Biochar for climate change mitigation: Navigating from science to evidence-based policy

Concept of Soil Biochar Sequestration

Biochar is the carbon-rich solid formed by heating biomass in an anaerobic environment (a process called pyrolysis). This pyrogenic carbonized material is typically known as biochar when it is intended as a soil amendment or to provide related environmental benefits. Biochar's climate-change mitigation potential stems primarily from its slower decomposition than the raw biomass from which it is generated, thus lowering the rate at which photosynthetically-fixed C is returned to the atmosphere. It is this difference in decomposition rates that is critical in determining how net carbon stocks evolve over time. Although approximately half of the carbon in a biomass feedstock is emitted as CO_2 during biochar production; by comparison, more readily-decomposed un-pyrolysed biomass will rapidly return most of its carbon to the atmosphere if allowed to decompose. Therefore, the carbon stocks remaining over time are larger for biochar than for raw biomass (Figure 1), leading to a net increase in soil carbon stocks. Thus, although embedding carbon in biochar is, in one sense, a redistribution of biomass carbon rather than newly fixed carbon, nonetheless the greater persistence of the biochar drives a net sequestration of carbon. Most studies have concluded that this persistence-derived carbon sequestration is the largest individual influence of biochar on net greenhouse gas balances, while other mechanisms serve to mediate this primary influence (Figure 2).

