Steigerung von Pflanzenkohleerträgen mit Holzasche als Pyrolyseadditiv

Increasing biochar yield in pyrolysis by adding ash

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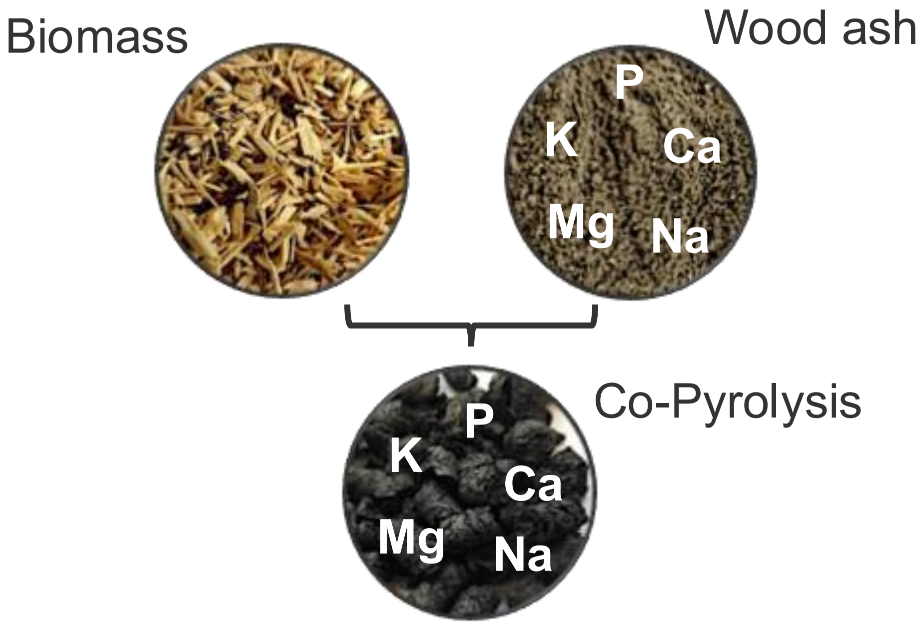
Wood ash as an additive in biomass pyrolysis

Rationale for using wood ash as additive in biomass pyrolysis:

- Wood ash represents a valuable resource which often has to be deposed.[1]
- Wood ash contains alkali and alkaline earth metals, which are known to increase biochar and carbon yield.[2]
- Recycling of ash-derived nutrients through biochar soil application.[3]



Combination of pyrolysis process optimization and production of a biochar-based fertilizer.

