A Mechanistic Look at Biochar's Effect on GHG Emissions Across Agricultural Soils

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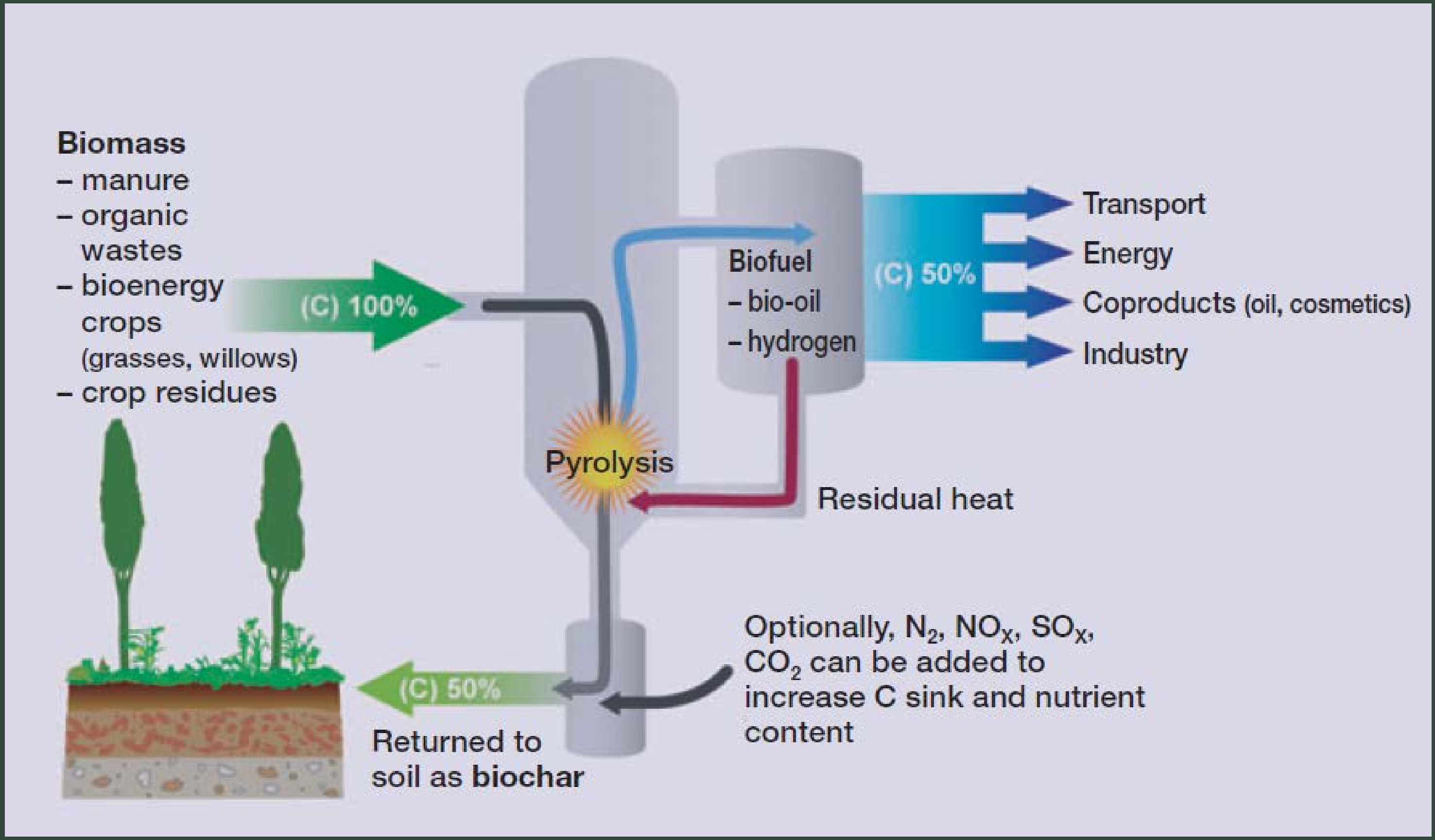
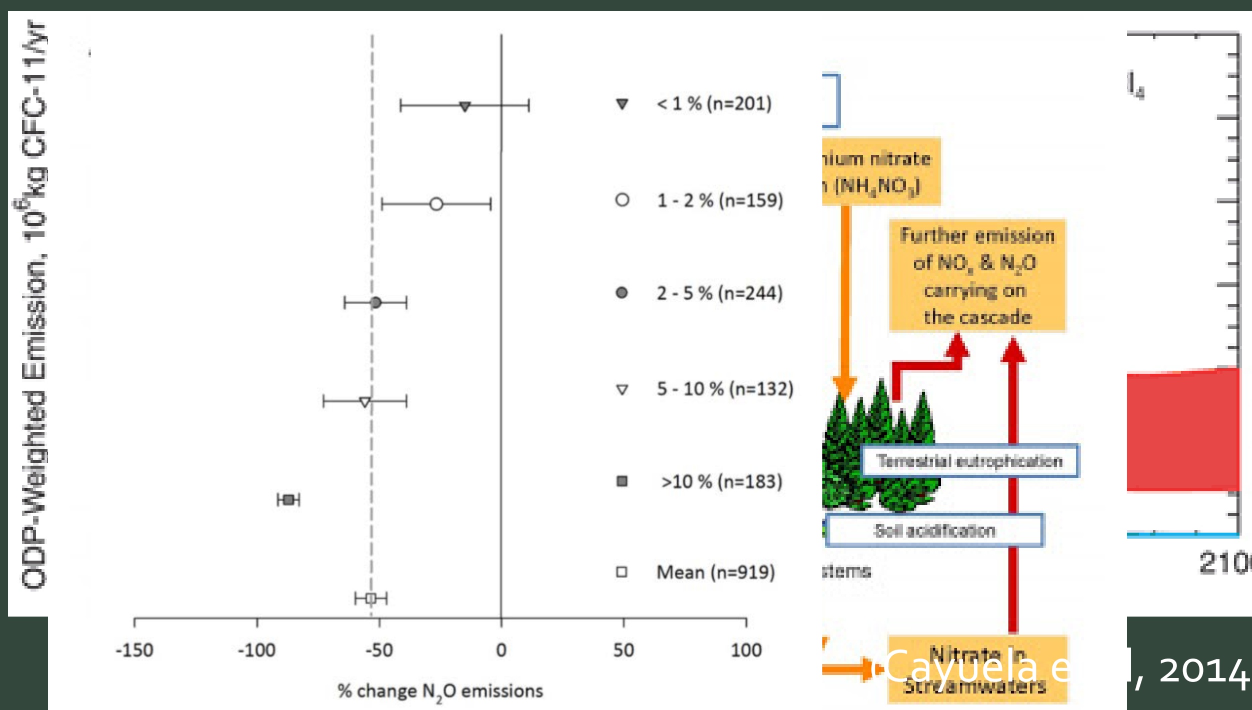
Carbon Sequestration