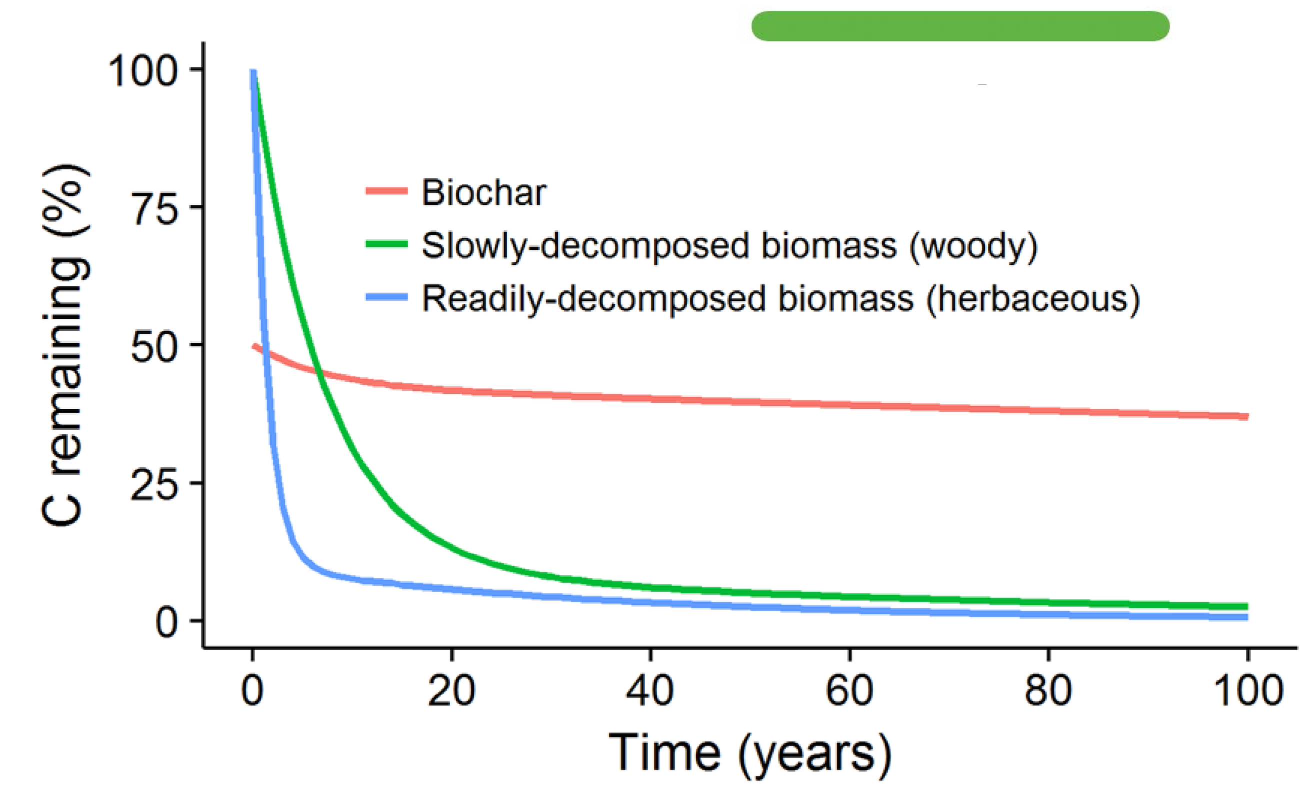


Figure 1: Conceptual comparison of un-mineralized biomass carbon (C) remaining from different grades of organic matter, as a function of time. The lines are modeled using a two pool exponential decay model, comparing slow-turnover woody biomass (green line), fast-turnover herbaceous biomass (blue line), and biochar (red line). Assumed representative fast and slow fraction half lives, respectively, were 4 and 25 years for woody biomass, 1 and 25 years for herbaceous biomass, and 5 and 500 years for biochar. It was also assumed that half of the initial biomass carbon is lost during biochar production, hence the carbon remaining in biochar starts at 50% at time equal to zero

