THEME 2

Ecological intensification increases soil C stocks via changes in crop residue traits

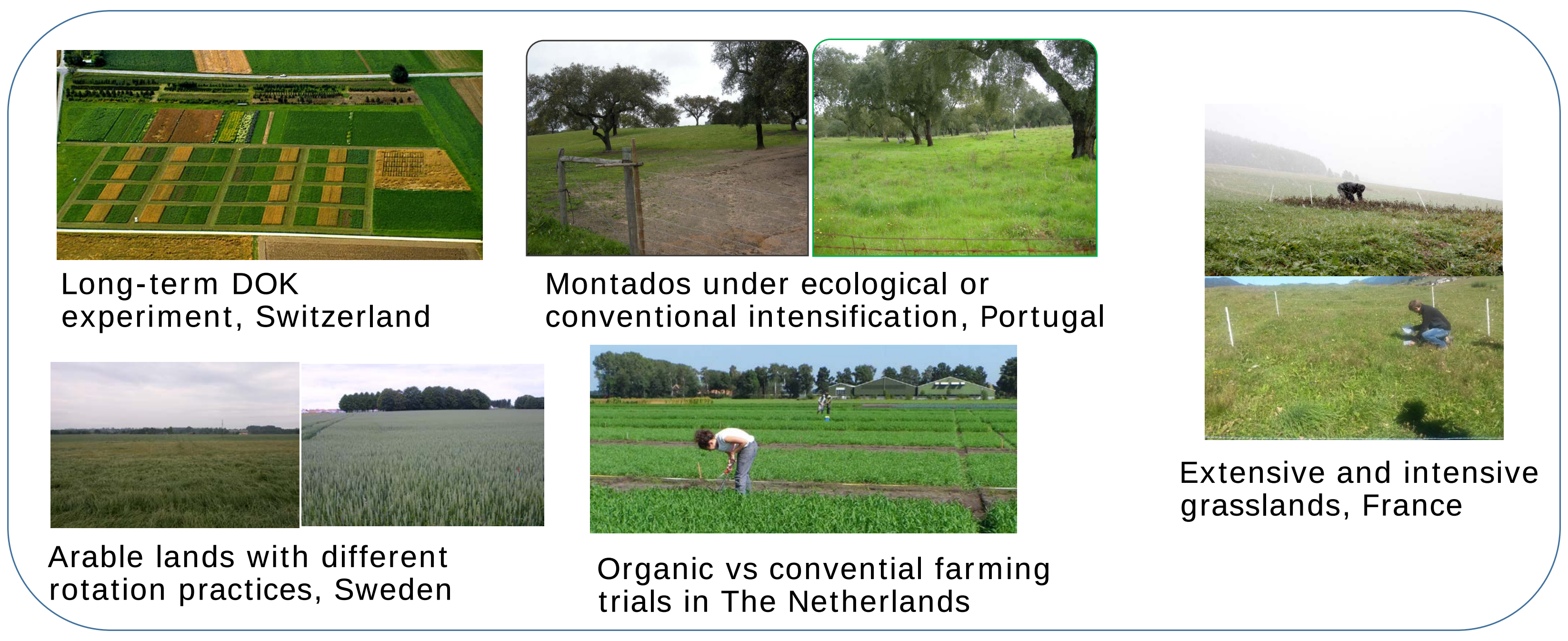
Pablo García-Palacios, Andreas Gattinger & the Eco-Serve consortium
Universidad Rey Juan Carlos; FIBL Research Institute of Organic Agriculture; University of Coimbra; University of Wageningen; University of Lund; University of Grenoble

INTRODUCTION

Ecological intensification (EI) practices such as organic farming (OF) enhance soil C stocks. However, increased C inputs typical of OF are not enough to explain why OF outweighs the C sequestration capacity of conventional farming (CF). Higher soil C stocks are also found in organic farms with low manure rates, and C inputs via plant residues from crop production are likely lower under OF. Thus, altered soil C losses (e.g. decomposition rates of residues) between farming systems might play a role.

