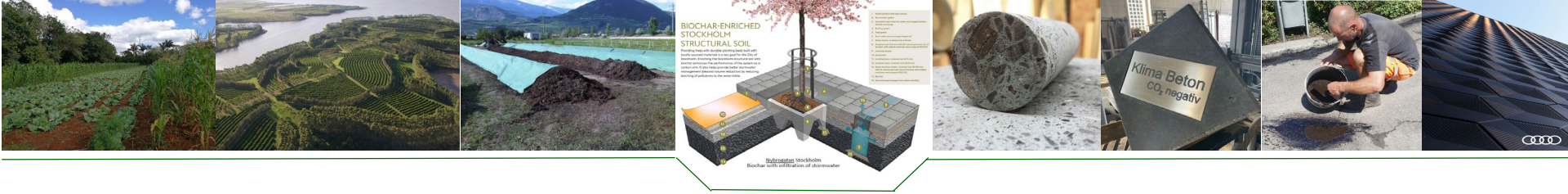
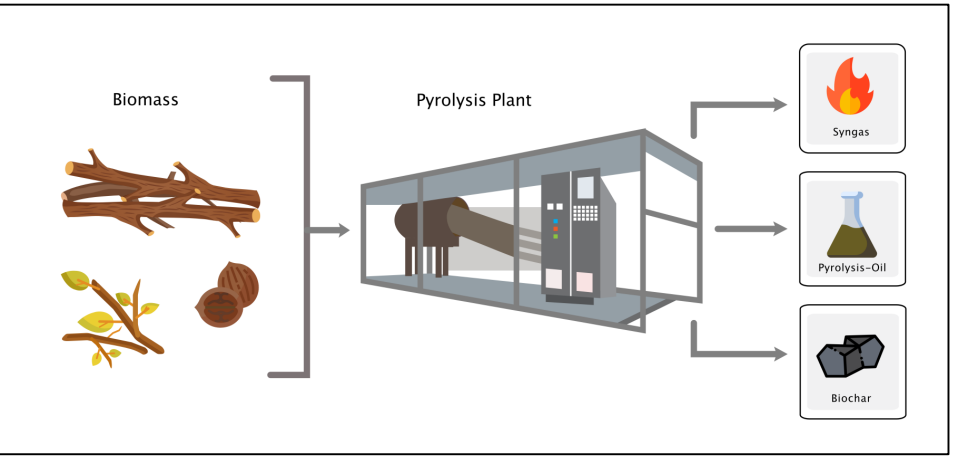


State of Biochar-CDR: Industries & TRL, C persistence, co-benefits and VCM certification and trading schemes



Claudia Kammann & Annette Cowie

Hochschule Geisenheim University

NSW GOVERNMENT Department of Primary Industries

Structure of Talk

- What is pyrolysis and biochar?
- State of CDR report, biochar industries & trading (cdr.fyi)
- C persistence: State of scientific knowledge
- SDG- and CDR-relevant: Co-benefits (by metastudies)
- Overview: Existing MRV schemes & VCM CDR trading
- Summary: Scientific state of knowledge for calculating (national) CDR budgets via biochar production and use

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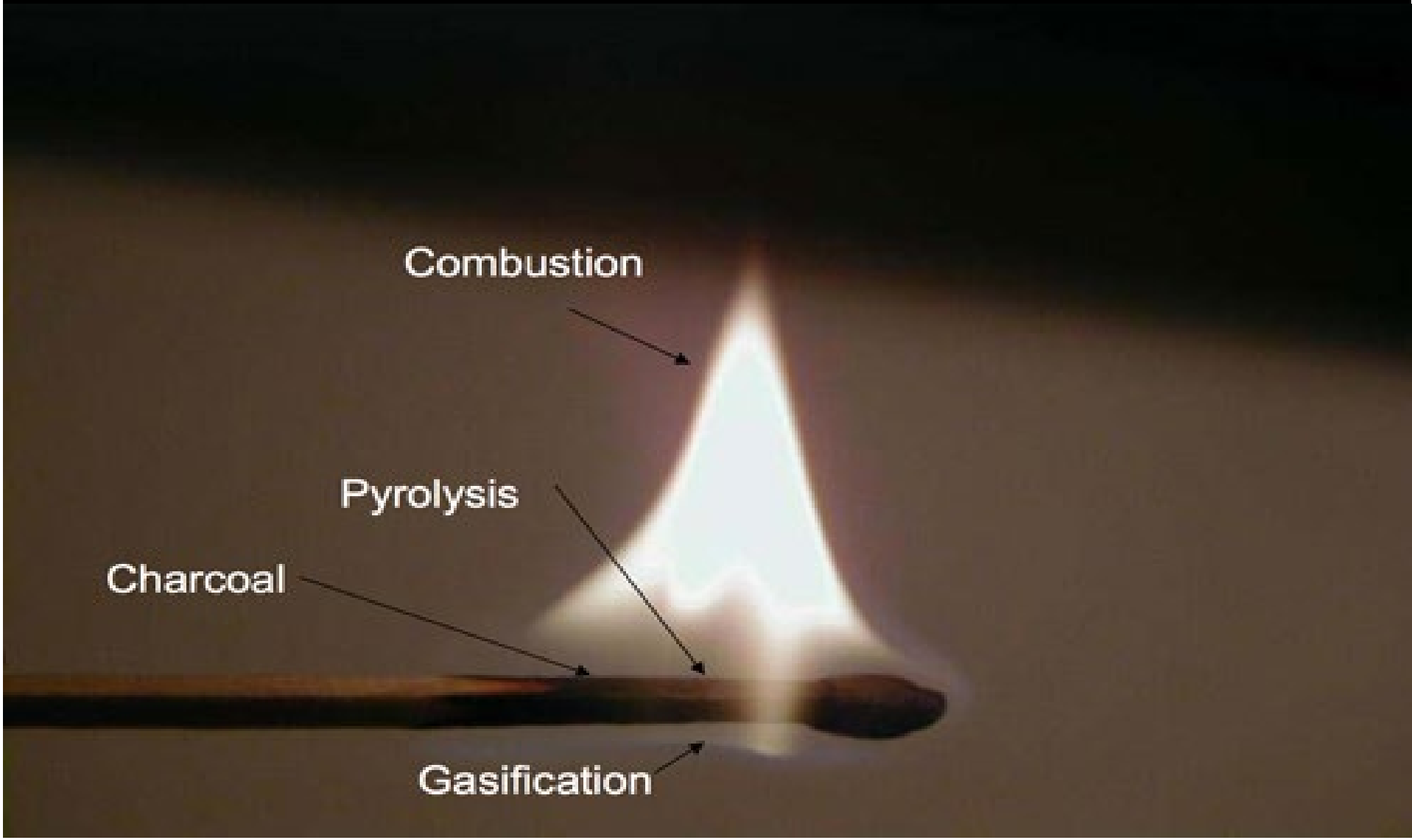
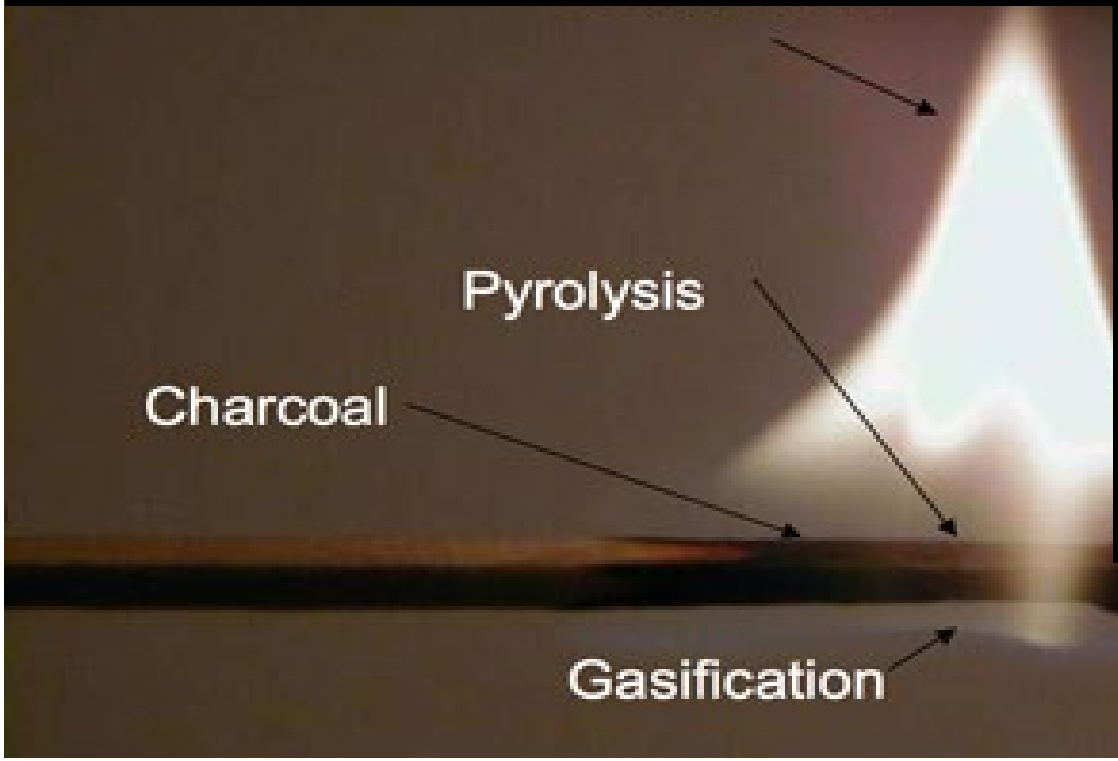
- Current number of papers >38.000 (keyword biochar)
- Current conservative estimate of global production: 350,000 t biochar (2023); CAGR (2021-2023) 91%;
  Revenue biochar producers, distributors, value-added producers & equipment manufacturers exceeded $600M USD in 2023; CAGR 97% (IBI & USBI Global market report)

What is Pyrolysis?



What is Pyrolysis?

Slow pyrolysis:
~50% of Biomass-C into biochar,
~50% into thermal energy
Current TRL level is 8 - 9



Swiss Sugar, Frauenfeld CH:
Biochar + Process heat +
District heating + electricity
Feedstock forest residues
=> 9000 t CO_2e p.a.


