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Carbonization as recycling strategy for carbon and nutrients

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Outline

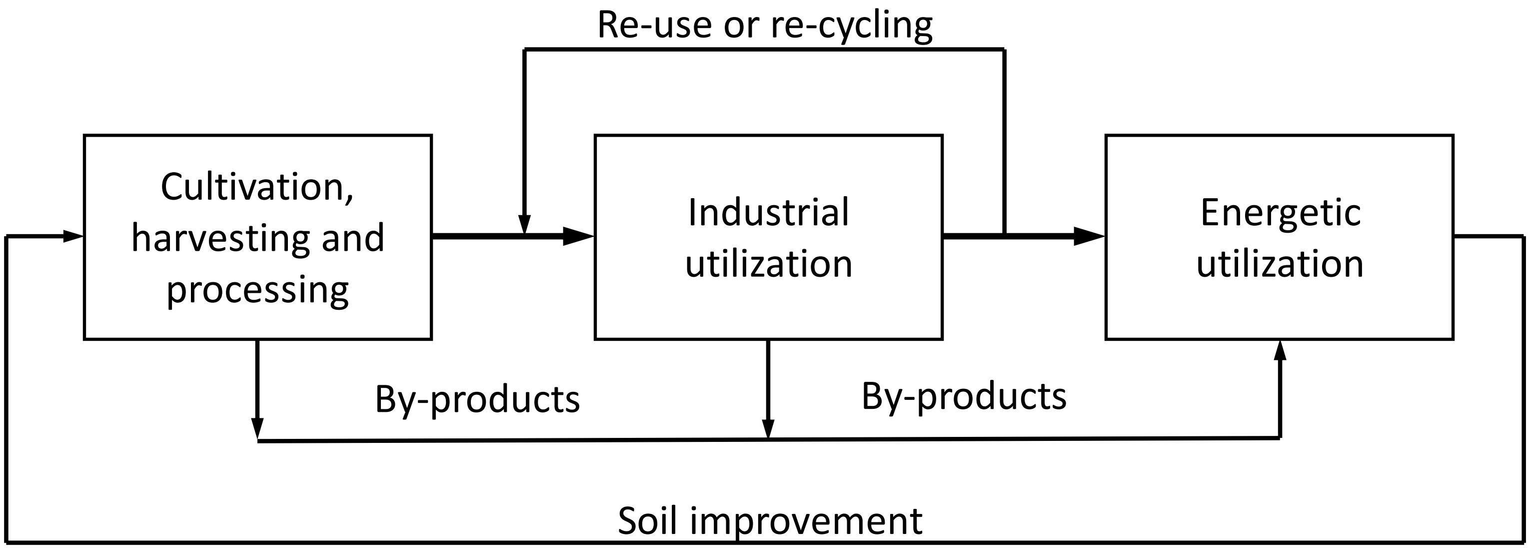
- Motivation
- Thermo-chemical conversion
- Pyrolysis and HTC processes
- Products and use as soil amendment
- Nutrient availability tests:
  - Plant tests
  - Fertilizer extraction tests
- Situation in Austria and Germany
- Conclusion and outlook

Motivation

- Mitigation of Climate Change
- Thermochemical Conversion
- Carbonization - > Production and Use of Biochar
  - Soil amendmend
  - Carbon sequestration
- IPCC Special Report (2018):
  - *„Biochar sequestration provides an additional route for terrestrial carbon storage.“*
  - *„Biochar […] can increase soil carbon sequestration leading to improved soil fertility properties”*

