Ash, Biochar, Charcoal
Ingredients and Properties

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Structure

- Differences between ash, biochar and charcoal
- Production options
- Application potentials
- Quality requirements, product certification

In the beginning there was biomass ....

Combustion
(with oxygen)

Ash
(no carbon left)

Yard & garden uses

Pyrolysis
(oxygen deficiency)

Biochar
(70-90 % carbon)

Agricultural uses
Soil amendment
C-sequestration

Charcoal
(70-90 % carbon)

Thermal uses
Barbecue fuel

What is activated carbon etc.?

- Activated carbon = activated charcoal = activated biochar
- Activation = enhancement of specific sorption characteristics
  - Physical activation: steam application to common charcoal at 900 – 1000 °C
  - Chemical activation: strong acids or bases applied pre- or post-pyrolysis
- Main effect: creation of additional pores → higher specific surface area and higher sorption potential
- Main uses:
  - Medicinal uses
  - Environmental technology (cleaning of water, gas, atmosphere …)

- Attention: sometimes the term „activation“ is (inappropiately) used for biologically inoculated or nutrient-enriched biochars.

Wood ash

- (Nearly) no nitrogen, no carbon
- Most abundant element: Ca (<30 %)
- <10 % K, <2 % P, trace elements
- pH 10-11
- Maximum application rate for crops: 1 t/ha.yr
- Maximum application for grassland: 0.5 t/ha.yr
- Threshold values of pollutants

	Aqua regia-digestion (mg/kg)	
	class A*	class B*
Zn	1000	1250
Cu	140	180
Cr	65	105
Pb	55	110
Ni	80	110
Cd	3.5	5.5
As	20	20
Cr (VI)	2	2
PAH (6 WHO)	6	6


lebensministerium.at

RICHTLINIE FÜR DEN SACH-GERECHTEN EINSATZ VON PFLANZE-NASCHEN ZUR VERWERTUNG AUF LAND- UND FORSTWIRTSCHAFTLICH GENUTZTEN FLÄCHEN

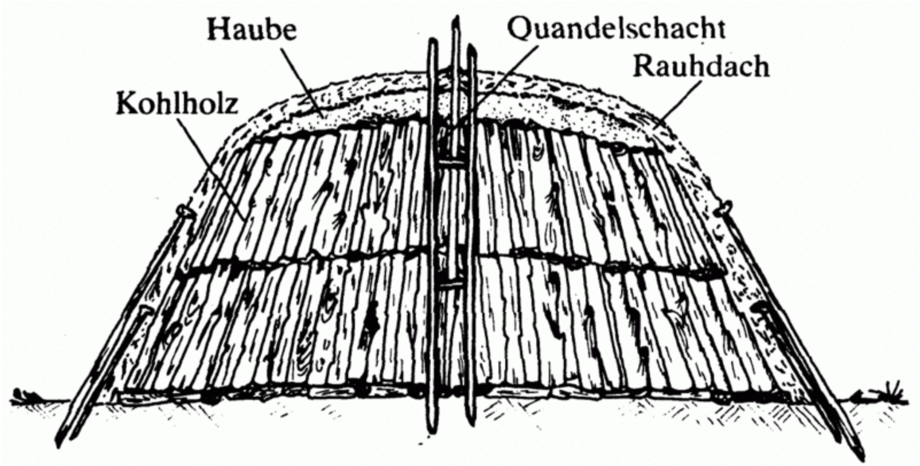
Fachbeirat für Bodenfruchtbarkeit und Bodenschutz

Austrian Guideline for plant-based ashes in agriculture and forestry, 2011, ed. 2017

* Exceedance of class A thresholds requires check for soil guide values according to ÖNORM L 1075. If exceeded, class B may not be used.