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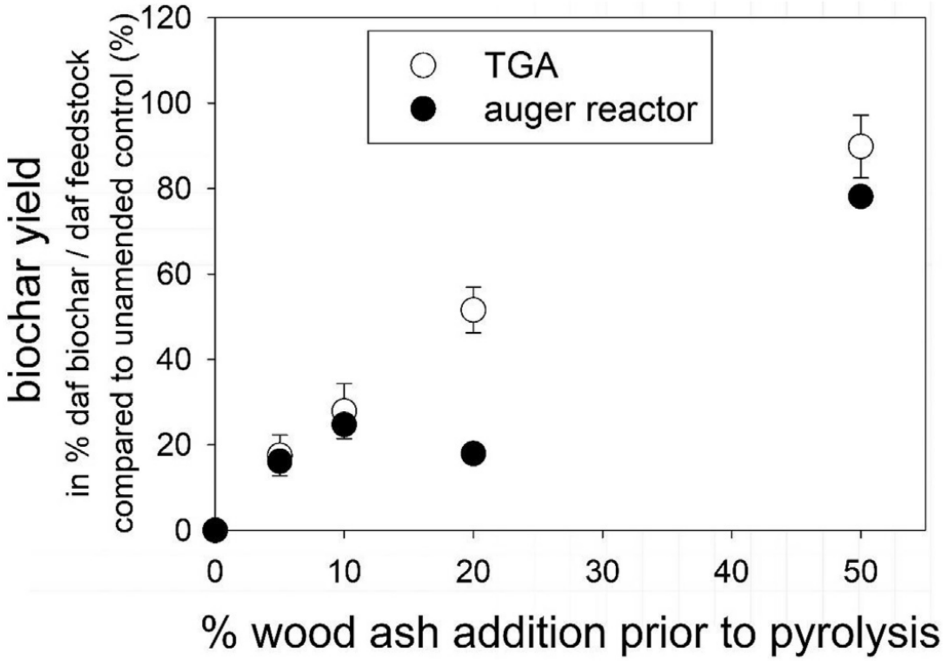
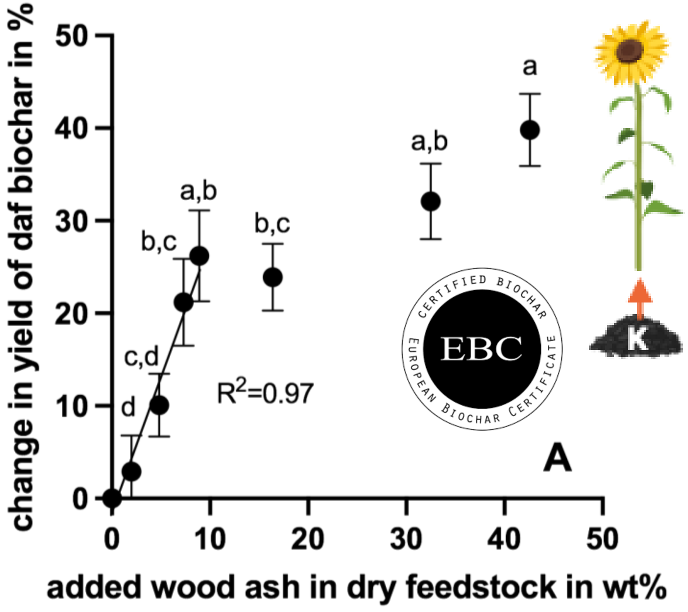
Previous research and open questions

[2]Buss et al. 2019



Spruce wood + bottom ash

[3]Grafmüller et al. 2022



Softwood + bottom ash

Open questions:

- How do different biomasses respond to an ash amendment?
- Different ashes = different yield increases?
- Can this strategy be applied to industrial-scaled biochar production?

Hypotheses

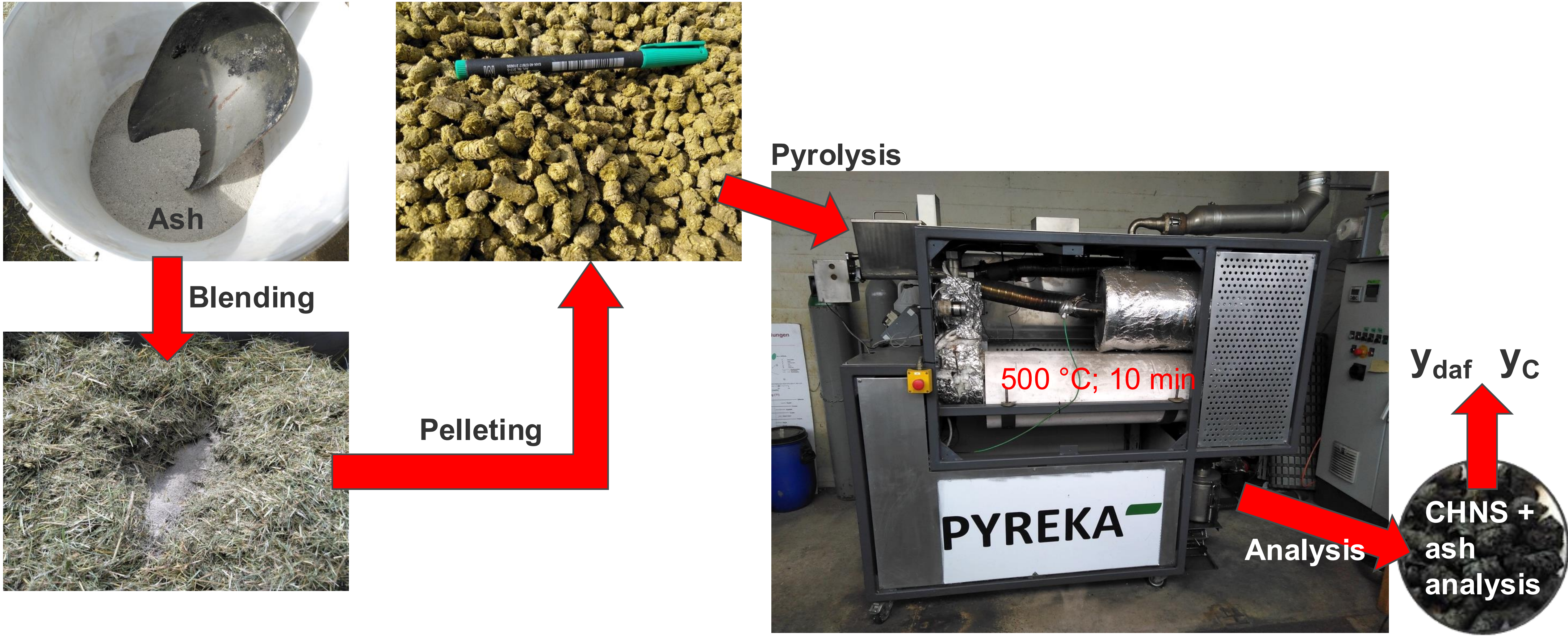
1. Increases in y_{daf} and y_C upon ash addition solely depend on the intrinsic ash content of the biomass.

