Environmental implications of interactions between biochar and the nitrogen cycle

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Outline

- Short-term effects of competition for N in the soil
- Benefits of biochar–N interactions in the field
- Effects of biochar on N cycle processes in the soil

Biochar pot experiment with microlysimeters:

Seepage water collection and N_2O measurements

Cropping pattern:

- Mustard
- Barley
- Red clover

→ First crop after start: yield depressions

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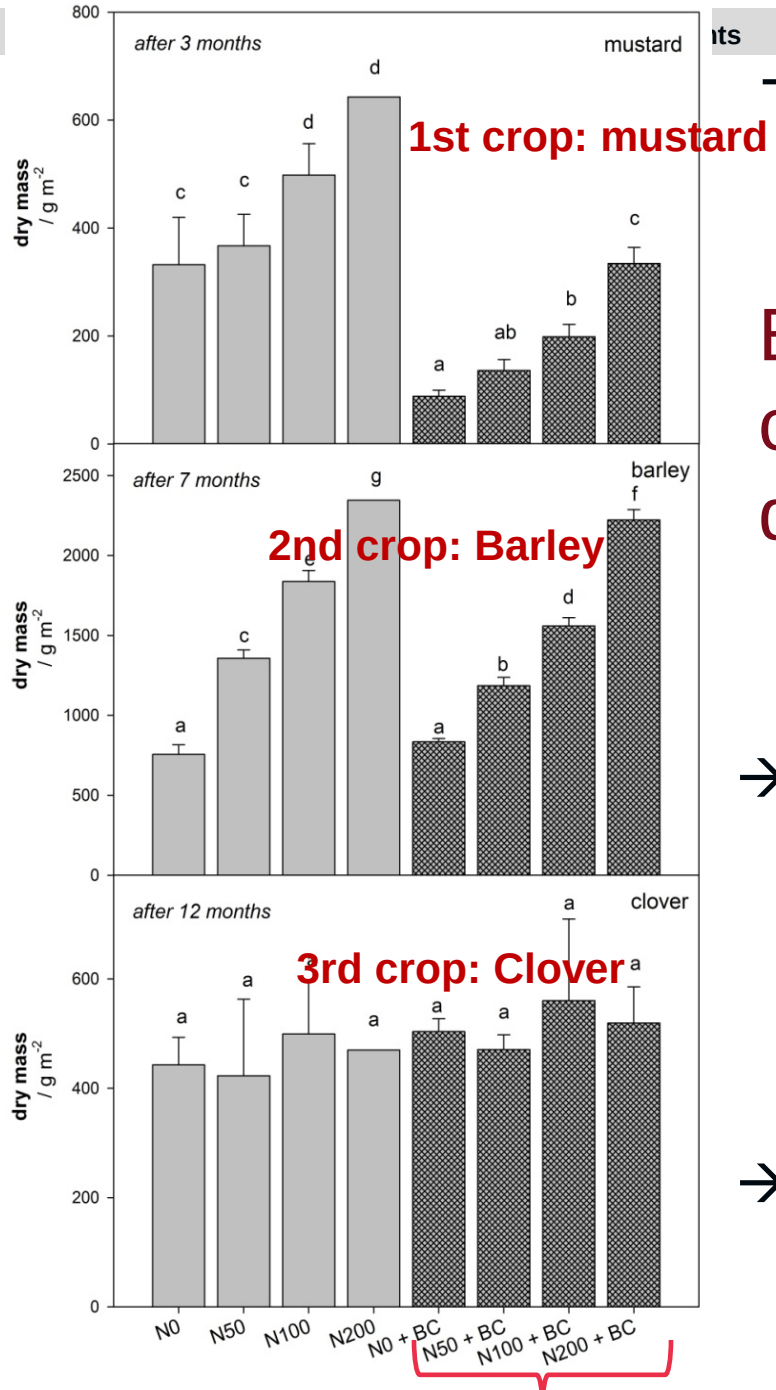
Effects of different N-levels on crop yield (total above-ground d.m.)