THE STATE OF
Carbon
Dioxide
Removal
A global, independent scientific assessment of Carbon Dioxide Removal
2nd EDITION | 2024
A collaboration led by Oliver Geden (German Institute for International and Security Affairs, SWP), Matthew J Gidden (International Institute for Applied Systems Analysis, IIASA) , William F Lamb (Mercator Research Institute on Global Commons and Climate Change, MCC), Jan C Minx (Mercator Research Institute on Global Commons and Climate Change, MCC), Gregory F Nemet (University of Wisconsin-Madison) and Stephen M Smith (University of Oxford)

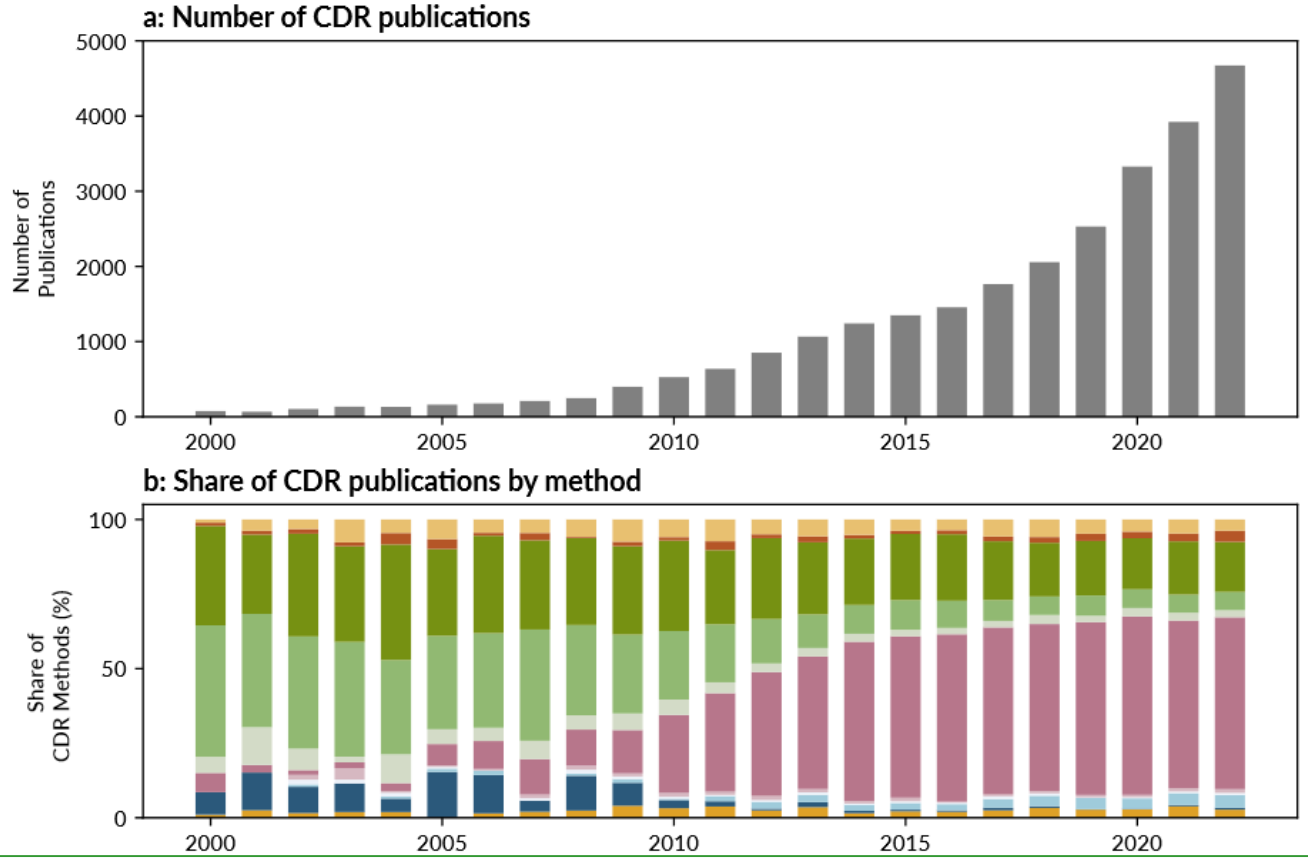


Figure 2.1 *Growth in the number and value of grants for carbon dioxide removal (CDR) research: (a) Total number of active research grants and their total value between 2000 and 2022; (b) CDR methods being researched in these grants over time as a share of the total number of all active grants; (c) CDR methods by region of funding organization as share of active grant years. BECCS = bioenergy with carbon capture and storage; DAC(CS) = direct air capture (with or without carbon storage).*

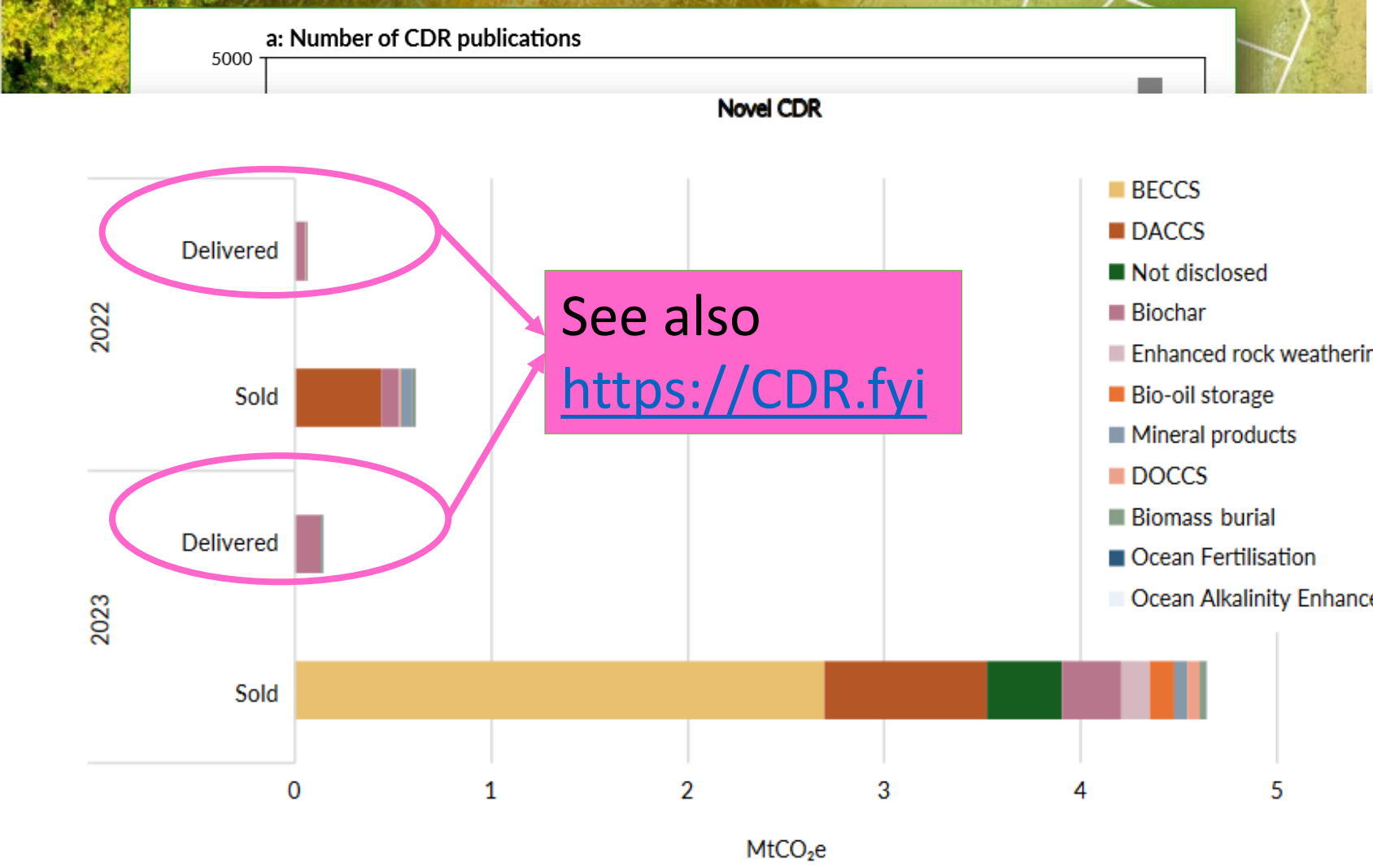


Figure 4.4 *Breakdown of the volume of carbon dioxide removal (CDR) in the voluntary carbon market (VCM) by CDR method, 2022–2023. Top panel: conventional CDR; bottom panel: novel CDR. BECCS = bioenergy with carbon capture and storage; DACCS = direct air carbon capture and storage; DOCCS = direct ocean carbon capture and storage.*

Production scalable to biomass availability

Biochar:

Global mitigation potential:

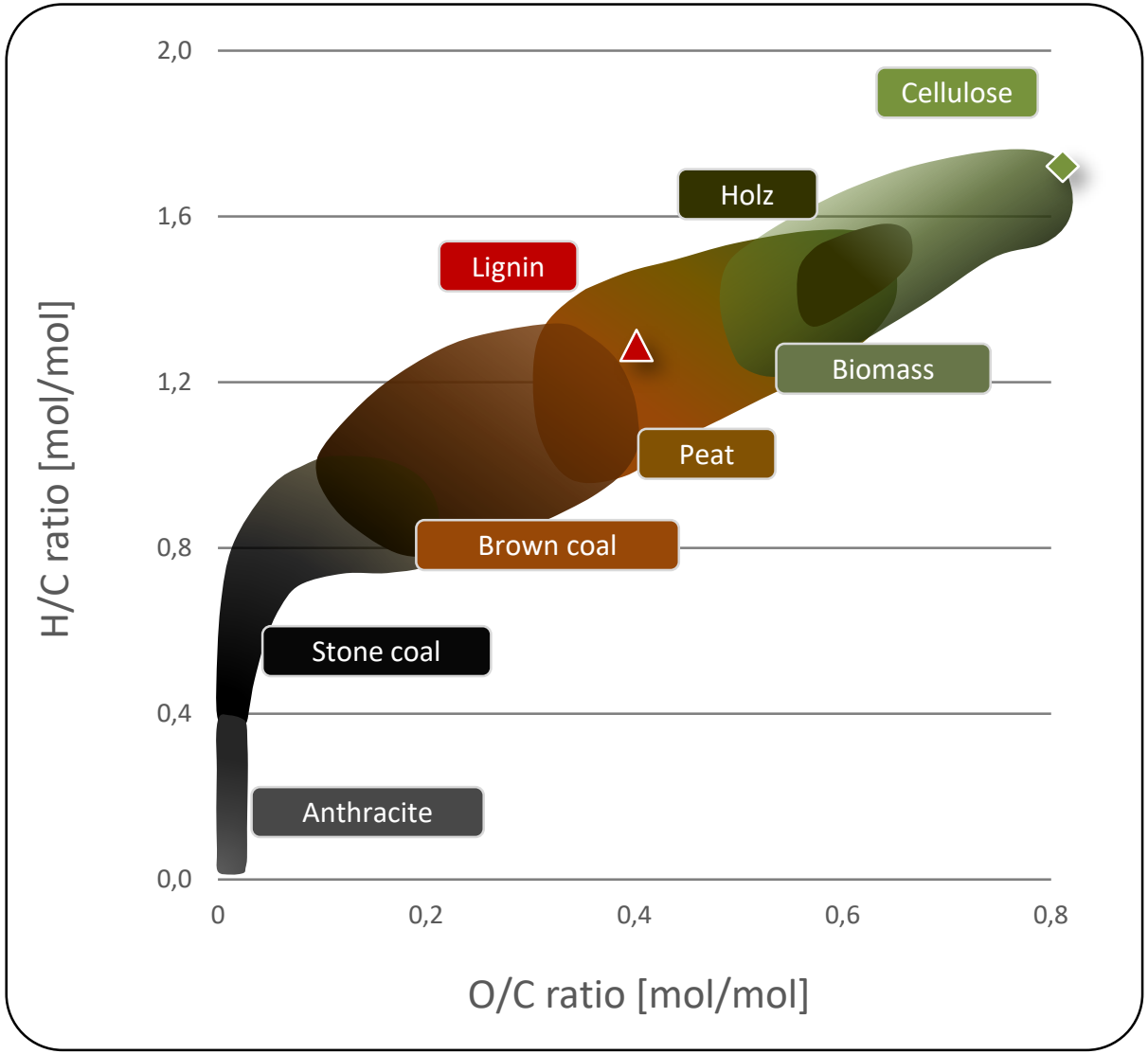
0.3 - 6.6 $GtCO_2/yr$

(Weng, Cowie et al., Review in prep.)

