Soil organic carbon stock change following perennialization: A meta-analysis

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Abstract: Perennial cropping (PC) systems are attracting global attention as sustainable biomass producers and as a climate change mitigation strategy due to their potential to sequester soil carbon (C). However, questions remain on how long PCs can sequester C in soils and how global climate, soil, and plant properties affect soil organic carbon (SOC) stocks. We conducted a meta-analysis synthesizing 51 publications (351 observations at 77 sites) distributed over different pedo-climatic conditions to scrutinize the effect of perennialization on SOC accumulation compared with two benchmark annual systems (monoculture and crop rotation). To better understand the factors influencing SOC accumulation, we used moderator analysis including potential factors like climate zone, soil textural class, soil pH class, perennial crop age, perennial vegetation type, and functional photosynthetic types. Results showed that PCs significantly increased SOC stock by 16.6% and 23.1% at 0-30 cm depth relative to reference annual monoculture and crop rotation systems, respectively. Shortly after establishment (<5 years), PCs reduced SOC stock, while long duration (>10 years) of perennialization significantly increased SOC stock by 30% and 36.4% compared with annual monoculture and crop rotation system. Compared with both reference annual systems, PCs significantly increased SOC stock regardless of their functional types (C3, C4, or C3-C4) and vegetation type (woody or herbaceous). Soil pH had a significant impact on SOC, with more C accumulation in alkaline soils. In contrast, the effect of soil textures showed no significant impact, possibly due to a lack of observations from each textural class and mixed pedoclimatic effects. Time effect of perennialization revealed a sigmoidal increase of SOC stock until about 20 years thereafter reaching a steady-state level.

Annex:

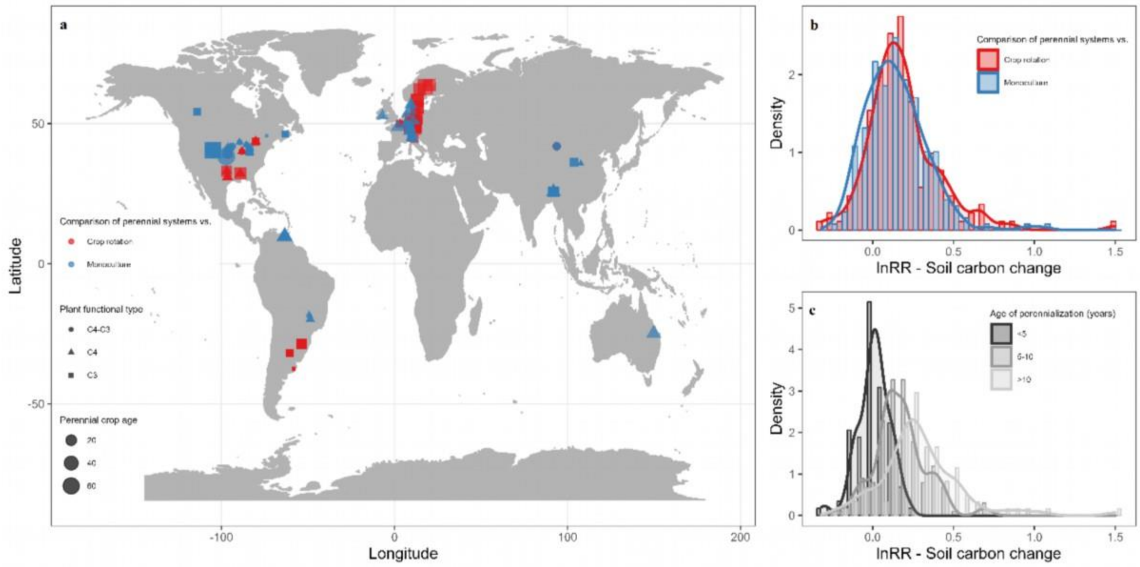

Figure 1: Geographical distribution of the 51 studies across 77 experimental sites included in the analysis (a). Colours indicate the reference annual systems to compare with perennial crops, shapes indicate the functional types of perennial crops (PFT; C3, C4, or C3-C4), and sizes indicate the age of perennial crops, distribution of the log-transformed response ratio (lnRR) of soil carbon change under reference annual systems (b) and distribution of perennialization age (years) (c)

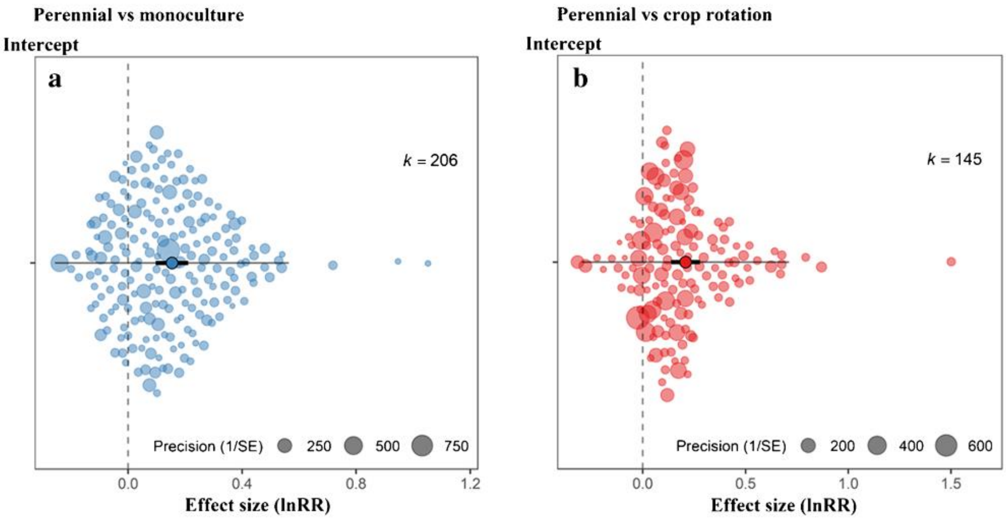

Figure 2: Effect of perennialization on soil organic carbon stock change compared against (a) monoculture and (b) crop rotation. Meta-analytic model showing mean estimates with dark coloured circles, 95% confidence interval with thick whisker, 95% prediction interval with thin whisker, and individual effect sizes scaled by their precision (i.e. inverse of the standard error) with light coloured circles. k indicates the number of effect sizes. The dashed vertical line shows null log response ratio