IPCC, 2018: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial level

Sustainable biomass value chains

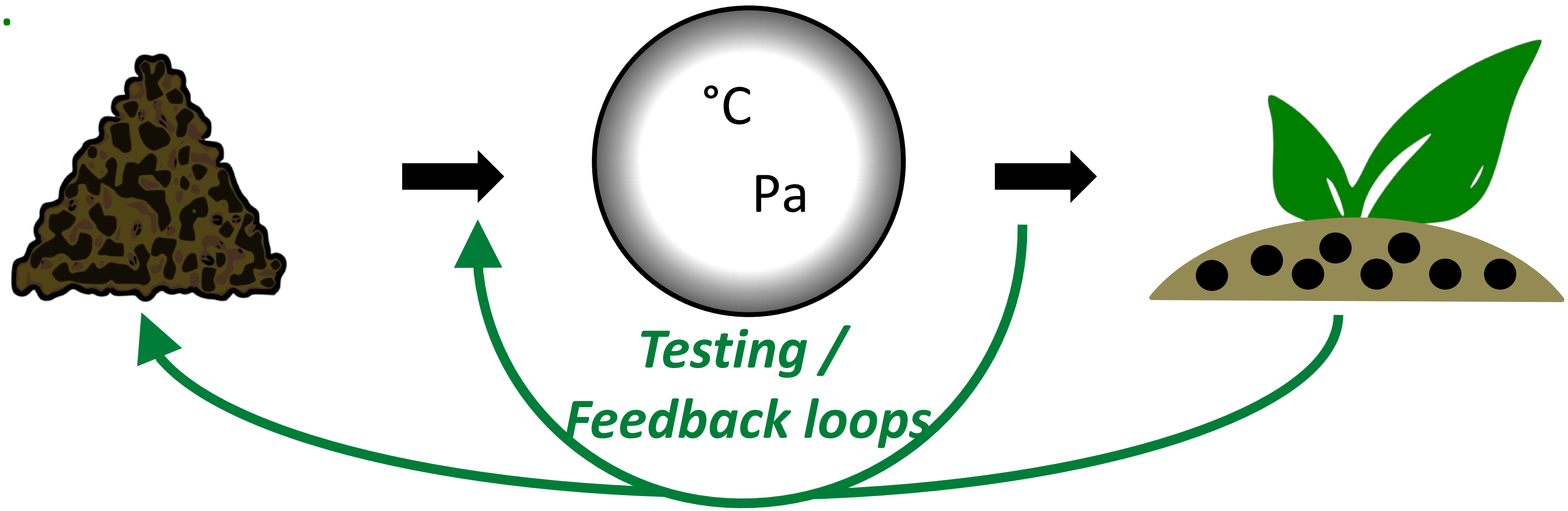


Source: Pröll et al., GHGT-13, 14-18 November 2016, Lausanne, Switzerland

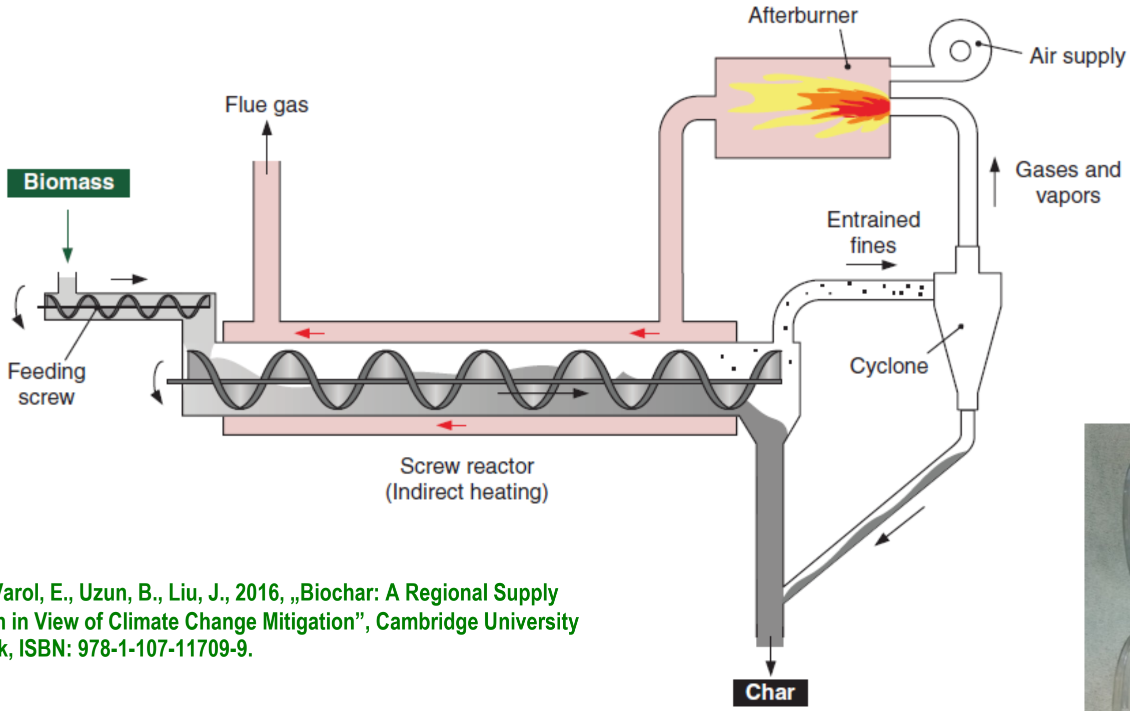
- Priority is given to food, feed and other industrial utilization
- By-products for energetic use appear in all process steps
- Closed life cycle including **sustainable soil management**