Cost:

10 - 345 USD/tCO_2

Biochar C persistence – state of knowledge



Quicker & Weber 2016

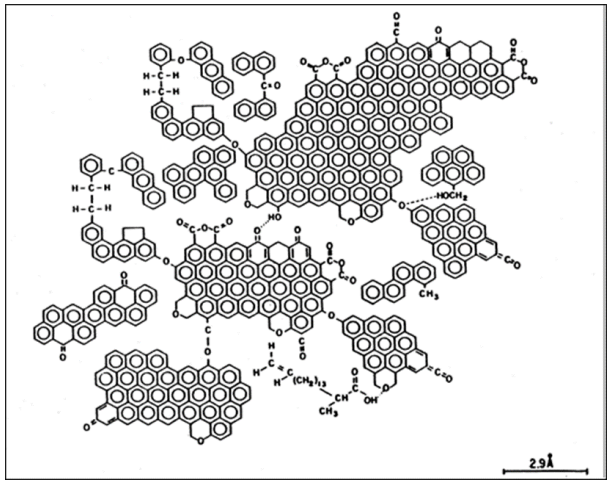
„Van-Krevelen Diagram“ (Coal chemistry >150 years)

Key papers to read:

Woolf et al. 2021

Azzi et al. 2024

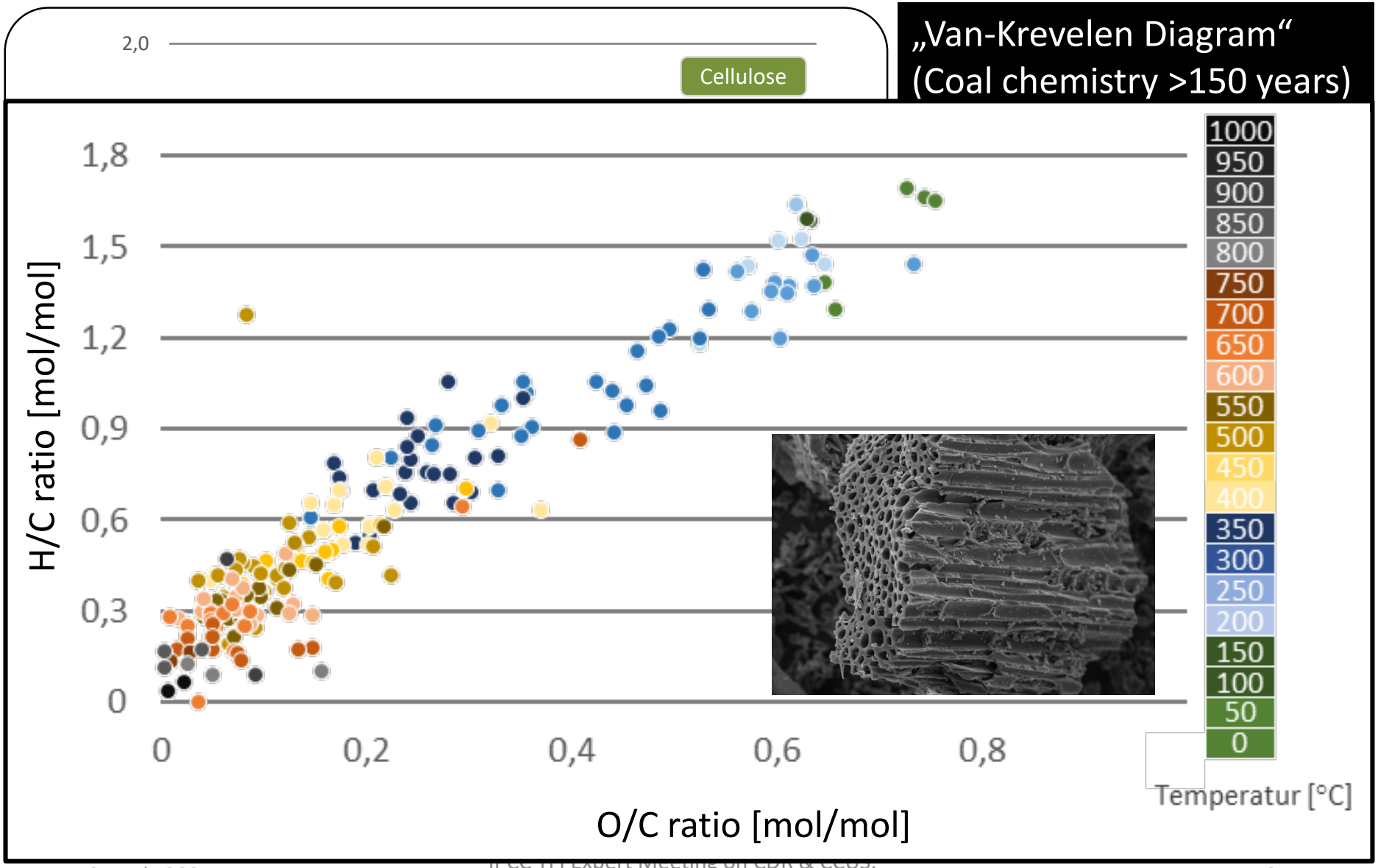
Sanei et al. 2024



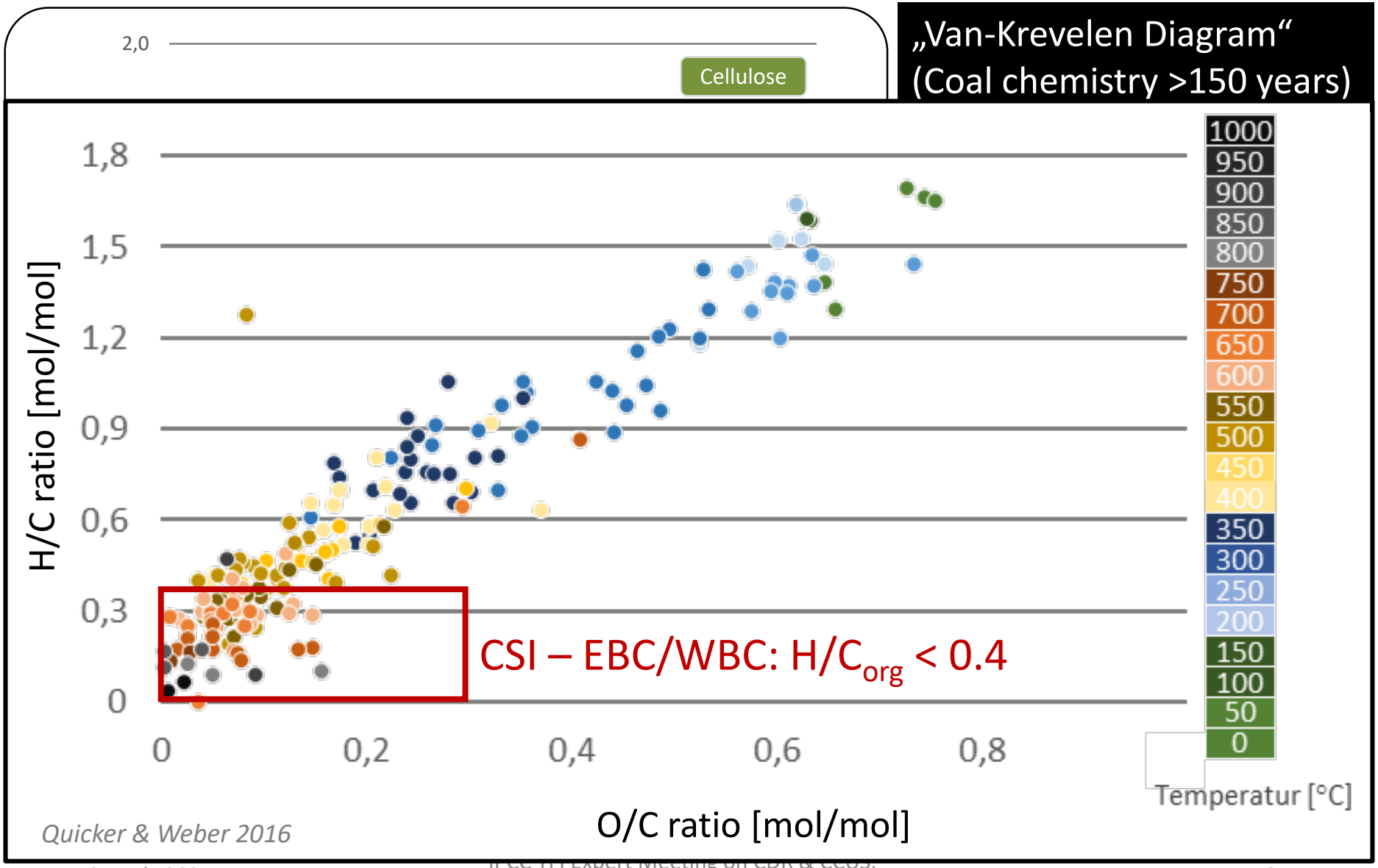
After E. Krull

Biochar C persistence – state of knowledge

„Van-Krevelen Diagram“
(Coal chemistry >150 years)