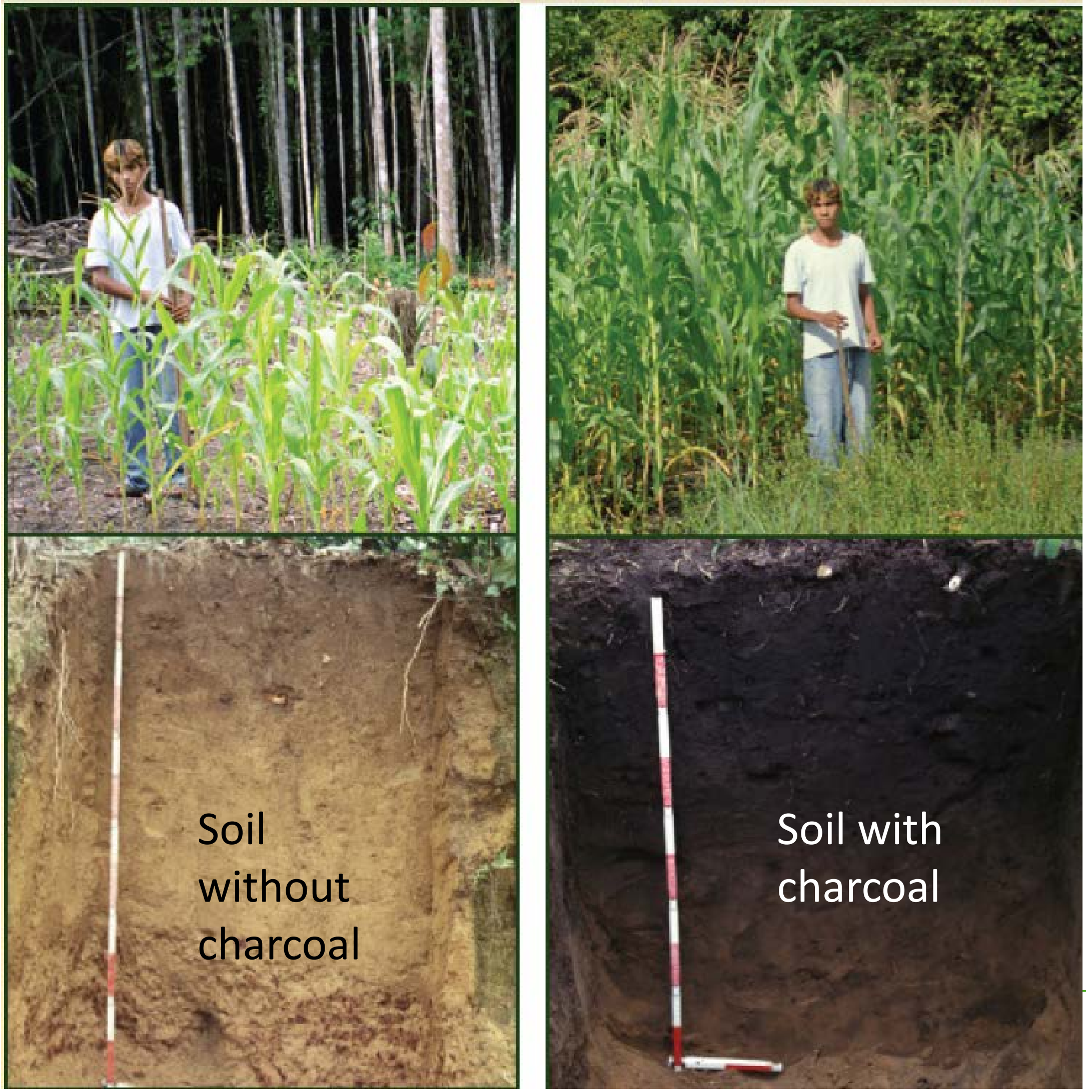
Pyrolysis, historically termed charcoal-burning, has been used since centuries

Pyrolysis:
Thermochemical process of heating under O_2-deficient oder O_2-free conditions



Source: https://www.kohlenmeiler.net/index.php?id=52

Discovery of ancient agricultural charcoal applications: Terra Preta in the Amazonas region

