Chapter 2
What did we learn from meta-analyses about farmland arthropod conservation?

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Abstract Quantitative evidence syntheses appeared in agroecological research in the early 2000 and gained momentum during the last decade for summarising the growing knowledge about the importance of farmland biodiversity conservation. Among other evidence syntheses, meta-analyses have a significant role in quantitatively synthesising findings of primary studies, typically in the frame of systematic reviews. Here we provide a global overview via a scoping review of the essential quantitative synthesis studies testing land-use extensification or diversification effects on arthropod biodiversity. Most meta-analyses showed a positive impact of the studied different extensification or diversification measures on arthropod species richness, with varying effects depending on the studied arthropod functional group, ecosystem, measure type and landscape context. Our findings highlight a serious research gap from the tropics, envisage future directions of agroecological meta-analyses, and provide recommendations for insect conservation in farmland. Finally, we finish our review by emphasising the importance of closing the science-policy gap in order to support the transformative change in the European food system.

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2.1 Introduction

Arthropods are undergoing global population declines and extinctions due to a range of interacting stressors including habitat loss, habitat degradation, and climate change (Cardoso et al., 2020; Harvey et al., 2022). Agricultural intensification is among the top proximate drivers of these processes (IPBES 2019). Production areas that are intensively managed through e.g. heavy tillage, mechanisation, intensive grazing, short crop rotations, and high levels of agrochemical inputs represent an inhospitable environment to most arthropods (Tscharntke et al. 2005a; Desneux et al. 2007; Geiger et al. 2010). Along with this, farmland simplification has greatly reduced the resources available to farmland arthropods. Consolidation of crop fields has led to increased field sizes and the loss of non-crop elements, such as hedgerows and field margins, which provide essential resources for arthropods (Fahrig et al. 2015). Furthermore, crop and livestock diversity loss means farmland has become increasingly homogenised (Sirami et al. 2019).

A wide variety of conservation interventions ranging from targeted, individual measures to more holistic farmland conservation programmes, have played a critical role in mitigating these impacts. These include extensification approaches that aim to reduce in-field management intensity, and diversification measures that aim to re-introduce complexity in agroecosystems at the local and landscape scales, and at temporal scales (Schellhorn et al. 2015; Tamburini et al. 2020). However, there is great variation in success between agroecosystem types, taxa, landscape context and spatial scale considered (Birkhofer et al. 2014; Dainese et al. 2015; Tscharntke et al. 2005b; Tuck et al. 2014).

Synthesising research evidence is vital to identify knowledge gaps and showcase best practices in agroecology. There is a surprisingly great diversity of research or knowledge synthesis methods from simple, narrative reviews through focus groups to systematic reviews and quantitative meta-analyses. Dicks et al. (2017) identified and described over 20 such synthesis methods in environmental sciences, which all review, condense and communicate evidence-based findings vital for the science-policy interface. Two strongly linked methods stand out in responding to scientific ecological or conservation biological questions with their low risk and strong synthesis outcome: systematic reviews and meta-analyses. Systematic reviews identify, appraise, select and synthesize all high-quality relevant research evidence (Haddaway et al. 2018). Furthermore, systematic reviews often use meta-analysis as a statistical technique to combine results of the eligible studies, where effect sizes are calculated for the individual primary studies to put them on the same scale, and heterogeneities (random or systematic, e.g. by environmental moderators) among these effect sizes are tested in meta-analysis models (Gurevitch et al. 2018). Meta-analyses emerged in the 2000s in ecology (also in agroecology; see Pywell et al. 2003), and have become a standard, well-known and highly accepted method during the last decade with an ever-increasing number of published articles, even though there is still a high need to improve their quality (Philibert et al. 2012; Koricheva and Gurevitch 2014).

Here, we aimed to perform a scoping review for meta-analysis studies on farmland arthropod conservation to extract the evidence base by putting all relevant meta-analyses on the same scale. Scoping reviews, also termed quick scoping reviews, use a step-wise methodology following an a priori protocol and is similar to systematic reviews and maps but in a simplified process to produce information in a short time period (Dicks et al. 2017).