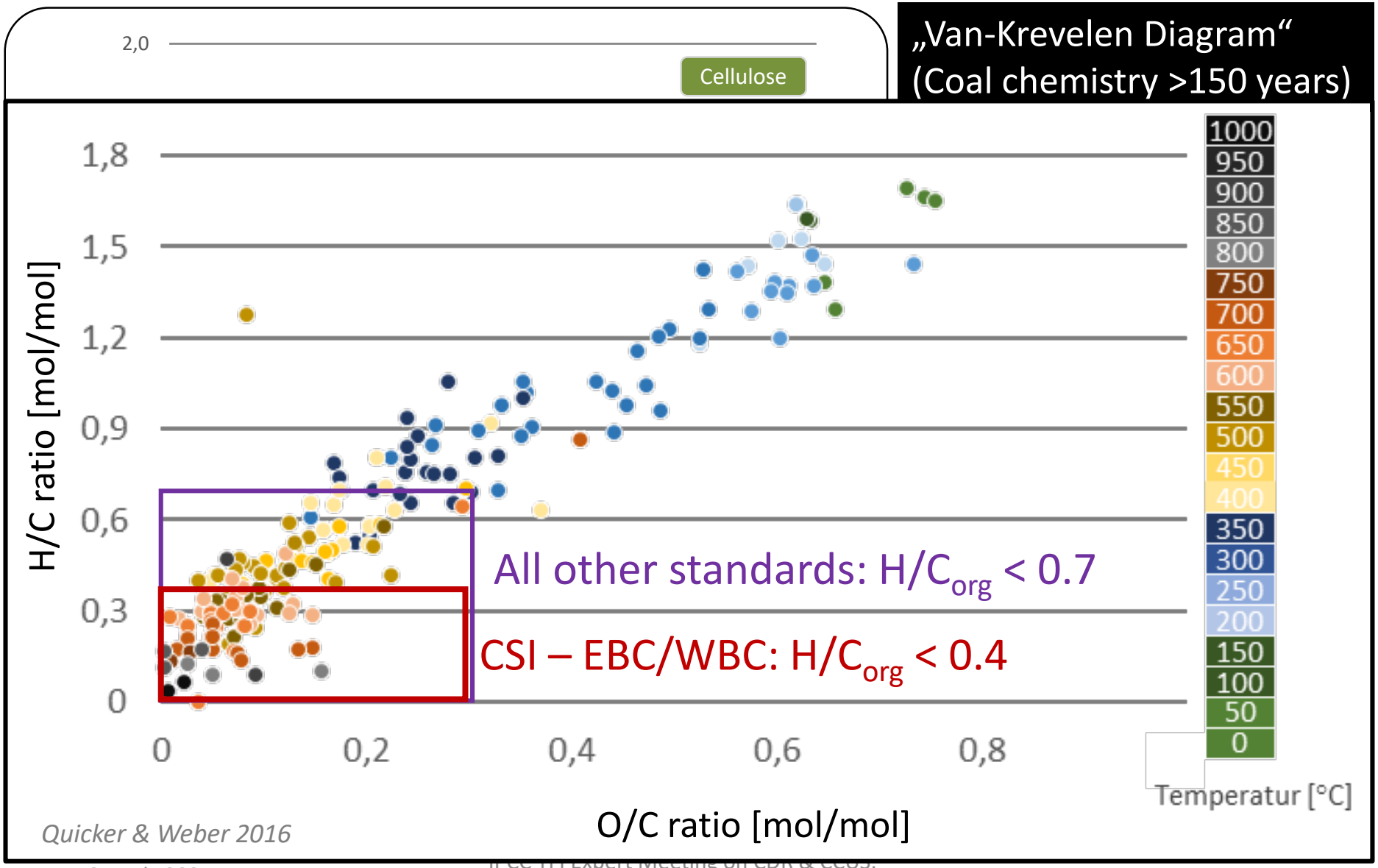


Biochar C persistence – state of knowledge



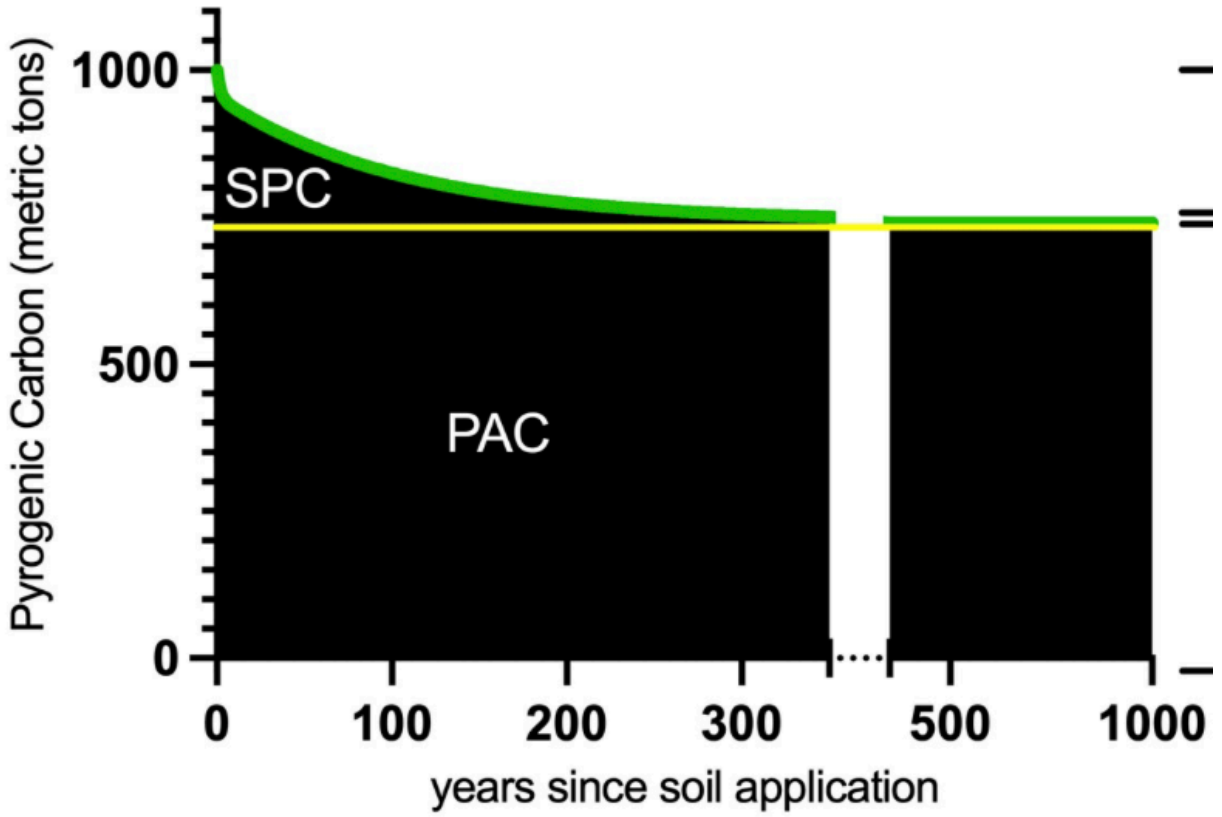
Quicker & Weber 2016

Biochar C persistence – state of knowledge



Quicker & Weber 2016

Persistent and semi-persistent biochar C



SPC = semi-persistent carbon

PAC = persistent aromatic carbon

PAC quantification:

- 7 fused aromatic rings
- Quantification HyPy
- Correlates well with H/C_{org} and production temperature
- Random Reflectance as a novel method („Inertinite“)?

Schmidt, Hagemann et al. 2022

SDG- & CDR-relevant Co-benefits

Received: 22 May 2021 | Revised: 11 August 2021 | Accepted: 12 August 2021

DOI: 10.1111/gcbb.12889

WILEY

RESEARCH REVIEW

Biochar in agriculture – A systematic review of 26 global meta-analyses

Hans-Peter Schmidt[1] | Claudia Kammann[2] | Nikolas Hagemann[3,4] | Jens Leifeld[4] | Thomas D. Bucheli[4] | Miguel Angel Sánchez Monedero[5] | Maria Luz Cayuela[5]

[1]Ithaka Institute, Arbaz, Switzerland

[2]Department of Applied Ecology, Hochschule Geisenheim University, Geisenheim, Germany

[3]Ithaka Institute, Freiburg, Germany

Abstract

Biochar is obtained by pyrolyzing biomass and is, by definition, applied in a way that avoids its rapid oxidation to CO_2. Its use in agriculture includes animal feeding, manure treatment (e.g. as additive for bedding, composting, storage or an-

SDG- & CDR-relevant Co-benefits

Received: 22 May 2021

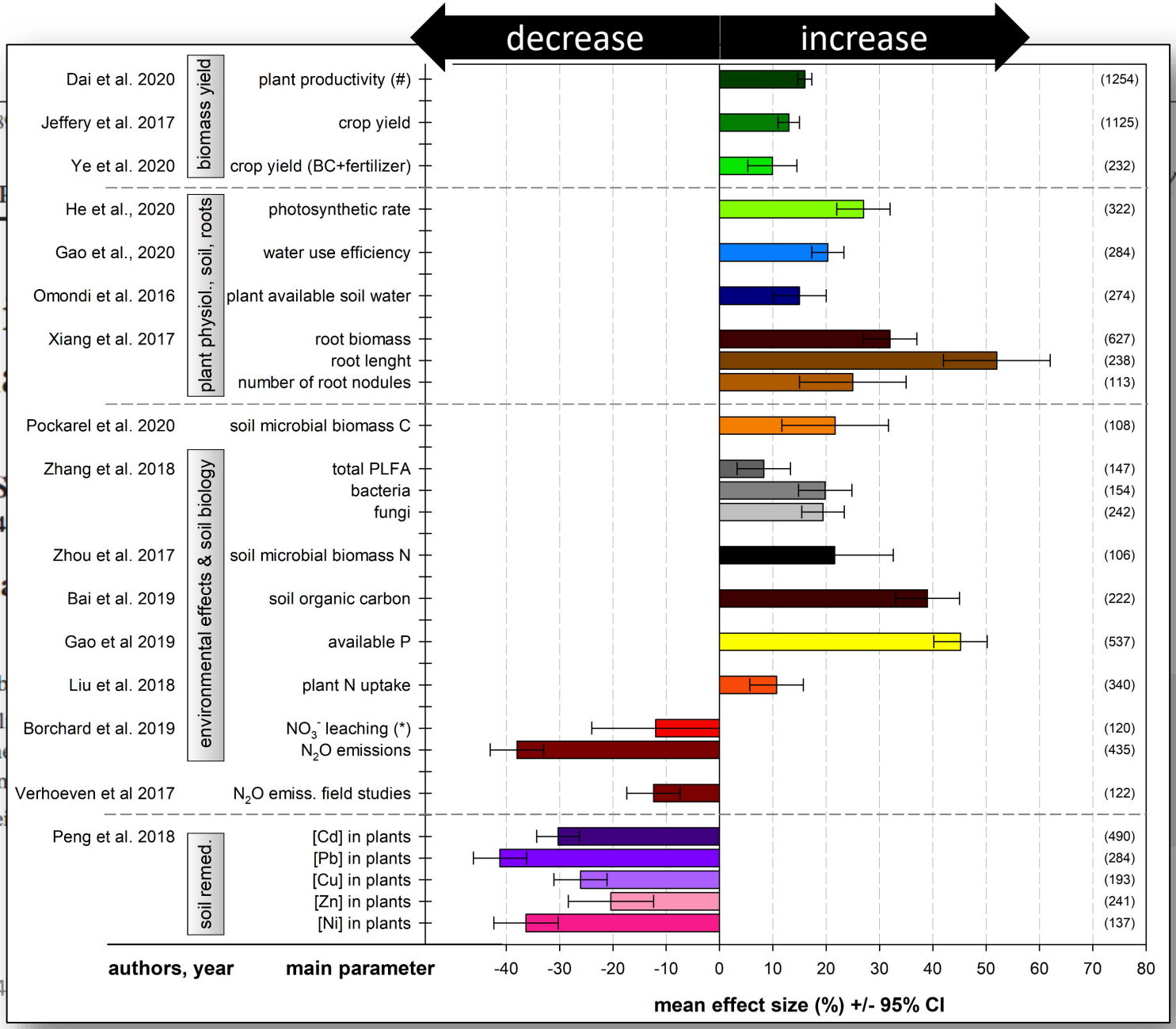
DOI: 10.1111/gcbb.1288

RESEARCH

Biochar
meta-an

Hans-Peter S
Jens Leifeld[4]
Maria Luz C

[1]Ithaka Institute, Arb
[2]Department of Appl
Hochschule Geisenh
Geisenheim, Germa
[3]Ithaka Institute, Fre



