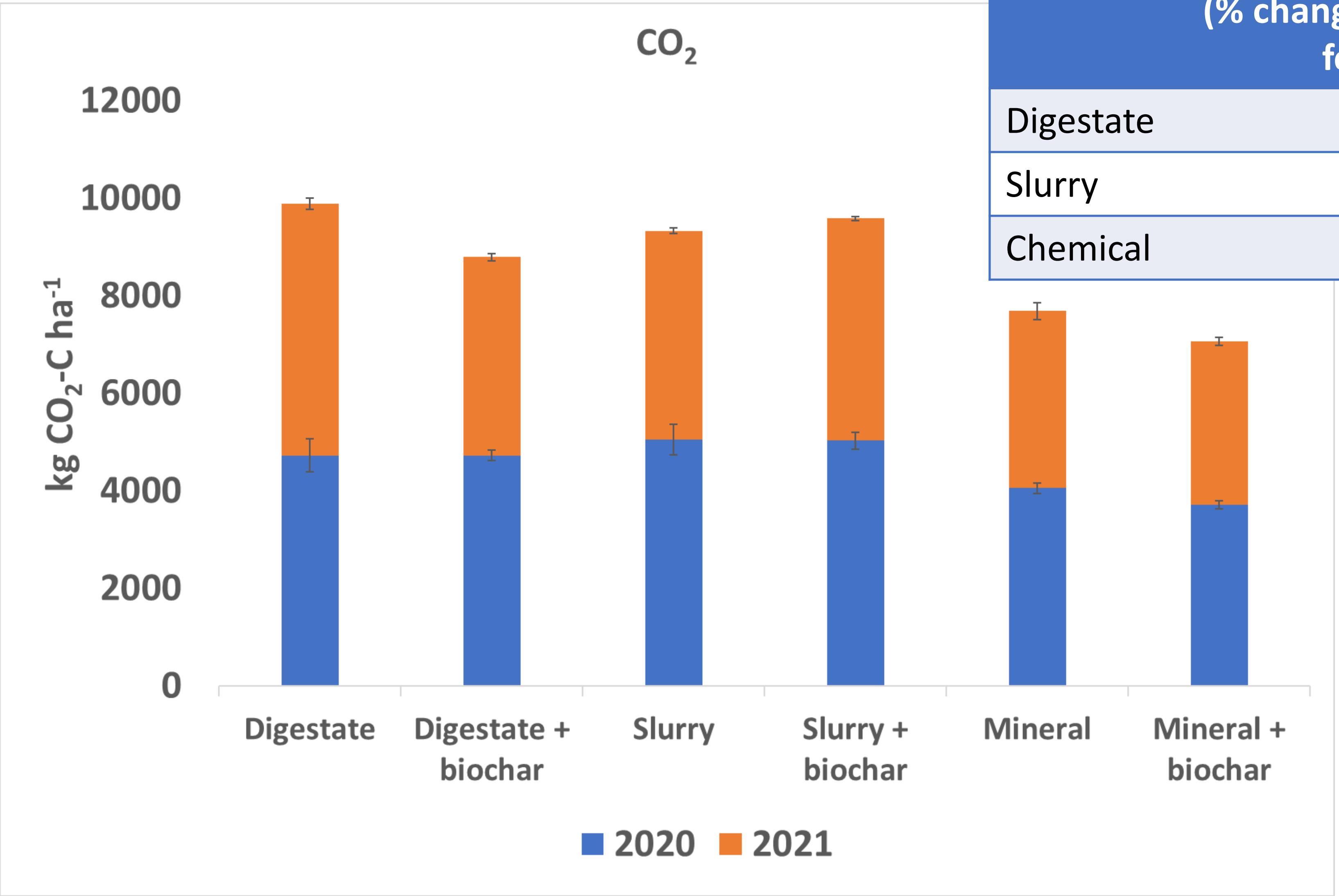


emission only in the first hour

slurry emission 6 times higher

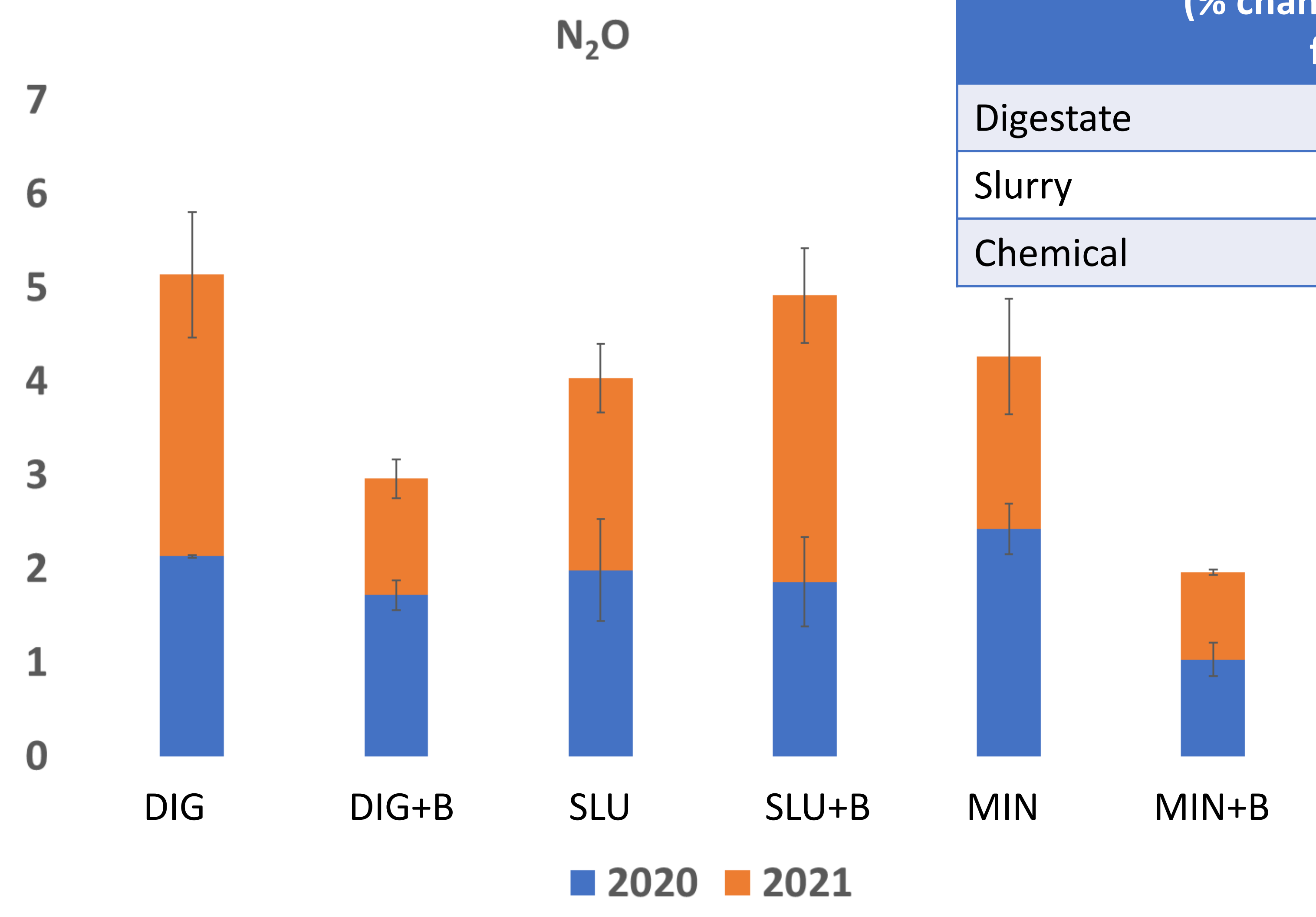
No biochar effect

GREENHOUSE GAS EMISSIONS - CUMULATIVE CO2 FLUXES



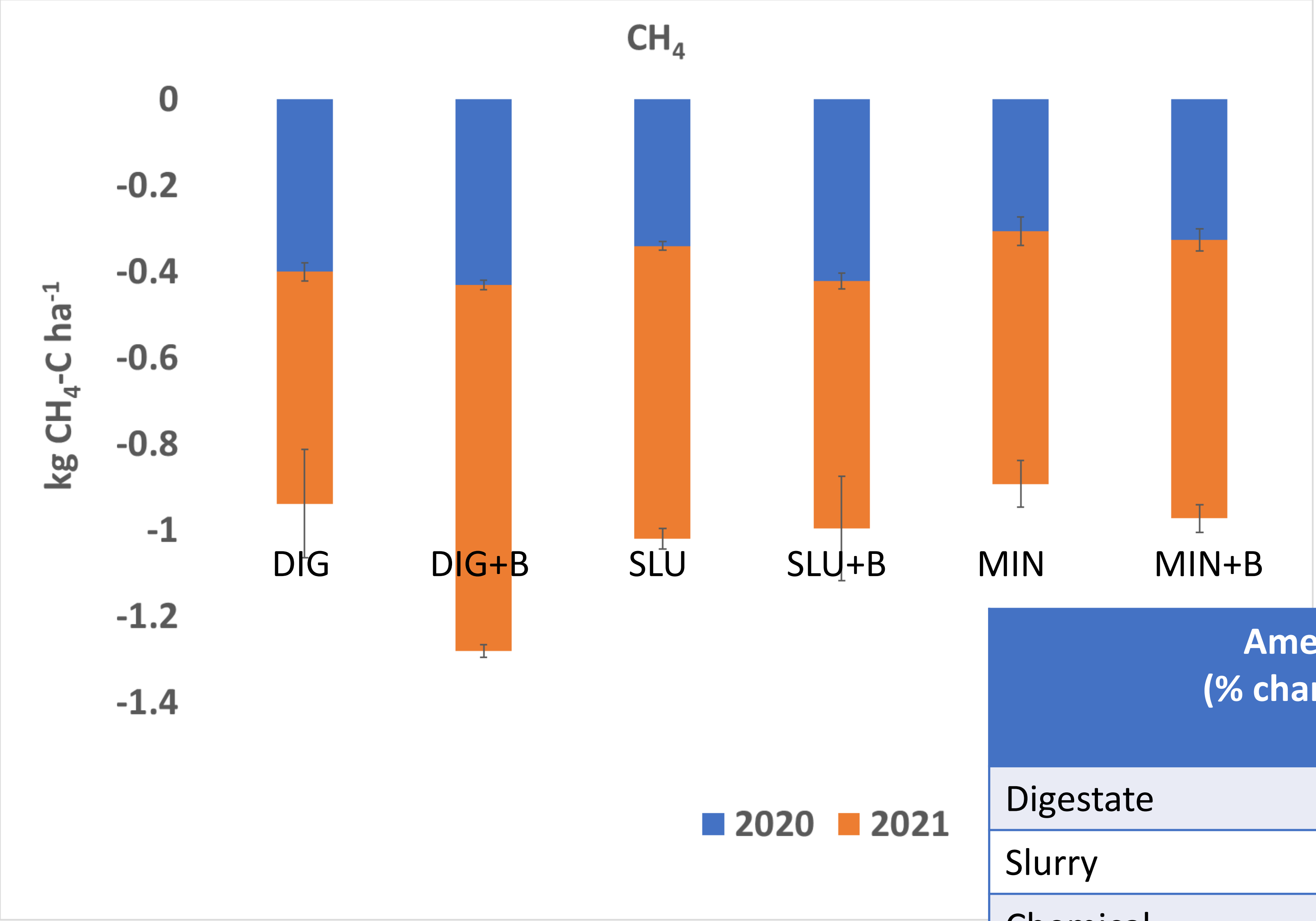
	Amendment effect (% change from mineral fertilizer)	Biochar effect (%)
Digestate	+29*	-11*
Slurry	+21*	+3
Chemical		-8*

GREENHOUSE GAS EMISSIONS - CUMULATIVE CO2 FLUXES



	Amendment effect (% change from mineral fertilizer)	Biochar effect (%)
Digestate	+20*	-42*
Slurry	-6	+22
Chemical		-54*

GREENHOUSE GAS EMISSIONS - CUMULATIVE CO2 FLUXES



	Amendment effect (% change from mineral fertilizer)	Biochar effect (% UPTAKE)
Digestate	+5	+36*
Slurry	+14	-2
Chemical		+9