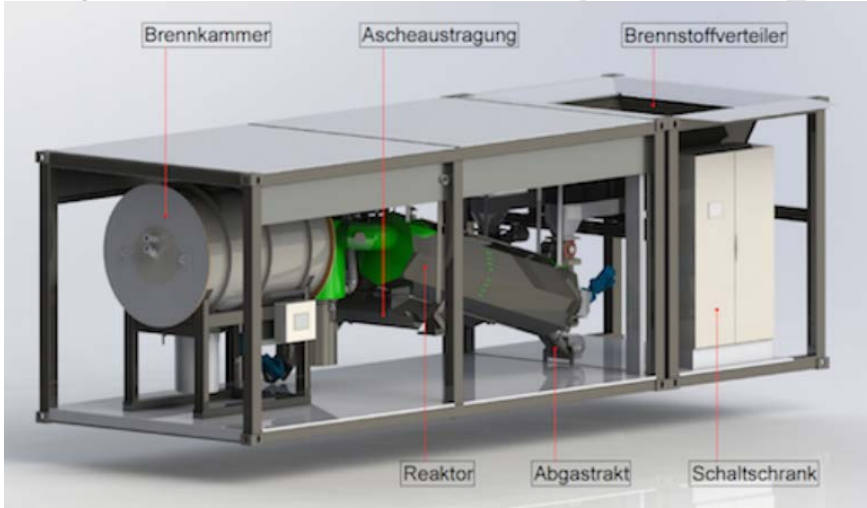


Source:
International Union of Soil Sciences

Wim Sombroek (1934-2003) discovered the „Terra Preta dos Indios“ in the 1990ies .

Source: Kammann und Glaser, 2010

Slow and fast pyrolysis(gasification) plants (flash pyrolysis)



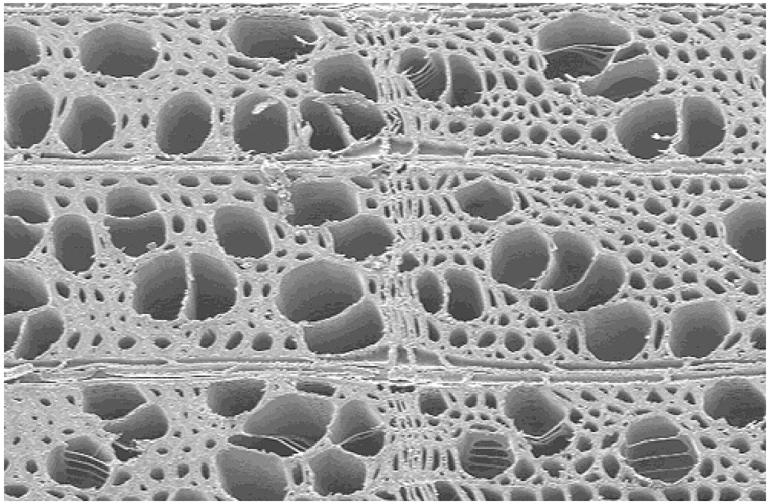
Pyreg-plant; www.pyreg.de

Rice straw and rice husk gasification in China

Biomass heating unit with biochar production