All feedstocks pyrolyzed at 500°C with or without 5% ash amendment.

2. Different ashes vary in their effectiveness depending on their content of alkali and alkaline earth metals (AAEM = K + Ca + Mg + Na).

5 different ashes with a range of AAEM contents: 330-510 mg kg^{-1}

Pilot-plant pyrolysis



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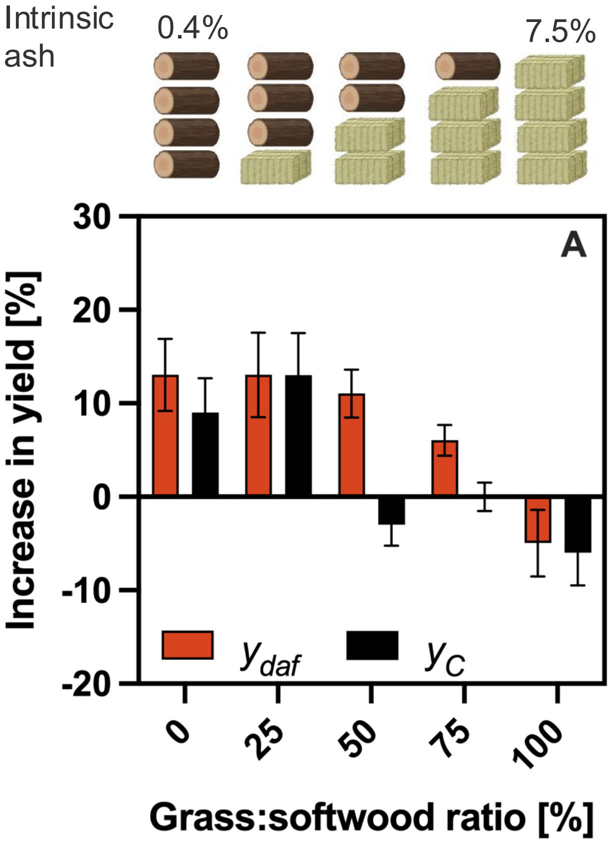
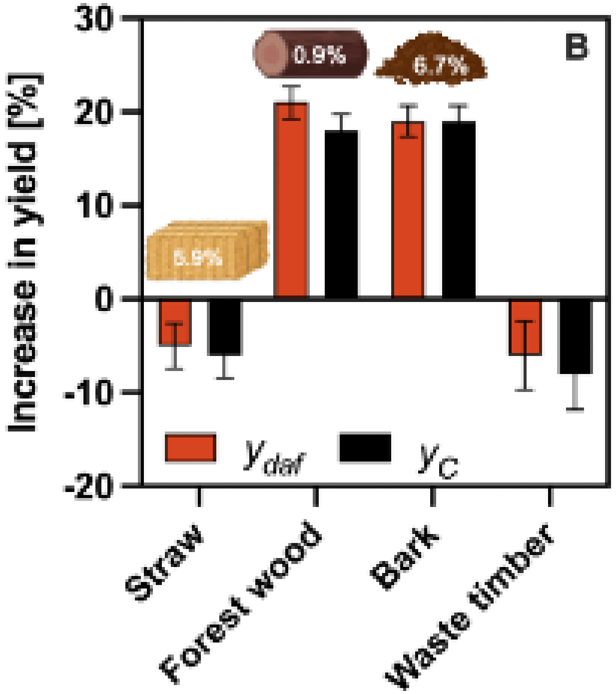
Variation of biomass feedstocks