(Lehmann, 2007)

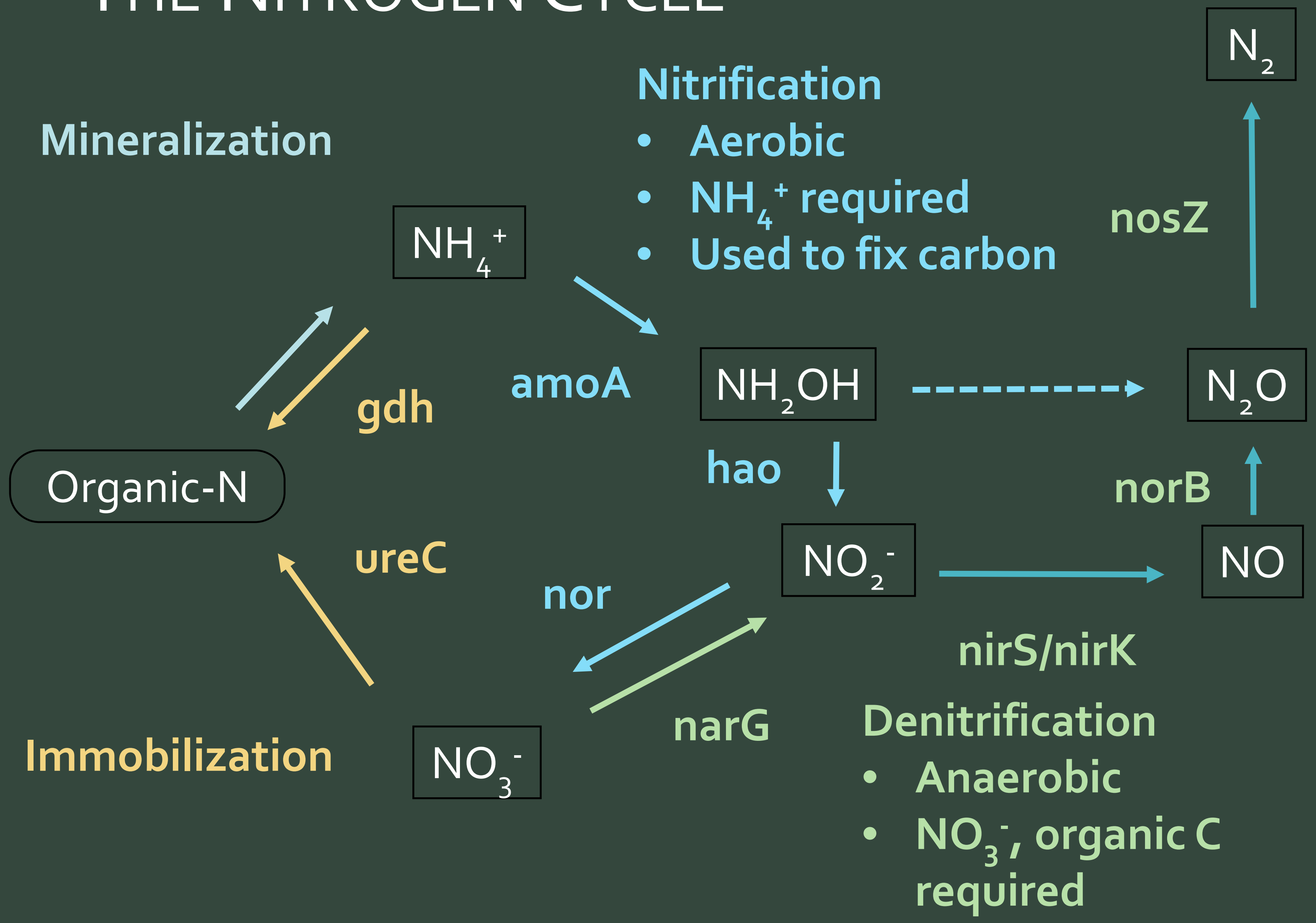
Why N_2O?

- Agricultures' largest contributor to climate change
- Delivers N to stratosphere leading to O_3 destruction
- Addressing N_2O also addresses the N cascade
- Biochar can decrease 49% of N_2O emissions (Cayuela et al, 2015)



Cayuela e , 2014)

The Nitrogen Cycle



Biochar-N_2O Hypotheses

Substrate Availability

1) Surface chemistry alter N availability
   - (Case et al., 2012; Kameyama et al., 2012)
2) Retention of mobile N
   - (Knowles et al., 2011; Van Zweiten et al., 2010; Kammann et al., 2012; Stewart et al., 2012; Zheng et al., 2012; Clough et al., 2013)
3) Alters availability of organic C
   - (Joseph et al., 2010; Troy et al., 2013)