Process development route

FEEDSTOCK (Residues & Waste)	PROCESS	PRODUCT
- Municipal Sewage Sludge	- Pyrolysis	- Fertilizer
- Meat & Bone Meal	- Gasification	- Soil conditioner
- Animal Manures & Slurry	- HTC	- C-Sequestration
- Biogas slurry		
- ...		



Pyrolysis



Bruckman, V., Varol, E., Uzun, B., Liu, J., 2016, „Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation", Cambridge University Press, New York, ISBN: 978-1-107-11709-9.

- Input: Biomass -> biogenic byproducts (>50% d.m.)
- Process: no O_2, high T and p, volatiles released
- **Pyrolysis gas**: mainly CO, CO_2 and water, condensable hydrocarbons
- **Biochar**: very porous solid with very high C-content
- **Bio-oil**: or tar - consists of large variety of HC larger than Benzene => Precursor for biofuels and chemicals

Hydrothermal carbonization

p ~ 10 to 25 bar(g)
T ~ 170 to 250 °C

$C_6H_{12}O_6$ → C_6H_2O + $5\,H_2O$ (~ 950 kJ/mol)

Carbohydrate — *Exothermal process* — „hydrochar“ + Water (+ excess heat)

Advantages HTC

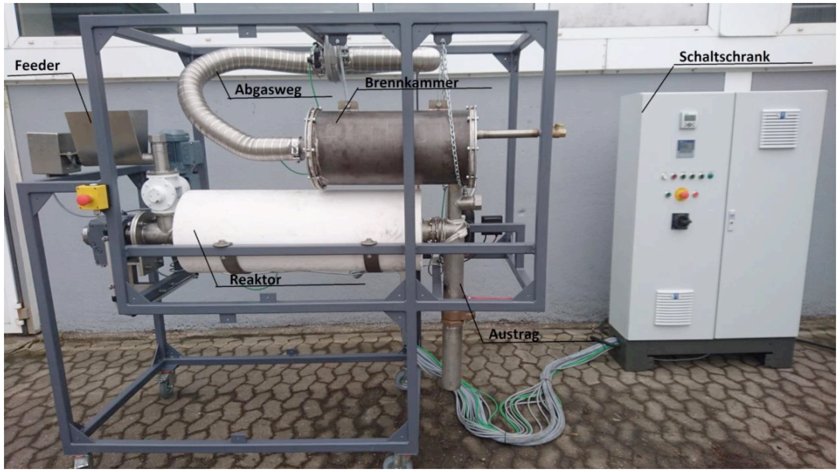
- - Feedstock with high moisture content possible
- - Exothermal process
- - Hydrochar mechanically drainable

<u>Example:</u> 1000 t Bioresidue (30% DM)

