LOOKING AHEAD Meta-analysis as a powerful approach to identify trade-offs and synergies

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Providing evidence of how different agricultural practices impact on agronomic and ecological goals in tandem may be of great practical use to farmers, policymakers and other food system actors. Meta-analysis is a technique that can help provide this evidence at multiple scales. It can be used to shed light on which agricultural practices are most effective at achieving agronomic and ecological goals in specific farming contexts. This approach is relevant to multiple spatial and temporal levels as meta-analysis can be applied at site (plot), farm and landscape level, with effects disaggregated based on study temporal duration or date that the experiments were conducted. However, keep in mind that in order for this approach to provide robust insights, it requires large datasets that pool comparable information.

Overview

Quantitative systematic reviews that compile and synthesize data from published field experiments of how agricultural practices affect biodiversity and yields or other pairs of outcomes provide insights into synergies and trade-offs between outcomes. Data can be analyzed using a statistical approach called meta-analysis. This approach collates quantitative information from hundreds or even thousands of field experiments that, for instance, measured biodiversity (e.g. species richness, abundance or evenness) and yield performance in sites with contrasting agricultural practices. Through meta-analysis, researchers can obtain estimates of the average change (also called average or global 'effect size') in multiple outcomes when moving from one farming system to another. For example, Beckmann et al. (2019) compared outcomes for biodiversity and yields for sites with contrasting land-use intensities, while Beillouin et al. (2021) compared outcomes for biodiversity and multiple ecosystem services for sites with different levels of crop diversification (Figure 1).

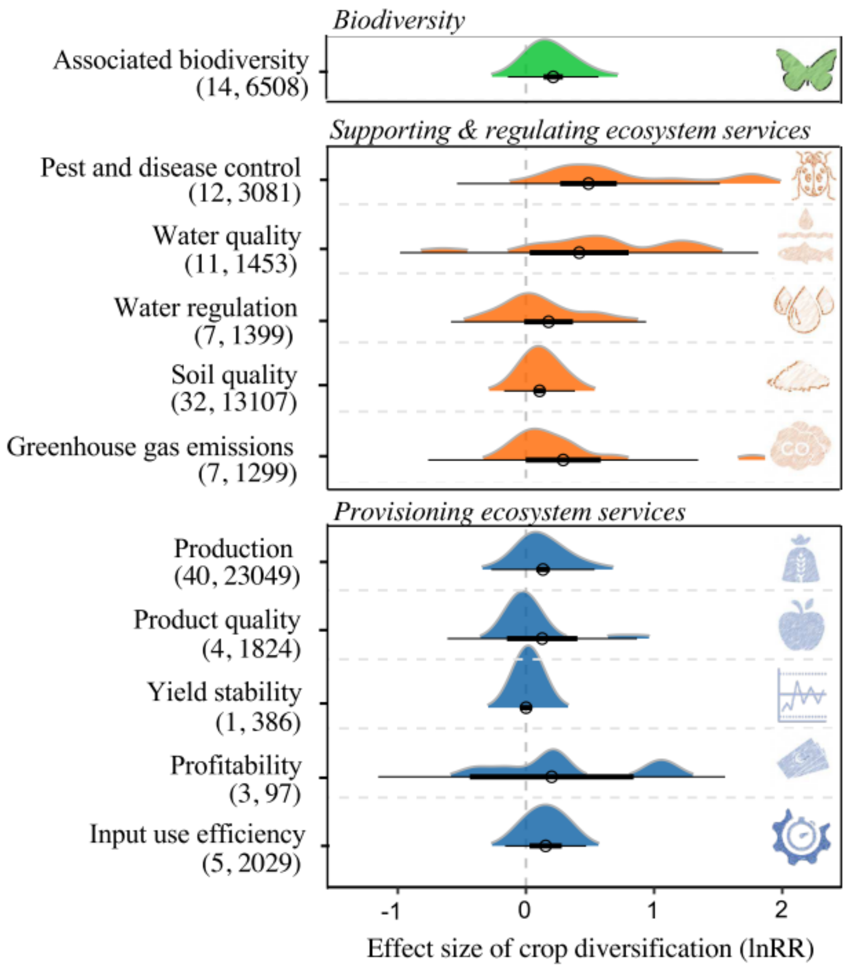

Figure 1: *Effect of crop diversification on biodiversity and multiple ecosystem services. Colored areas on the plots represent probability distributions of the effect sizes, measured as the natural logarithm of the response ratio (mean value of biodiversity and each ecosystem service in a diversified cropping system as a proportion of the mean value in a comparable simplified cropping system). The points on each plot represent the average effect size; thick error bars represent 95% confidence intervals, and; thin error bars represent prediction intervals. Scores above zero mean crop diversification has a positive effect, while scores below zero mean that crop diversification has a negative effect. The number of meta-analyses and individual experiments are displayed in parentheses below each biodiversity and ecosystem service category. Source: Figure 2 in Beillouin et al. (2021), reused with permission.*

Important Details

Meta-analyses can be conducted globally or based on experiments from a specific region, such as Africa or the humid tropics. In the final analysis it is important to compare results from pairs of experimental controls and treatments that are similar across studies. For example, in a meta-analysis of the effects of diversified farming systems (the treatment) relative to simplified farming systems (the control) on biodiversity, studies that compared intercropping to monocropping systems could be included while studies that compared intercropping to primary forest should not.

Controls and treatments should, ideally, only vary in terms of the characteristic being tested, such as in terms of the level of farming system diversity while other factors such as pesticide use, soil and water management, climate, soil type, field size, and landscape complexity, stay constant. In reality, this is challenging because working farms have different management approaches and different crops are often managed in different ways. Contrasting sites may not be found or accessible on the same farm or in close proximity. To help handle this issue, as well as to show true variability in outcomes, meta-analysis includes methods for calculating confidence intervals (the level of confidence given to an estimate of the change in biodiversity or yields), prediction intervals (the range of values that estimated change in biodiversity or yields for a new data point could take, based on the range of the estimates found in the existing dataset), and inter and intra-study variability. This helps researchers to make statements about how robust their results are and to spot instances when control-treatment pairs differ too much to make it reasonable to pool them for analysis.

When the level of unexplained variability is high, or to answer specific research questions, the researcher can check if certain site and experiment specific characteristics help explain the results. Characteristics that have a significant influence on the change in biodiversity or yields are said to have a moderating effect on the average effect size. For example, the length of time over which the study was conducted can influence biodiversity responses, since it may take several years before there is a significant difference in species richness or abundance in a more diversified farming system.

Conducting meta-analyses is a powerful way to i) understand the state of evidence and where the biggest knowledge gaps are on a topic, ii) quantify the expected change in biodiversity, yields, profits, and other outcomes when moving from one agricultural practice to another, iii) identify synergies and trade-offs between multiple outcomes under specific practices.

Key term

- **Trade-offs:** a situation which leads to a positive change (gain) for one outcome and a negative change (loss) for another.
- **Synergies:** a situation which leads to changes in two outcomes and their direction of change is the same (both outcomes gain, or both lose).
- **Systematic review:** a type of literature review that uses repeatable methods to collate and analyse secondary data.
- **Meta-analysis:** a statistical method to combine results of multiple scientific studies.

Key references

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