mit 3 % Biokohle

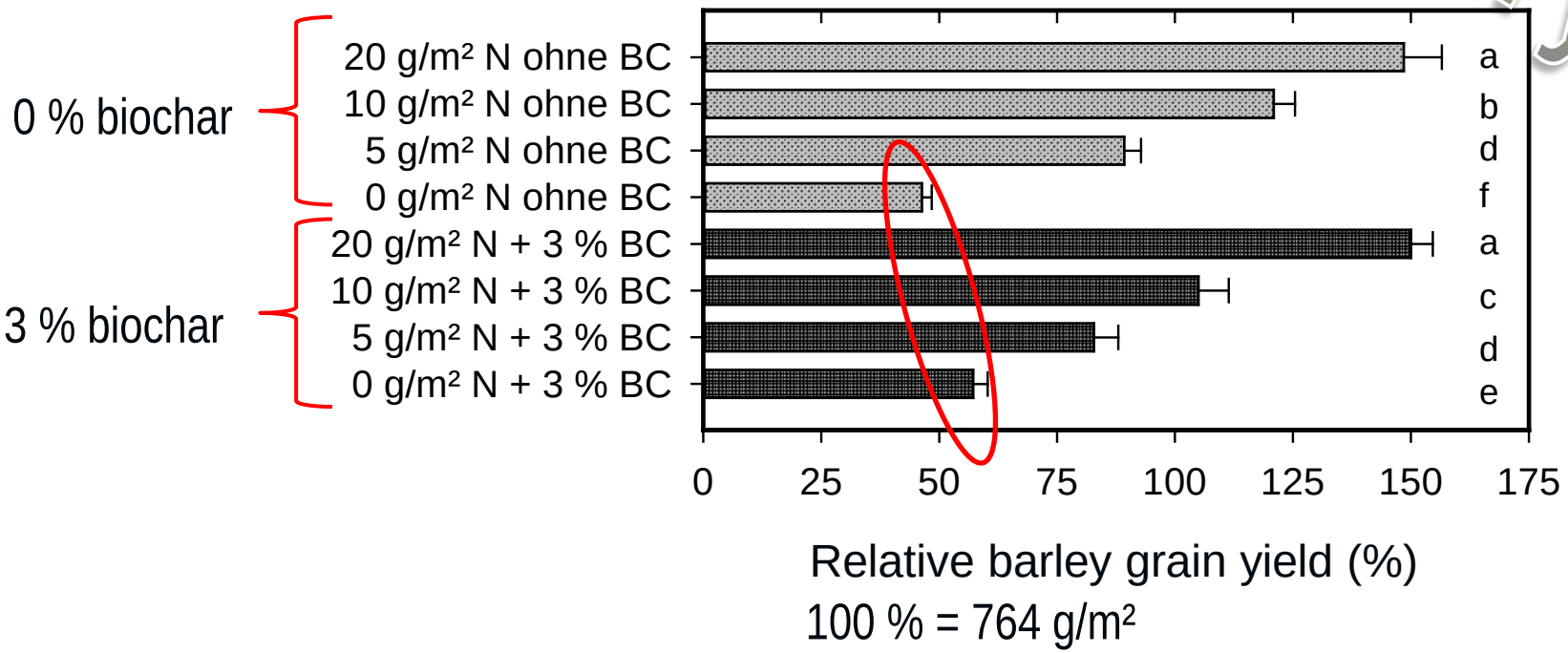
→ after 7 months: N0 and N0 + BC similar