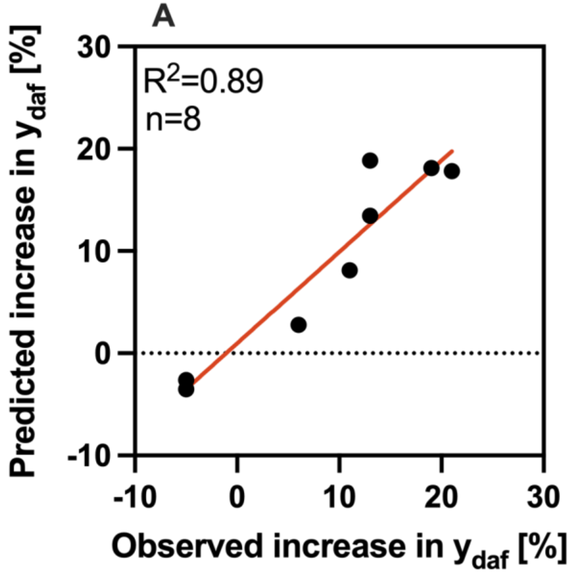




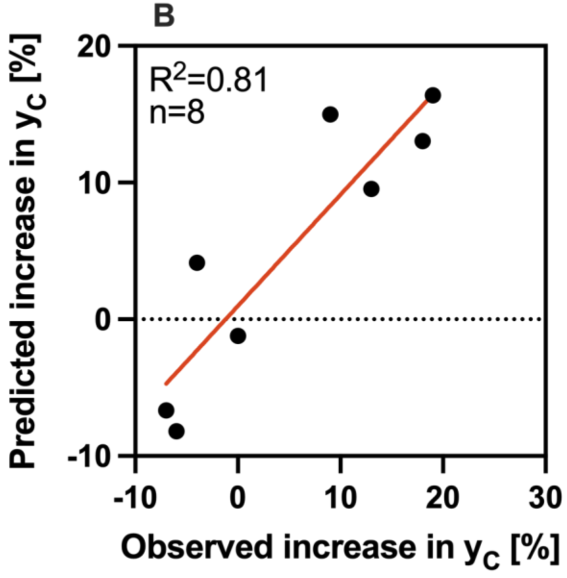
How do different biomasses respond to an ash amendment?

- Increases in y_{daf} and y_C become smaller with an increasing content of grass in the mixture.
- For pure grass, there is even a decrease in y_{daf} and y_C when ash was added.
- Unexpectedly, ash-amendment to bark (high intrinsic ash content) increased y_{daf} and y_C by 20%.
- No correlation of y_{daf} and y_C with intrinsic ash content observed, **Hypothesis 1** was withdrawn.

Variation of biomass feedstocks



Δy_{daf} = -4.3 + 0.6 · $x_{Cellulose}$ - 0.8 · $x_{Hemicellulose}$



Δy_C = -3.8 + 0.6 · $x_{Cellulose}$ - 0.9 · $x_{Hemicellulose}$

How do different biomasses respond to an ash amendment?