GREENHOUSE GAS EMISSIONS STORAGE MEASUREMENT METHODS

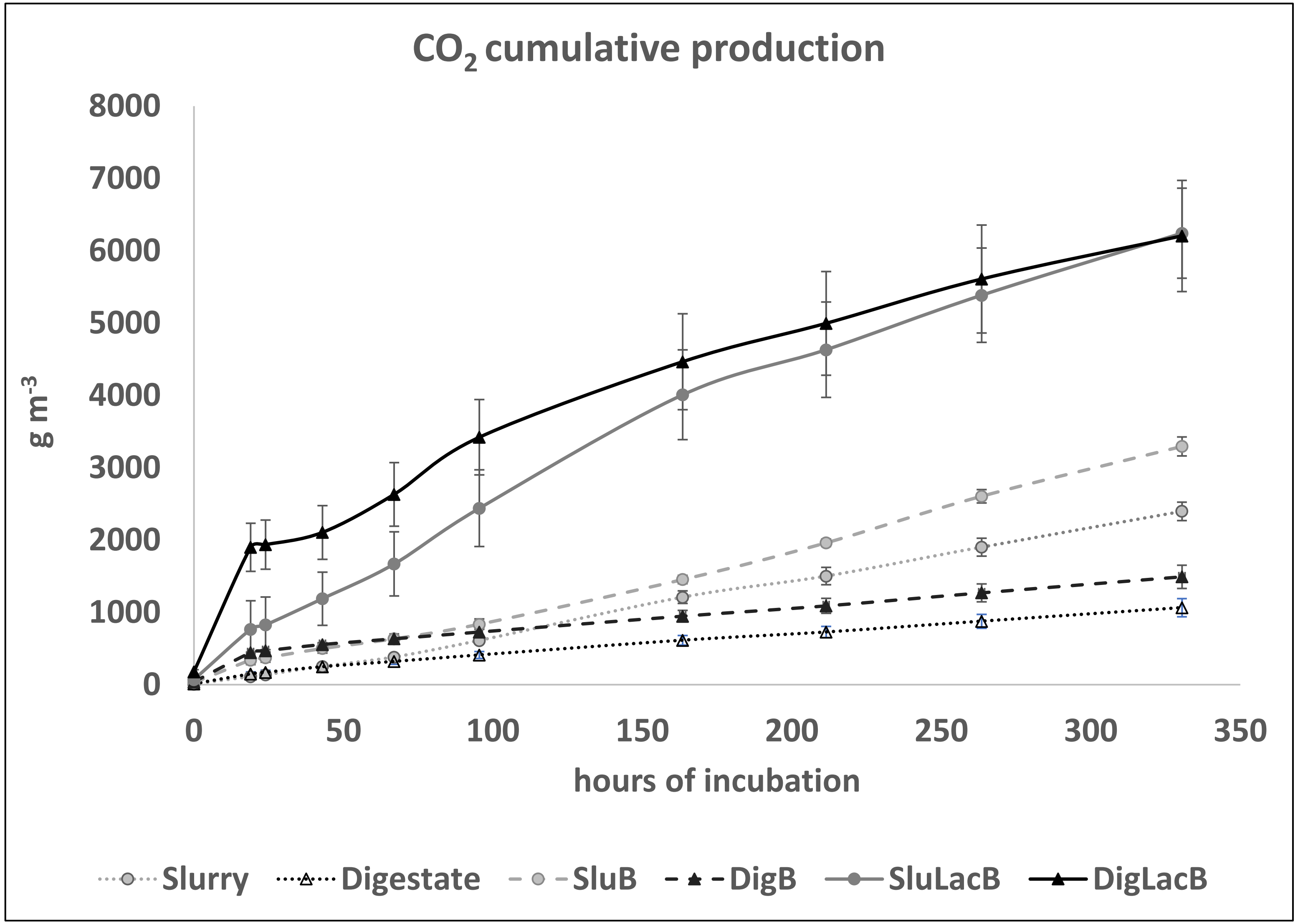
The experiment was conducted in a controlled environment (20 °C Temperature) at Fondazione Minoprio between February 21st and March 7th 2022. Eighteen tanks of 20 L capacity and hermetical closure have been prepared and positioned within the green-house in a randomized design in tri-replicates, following the setup reported in Table 1.

Table 1. Slurry, digestate and biochar characterization and their combination thesis.

Thesis	Moisture %	$N\text{-}NH_4^+$ (g kg^{-1})	Dig	Slu	DigB	SluB	DigLacB	SluLacB
Digestate	93.1	21.45	10 L		10 L		10 L	
Slurry	94.7	8.68		10 L		10 L		10 L
Biochar	68.3	0,09			500 g	500 g	500 g	500 g
Glucose							25 g	25 g
Saccarose							25 g	25 g
Lactic acid							20 mL	20 mL
Lactosil 3.0							0.03 g	0.03 g

Ten measurements have been conducted during the two weeks of storage, at 0, 19, 24, 43, 67, 96, 164, 212, 264 and 330 hours from the substrate's addition. The tanks have been left open between each measurement time to avoid saturation and were closed during measurements.