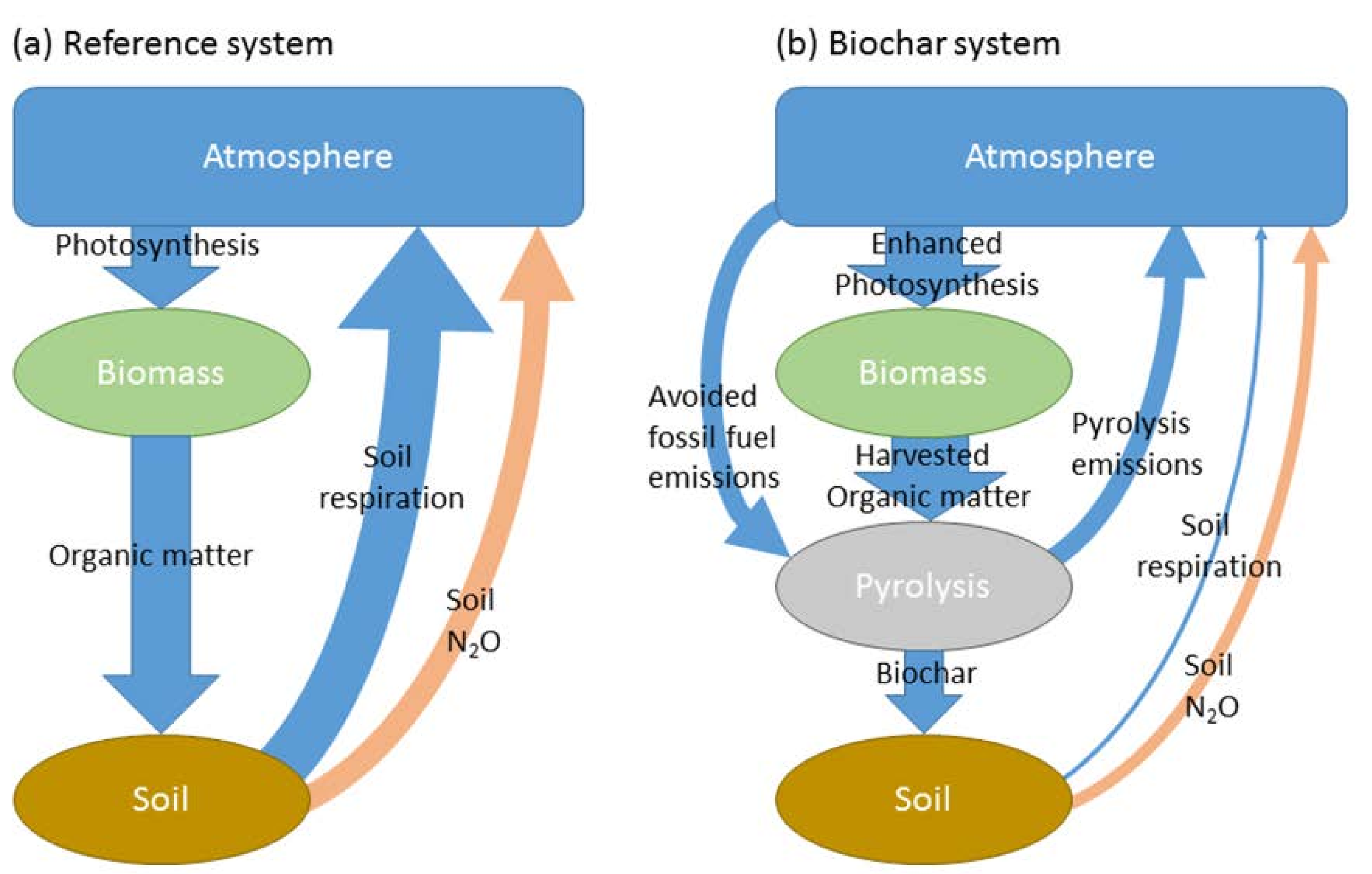


Figure 2:Main impacts of biochar on greenhouse gas (GHG) fluxes.