OBJECTIVES

Here we assess whether changes in crop residue traits that are key for decomposition, and thus influence soil C loss, drive soil C sequestration responses to OF. Specifically, we tested the hypotheses that (1) crop residue traits are as important as fertilization inputs and climate to determine soil C storage responses to organic farming; and (2) that EI enhances soil C storage by reducing crop residue quality for decomposers (low N concentration).


Long-term DOK experiment, Switzerland

Montados under ecological or conventional intensification, Portugal

Extensive and intensive grasslands, France

Arable lands with different rotation practices, Sweden

Organic vs convential farming trials in The Netherlands

Fig. 1: Conventional vs Ecological Intensification trials and experimental fields in five different types of agroecosystems across Europe

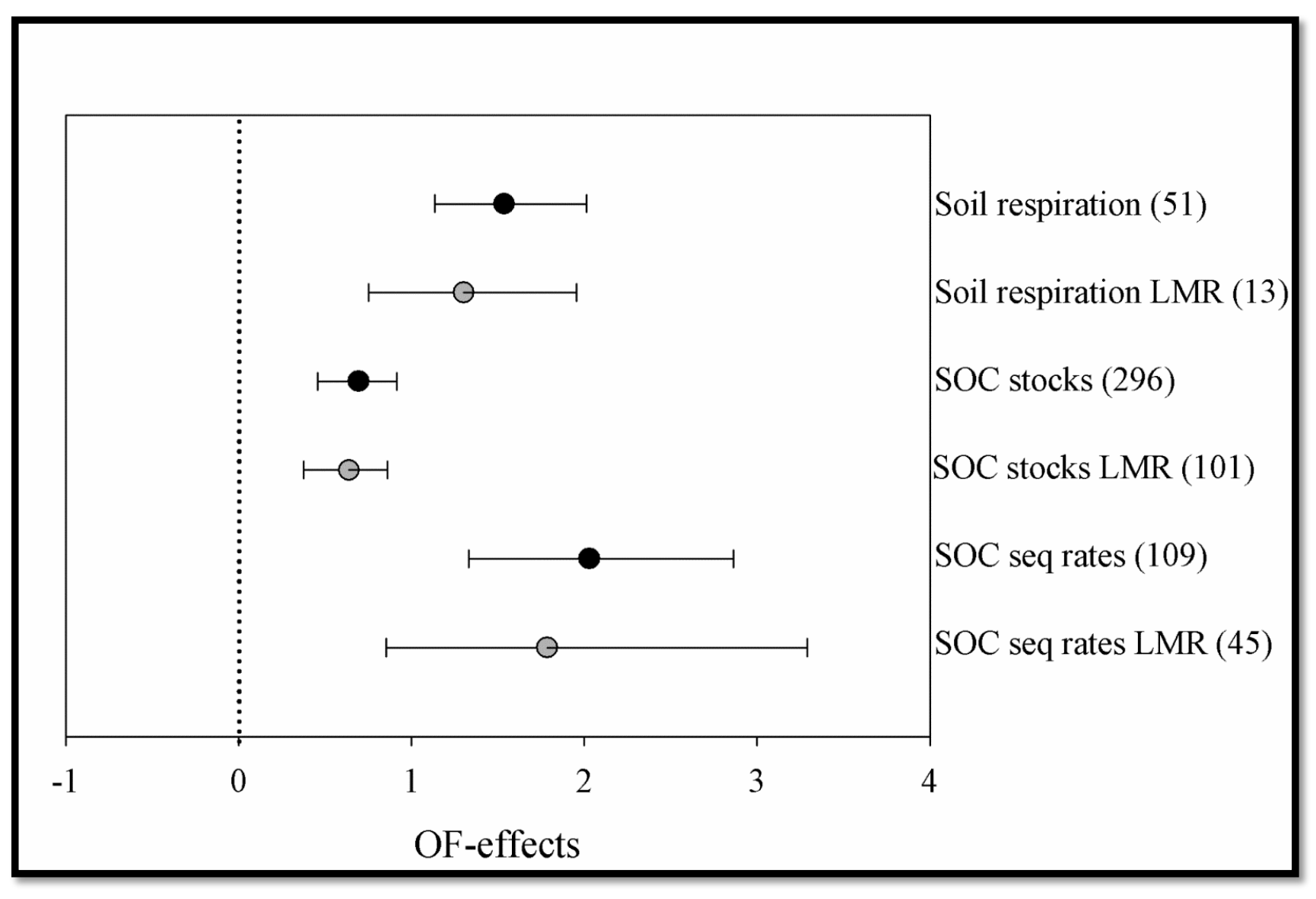


Fig. 2: Effects of organic compared with conventional farming (OF-effects) on soil C and respiration in global meta-analyses. Data are standardized mean differences (Cohen's d) in soil respiration, SOC stocks and SOC sequestration (seq) between OF and CF across farms worldwide. The bars around the means are bias-corrected 95%-bootstrap confidence intervals. If they do not overlap with zero, the means are significantly different from zero. Analyses were conducted separately for all case studies (black circles) and for comparisons where organic farms applied low manure rates (LMR, grey circles). Number of study cases are shown in brackets.

MAIN RESULTS

Using a global meta-analysis on case studies reporting OF vs CF paired farms, we found support for OF increasing SOC (Fig 2). Also, we found that the positive OF effect on soil C sequestration was dependent on the leaf nitrogen (N) concentration of each crop species. The positive OF effect on soil C sequestration at global scales was dependent on the crop leaf N concentration (Fig 3). Crop residue changes with management were further investigated across six European sites comparing ecological (e.g. organic) vs. conventional intensification (Fig 1). Increased crop residue lability (e.g. high leaf N) promoted higher and lower SOC stocks, respectively, in conventional and in ecological intensification (Fig 4). Thus, intraspecific changes towards crop residue lability in conventional intensification were related with a higher response of SOC stocks to OF.