Soil Ecology

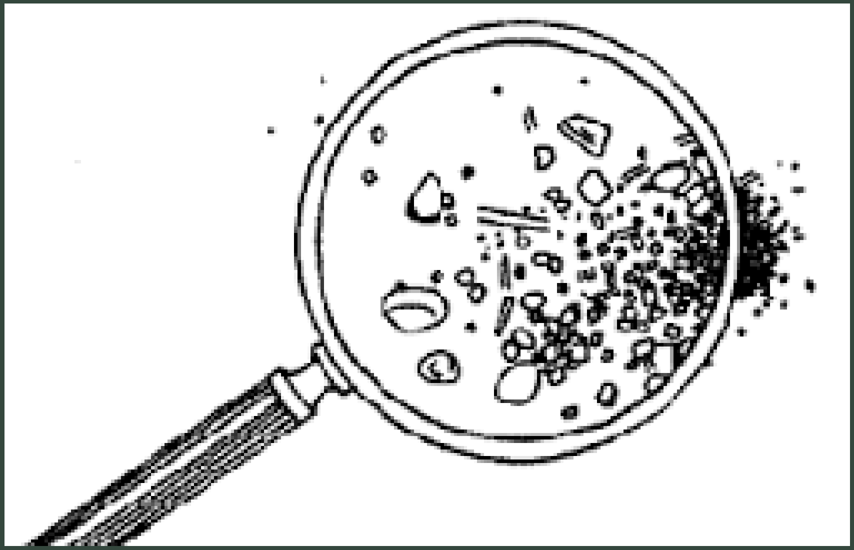
1) Alters soil pH
   - (Singh et al., 2010; Van Zweiten et al., 2010; Kammann et al., 2012; Stewart et al., 2012; Zheng et al., 2012; Ameloot et al., 2013)
2) Alters soil redox status
   - (Yanai et al., 2007; Van Zweiten et al., 2010; Rogovsky et al., 2011; Augustenborg et al., 2012; Stewart et al., 2012; Ameloot et al., 2013)
3) Alters microbial community dynamics
   - (Lehmann et al., 2011; Case et al., 2012; Kammann et al., 2012; Stewart et al., 2012; Zheng et al., 2012)
4) Introduces inhibitory compounds
   - (Spokas & Reicoski, 2009; Taghizadeh-Toosi et al., 2011; Dempster et al., 2012)

Other

1) Microbial e^- shuttle
   - (Cayeula et al., 2013)
2) Abiotic redox reactions
   - (Oh et al., 2013; Quin et al., 2015)

Why Does this Matter?

1) Determines long term impacts
2) Allows modeling of biochar-soil biogeochemical interactions
3) Essential for targeted biochar applications



Study Hypotheses

H1) Biochar preferentially retains N preventing microbial transformation

Expect: ↑ N on biochar ↓ N_2O from biochar –amended soils

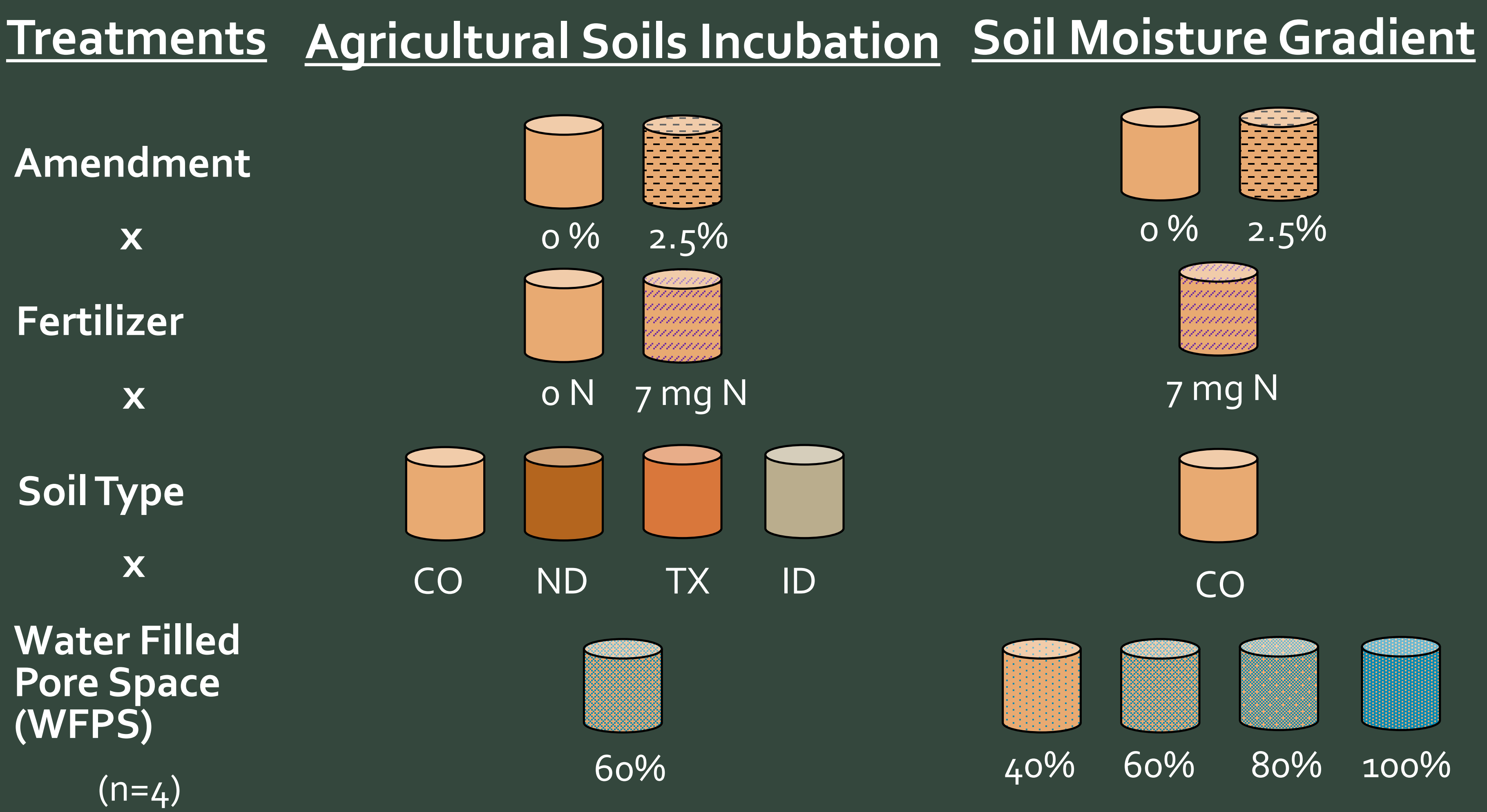
H2) Biochar leads to C priming impacting soil denitrifiers