→ After 12 months: no significant difference

Barley yield in dependence on biochar and nitrogen supply

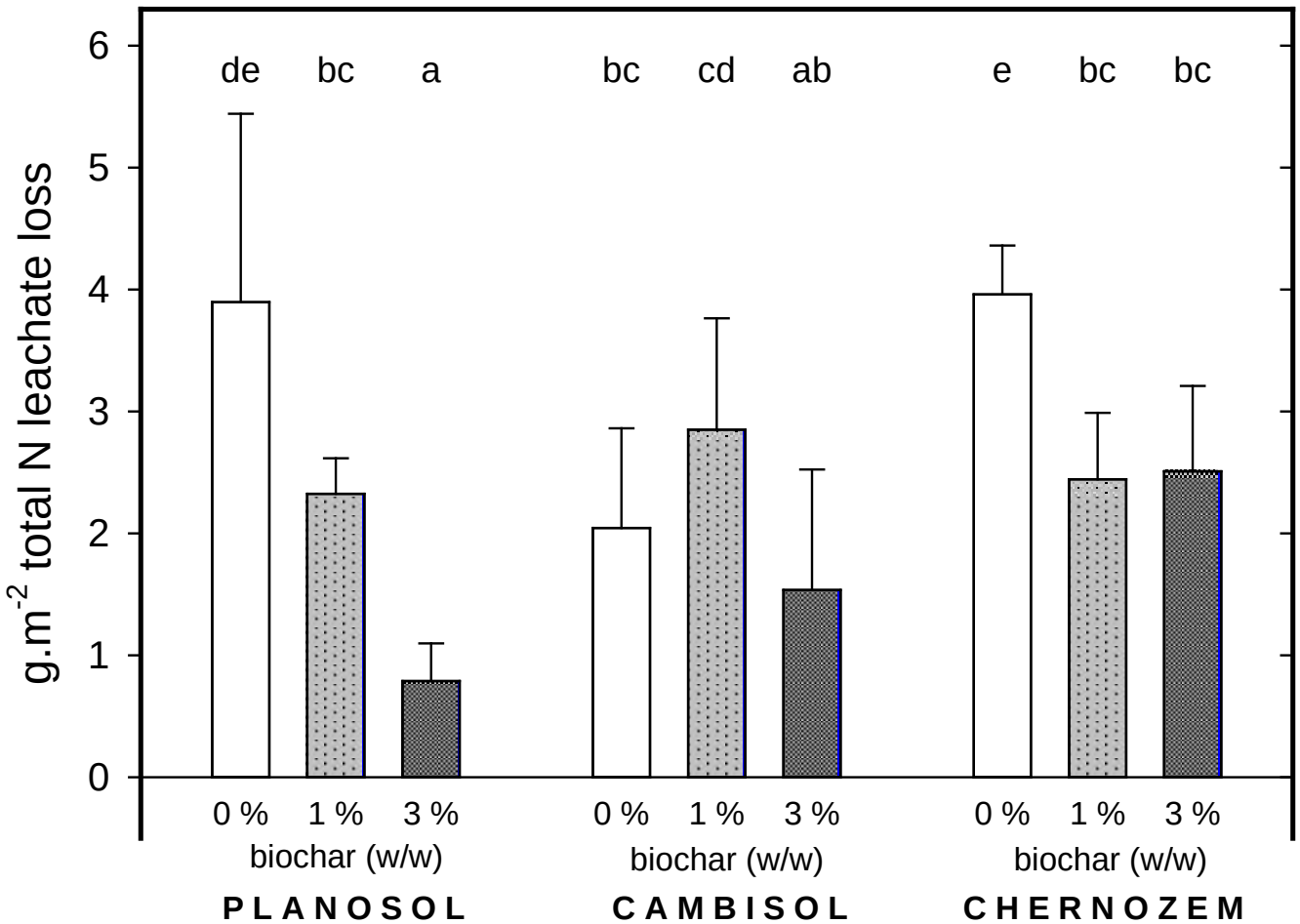
Grain yield

N-release slowly starting at lowest N level



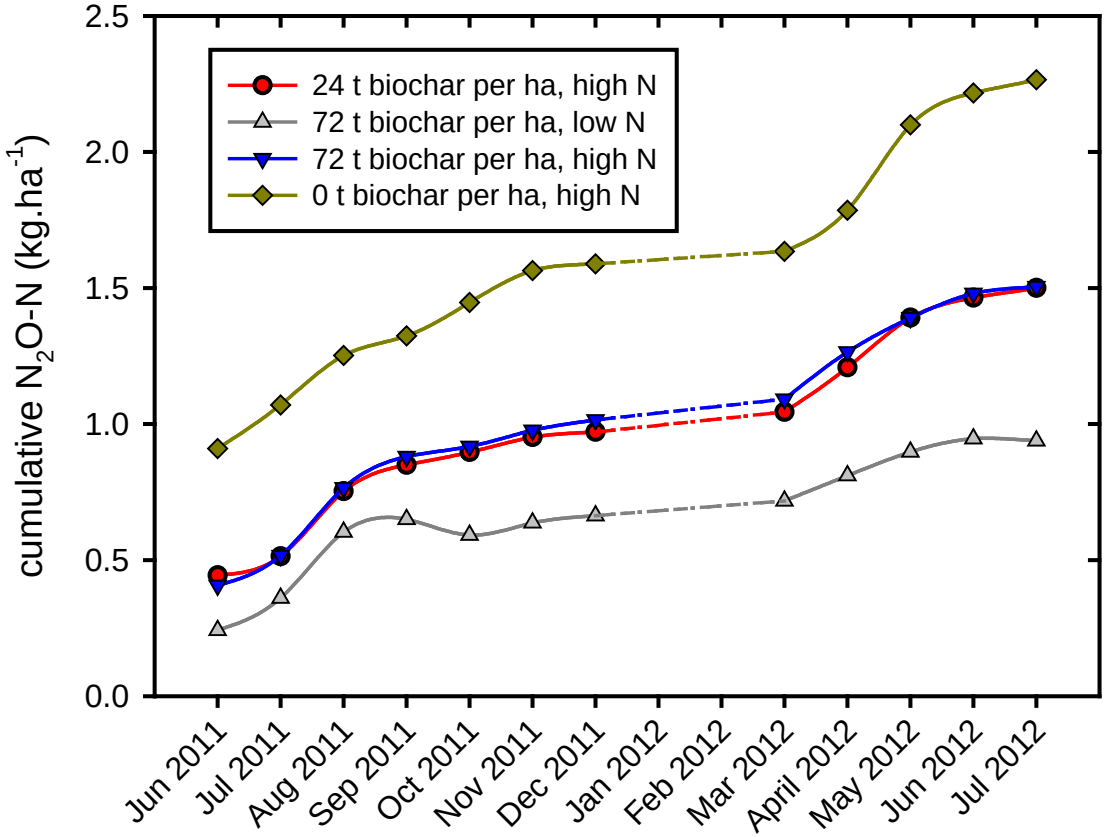
Woodchip-based biochar.
Soil: Planosol

Cumulative N-losses in seepage water with and without biochar



- N addition: 12 g N m^{-2}