- Increases in y_{daf} and y_C become smaller with an increasing content of grass in the mixture.
- For pure grass, there is even a decrease in y_{daf} and y_C when ash was added.
- Unexpectedly, ash-amendment to bark (high intrinsic ash content) increased y_{daf} and y_C by 20%.
- No correlation of y_{daf} and y_C with intrinsic ash content observed, **Hypothesis 1** was withdrawn.
- Increase in y_{daf} and y_C could be best modelled by a multivariate approach considering cellulose and hemicellulose contents.

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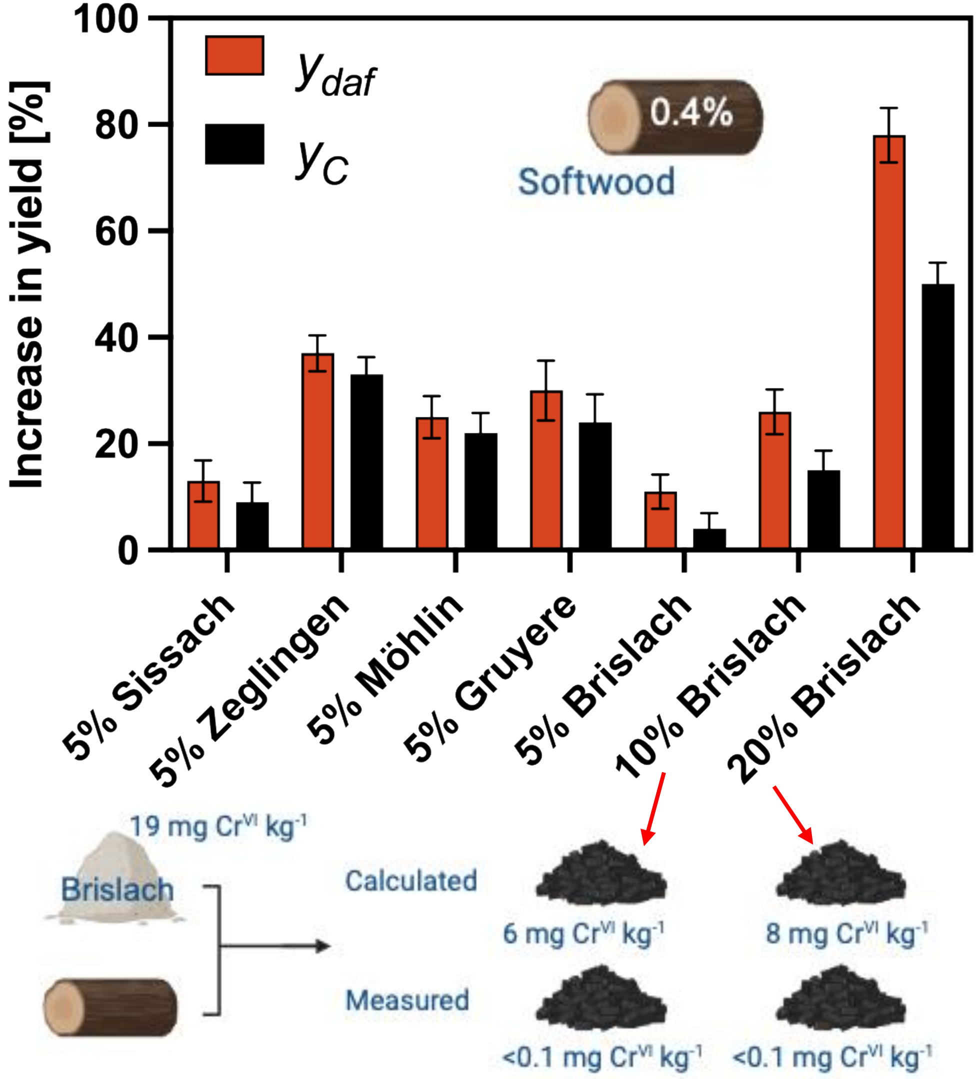
Trace metals in ash samples