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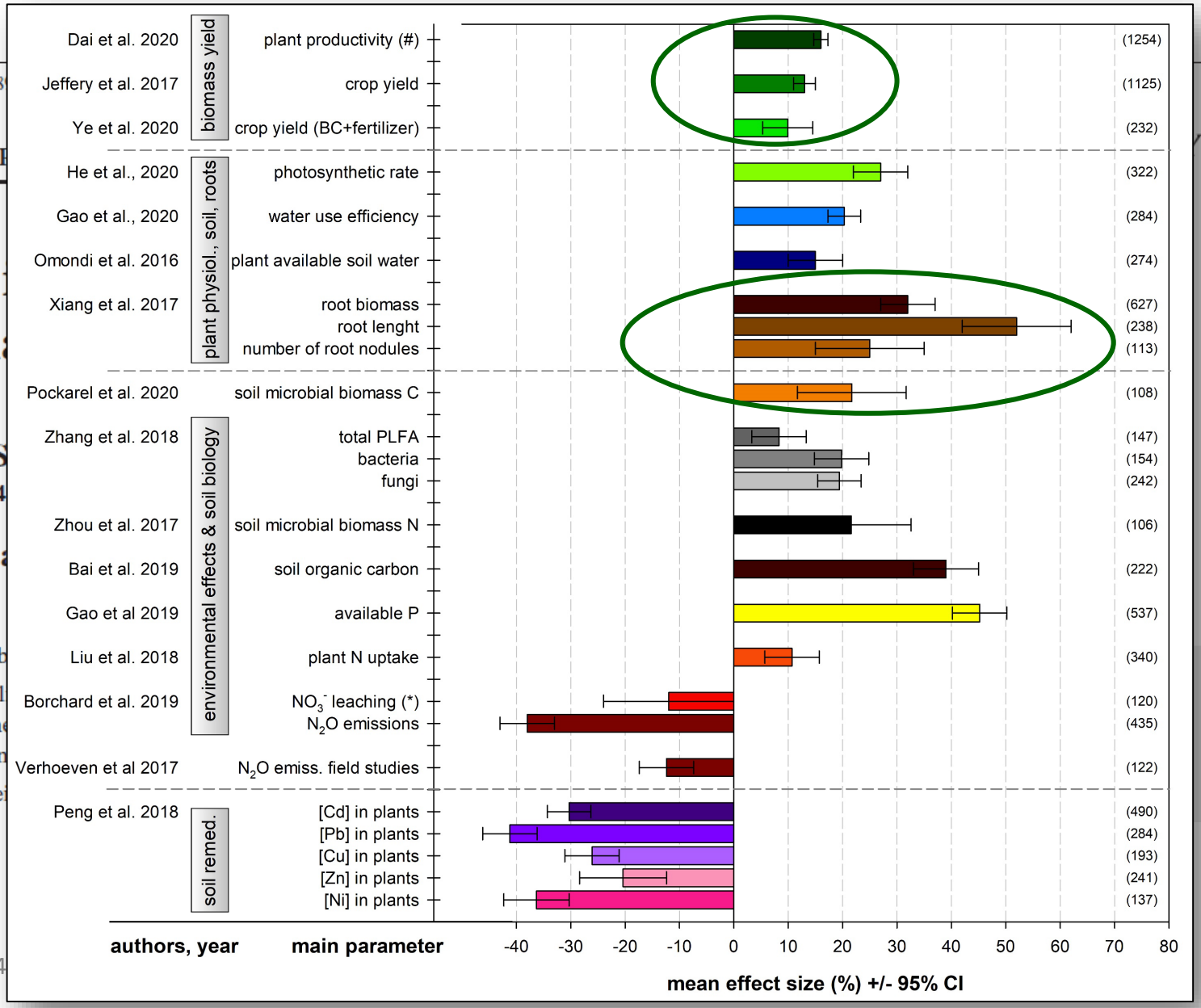

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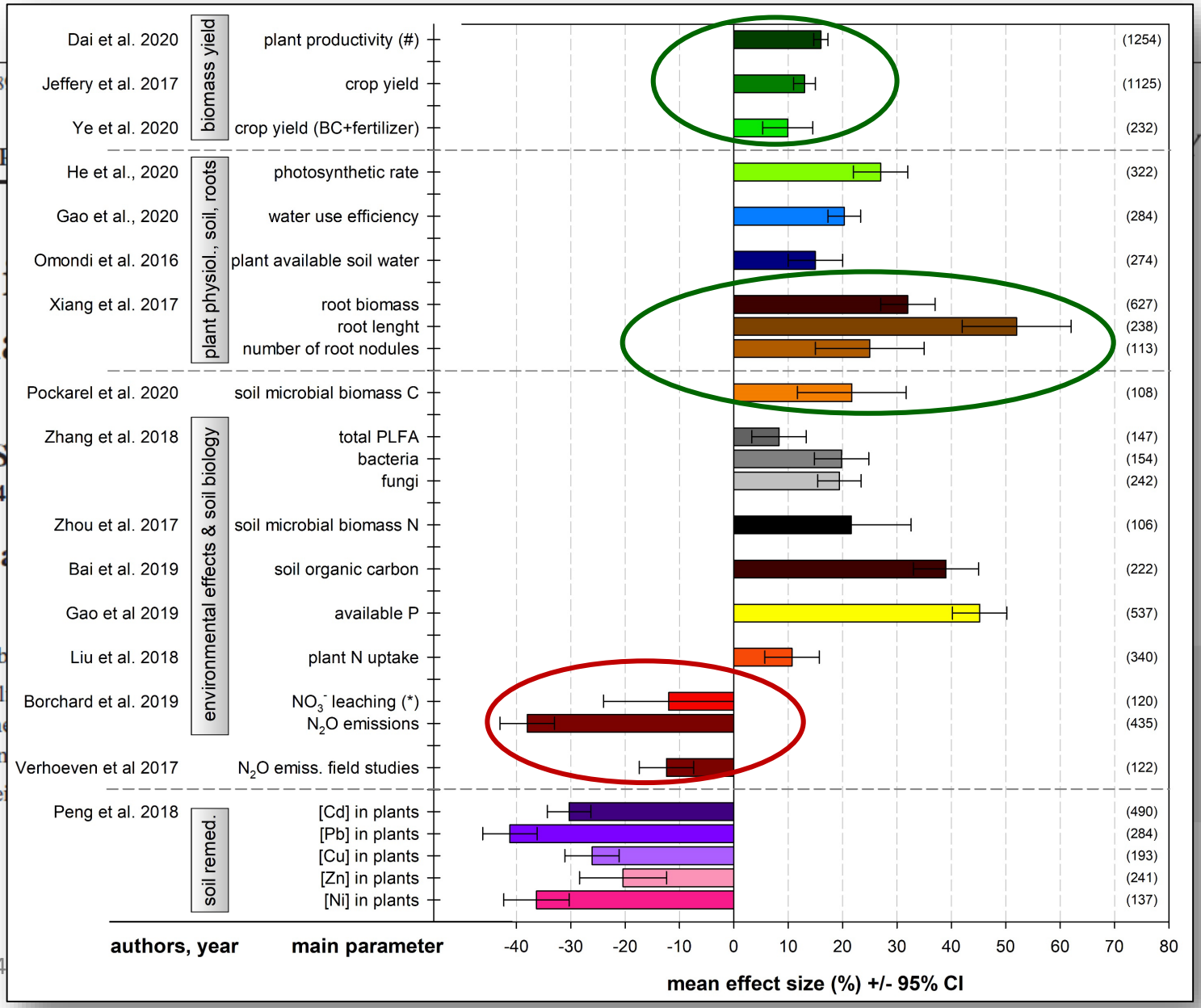

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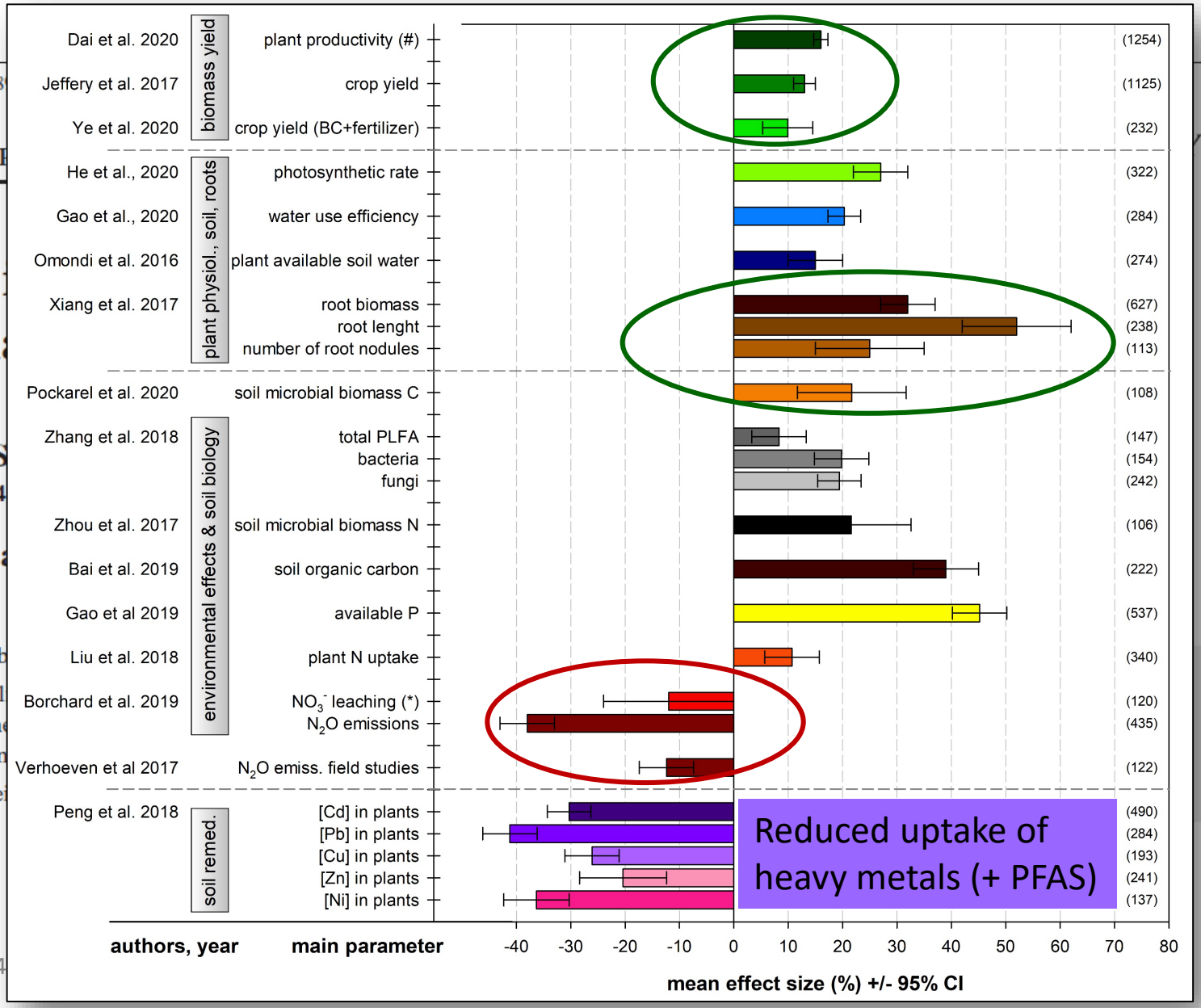