- N-retention is dependent on soil type
- Acidic, sandy soil: 80 % reduction of N-losses
- Other soil types: 25-40 % reduction

N_2O-emissions with and without biochar



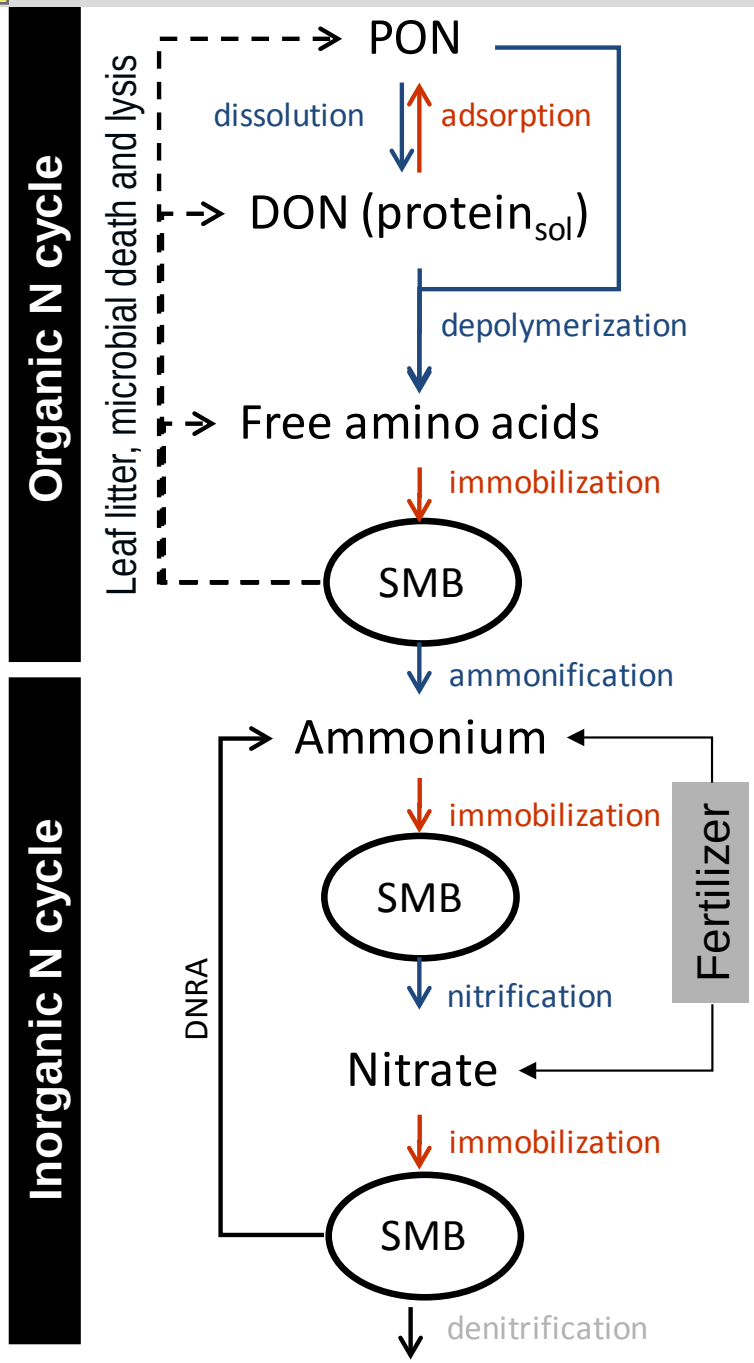
- 35 – 50 % N_2O emission reduction
- 24 und 72 t biochar per ha cause a similar degree of reduction
- At high N-level (120 kg N/ha) **without biochar:**