	Element	Pb	Cd	Cu	Ni	Hg	Zn	Cr	Cr(VI)	As
Richtlinien	EU-FPR	120	3	600	100	1	1500	400	2	40
	BGH	150	1,5	900	80	1	5000		2	40
	BMLFUW A/B	100/200	5/8	200/250	150/200	1200/1500	1200/1500	150/250	2/2	20/20
Aschen	Sissach	183	<0.2	166	22	<0.07	96	39	1,6	3,9
	Zeglingen	5	0,6	88	21	<0.07	592	7	<0.1	<0.8
	Brislach	3	1,3	89	68	<0.07	107	75	19	1,5
	Möhlin	8	0,2	225	72	<0.07	82	57	17	1,3
	Gruyère	5	0,6	104	31	<0.07	157	78	4,7	2,9
	Gruyère 2. Charge	7	<0.2	230	44	<0.07	49	204	7,5	2,1

EU-FPR: EU-Fertilizer Product Regulation – CMC 13 „Thermal Oxidation Materials or Derivates“
BGH: Bundesgütegemeinschaft Holzasche **(DE)**
BMLUFW: Bundesministerium für Land- und Forstwirtschaft, Klima- und Umweltschutz [..] **(AT)**

- Only the Zeglingen sample complies with all three regulations.
- In most cases, Cr^{VI} values are a hindrance for direct soil application of the ashes.

Comparison of different ashes



Different ashes = Different yield increases?

- High variation of increases in y_{daf} (11-37%) and y_C (2-33%) when adding different ashes.
- Differences not related to AAEM contents in the ash, nor their solubility or their speciation: **Hypothesis 2** was withdrawn.
- Experiments using pure AAEM additives are needed to elucidate underlying mechanisms.
- Promising and incidental observation: **Cr^{VI}** initially present in the **Brislach** ash sample was not recovered in biochars.