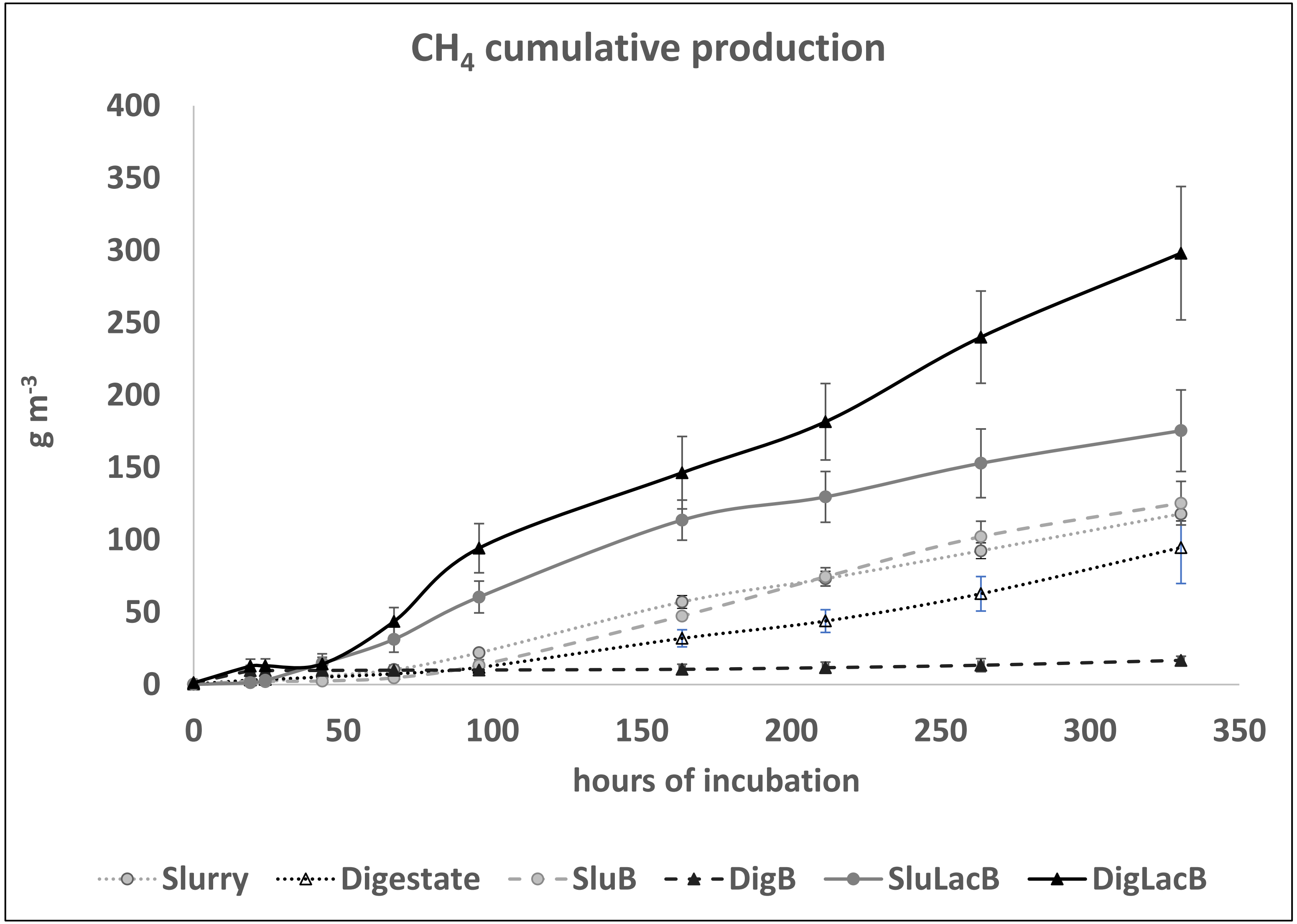
GREENHOUSE GAS EMISSIONS
CO2 FLUXES



SLURRY EMISSION 2 TIMES HIGHER THAN DIGESTATE (MORE CARBON CONTENT).
NO BIOCHAR EFFECT.

		DIFFERENCES %
SLURRY	+ BIOCHAR	+ 38
DIGESTATE	+ BIOCHAR	+ 40
SLURRY + BIOCHAR	+ LACTIC ACID	+ 89
DIGESTATE + BIOCHAR	+ LACTIC ACID	+ 316

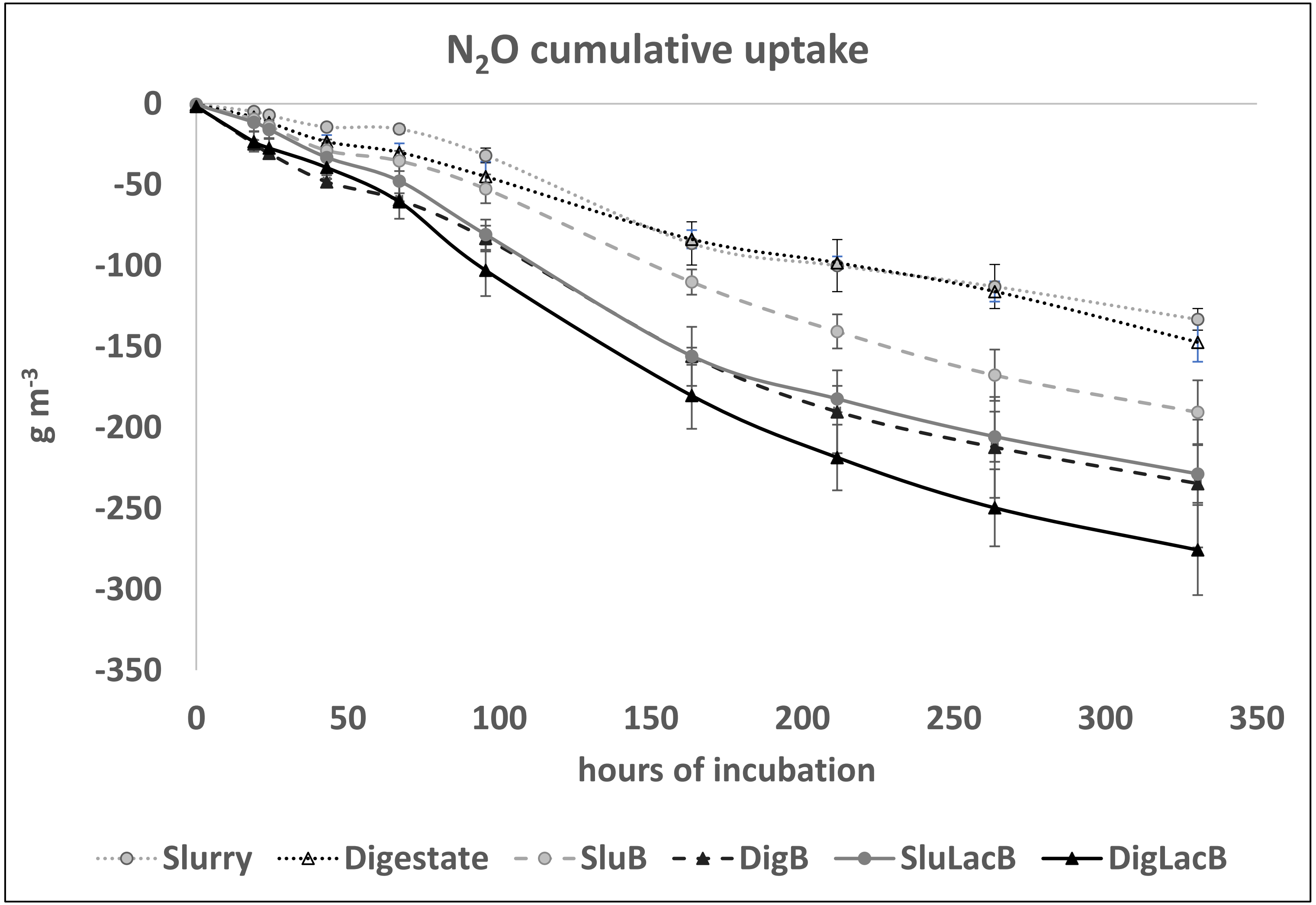
GREENHOUSE GAS EMISSIONS
CH4 FLUXES



SLURRY EMISSION SIMILAR TO DIGESTATE.
BIOCHAR CLEARS DIGESTATE EMISSION.