www.biomacon.com

Syncraft-gasifier Ternitz (Floating fixed bed reactor)
www.syncraft.at

Quelle: E.V. Kultikova, 1999



Anatomical changes during pyrolysis

Pore structure of the plant material persists
AND
additional micropores are formed

consequence: high specific surface area, high sorption potential

Pyrolysis

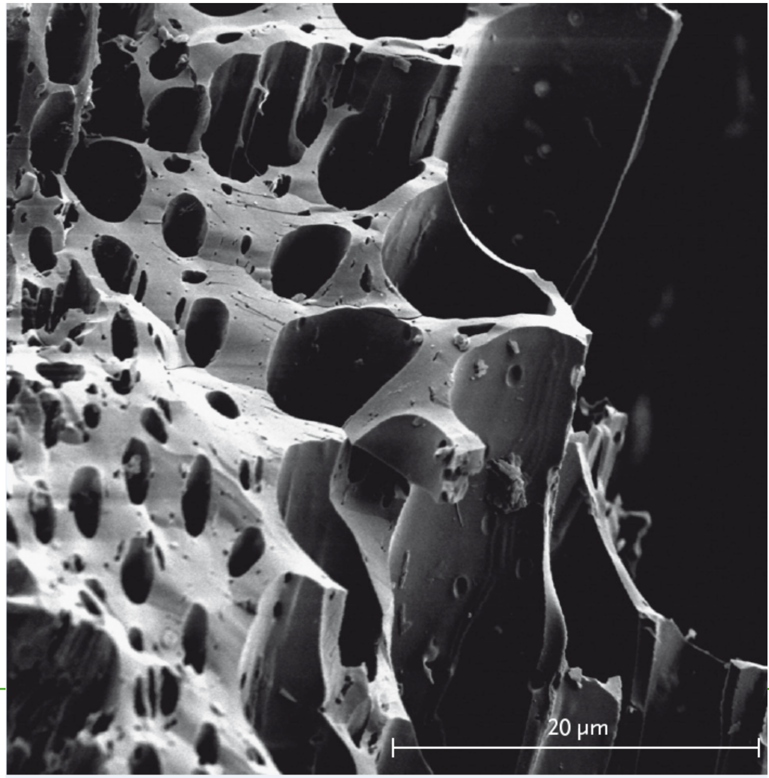
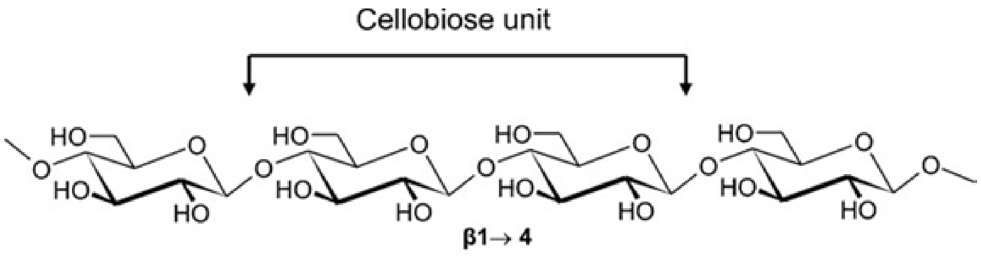
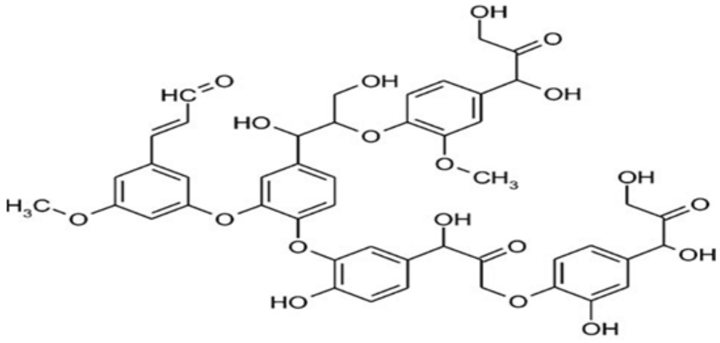