Expect: ↑ CO2 ↓ N2O from biochar –amended soils

H3) Biochar alters soil aeration status favoring fully denitrifying conditions

Expect: ↓ O_2 in pore space ↓ N2O from biochar –amended soils

EXPERIMENTAL DESIGN



SOILS

Soil	Land Use	MAT	MAP	% Sand	% Silt	% Clay	Inorganic C	Organic C	Total N	pH
CO	Cultivated Corn	9°C	276 mm	35%	32%	34%	0.43%	0.88%	0.13%	7.99
TX	Cultivated Wheat	17°C	665 mm	14%	50%	36%	0.03%	0.90%	0.11%	8.04
ID	Rangeland	7°C	278 mm	28%	54%	19%	0.02%	5.04%	0.47%	5.86
ND	Cultivated Wheat	5°C	402 mm	11%	60%	29%	0.03%	2.37%	0.24%	7.27

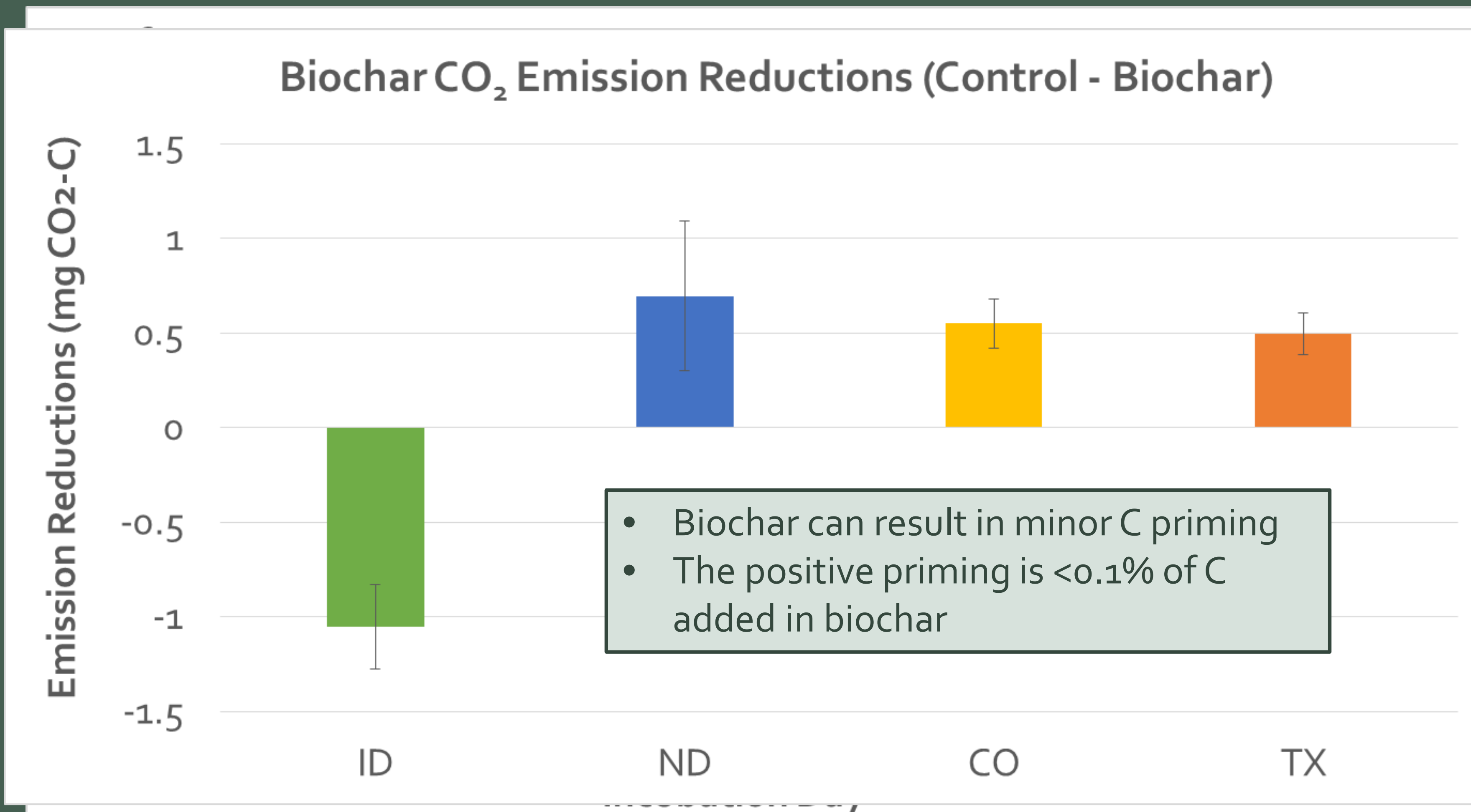
Biochar

Description	Biochar Properties
Feedstock	Beetle-killed lodgepole pine
Pyrolysis	Slow Pyrolysis, 550°C (Biochar Now)
Particle Size	Sieved to between 2 – 2.8 mm
Application Rate	2.5 % by mass (equivalent to 30 tonnes/ha)
C:N	255.3
pH	8.49
BET	100.7 m^2/g