		DIFFERENCES %
SLURRY	+ BIOCHAR	+ 6
DIGESTATE	+ BIOCHAR	- 82
SLURRY + BIOCHAR	+ LACTIC ACID	+ 40
DIGESTATE + BIOCHAR	+ LACTIC ACID	+ 1690

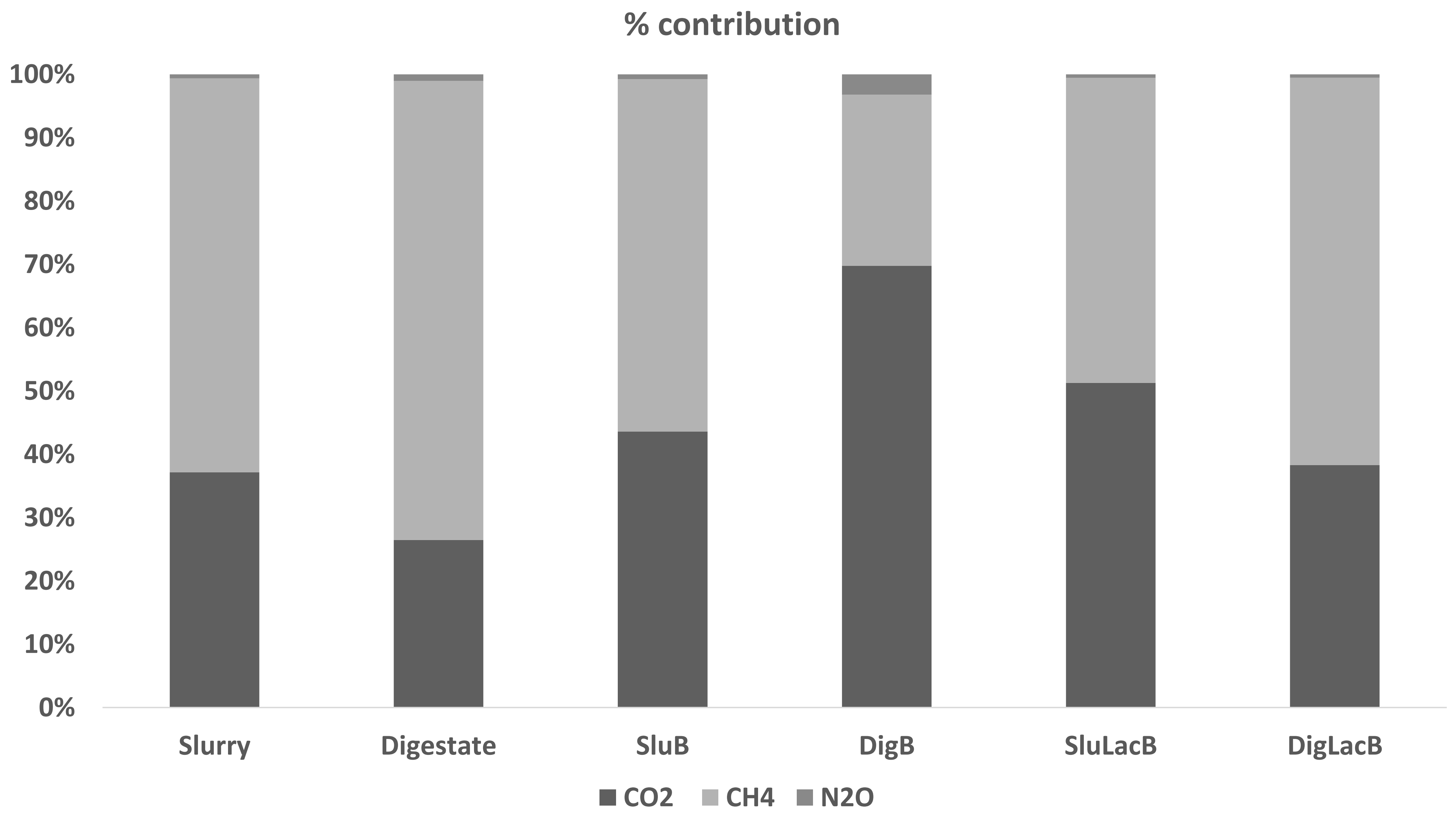
GREENHOUSE GAS EMISSIONS
N2O FLUXES



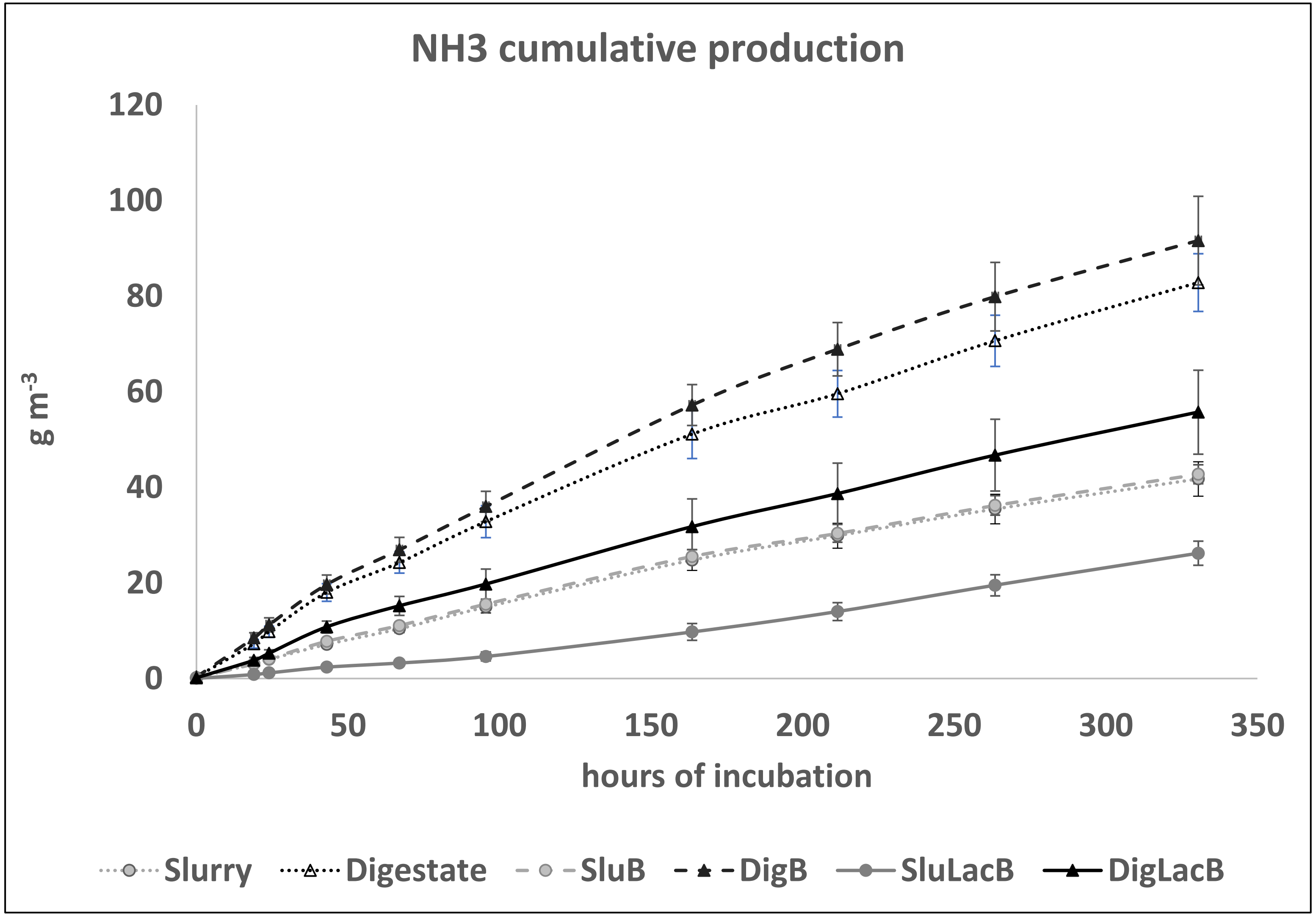
N2O UPTAKE FROM DIGESTATE AND SLURRY. BIOCHAR INCREASES UPTAKE.