Photo: Martin Brandstetter

Starting with cellulose and lignin….

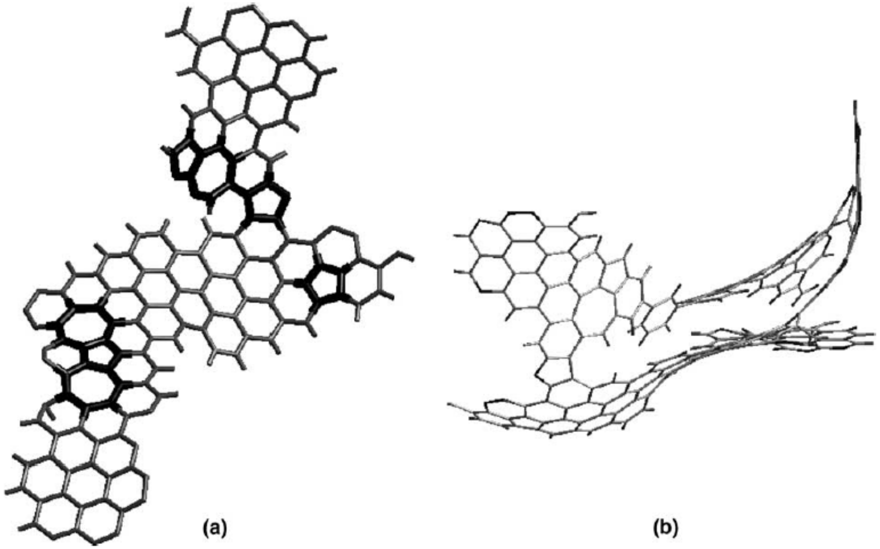


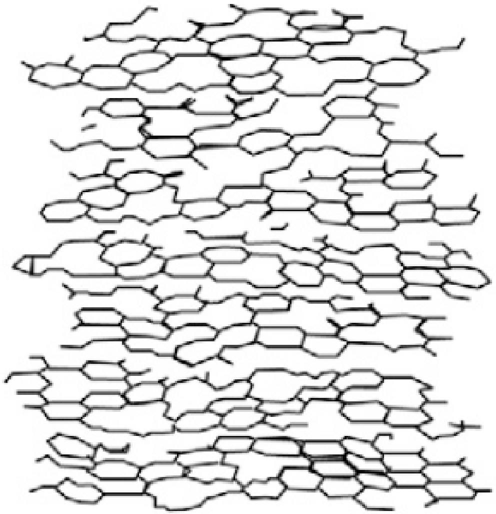
Cellulose



Lignin

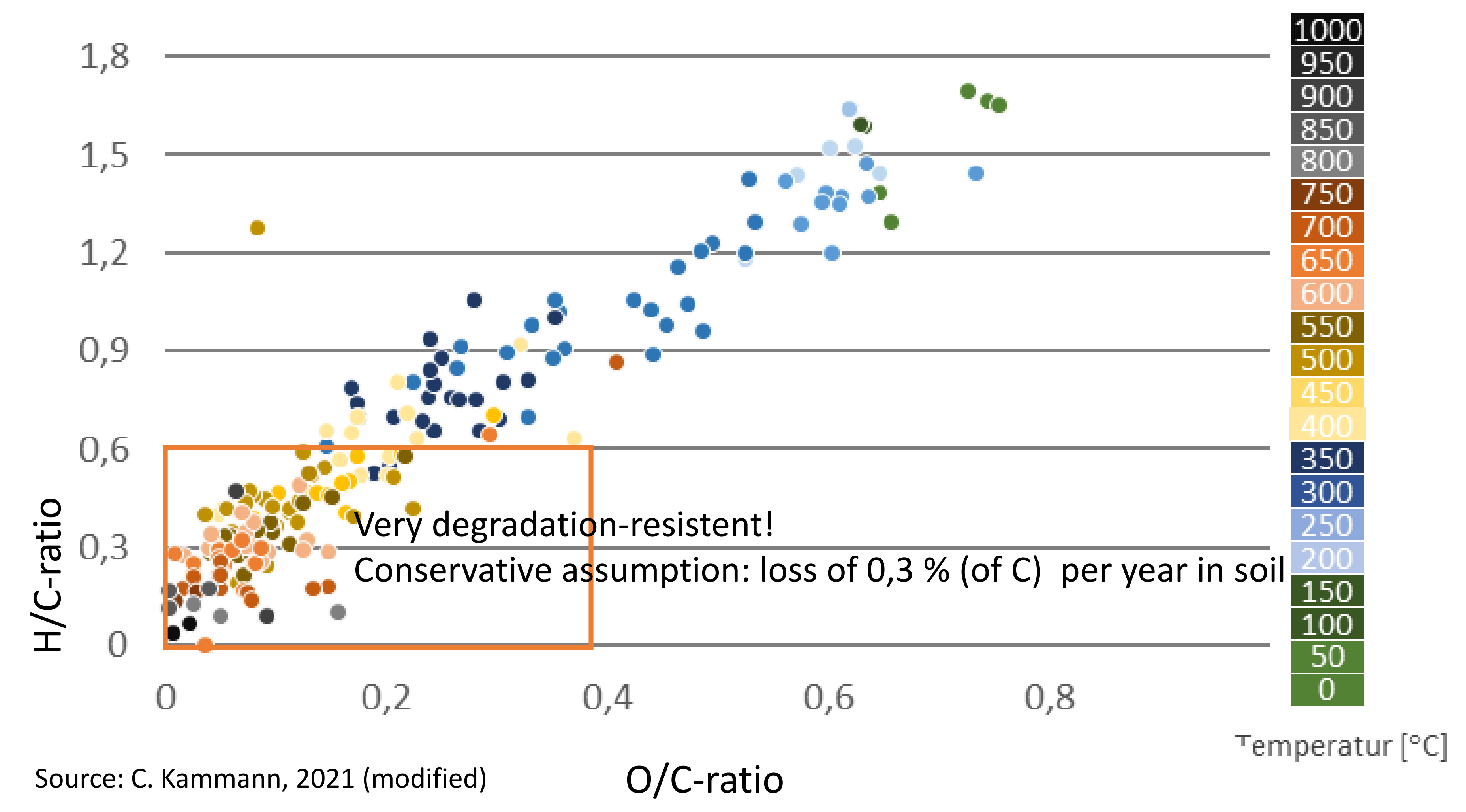
…. pyrolysis creates graphene-like structures, highly resistant against biological degradation





Sources: http://usmle.biochemistryformedics.com/role-of-dietary-fibre/
Kumar et al., 2005; Schimmelpfennig & Glaser, 2012

During pyrolysis:
Loss of hydrogen, oxygen
Accumulation of carbon („carbonization“)



Source: C. Kammann, 2021 (modified)