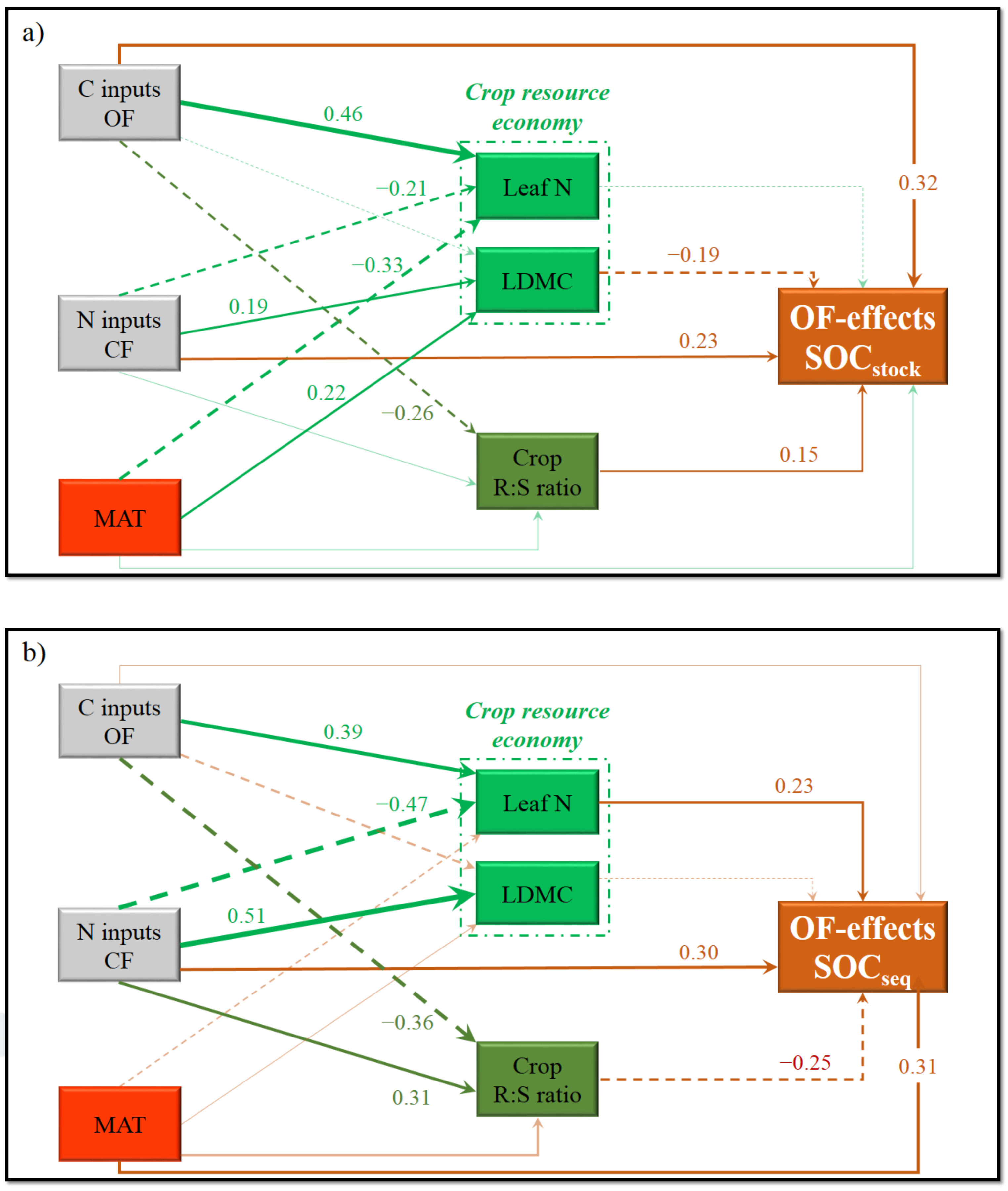


Fig. 3: Structural equation models testing the importance of crop resource economics traits on the effects of organic farming (OF-effects) on SOC stocks (a) and sequestration rates (b) in global meta-analyses. The Cohen's d (standardized mean difference between OF and CF) is computed as the response variable (in brown). The model also includes the influence of fertilization intensity (annual C and N inputs, in grey), mean annual temperature (MAT, in red), and crop R:S ratio (in dark green). Continuous and dashed arrows are positive and negative relationships, respectively. The widths of the arrows are proportional to the strength of the path coefficients. Non-significant (P > 0.05) path coefficients are softened. Goodness-of-fit metrics for each model are: SOC stocks (Bootstrap P = 0.251; RMSEA = 0.035, P = 0.476; GFI = 0.997) and SOC sequestration (Bootstrap P = 0.472; RMSEA = 0.042, P = 0.426; GFI = 0.496). R^2SOCstocks = 0.23, R^2SOCseq = 0.24

Fig 4: Members of the Eco-Serve consortium at Frick (Switzerland). 17th January 2017