Methods

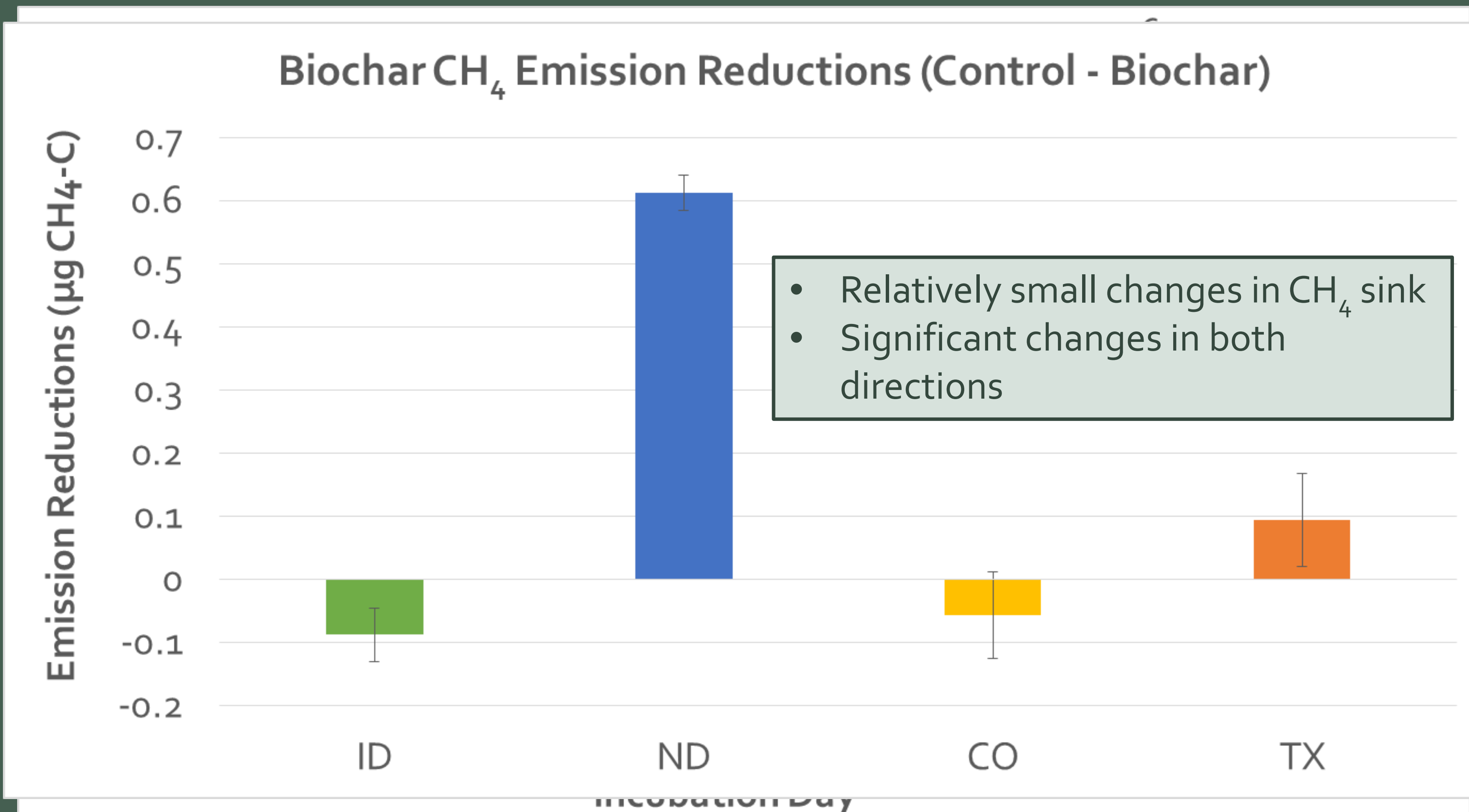
- GHG Emissions
- Inorganic N
  - Bulk Soil
  - Biochar Extraction
- Total C and N
- pH

GHG Dynamics: CO_2

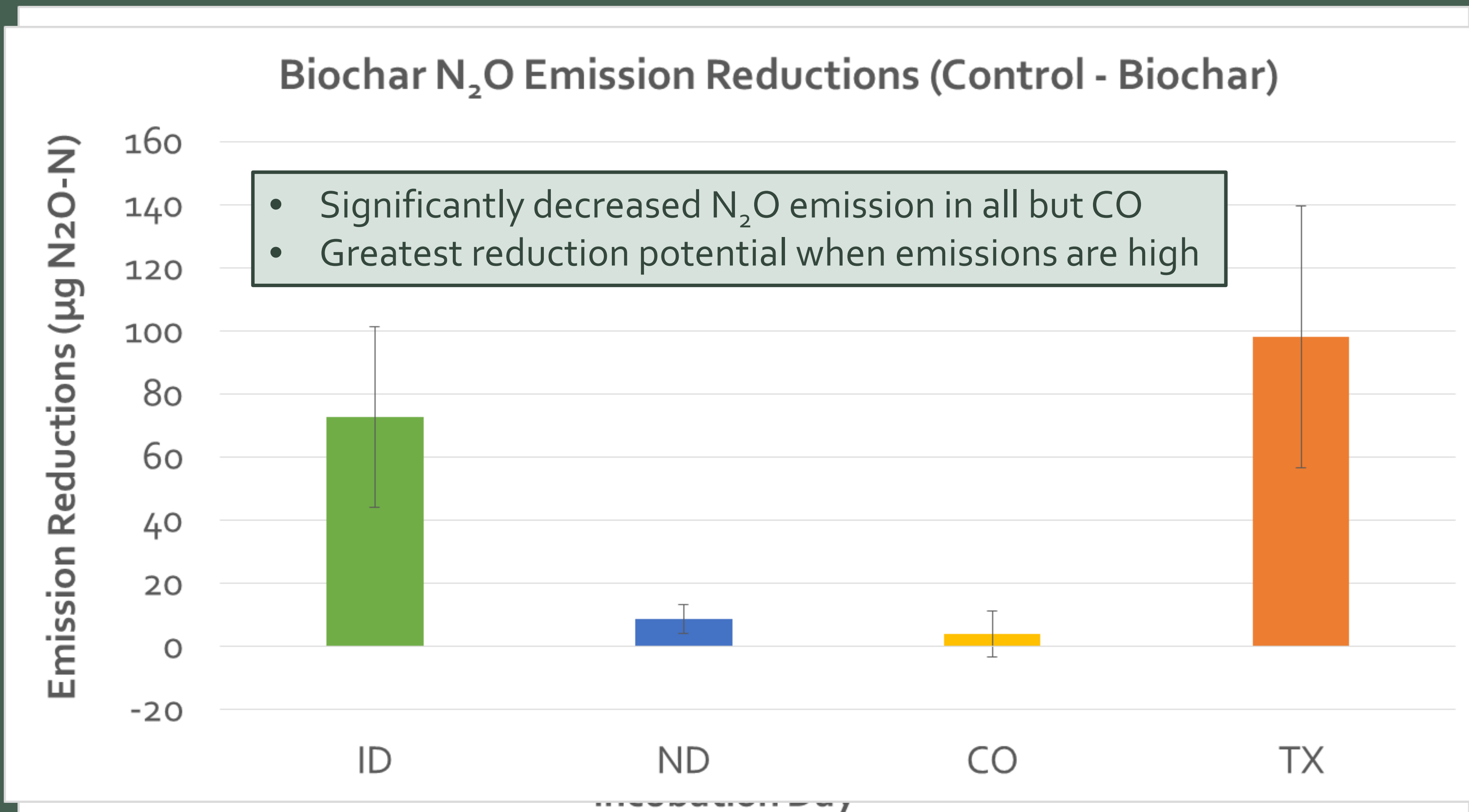


- Biochar can result in minor C priming
- The positive priming is <0.1% of C added in biochar