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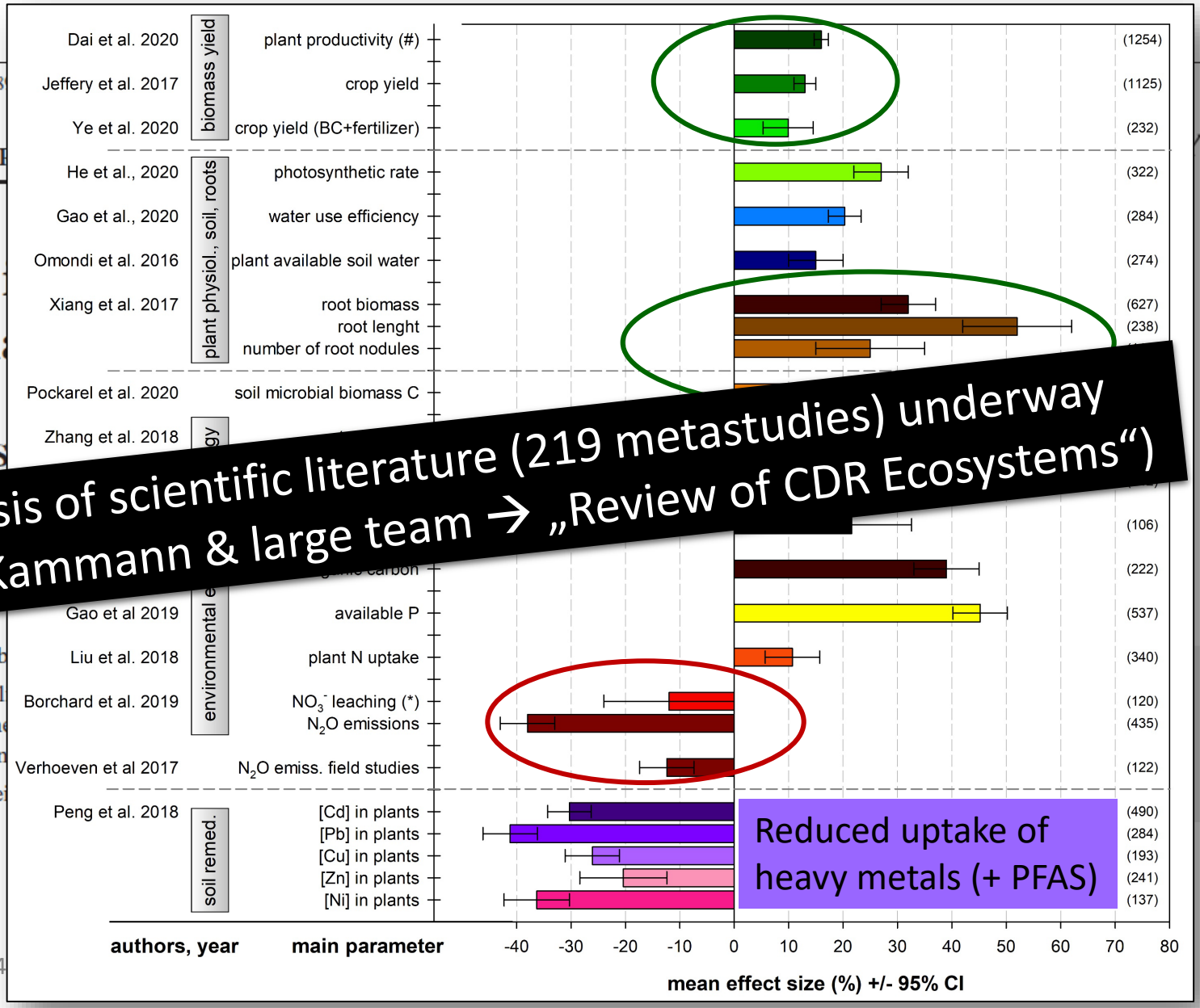
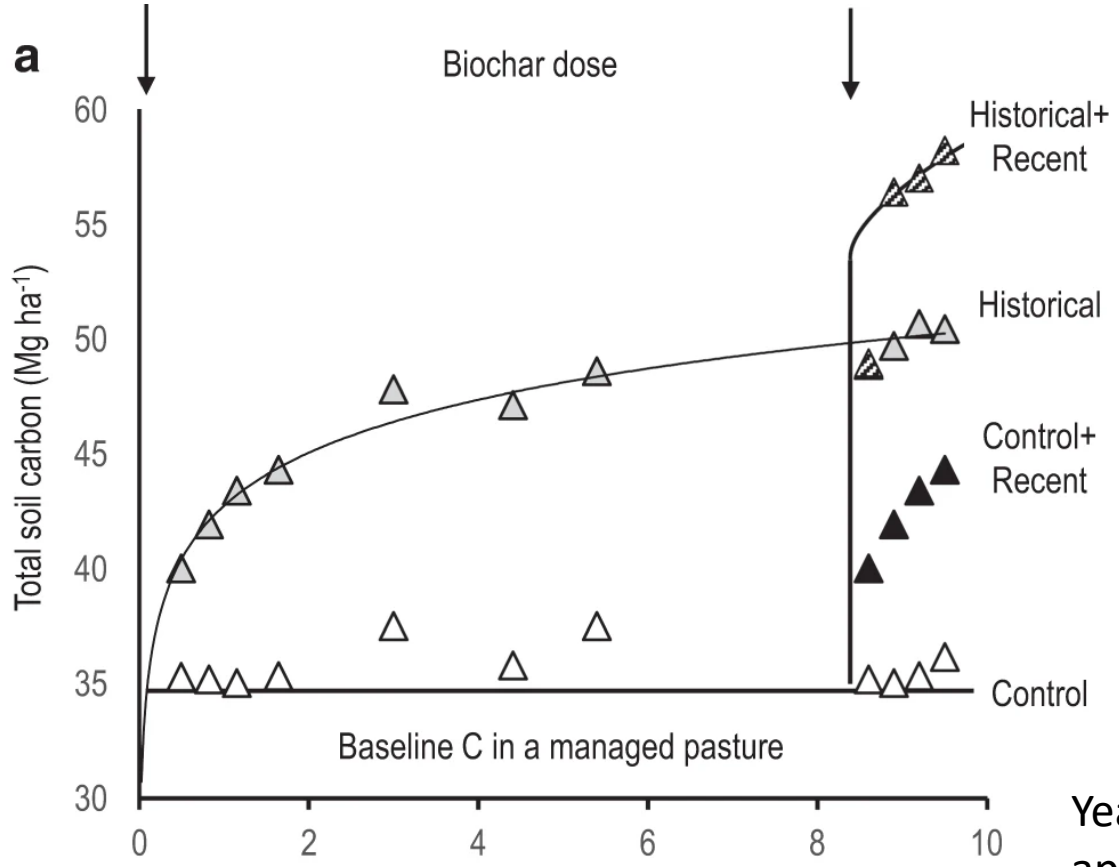
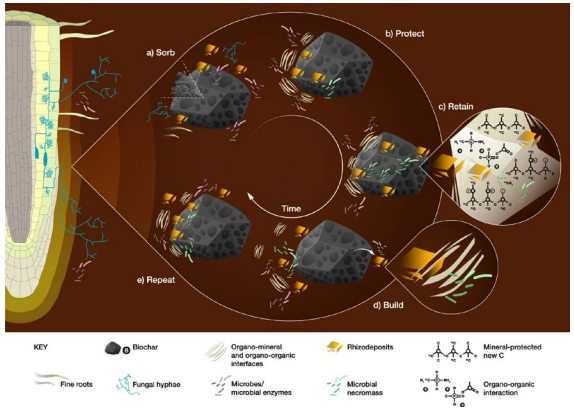


Re-Analysis of scientific literature (219 metastudies) underway (Cowie, Kammann & large team → „Review of CDR Ecosystems“)