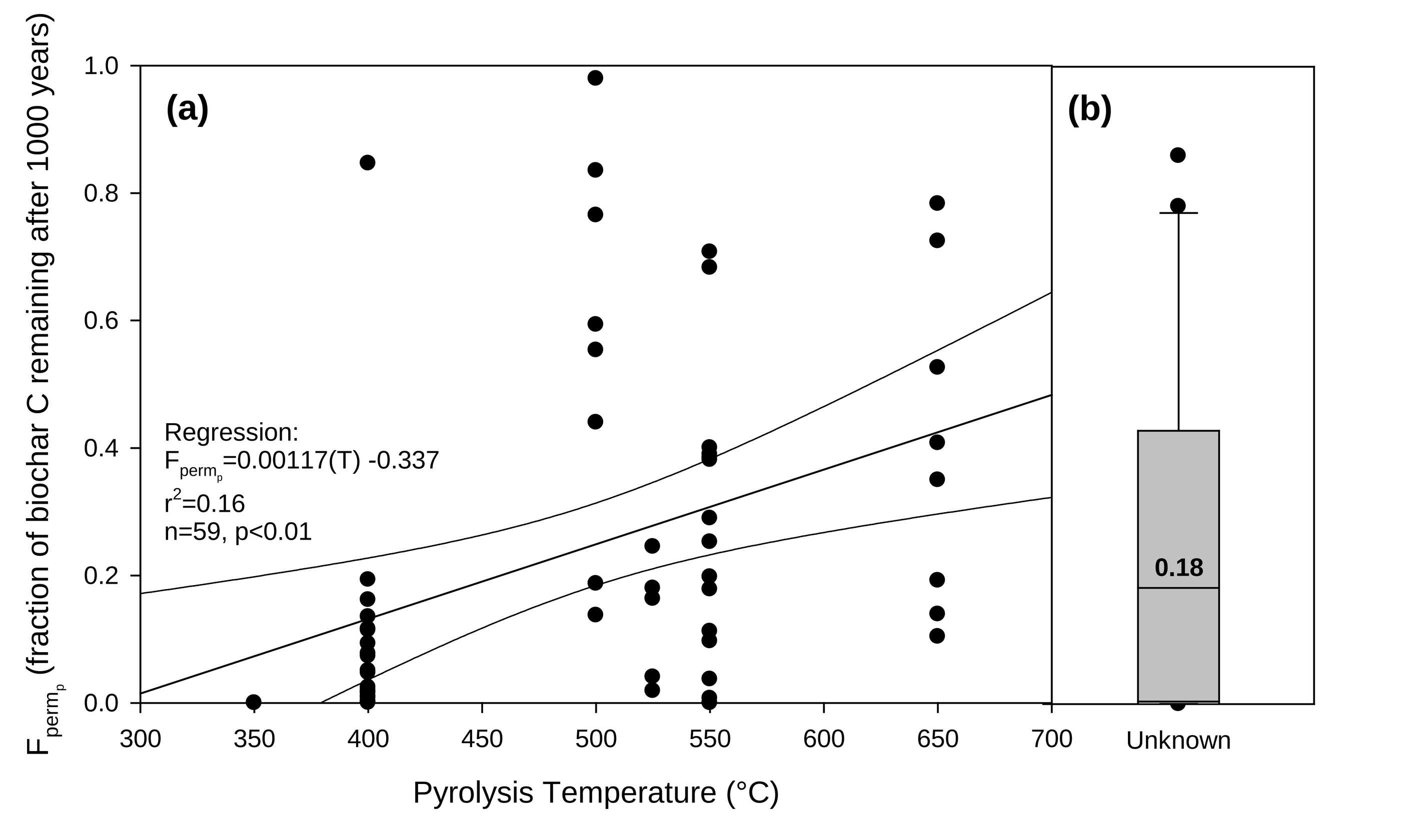


Figure 1b: Biochar carbon remainaing after 1000 years (Fpermp) calculated from field and laboratory studies: (a) Fpermp estimated for biochars with known biochar production temperature by fitting a two-pool double-exponential model to 59 datasets from eight mineralization experiments that exceeded one year and allowed a two-pool model to be fitted recalculated as in Lehmann et al. (2015) for 10°C (Major et al., 2010; Zimmerman, 2010; Singh et al., 2012; Zimmerman and Gao, 2013; Fang et al., 2014; Herath et al., 2014; Kuzyakov et al., 2014; Dharmakeerthi et al., 2015; Wu et al., 2016); (b) Fpermp estimated for biochars with unknown biochar production temperatures using 20 observations from eight long-term field assessments (decadal to millennial time scales) whereby physical export is unaccounted for (Preston and Schmidt, 2006; Cheng et al., 2008; Hammes et al., 2008; Lehmann et al., 2008; Liang et al., 2008; Nguyen et al., 2008; Vasilyeva et al., 2011; Lutfalla et al., 2017; mean residence times taken directly from the sources without recalculation).