		DIFFERENCES %
SLURRY	+ BIOCHAR	+ 43
DIGESTATE	+ BIOCHAR	+ 59
SLURRY + BIOCHAR	+ LACTIC ACID	+ 20
DIGESTATE + BIOCHAR	+ LACTIC ACID	+ 18

GREENHOUSE GAS EMISSIONS: GWP



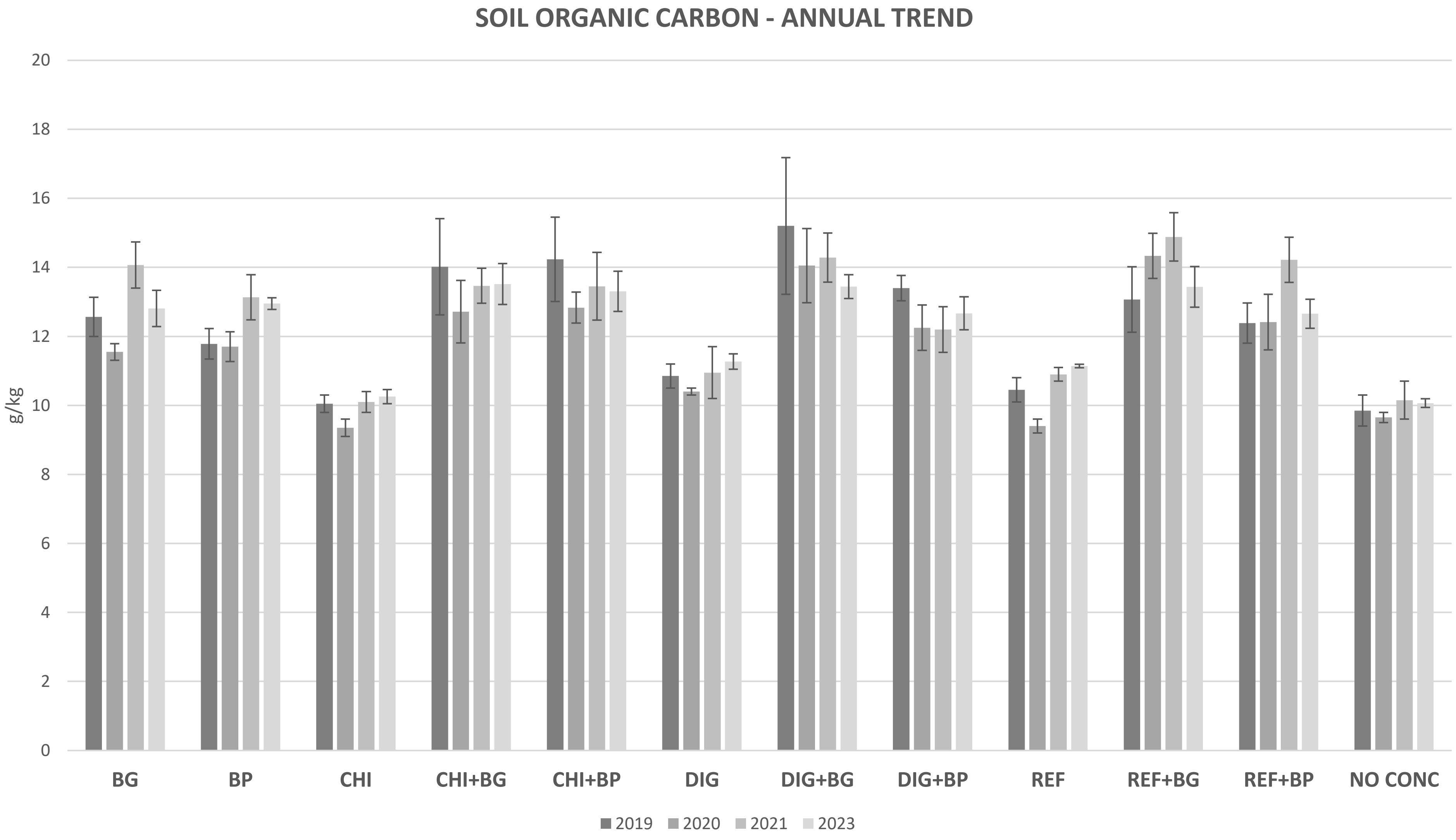
GREENHOUSE GAS EMISSIONS
NH3 FLUXES



DIGESTATE EMISSION 3TIMES HIGHER THAN SLURRY (MORE NITROGEN CONTENT). BIOCHAR REDUCE SLURRY EMISSION.