GHG Dynamics: CH_4

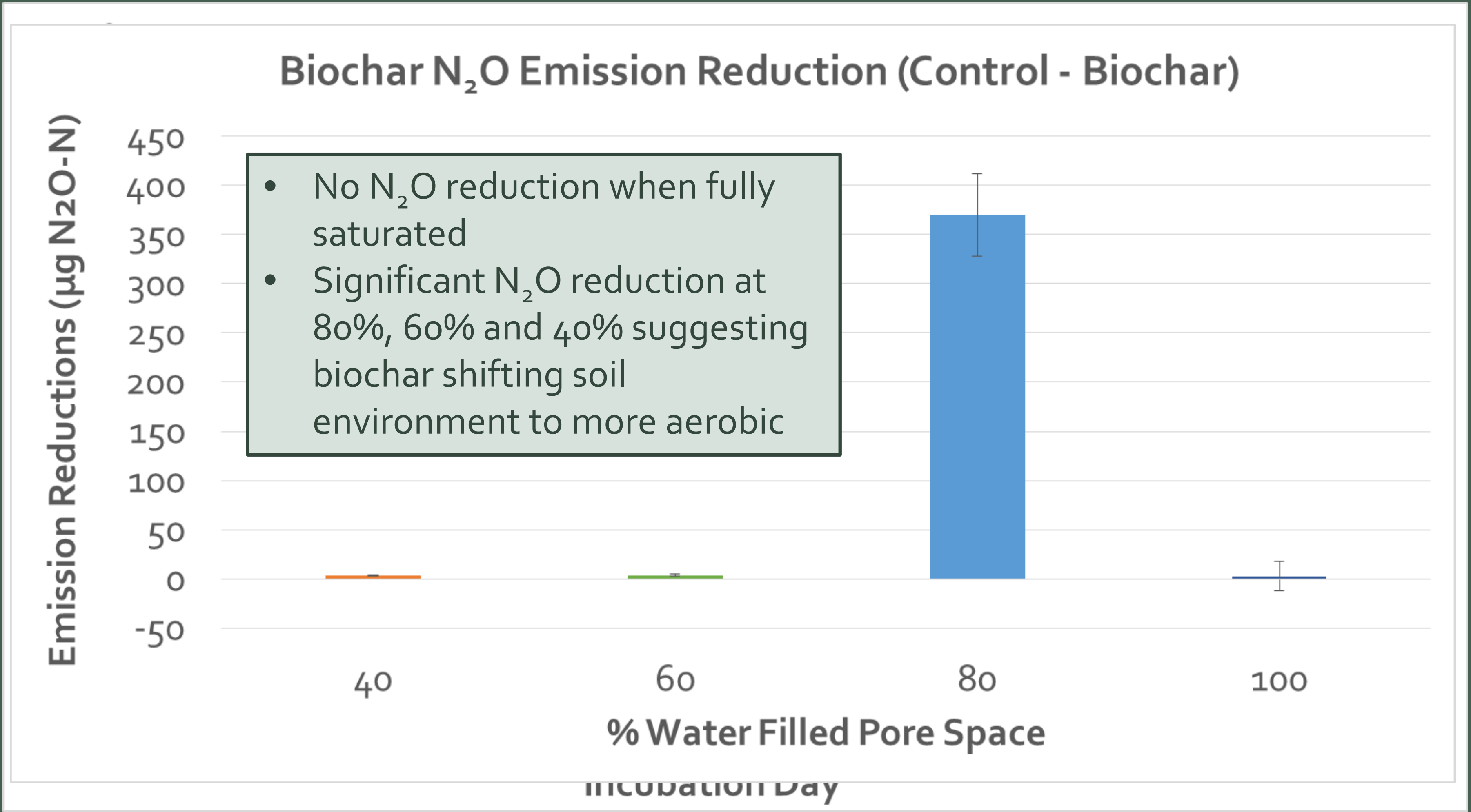


GHG Dynamics: N_2O

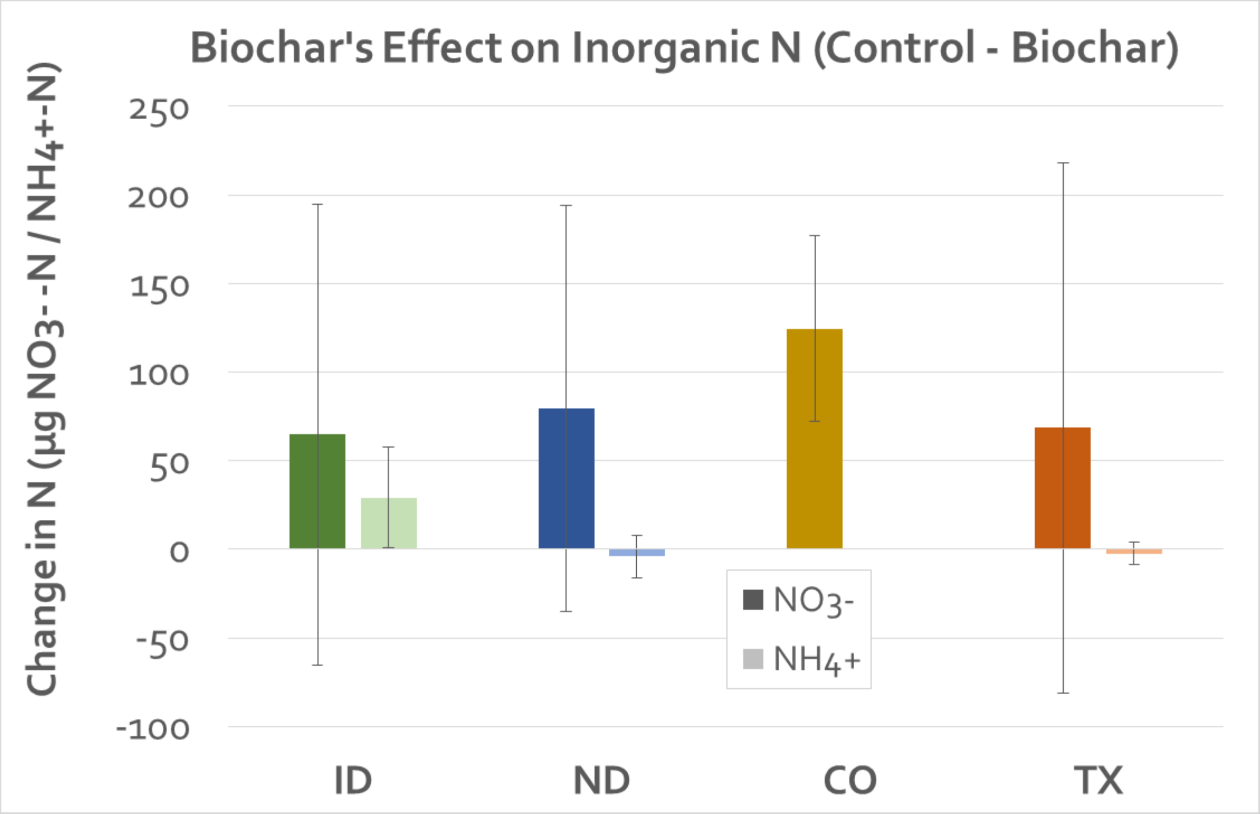


- Significantly decreased N_2O emission in all but CO
- Greatest reduction potential when emissions are high