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Industrial pyrolysis

iwb

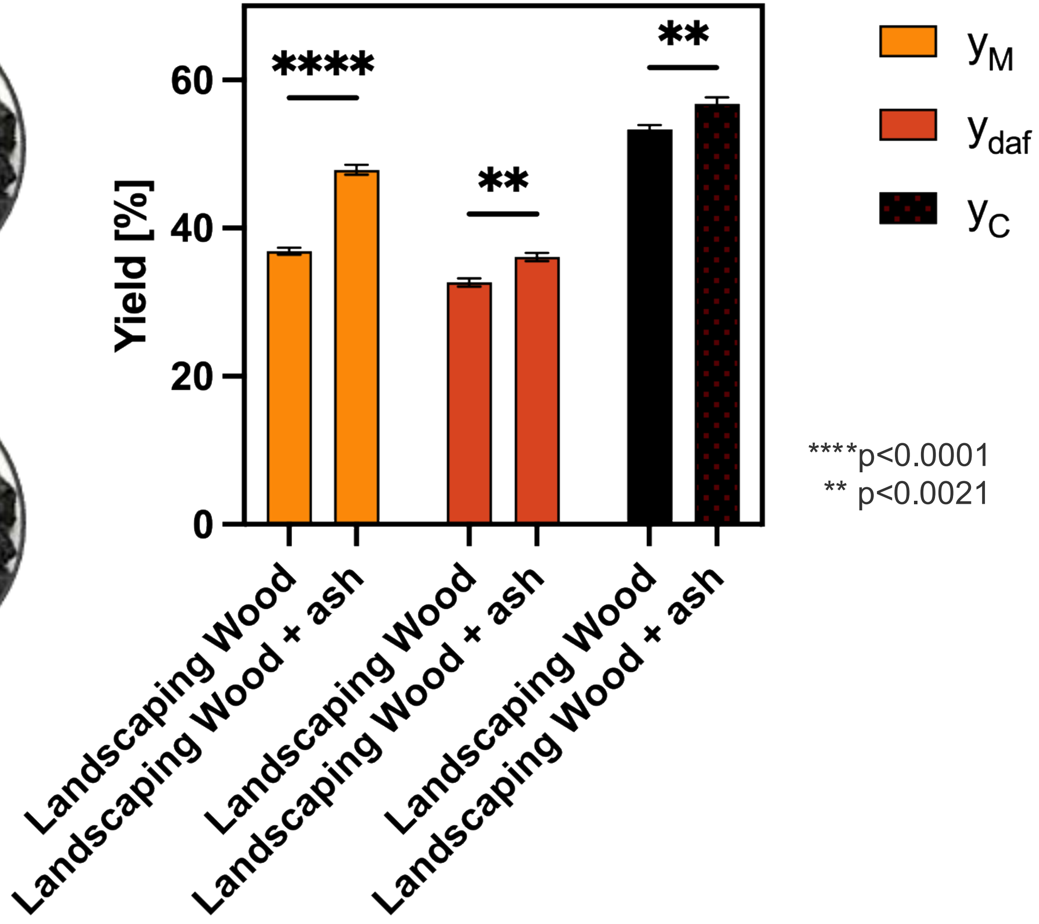
****p<0.0001
** p<0.0021

Can this strategy be applied to industrial-scaled biochar production?

Industrial pyrolysis

No ash

With ash



Can this strategy be applied to industrial-scaled biochar production?

- Adding 4% (w/w) of wood ash to landscaping wood increased:
  - Biochar yield (y_M) by 30%
  - Dry and ash-free biochar yield (y_{daf}) by 11%
  - Carbon yield (y_C) by 7%
- Additional 33 % revenue for plant operator per year:
  - 21,000 € for additional CO_2 sequestration
  - 200,000 € for additional biochar production
- Biochars met the EBC-AgroBio limit values.

Intermediary conclusion on wood ash as additive in biochar production

- Wood ash is a promising additive in biochar production for woody feedstocks to improve
  - biomass conversion into biochar.
  - AAEM nutrient recycling.
  - economic efficiency of biochar production.

- **Industrial pyrolysis:** No need for combined pelleting of ash and wood. Addition of ash e.g., in biomass feed container is sufficient.

- **Research gaps:**
  - Mechanistic understanding of interaction between ash and biomass type
  - Pyrolysis temperatures > 550 °C?

Current legal framework conditions in Europe

- **European Biochar Certificate:** Wood ash is **permitted** as pyrolysis additive, as long as the resulting biochars comply to the limit values.
- **EU Fertilizer Product Regulation (CMC 14):** Additives up to 25wt% are **permitted** in case they "improve the process or environmental performance of pyrolysis [..]"
  - **BUT: Not allowed** if additives are considered wastes according to Directive 2008/98EC (Article 3, point 1). Ashes are considered wastes, as they are a byproduct of wood combustion, where the primary product is heat.