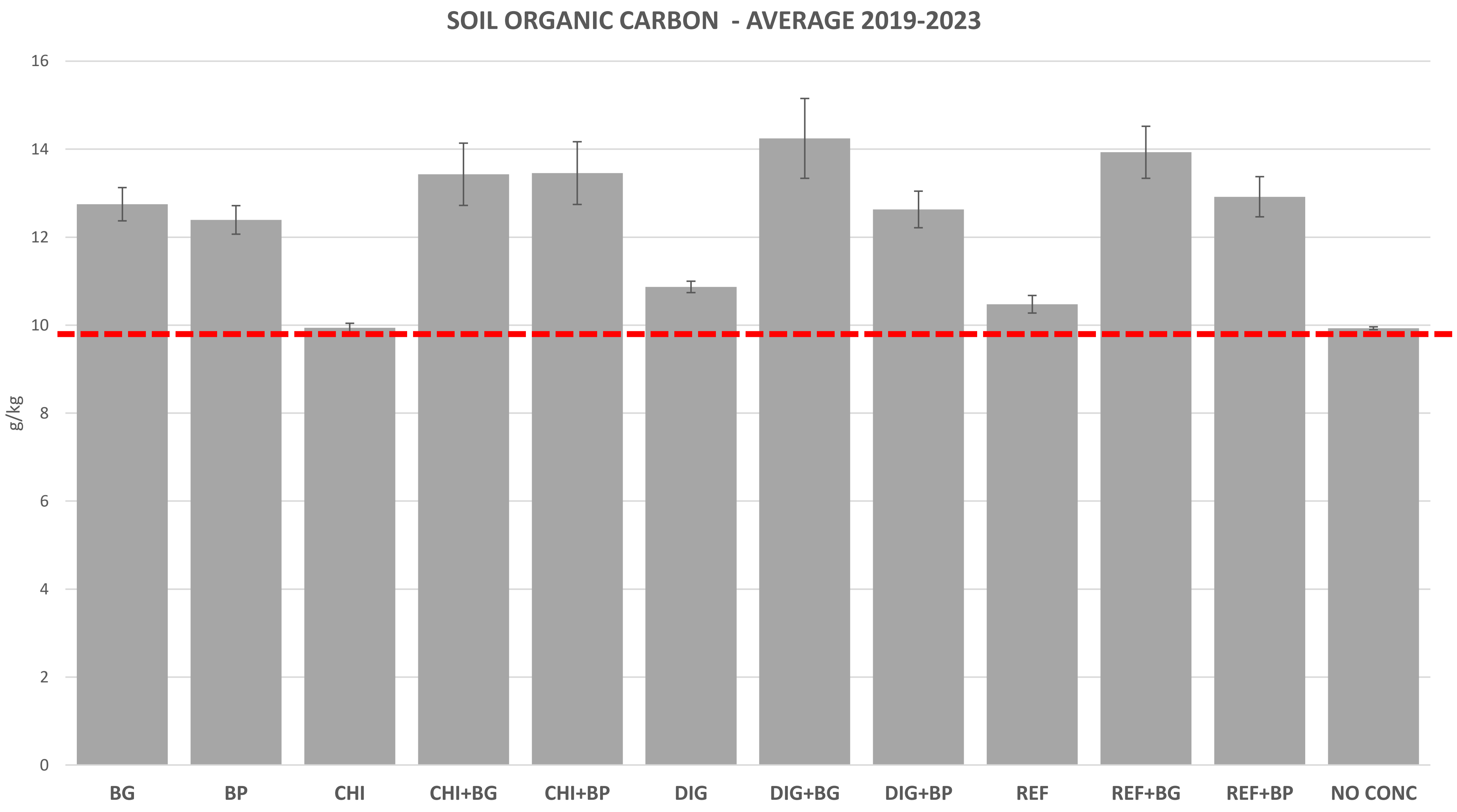
		DIFFERENCES %
SLURRY	+ BIOCHAR	+ 2
DIGESTATE	+ BIOCHAR	+ 11
SLURRY + BIOCHAR	+ LACTIC ACID	- 39
DIGESTATE + BIOCHAR	+ LACTIC ACID	- 39

SOIL CARBON STOCK



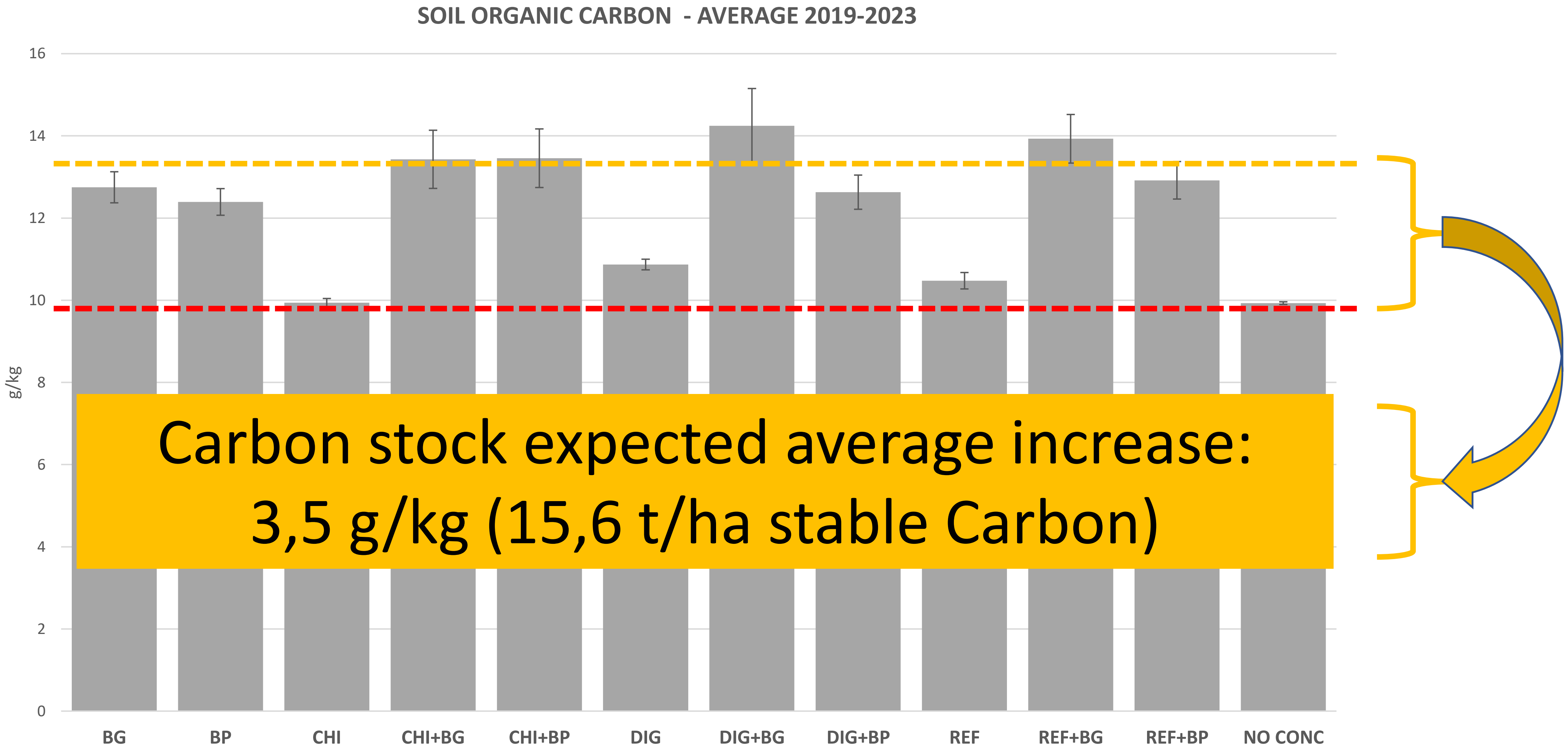
BG: gasification biochar – BP: pyrolysis biochar (bars is standard error)