  1.9 % loss of added N
- At high N-level (120 kg N/ha) **with biochar:**

  1.2 % loss of added N

Installation of a field experiment with biochar plots (0, 24, 72 t ha^{-1})

Overview of the N cycle in agricultural soils



DNRA: dissimilatory nitrate reduction to ammonium,

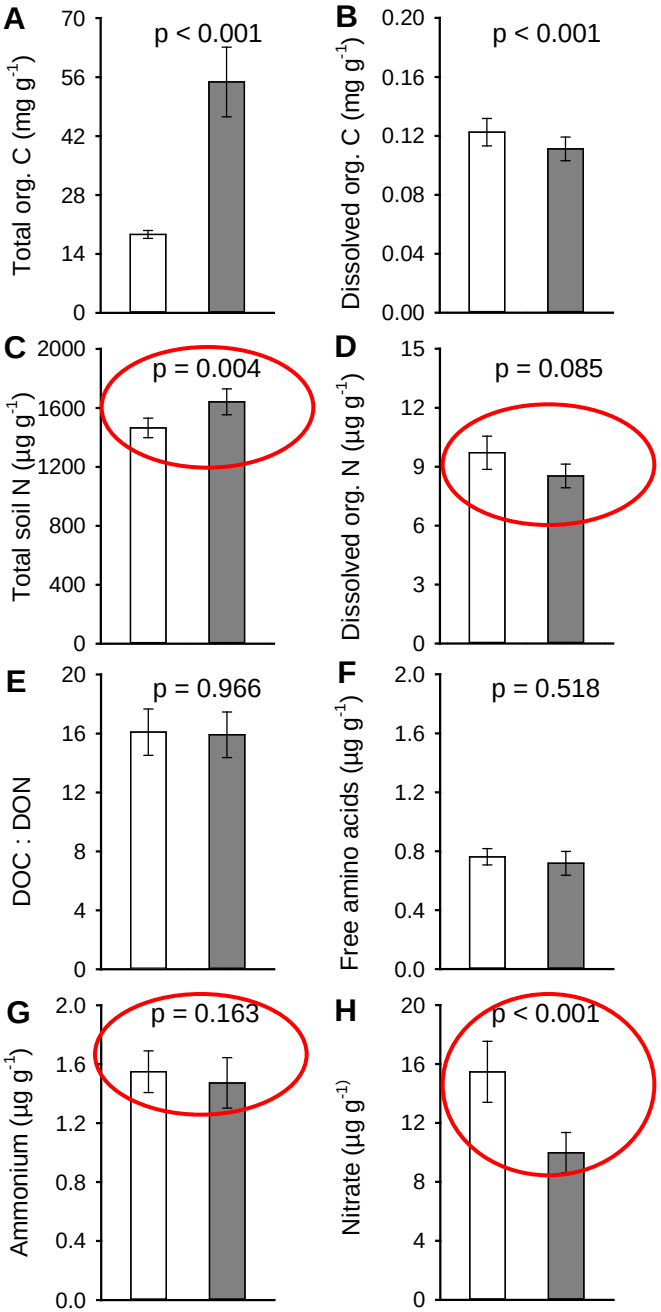
DON: dissolved organic N

PON: particulate organic N

SMB: soil microbial biomass

Source: Prommer et al., PLOS ONE, e86388, 2014

Soil C and N pool sizes for control and biochar treatments



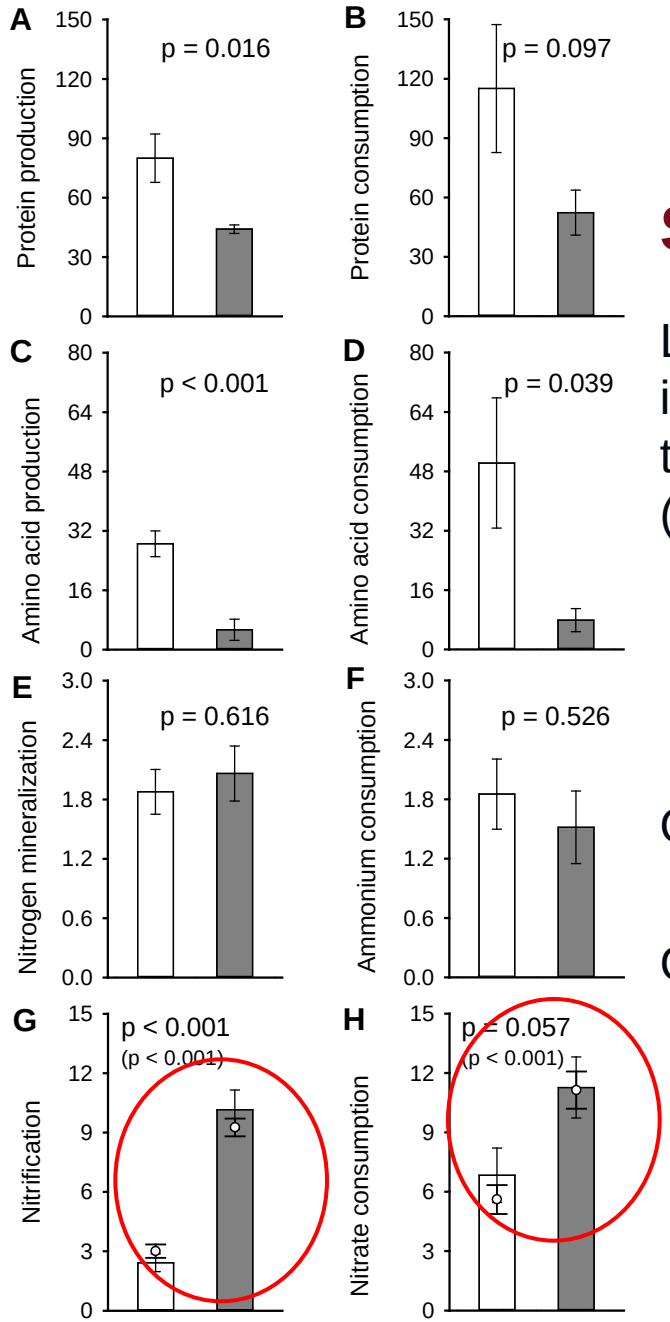
Open bars: control treatment
(0 t biochar, 120 kg N ha^{-1})

Grey bars: biochar treatment
(72 t biochar, 120 kg N ha^{-1})

Units in mg C g^{-1} dry soil and µg N g^{-1} dry soil.

Extractable N pool was nitrate-dominated

Source: Prommer et al., PLOS ONE, e86388, 2014



Soil N transformation rates

Left panels: gross influx rates into the target pools (production rates)

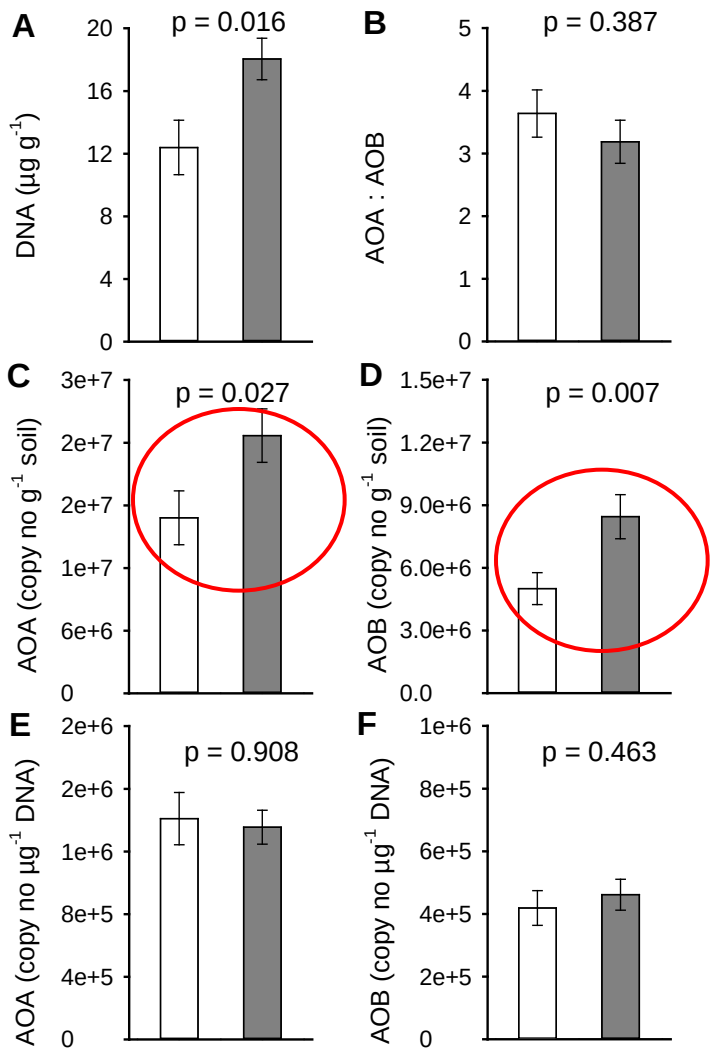
Right panels: gross efflux rates (consumption rates).

Units in µg N g^{-1} dry soil d^{-1}, equivalent to mg N kg^{-1} d^{-1}.