SOIL MOISTURE AND N_2O



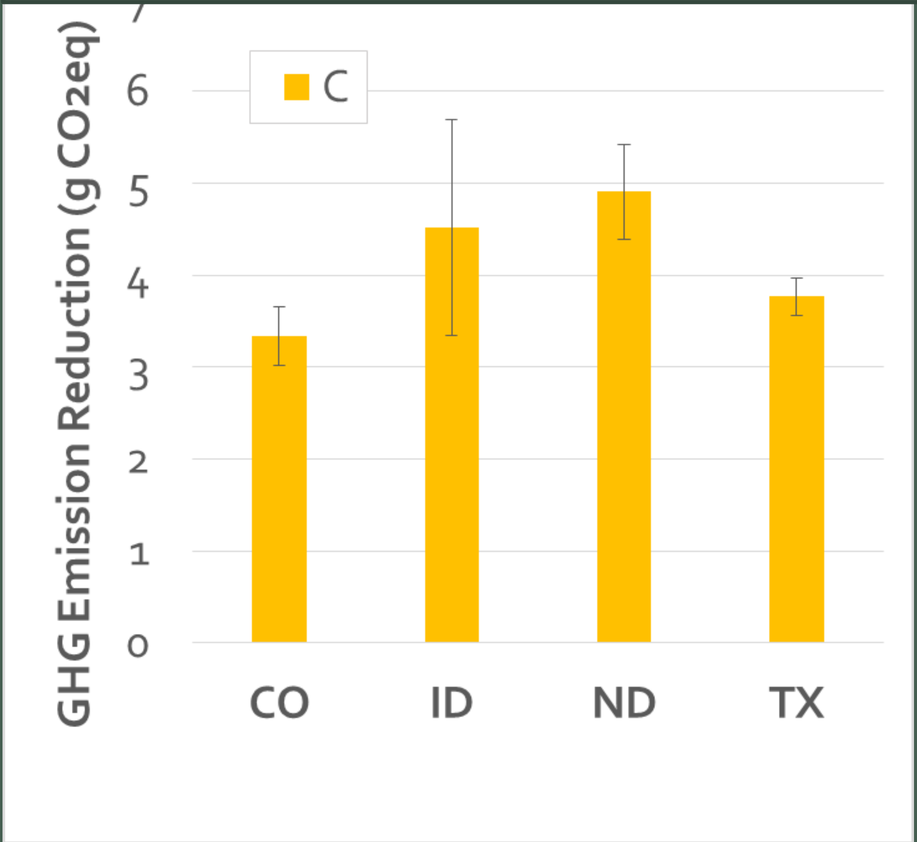
Inorganic N Dynamics

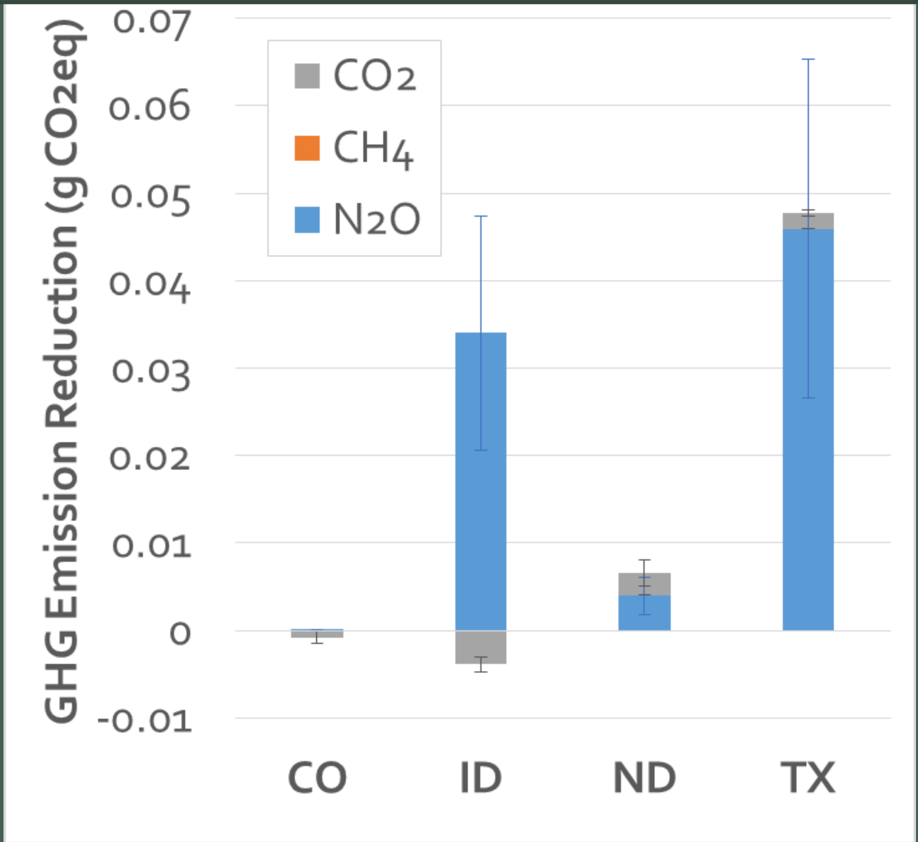


- No significant change in NO_3^- or NH_4^- at end of incubation (except increase in NO_3^- by biochar)
- Extracted biochar exhibited same dynamics as bulk soil with greater NO_3^- retention by mass

Overall GHG Budget

- C sequestration generates 100x the GHG emission reductions from N_2O
- If biochar's effects last, N_2O could match the C sequestration potential on the long term





Conclusion

- Findings
  - C sequestration provides the greatest GHG benefit
  - N_2O mitigation may also have high GHG mitigation potential, depending on the mechanisms and thus persistence of effects