20 – 30 w.% HTC-Coal

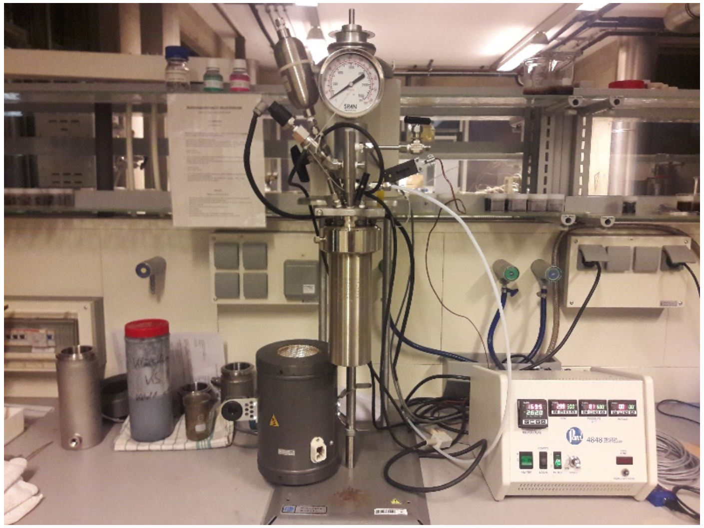
70 – 80 w.% Process water

Experimental pyrolysis and HTC reactor at BOKU and AIT



- 300-900 °C
- Variable residence time
- Flush gas: N_2
- Possibility of vapour activation at 900 °C
- Throughput: 2 kg/h biomass d.m.
  = 0.4-0.6 kg biochar/h
- Volatiles are completely burnt

- ~ 280 °C
- ~ 60 bar
- 600 ml
- stirrer



Properties of Biochar

- Input Material + Process Parameters => Properties of Biochar
  - Specific surface area
  - Cation exchange capacity
  - pH
  - Elemental composition
  - Pollutant concentrations
- European Biochar Certificate (EBC):
  - Production and Quality:
  - > 50% C (d.m.)
  - $H:C_{org} < 0,7$
  - $O:C_{org} < 0,4$
  - Indication of VOC-, N-, P-,K-, Mg-, Ca- concentration
  - Limiting values of heavy metals and PAH

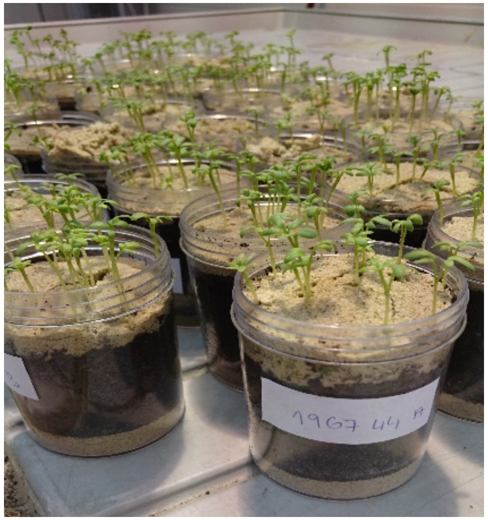
Biochar as soil amendment

- Carbon sequestration
- Higher water retention
- Immobilisation of pollutants
- Mitigation of N_2O – Emission from soil
- Often support of micro-organisms
- Often better availability of nutrients

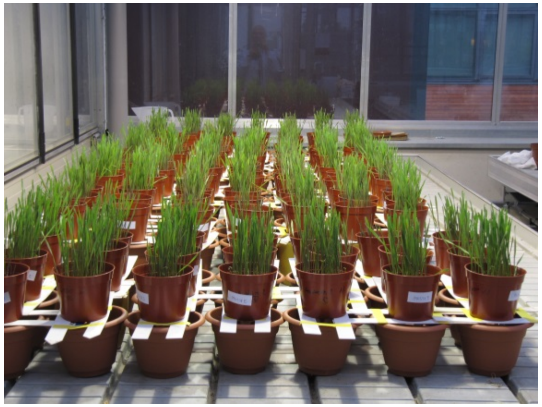
Source: https://i1.wp.com/terra-preta.de/wp-content/uploads/2014/07/terra-preta-picture-09.jpg?w=800&ssl=1