Open bars: control treatment (0 t biochar, 120 kg N ha^{-1})

Grey bars: biochar treatment (72 t biochar, 120 kg N ha^{-1})

Source: Prommer et al., PLOS ONE, e86388, 2014



Soil microbial community size and ammonia oxidizers

DNA: soil DNA content

AOA: archaeal amoA copy numbers
AOB: bacterial amoA copy numbers

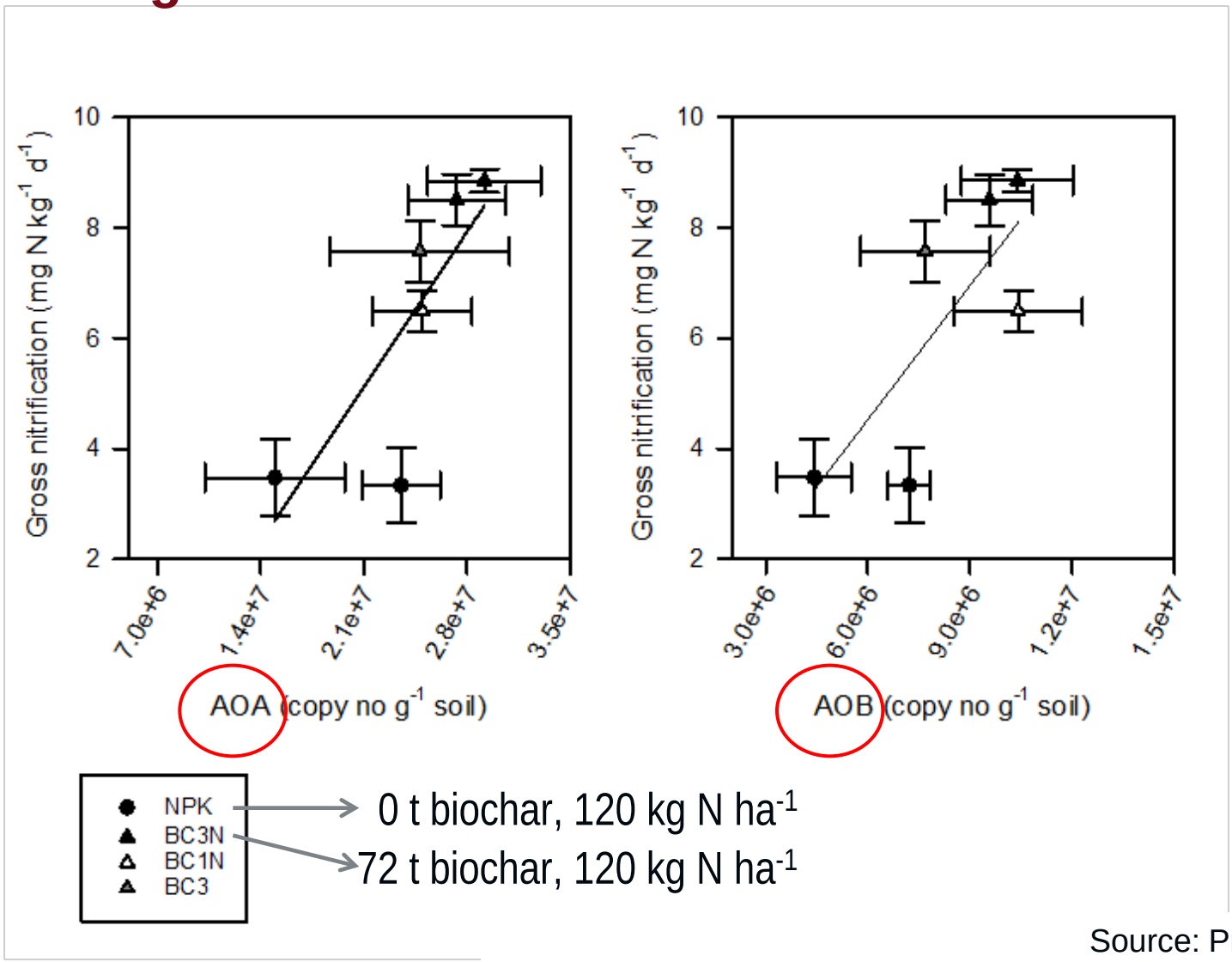
Microbial community and ammonia oxidizers were stimulated by biochar!

Open bars: control treatment
(0 t biochar, 120 kg N ha^{-1})