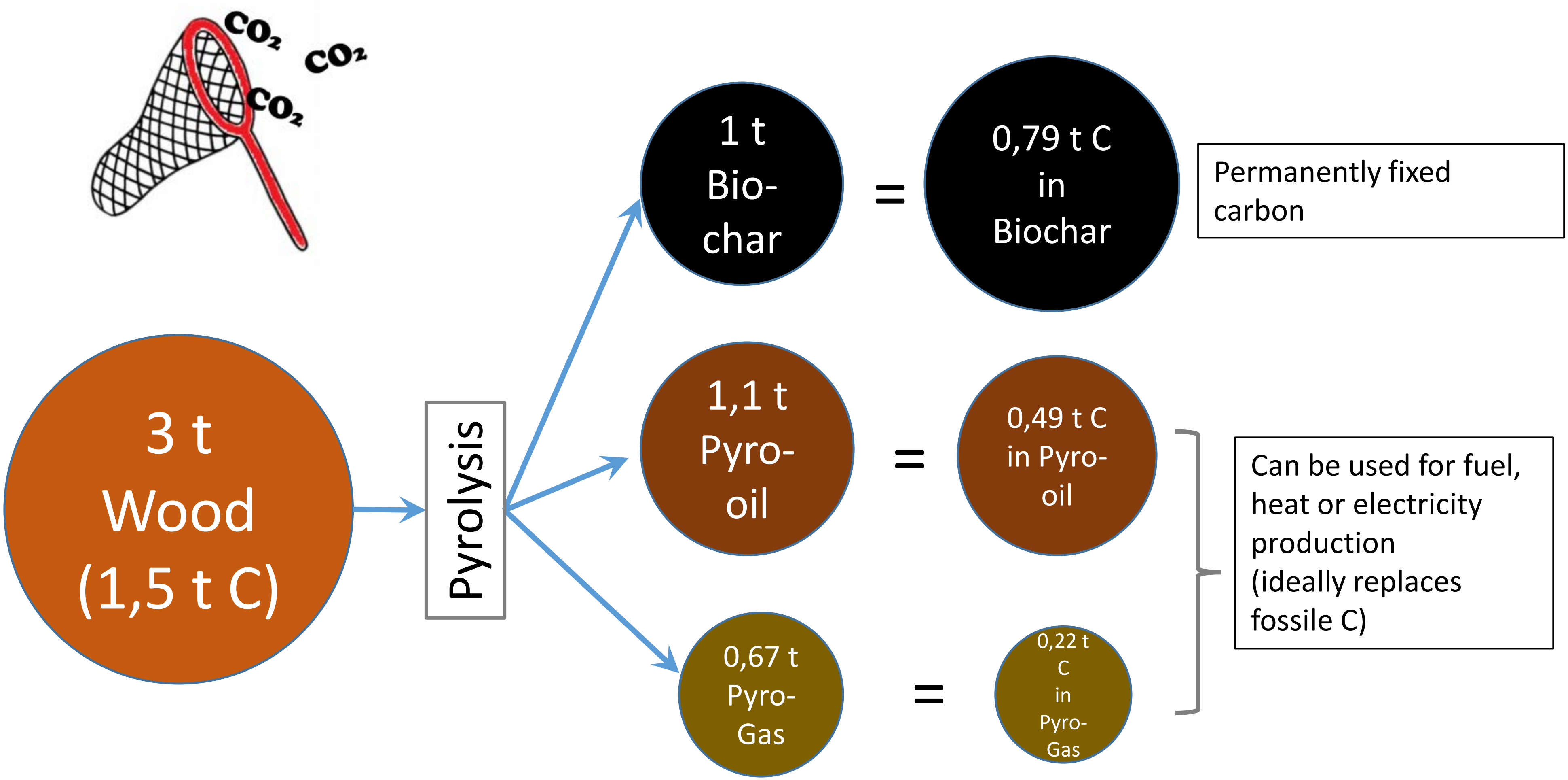
Which input materials are useful for pyrolysis?