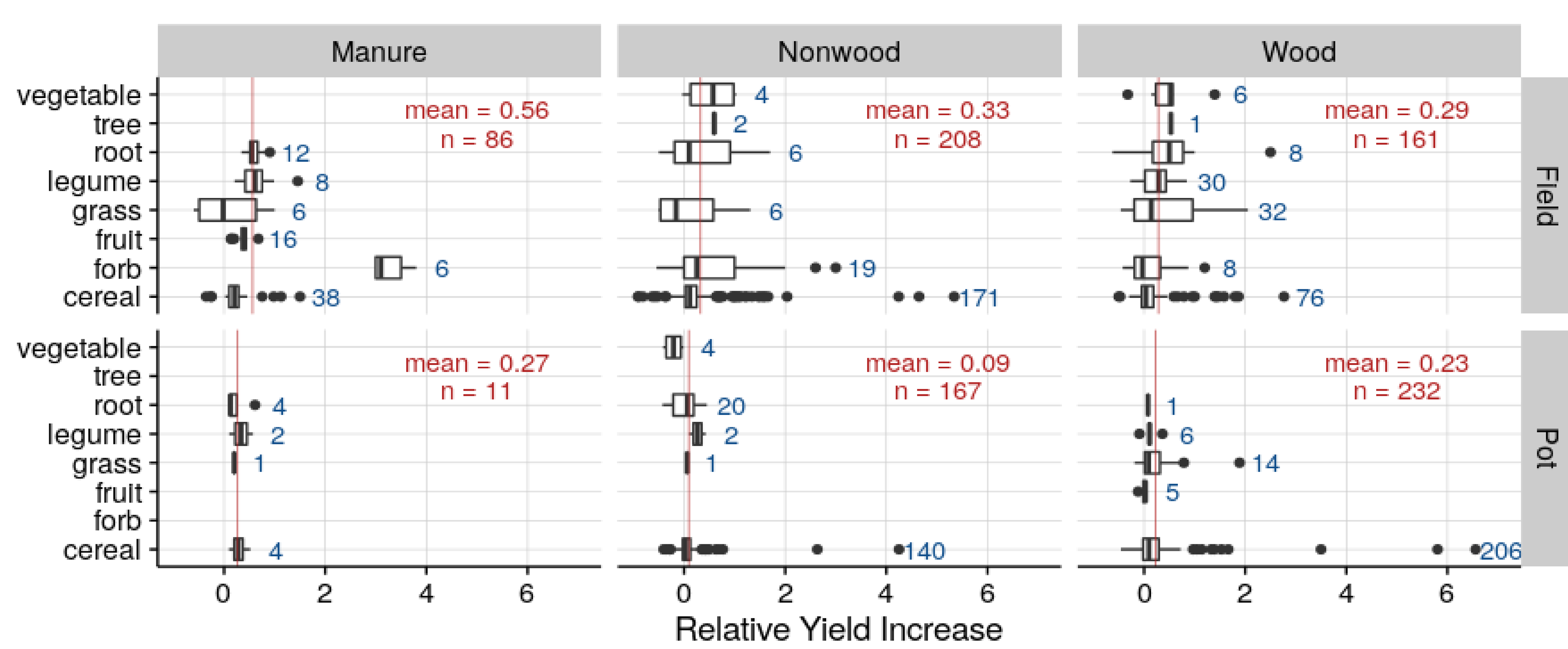
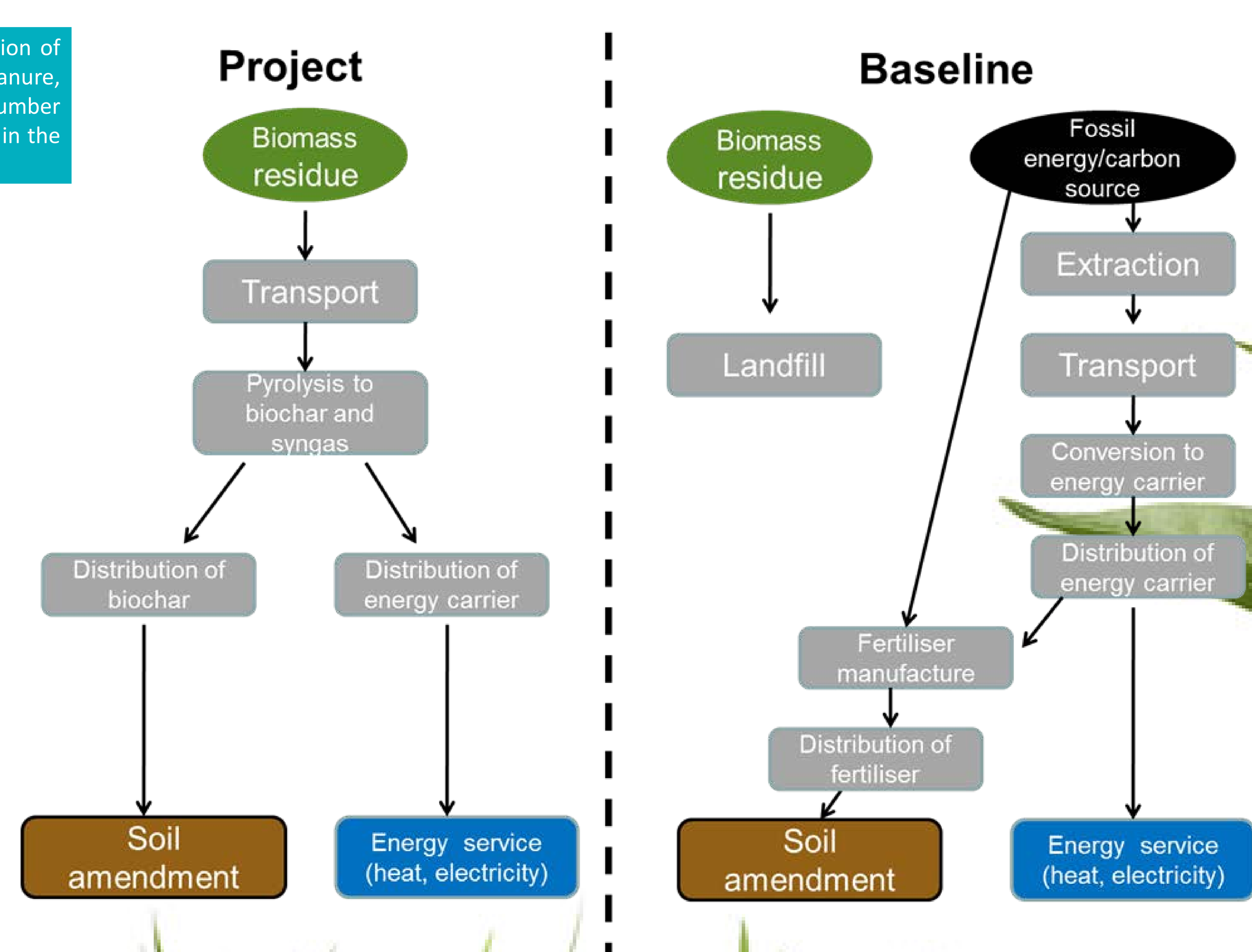