„CDR safety margin“: SOC stock increases with biochar use are likely

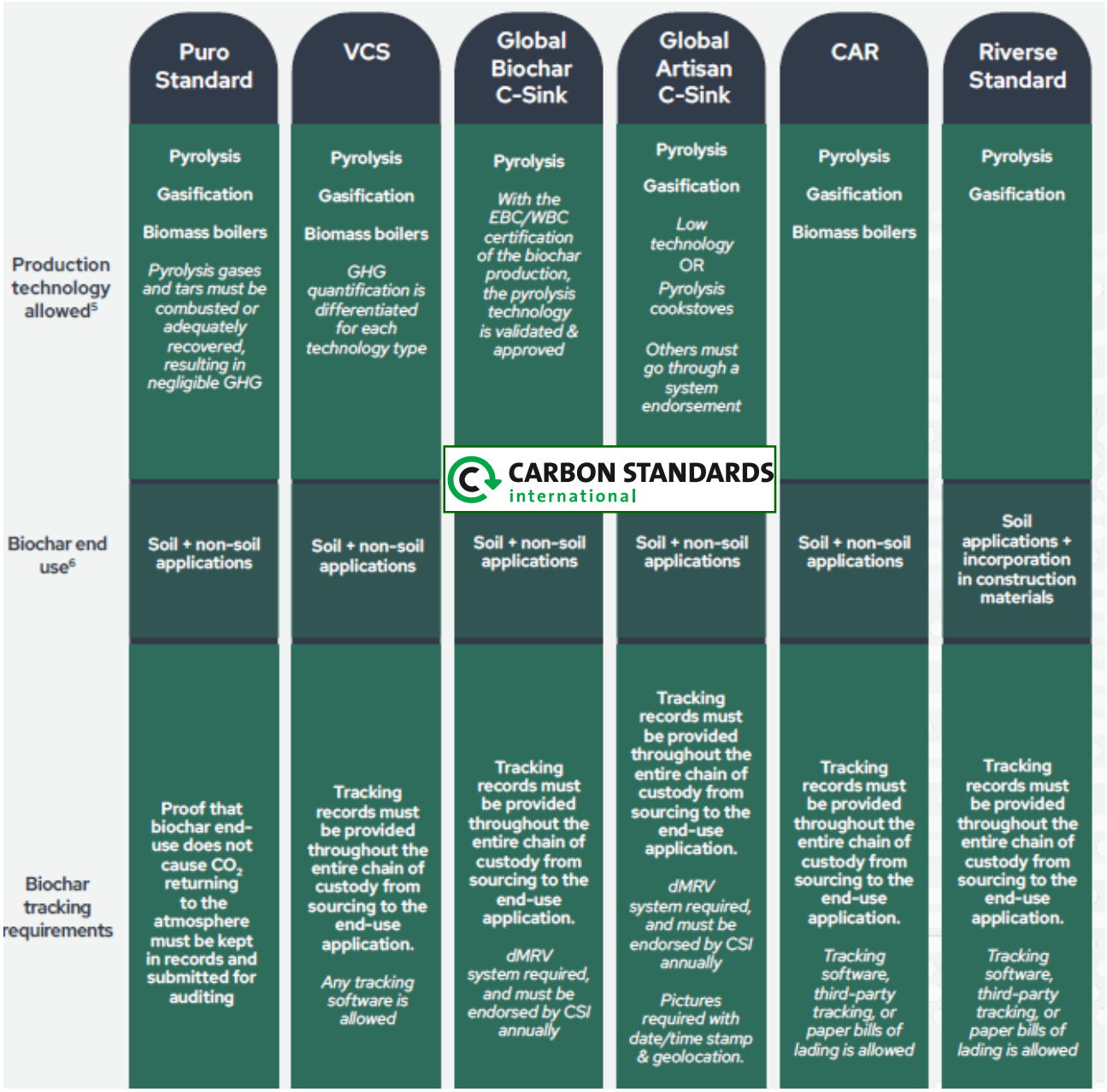


Weng et al, 2022
Nature Communications



Years after initial biochar application

Comparison of existing MRV schemes



	Puro Standard	VCS	Global Biochar C-Sink	Global Artisan C-Sink	CAR	Riverse Standard
Production technology allowed[5]	Pyrolysis Gasification Biomass boilers *Pyrolysis gases and tars must be combusted or adequately recovered, resulting in negligible GHG*	Pyrolysis Gasification Biomass boilers *GHG quantification is differentiated for each technology type*	Pyrolysis *With the EBC/WBC certification of the biochar production, the pyrolysis technology is validated & approved*	Pyrolysis Gasification *Low technology OR Pyrolysis cookstoves* *Others must go through a system endorsement*	Pyrolysis Gasification Biomass boilers	Pyrolysis Gasification
Biochar end use[6]	Soil + non-soil applications	Soil + non-soil applications	Soil + non-soil applications	Soil + non-soil applications	Soil + non-soil applications	Soil applications + incorporation in construction materials
Biochar tracking requirements	Proof that biochar end-use does not cause CO_2 returning to the atmosphere must be kept in records and submitted for auditing	Tracking records must be provided throughout the entire chain of custody from sourcing to the end-use application. *Any tracking software is allowed*	Tracking records must be provided throughout the entire chain of custody from sourcing to the end-use application. *dMRV system required, and must be endorsed by CSI annually*	Tracking records must be provided throughout the entire chain of custody from sourcing to the end-use application. *dMRV system required, and must be endorsed by CSI annually* *Pictures required with date/time stamp & geolocation.*	Tracking records must be provided throughout the entire chain of custody from sourcing to the end-use application. *Tracking software, third-party tracking, or paper bills of lading is allowed*	Tracking records must be provided throughout the entire chain of custody from sourcing to the end-use application. *Tracking software, third-party tracking, or paper bills of lading is allowed*

CARBON STANDARDS international

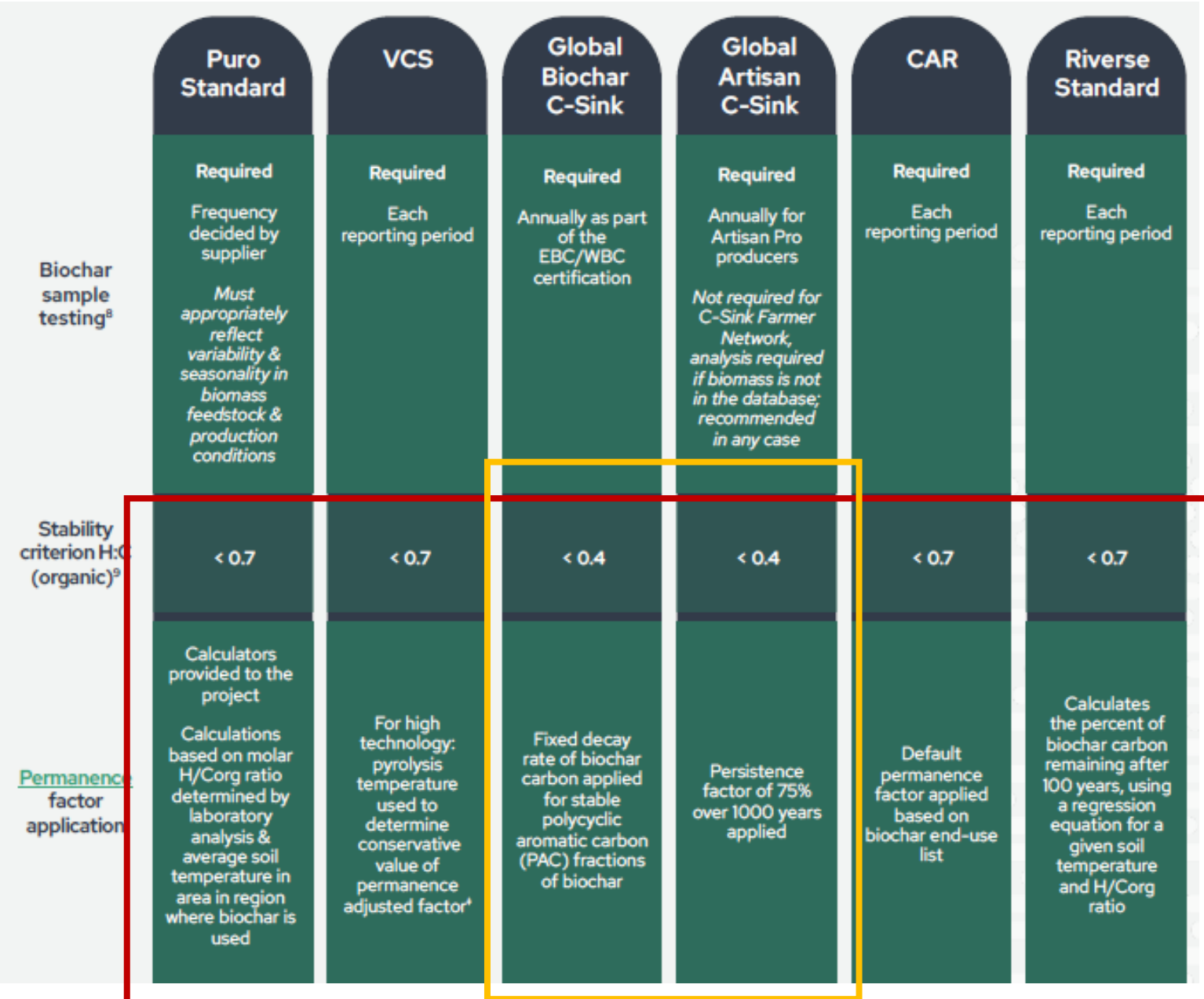
„A Manual for Biochar Carbon Removal - A comparative guide for the certification of biochar production as a carbon sink“

International Biochar Initiative

IN COOPERATION WITH:

HAMERKOP
CLIMATE CHANGE & FINANCE

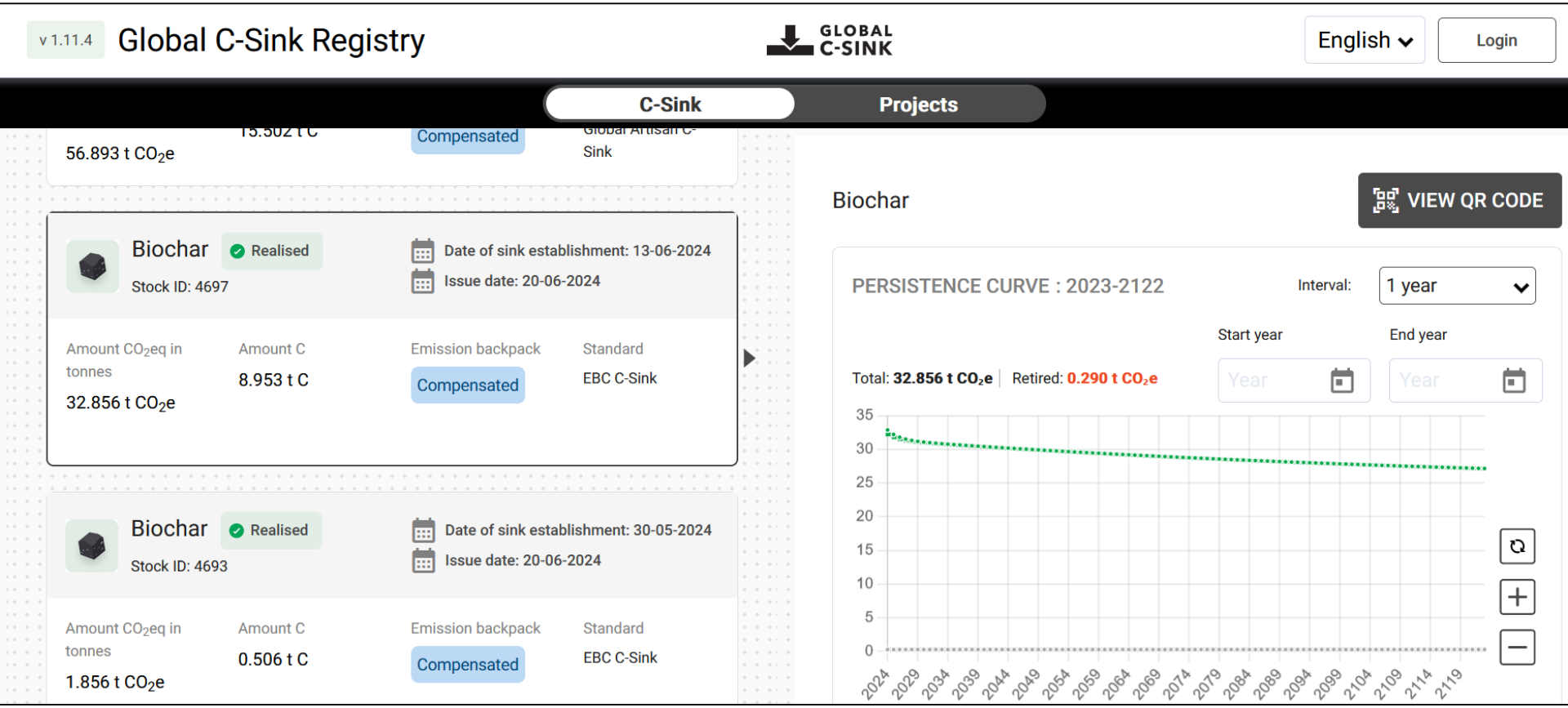
Comparison of existing MRV schemes



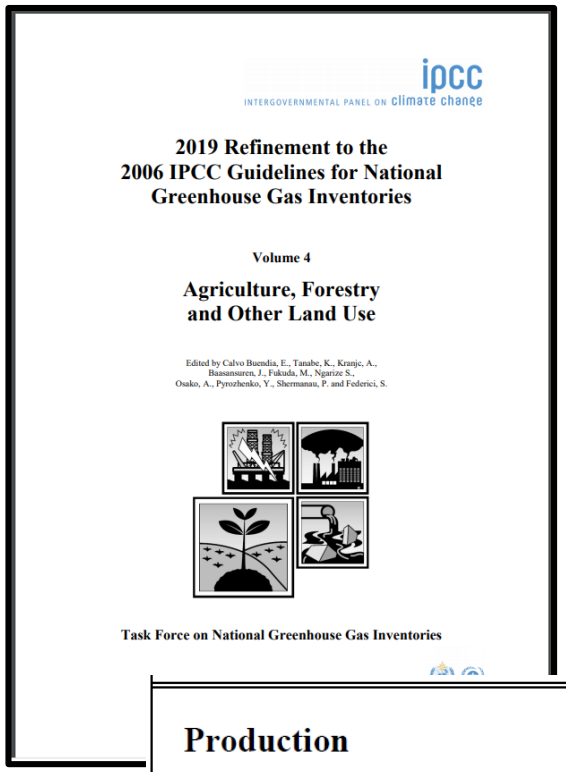
	Puro Standard	VCS	Global Biochar C-Sink	Global Artisan C-Sink	CAR	Riverse Standard
Biochar sample testing[8]	**Required** Frequency decided by supplier *Must appropriately reflect variability & seasonality in biomass feedstock & production conditions*	**Required** Each reporting period	**Required** Annually as part of the EBC/WBC certification	**Required** Annually for Artisan Pro producers *Not required for C-Sink Farmer Network, analysis required if biomass is not in the database; recommended in any case*	**Required** Each reporting period	**Required** Each reporting period
Stability criterion H:C (organic)[9]	< 0.7	< 0.7	< 0.4	< 0.4	< 0.7	< 0.7
Permanence factor application	Calculators provided to the project Calculations based on molar H/Corg ratio determined by laboratory analysis & average soil temperature in area in region where biochar is used	For high technology: pyrolysis temperature used to determine conservative value of permanence adjusted factor[4]	Fixed decay rate of biochar carbon applied for stable polycyclic aromatic carbon (PAC) fractions of biochar	Persistence factor of 75% over 1000 years applied	Default permanence factor applied based on biochar end-use list	Calculates the percent of biochar carbon remaining after 100 years, using a regression equation for a given soil temperature and H/Corg ratio

Global C-sink Registry Foundation: Data delivery for National balances is possible

https://global-c-registry.org/projects



Appendix 4 Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development



- (optional) method for estimating change in soil carbon stocks from biochar amendment
- For biochar applied to grassland and cropland soils
- Quantification based on
  - Total amount of biochar produced
  - C content (feedstock, product. process)
  - Fraction remaining at 100 years:

Production	Value for F_{perm_p} [1, 2]
High temperature pyrolysis and gasification (> 600 °C)	0.89 ± 13%
Medium temperature pyrolysis (450-600 °C)	0.80 ± 11%
Low (350-450 °C)	0.65 ± 15%

See also update: Woolf et al.2021
https://doi.org/10.1021/acs.est.1c02425

Summary: Estimating biochar-CDR at national level

Biochar-CDR….

- Can be quantified easily, accurately and affordably (batch weight, C-concentration, H/C ratio; novel methods emerging)
- Has proven co-benefits when used in soil
  a) for climate (N_2O emission reduction, soil C increase)
  b) for SDGs (higher yields, lower contamination)
- MRV schemes based on scientific understanding subtract manufacturing & transport/processing emissions & are used already for biochar CDR certification and trade
- CDR uses encompass besides agriculture / soils: Urban tree (macadam) substrates, building materials (concrete, plastics…) and asphalt

Estimating biochar-CDR at national level

Including Biochar-CDR requires….

- Quantification of biochar production (factory gate) towards its use-pathways including
  - Agricultural soil / animal husbandry uses
  - Non-agricultural biochar-CDR applications
- Through recording of national biochar producer sales & deliveries into CDR-relevant usage pathways
- Classified by type of biochar (grouped according to properties influencing fraction remaining at 100 years)
- Laboratory assessment of biochar properties by producers, especially H/C_{org} ratio

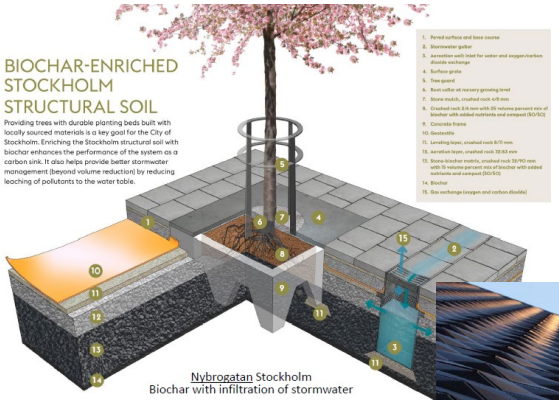
Thanks – Questions?

Metasequoia (Metasequoia glyptostroboides) in plant beds with structural soil – Grindsgatan.

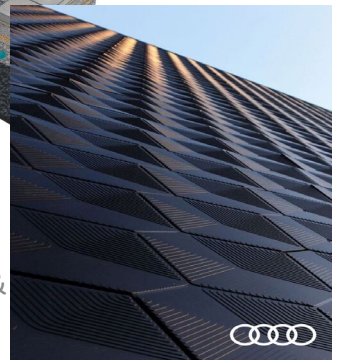
Lind (Tilia x vulgaris 'Pallida') in plant beds with structural soil – Odengatan.

Linden in poor condition on Kungsbroplan, before plant bed renovation 2002.

Same tree after plant bed renovation 2013.

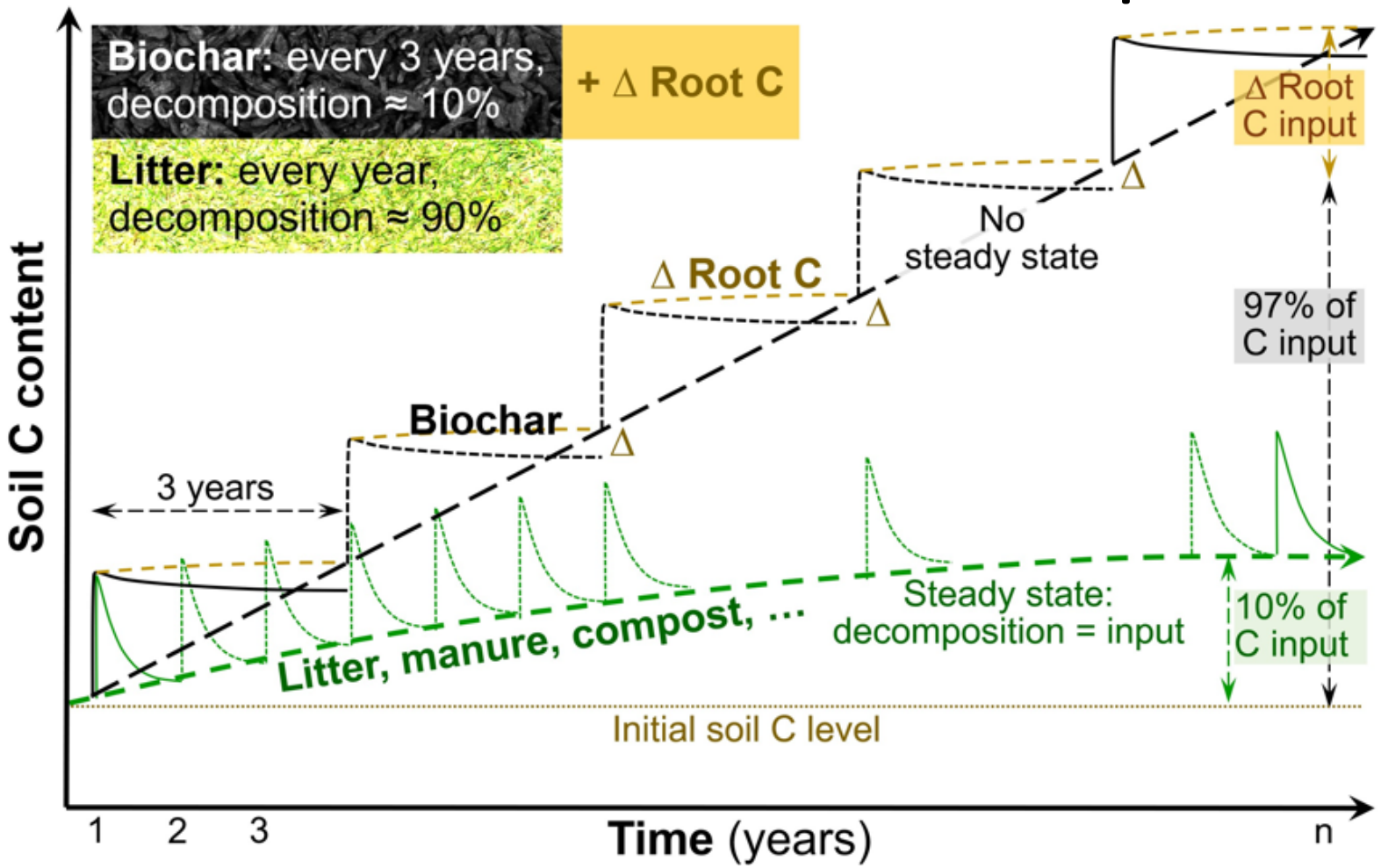


Nybrogatan Stockholm
Biochar with infiltration of stormwater



© Stockholm Stad Handbook 2017

Adding biochar to soils builds C steadily, other amendments decompose



Joseph et al 2021: *How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar. Global Change Biology - Bioenergy*

Limitation of incubation experiments

ithaka institute

Hagemann et al. 2024, Oral held at 3rd NE conference, Oxford