SOIL CARBON STOCK



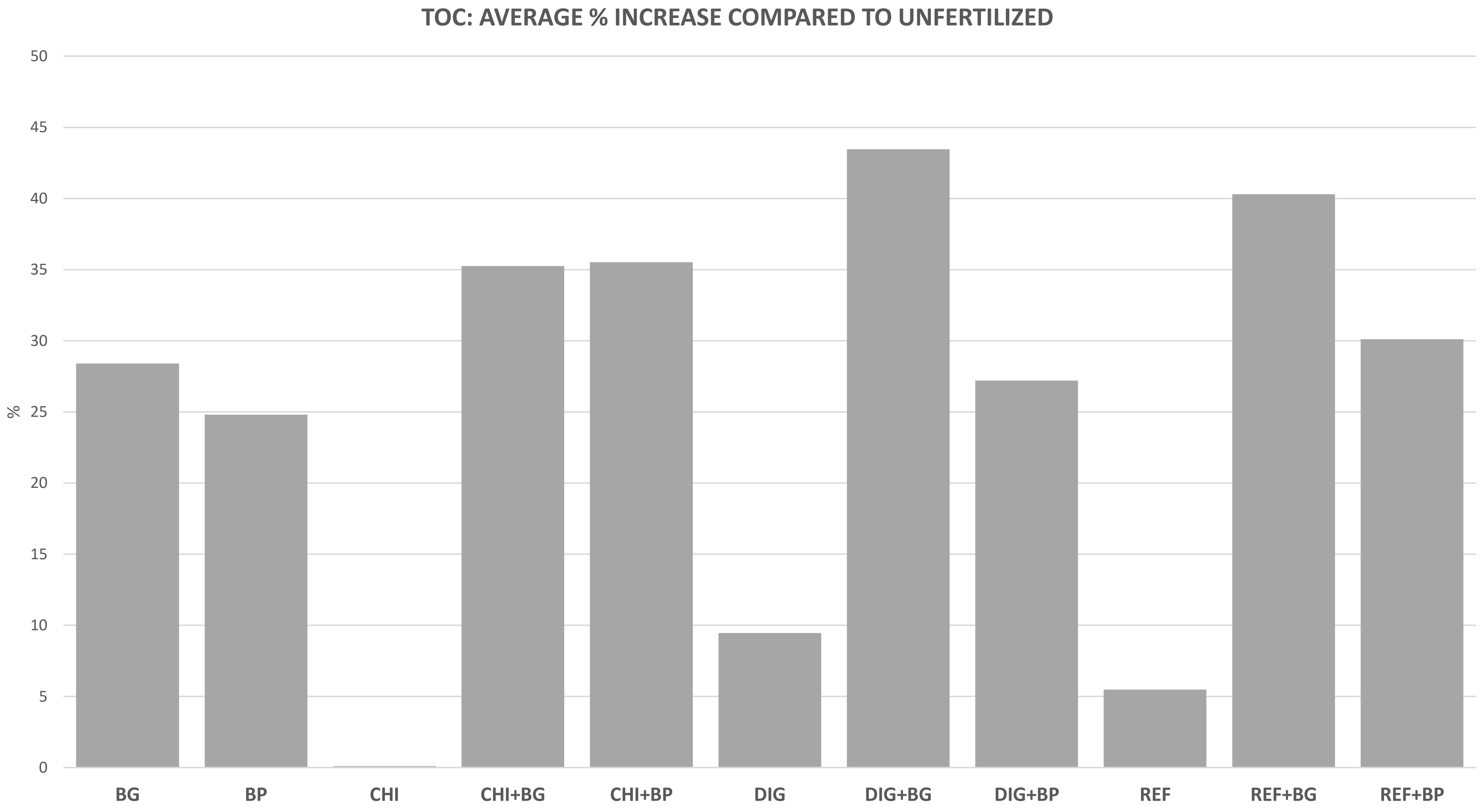
BG: gasification biochar – BP: pyrolysis biochar (bars is standard error)

SOIL CARBON STOCK



BG: gasification biochar – BP: pyrolysis biochar (bars is standard error)

SOIL CARBON STOCK



BG: gasification biochar – BP: pyrolysis biochar

WHAT EMERGES FROM THE PROJECT?

(RESULTS ARE VALID IN THE ANALYZED CONTEXT)

- GENERALLY, BIOCHAR DID NOT AFFECT SILAGE MAIZE YELD
- ASSOCIATION BETWEEN DIGESTATE AND BIOCHAR TENDS TO INCREASE SILAGE MAIZE YELD AND EAR COMPONENT
- THE PRESENCE OF BIOCHAR INCREASE THE YELD OF THE NO FERTILIZED SECOND CROP (ITALIAN RYEGRASS)
- BIOCHAR INCREASE CARBON STOCK IN SOIL
- BIOCHAR INCREASE SOIL CATION EXCHANGE CAPACITY AND, THEREFORE, THE ABILITY TO RETAIN ELEMENTS AND REDUCE LEACHING
- BIOCHAR CLEARLY REDUCE CO_2 EMISSIONS ONLY IN THE FOURTH YEAR (SUPPRESSION OF MINERALIZATION ONCE THE LABILE CARBON WAS CONSUMED?)
- THE DECREASE OF CO_2 EMISSION WAS VISIBLE WITH DIGESTATE AND NOT WITH SLURRY (LARGER AMOUNT OF FRESH LABILE CARBON IN SLURRY?)
- BIOCHAR WAS EFFECTIVE IN REDUCING N_2O EMISSIONS DERIVED FROM MINERAL FERTILIZATION AND DIGESTATE IN SILAGE MAIS CROP (EXCESS IN LABILE ORGANIC CARBON AND NITROGEN APPLICATION REDUCE SUCH INFLUENCE)
- APPLICATION OF BIOCHAR DURING STORAGE REDUCE CH_4 EMISSION AND N_2O UPTAKE; NO EFFECT ON NH_3 EMISSION
- THE COMBINATION OF BIOCHAR WITH LACTIC ACID CONTAINS THE INCREASE OF CH_4, REDUCE NH_3 AND INCREASE N_2O UPTAKE