Classical plant tests

- **Germination test**
  - Biological model: garden cress (*Lepidium sativum* L .)
  - Germination rate during the first 6 days of growth
  - Evaluation of phytotoxicity

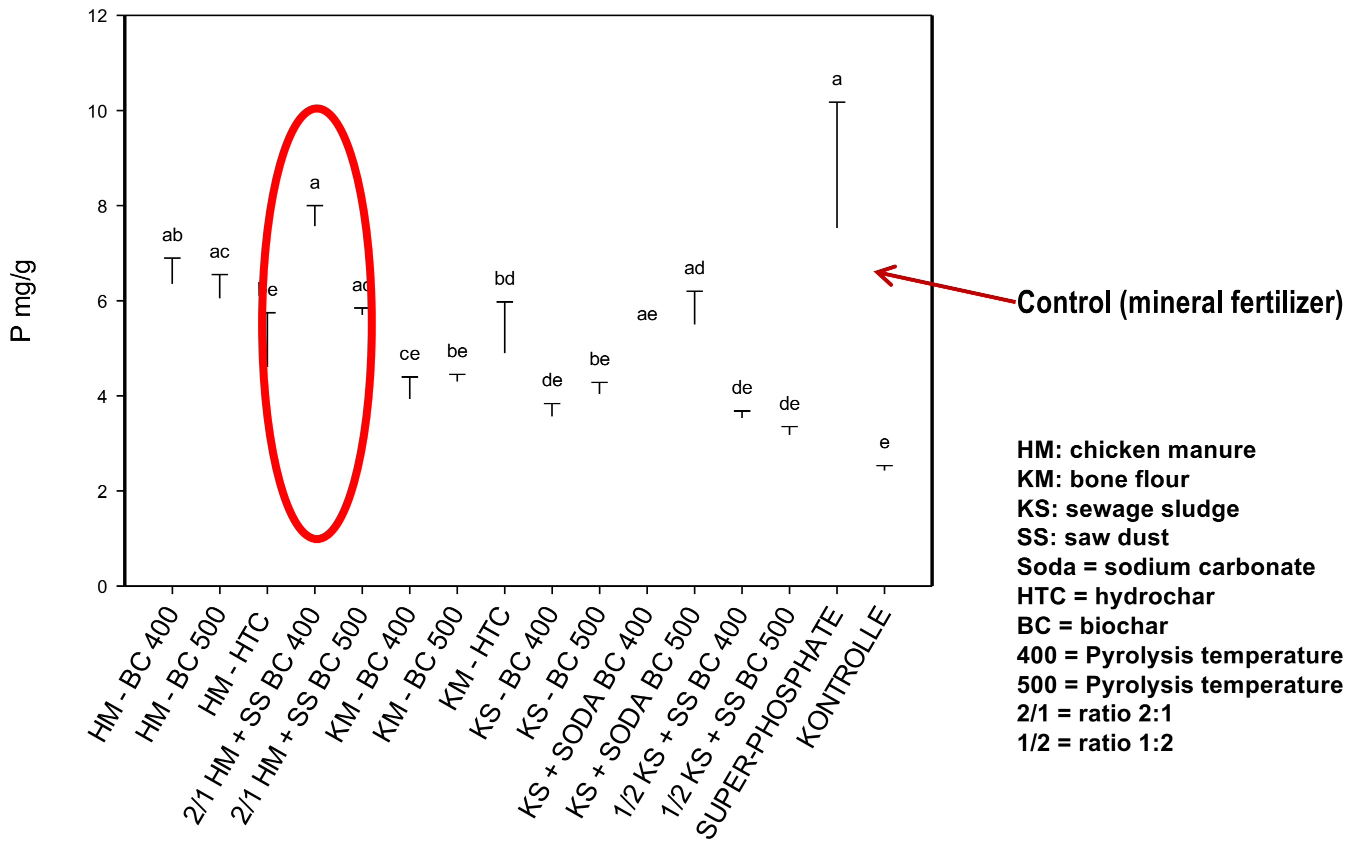


- **Neubauer test**
  - Rye (*Secale cereale* L.) grown in sand
  - Nutrient solution with essential macro nutrients but without P
  - P is tested as amendment to the solid substrate
  - 17 days of cultivation