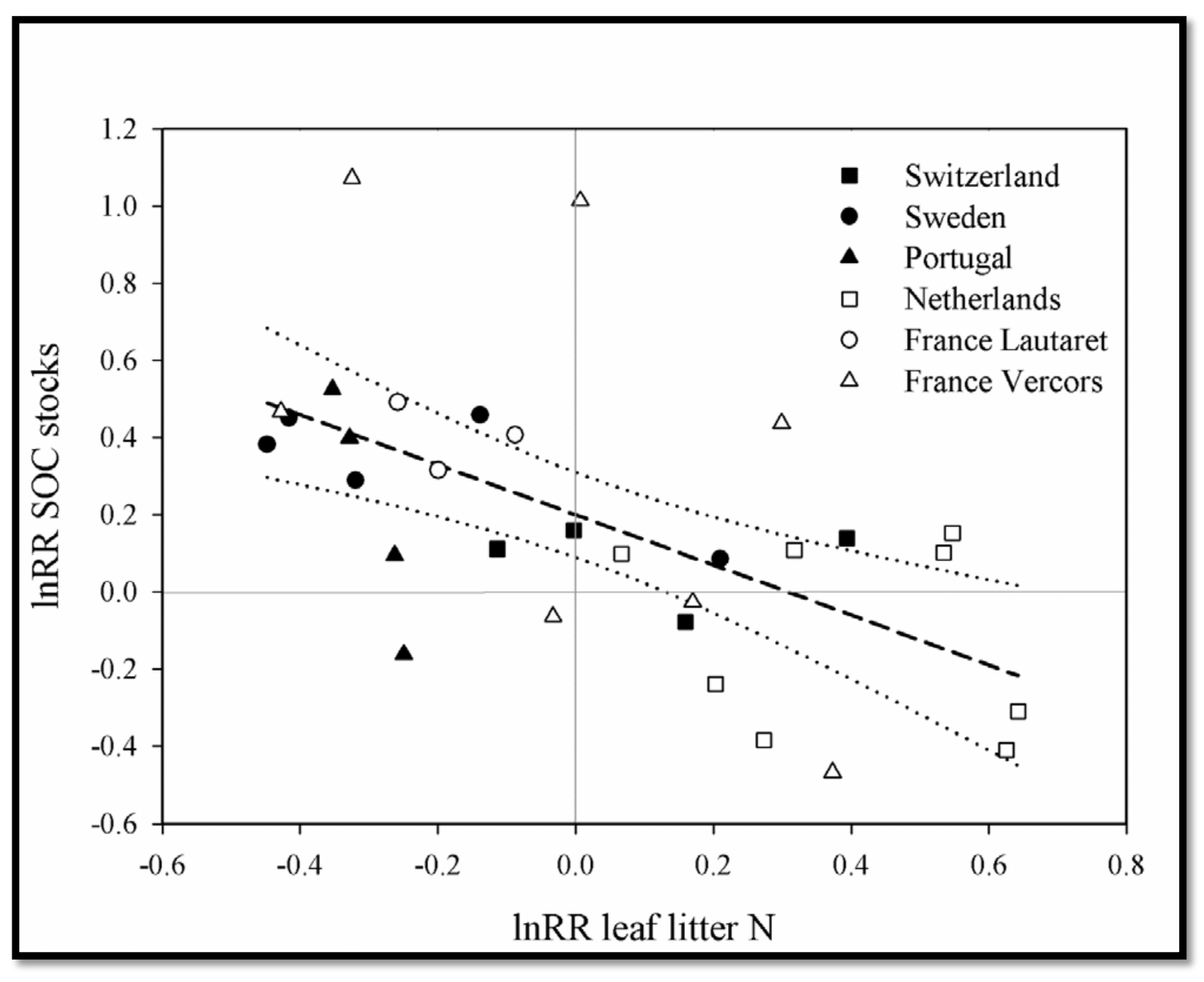


Fig. 4: Changes in crop residue traits account for the effect of ecological intensification (EI) on SOC stocks across six European sites. Relationships between the effect sizes of EI (lnRR, the ratio of ecological intensive to conventional farming) on SOC stocks and on crop leaf litter N concentration. The predicted-relationship (dashed line) and the 95 % confidence intervals are shown (dotted lines). P < 0.01, n = 31.

CONCLUSION

We have shown that the phenotypic traits of crops and their residues modulate the response of SOC to agricultural practices. Therefore, a trait-based framework of crop residues is fundamental when evaluating the ecosystem services delivered by ecological intensification practices such as organic farming.