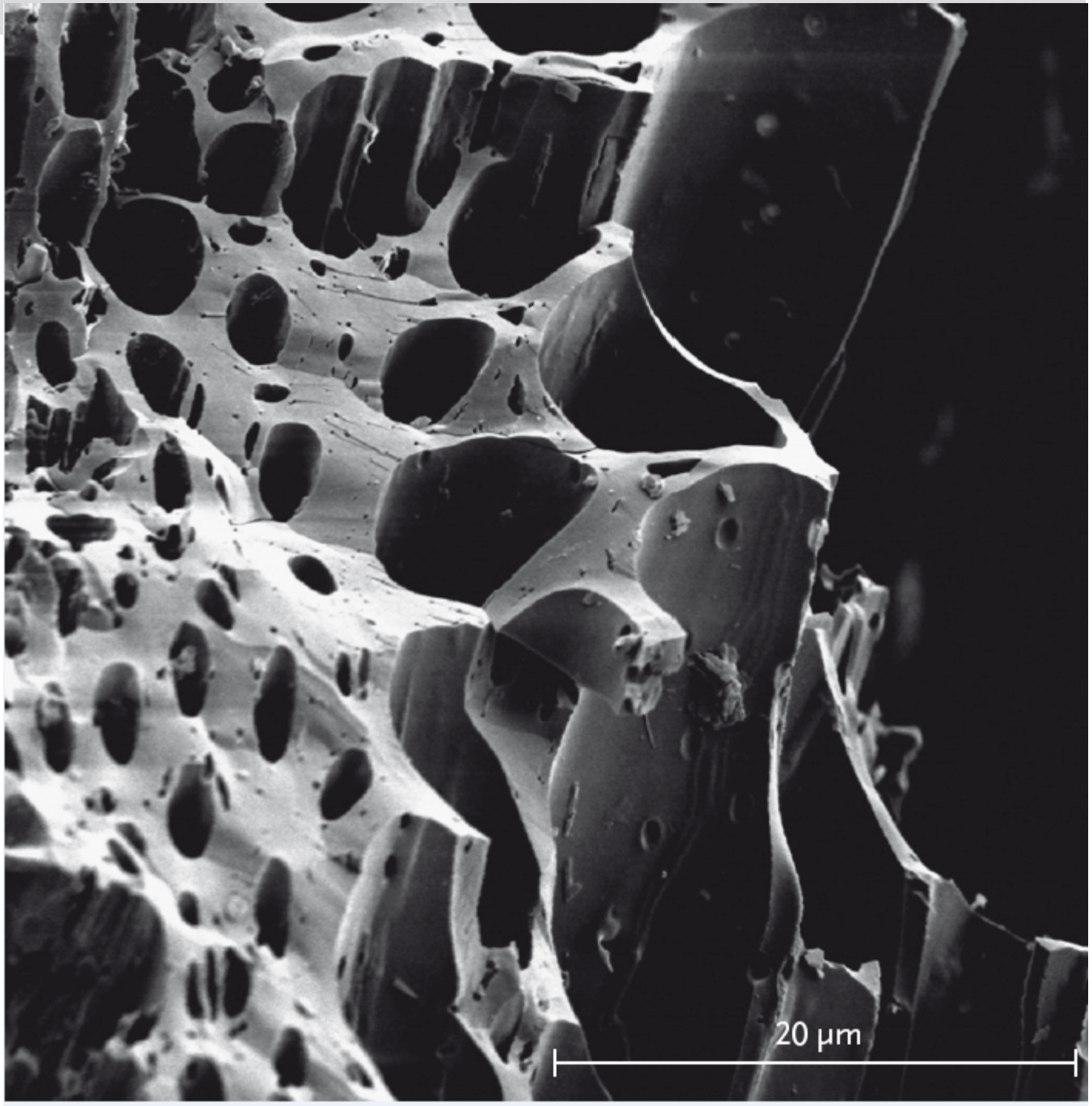
Grey bars: biochar treatment
(72 t biochar, 120 kg N ha^{-1})

Source: Prommer et al., PLOS ONE, e86388, 2014

Relationship of ammonia oxidizer abundance (AOA, AOB) with gross soil nitrification rates