→ **Ashes not allowed as additives for biochars for soil application**

→ **So far, only possible for biochars intended for material applications**

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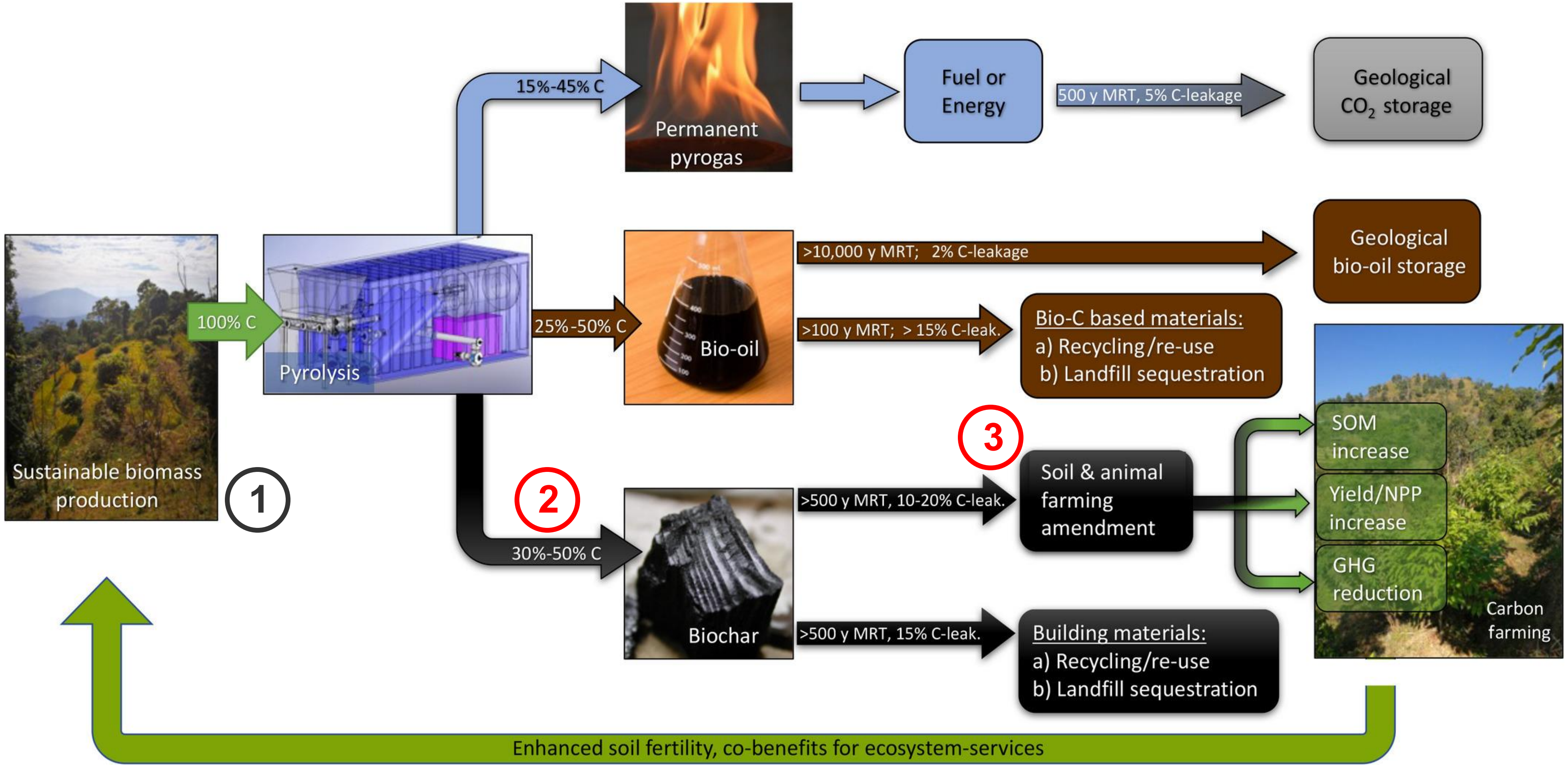
Pyrogenic Carbon Capture and Storage (PyCCS)



Limitations of PyCCS

1. Biomass availability

2. Carbon yield of pyrolysis

3. Biochar application

[4]Schmidt et al. 2019 in GCB Bioenergy, Volume: 11, Issue: 4, Pages: 573-591, First published: 17 August 2018, DOI: (10.1111/gcbb.12553)

Thank you for your attention!

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(3) Grafmüller, J., Böhm, A., Zhuang, Y., Spahr, S., Müller, P., Otto, T.N., Bucheli, T.D., Leifeld, J., Giger, R., Tobler, M., Schmidt, H.-P., Dahmen, N., Hagemann, N., 2022. Wood Ash as an Additive in Biomass Pyrolysis: Effects on Biochar Yield, Properties, and Agricultural Performance. ACS Sustainable Chemistry & Engineering 10, 2720–2729. https://doi.org/10.1021/acssuschemeng.1c07694

(4) Schmidt, H.-P., Anca-Couce, A., Hagemann, N., Werner, C., Gerten, D., Lucht, W., Kammann, C., 2019. Pyrogenic carbon capture and storage. GCB Bioenergy 11, 573–591. https://doi.org/10.1111/gcbb.12553