- Primarily **wastes and residues from agriculture and forestry**; in principle all organic materials with a d.m. of >50-60 % can be pyrolyzed

Biochar / charcoal

- Yield of pyrolysis: 25-35 % (m/m)
- Yield of gasification: 5-10 % (m/m)
- C-content of plant-based materials: 70-90 %
- Majority of N is lost, residual N has low bioavailability: necessity of N-enrichment of biochar if used in soils.
- P, K is enriched and may have a fertilizing effect.
- Sorption and availability of micronutrients depends on input material and cationic / anionic speciation in soil

Biochar for pyrolytic CARBON-SEQUESTRATION



Data source: N. Hagemann, 2019

CO_2-compensation with biochar

Average annual CO_2-footprint (CO_{2e}) of one person in Germany:

11,4 t

x = 11,4 / (C-concentration * molar ratio * losses in process chain)

x = 11,4 / (0,79 * 3,67 * 0,92)

x = 4,3

Necessary biochar for compensation: **4,3 t**

(= about 13 t biomass d.m. input)

Quelle: https://fachverbandpflanzenkohle.org/

Biochar –
the „jack of all trades device“?

Benefits of biochar applications – but they need the suitable framing conditions:

- Long-term carbon sequestration in soil
  - 1 kg biochar-carbon sequesters about 3.3 kg CO_2 (without indirect effects) + replaces ca. 1,5 kg CO_2 from fossil fuels when volatile substances are utilized
- Reduction of N_2O-emissions from soil
- Reduction of nitrate leaching from soil
- Improvement of physico-chemical soil properties (pH increase of acidic soils) and of soil water relations (enhancement of water storage capacity)
- Enhancement of soil microbiology
- Immobilisation of soil pollutants
- Improvement of farm animal health (as feed supplement); lower NH_3 losses when added to litter
- Improvement of plant growth (biochar as carrier for nutrients)
- Industrial applications (batteries, electrodes, reductants, …)
- IPCC lists biochar as „negative emission technology“ – supportive to achieve 1.5 °C-objective

The European Biochar-Certificate – international quality standard for biochar (both from pyrolysis or gasification)

EBC - Label EBC - Class		EBC-Feed Class I	EBC-AgroBio Class II	EBC-Agro Class III	EBC-Material Class IV
Organic contaminents	16 EPA PAH	4±2 g t^{-1} DM	4±2 g t^{-1} DM	6.0+2.2 g t^{-1} DM	30g t^{-1} DM
	Benzo[a] pyren	25 mg t^{-1} (88% DM)			

Polycyclic aromatic hydrocarbons (PAH) are often the most critical quality parameter.

Quelle: https://www.european-biochar.org/media/doc/2/version_en_9_3.pdf

ÖNORM
S 2211
Ausgabe: 2016-11-01

Universität für Bodenkultur Wien

AUSTRIAN INSTITUTE OF TECHNOLOGY

Österreichischer Verein für Biomasse-Karbonisierung

Trace element und PAH-thresholds for biochar according to Austrian national standard ÖNORM S 2211

Tabelle 1 — Schwermetall-Grenzwerte für Pflanzenkohle

Eignung	Pb	Cd	Cu	Ni	Hg	Zn	Cr
	mg · kg^{-1} TM						
Pflanzenkohle, geeignet für die Landwirtschaft	100[b]	3,0[b]	150[c]	100[b]	1,0[b]	500[c]	100[b]
Pflanzenkohle, geeignet für den Biolandbau[a]	45	0,7	70	25	0,4	200	70

[a] Die Grenzwerte entsprechen der Kompostqualitätsklasse A+ gemäß Kompostverordnung sowie der EU-Verordnung 834/2007.

[b] Die Grenzwerte entsprechen der Düngemittelverordnung 2004.

[c] Die Grenzwerte entsprechen der Kompostqualitätsklasse A gemäß Kompostverordnung.

Tabelle 2 — PAK-Grenzwerte

Eignung	PAK
	mg · kg^{-1} TM
Pflanzenkohle, geeignet für die Landwirtschaft	6,0 (PAK 16)
Pflanzenkohle, geeignet für den Biolandbau	4,0 (PAK 16)

Summary

- **Biochar is a carbonisation product of pyrolysis or gasification, ash is a product of combustion**
- **Ash** can be used as **soil amendment** and PK-fertilizer; compliance with pollutant thresholds provided
- **Biochar** is a carbonization product for agricultural applications and as environmental technology, **charcoal** is for thermal uses.
- **Activated carbon** is a purpose-designed modified biochar / charcoal.
- C-degradation of biochar in soil (if used for certificate trading): **0,3 % p.a.**
- Apart from reduction of atmospheric CO_2, biochar has multiple environmental benefits for agricultural applications.
- Pollutant thresholds are published in **European Biochar Certificate (EBC)**, ÖNORM S 2211; any biochar use should rely on **EBC-certified biochar** only.

Wishing you a Happy Charring …

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