Phosphorus supplying potential

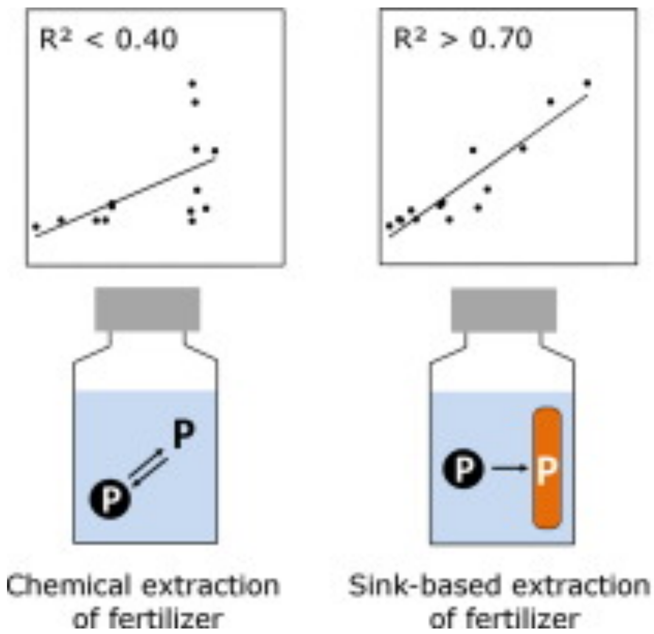
- P - concentration in rye plants
- Standardized Neubauer test => plants received the same amounts of P



HM: chicken manure
KM: bone flour
KS: sewage sludge
SS: saw dust
Soda = sodium carbonate
HTC = hydrochar
BC = biochar
400 = Pyrolysis temperature 400°C
500 = Pyrolysis temperature 500°C
2/1 = ratio 2:1
1/2 = ratio 1:2

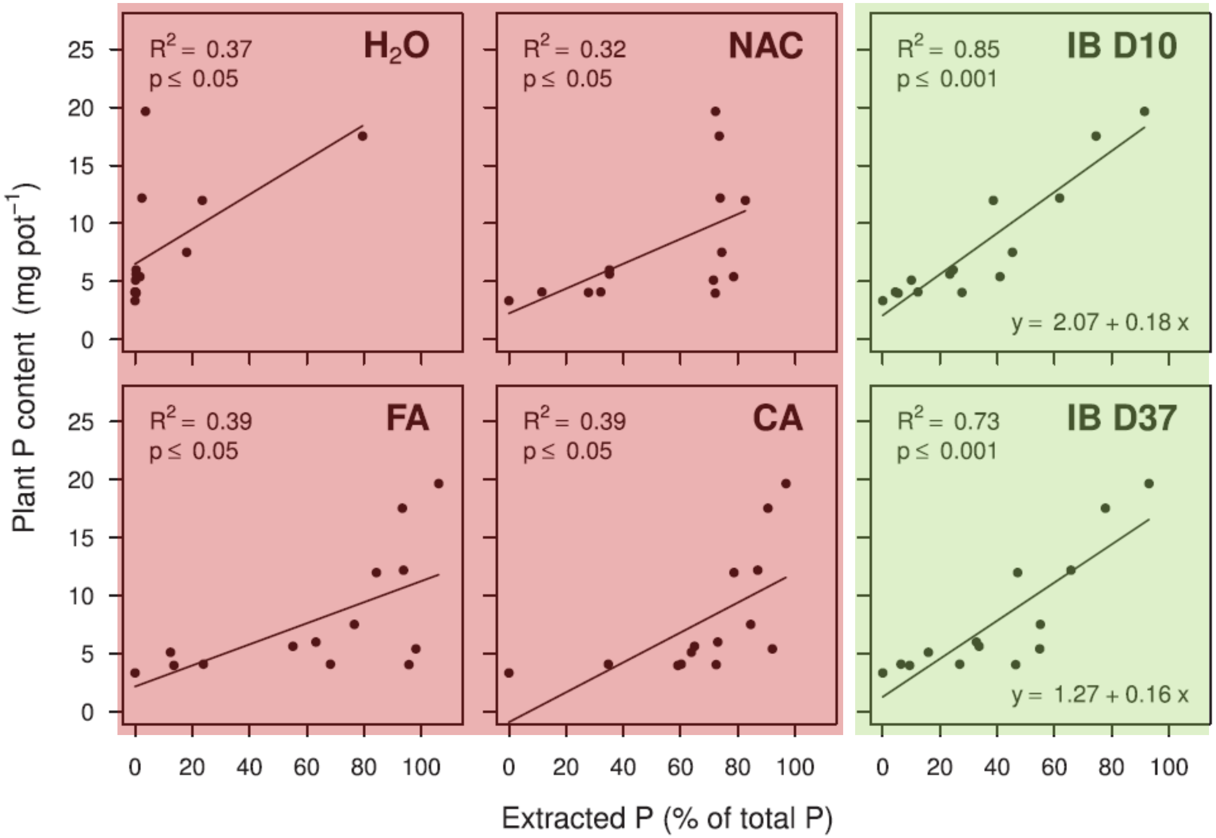
Methods for assessing nutrient availability