  - Inorganic N data did not indicate different N dynamics on biochar or changes in N substrates similar to the N_2O decrease
  - CO_2 data showed minimal priming
  - Soil moisture gradient indicated biochar shifting soil to more aerobic conditions
- Next Step
  - Further probe mechanisms through targeted experimental design
  - Use biochar literature to develop models for biochar-soil biogeochemistry
  - Confirm model predictions with applied field studies

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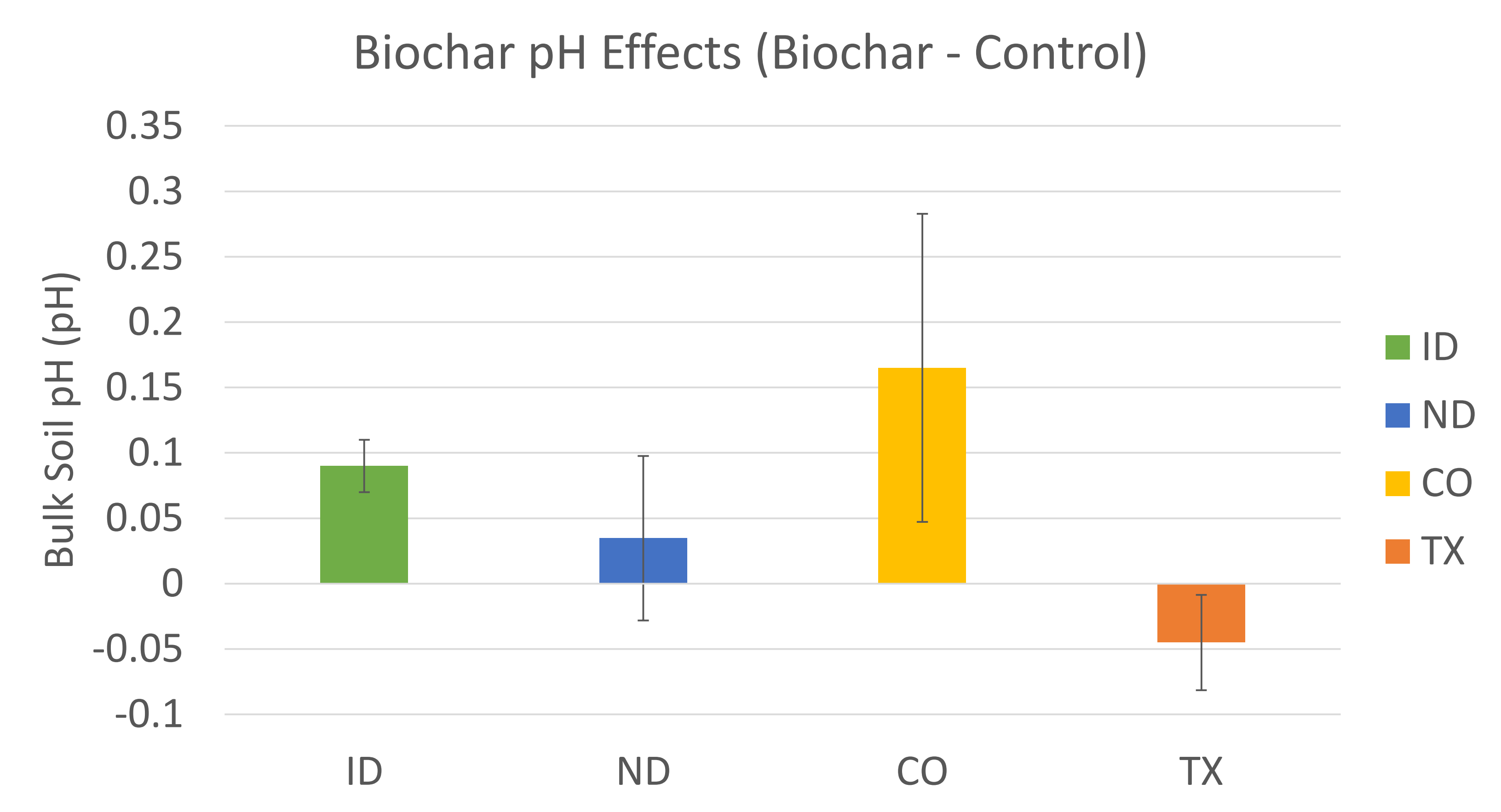
pH Effects



Biochar pH Effects (Biochar - Control)
Bulk Soil pH (pH)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
ID
ND
CO
TX
ID
ND
CO
TX