Source: Prommer et al., PLOS ONE, e86388, 2014

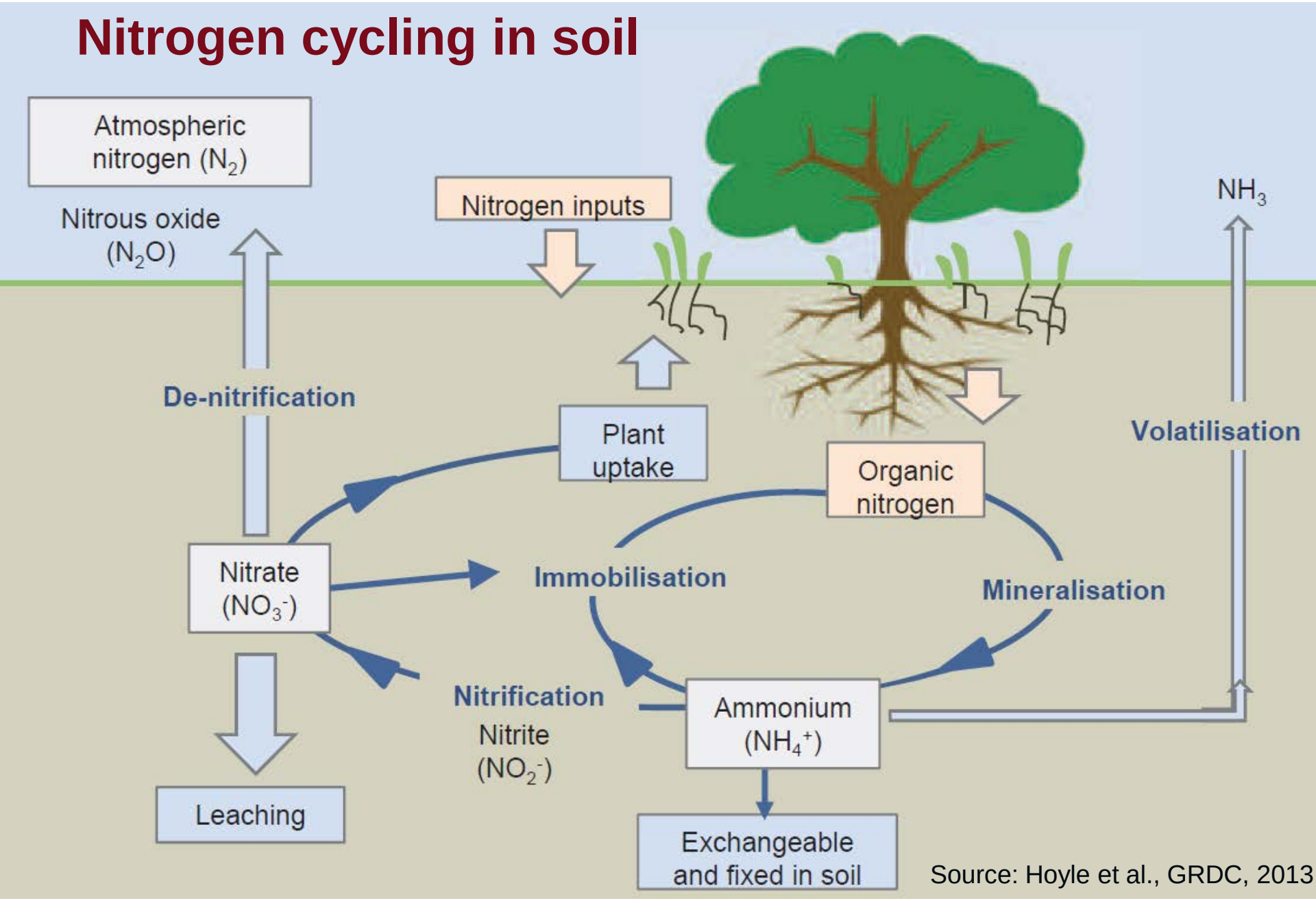


Biochar in the electron microscope

Porous structure of biochar may provide a protected micro-habitat for soil microbes

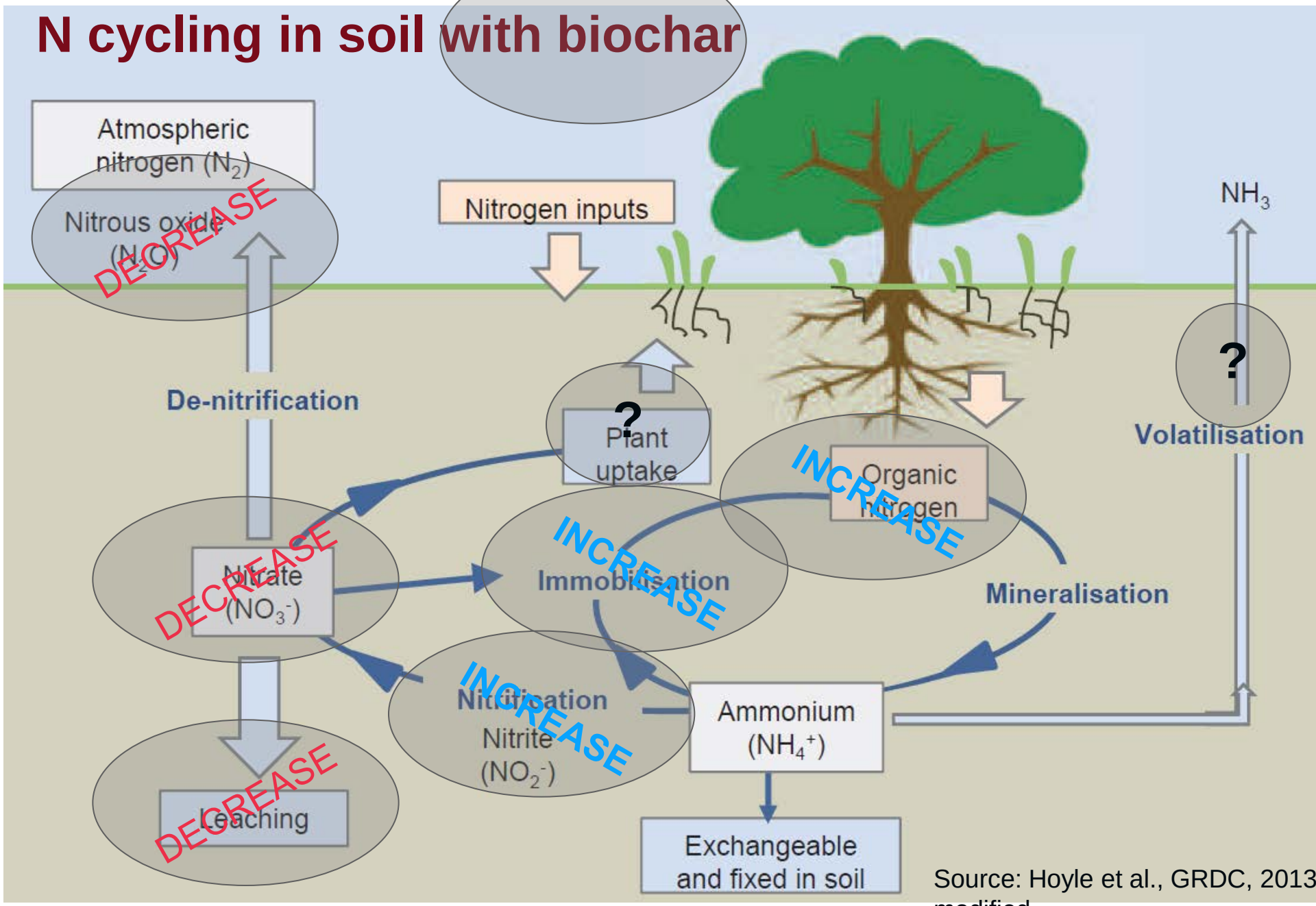
Photo: Martin Brandstetter

Nitrogen cycling in soil



Source: Hoyle et al., GRDC, 2013

N cycling in soil with biochar



Source: Hoyle et al., GRDC, 2013 modified

Conclusions

- Biochar **decouples the inorganic and organic N cycles** in soil
- Deceleration of organic N cycling → **increase of soil organic N pool**
- Stimulation of nitrification but **decrease of nitrate levels** in soil
- **Decrease of nitrate losses** in seepage water by 40-80 % and **decrease of N_2O losses** by 35-50 %
- Increase of soil microbial pool, and **increase of microbial nitrate utilization**
- Potential for increase of **non-biochar derived soil organic matter**
- Potential for financial compensation for the **protection of the natural resources air and groundwater** with biochar

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