- Equilibrium-based methods => cannot simulate plant uptake
- Infinite sink „Iron bag“ => similar to plant roots => predictor for nutrient availability



Source: Duboc, O., Santner, J., Golestani Fard, A., Zehetner, F., Tacconi, J., Wenzel, W.W. Predicting phosphorus availability from chemically diverse conventional and recycling fertilizers, Science of The Total Environment, Volumes 599–600, p1160-1170

Calibration of extraction procedures in plant experiments



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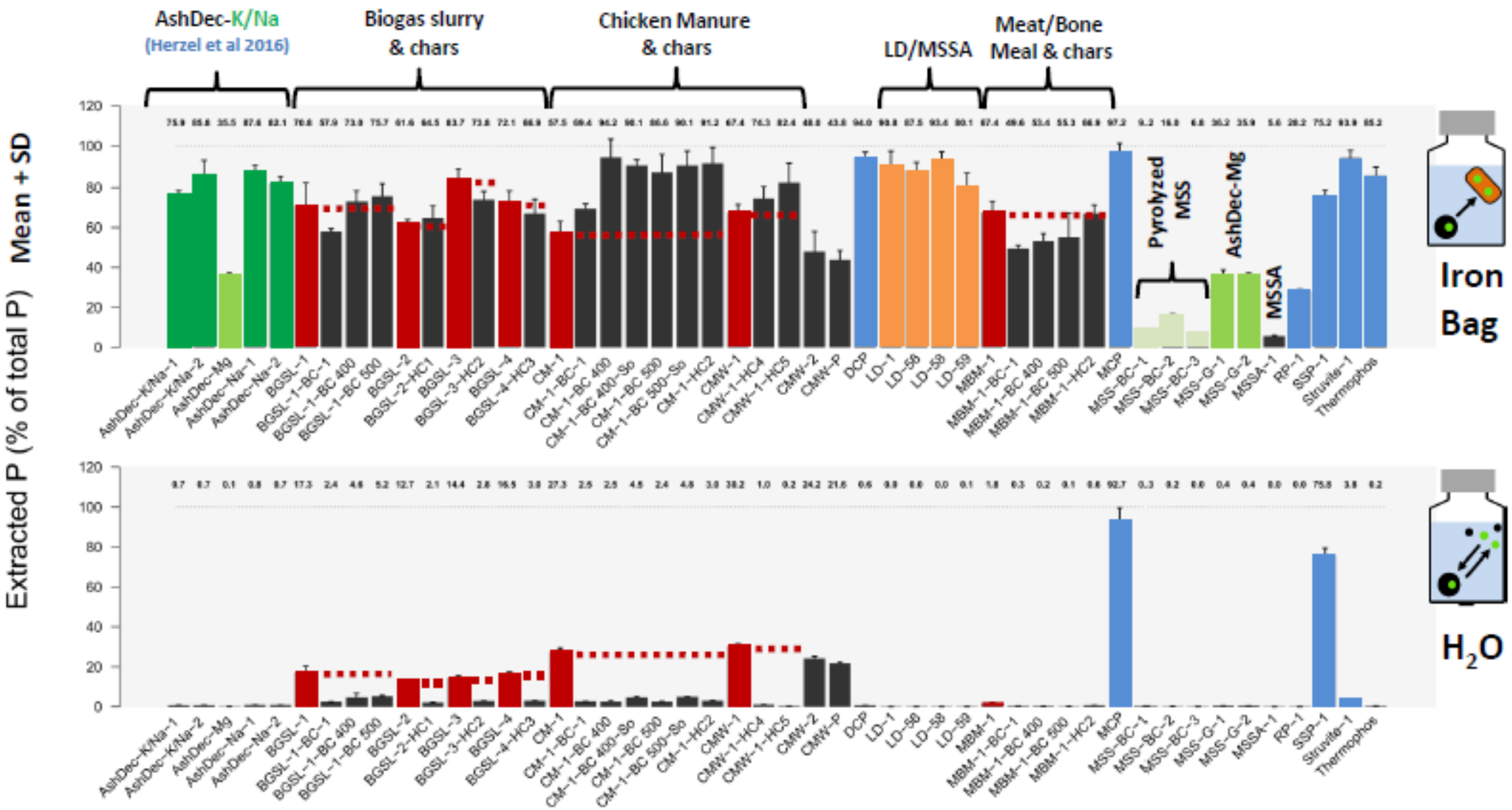
Product assessment for P availability using a combination of infinite sink (iron bag) and water-extractable fraction