Figure 3: Yield response of crops to biochar additions (difference between biochar amended yield and control, expressed as a fraction of control yield). Data from 865 treatments from 74 published articles are broken down by field trial versus pot trial, by feedstock type (manure, wood or non-wood), and by crop type. Vertical red line on each panel shows the mean crop response. Mean response and number treatments for each panel are also given in red text. Numbers shown in blue adjacent to each box indicate the number of treatments in the sub-category.

Increased Crop Growth: GHG and Implementation Benefits

1) Reduction of pressure on land use and positive impact on indirect land use
2) Improvement of fertilizer use efficiency, thereby reducing emissions, water pollution
3) Increased biomass available for mitigation to build SOC stocks
4) Value of increased yield and reduced fertiliser requirement to farmers.

It is important in this regard to take care to distinguish between uncertainty and manageable variability (Lehmann and Rillig 2014, Nature Climate Change), with much of the observed variation in crop response being attributable to predictable biochar-soil-crop interactions.



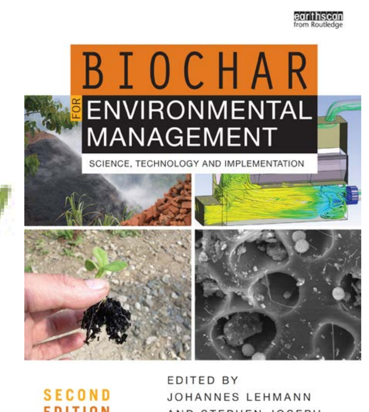


Figure 4: Project-level GHG accounting compares the life cycle emissions from the biochar system with those of the reference system providing the same services.

Références/Contact

Dominic Woolf[1], Johannes Lehmann[1,2], Annette Cowie[3], Maria Luz Cayuela[4], Thea Whitman[5], Saran Sohi[6]

[1] School of Integrative Plant Sciences, Cornell University, Ithaca NY 14853, USA.
[2] Atkinson Center for a Sustainable Future, Cornell University, Ithaca NY 14853, USA.
[3] University of New England, and New South Wales Department of Industry, Australia.
[4] Department of Soil and Water Conservation and Waste Management CEBAS-CSIC, Espinardo Murcia, Spain.
[5] Department of Soil Science, University of Wisconsin-Maddison, USA.
[6] School of Geosciences, Edinburgh University, Edinburgh UK.

In R. Lal and B.A. Stewart (Eds.) Soil and Climate (pp. 219-248). CRC Press.

« 4per1000 » Initiative Day, COP 24 - Katowice (Poland)
December 2018