- Iron bag (infinite sink) indicates availability of P on demand by plants
- Water solubility indicates risk of leaching from the root zone



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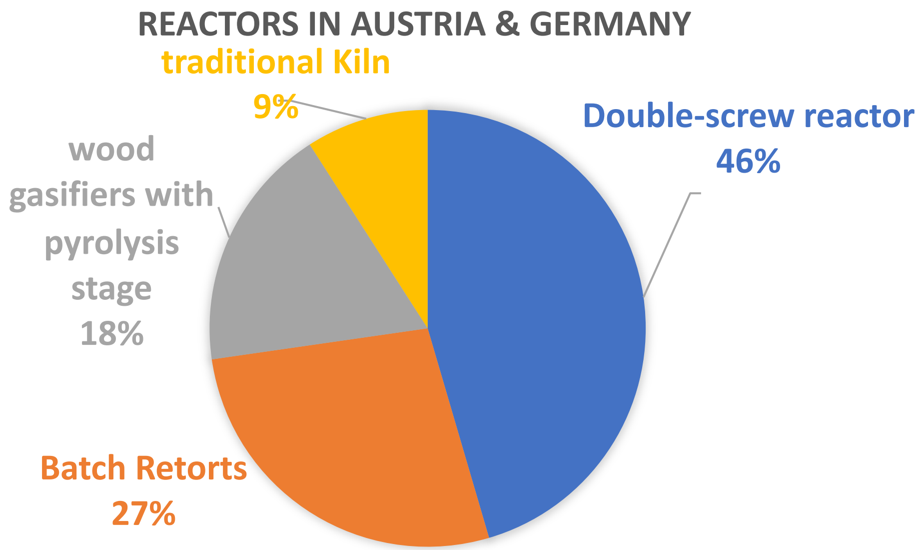
Biochar production in Austria and Germany

- Producers in A:
  - 2 producers with 250-350 t/a
- Producers in D:
  - 1 with ~3000 t/a, 2 with 600 – 1000 t/a, min. 3 with ~200 t/a



K.Mikula, 2018

Summary and conclusions

- Biochar utilization for soil application is a very promising utilization route
- Biochar from residues
- Technologies are available – optimization necessary
- Product characterisation as well as nutrient availability determination are important

Questions?

Source: Lehmann 2007

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