According to Munn et al. (2018), the scoping review is suitable for identifying knowledge gaps by scoping a body of literature, clarifying concepts or investigating research. For our review, we performed a systematic search for identifying the potential agroecological meta-analyses studying local and/or landscape scale management effects on arthropod diversity. We put all selected meta-analyses on the same scale (either percentage of change or percentage of explained variance) for better comparability to draw general conclusions (Spake et al. 2022). If it was available in the selected meta-analysis studies, we also summarised effects on different functional groups, landscape moderation effects, and occasionally we also considered effects on yield and profit data (but we did not search explicitly for ecosystem services).

2.2 Methods

In the scoping review, we followed the PICO (Population, Intervention, Comparison and Outcome) framework for considering and scoping for relevant search terms, with which we can identify relevant meta-analysis studies investigating local and landscape scale intensification or extensification effects on them (Higgins & Green, 2008). The population in this broad topic is various groups of arthropods in any kind of agricultural ecosystem, including temporary and permanent crop systems and managed grasslands, but we did not use any taxonomic group or insect or arthropod as a search term to apply a rather sensitive search. Also, instead of using many different intervention and outcome terms, we searched for the term meta-analysis. Finally, we used biodiversity and species richness as outcome terms to focus on community-level studies. Based on these, our search term combination was the following, which we used in topic search of ISI Web of Sciences (WoS), Science Citation Index on 05.01.2023: "(agri* OR grassland OR farmland OR agroforestry OR vineyard) AND (biodiversity OR "species richness") AND meta-analysis". Additionally, we made a refinement in WoS by excluding hits based on the document type. Thus, we excluded corrections, editorial materials and data papers, obviously not containing meta-analyses, but we also excluded early access studies.

This resulted in 402 potential articles. We set up the following inclusion/exclusion rules for the screening process. We included studies investigating the effects of any kind of agricultural activity at the local or landscape scale on species richness or species diversity of arthropods (i.e. we excluded meta-analyses on plants and vertebrates). Some meta-analyses analysed effects on biodiversity in general, but if most effect sizes used in the meta-analyses were on arthropods, we included them. Furthermore, we excluded agricultural expansion studies, where the reference level at the local scale is the natural habitat and agriculture is only a general land conversion impact (e.g. agriculture vs. forest or grassland vs. forest). In connection with this, we also excluded fragmentation studies. Finally, we included only primary meta-analyses using standard effect sizes (Hedges' d or g, log response ratio or Pearson's r). After title filtering based on the above criteria, we identified 127 potential meta-analyses, which were refined to 82 meta-analyses after abstract filtering. After full-text filtering, we included 24 meta-analyses in our scoping review, but also added one meta-analysis relevant to the topic, but not located in WoS: Gonthier et al. (2014). This meta-analysis was not detected because, quite unexpectedly, it did not mention the keyword "meta-analysis", but PB as well as Teja were co-authors.

All of the 25 meta-analyses grouped effect sizes based on population (e.g. functional groups of arthropods) or intervention (e.g. different agri-environment schemes) or population (species richness or abundance, the latter was not a search criterion) to test them in summary or subset analyses or by using them as a moderator in meta regressions. Therefore, we extracted effect sizes from each meta-analysis, which was first of all on arthropod species richness. In many meta-analyses, arthropods were the focus. Thus we extracted effect sizes directly from the main analyses. Still, there were many other meta-analyses with a broader focus, where we extracted effect sizes from the subset or side meta-analyses. Besides, we also extracted effect sizes about abundance, especially to put effects on them in relation to those on species richness. From some meta-analyses, we were able to extract yield and profit data, which are highly relevant in agriculture and of major interest to Teja (Batáry et al. 2017; Gong et al. 2022).

We extracted the above-identified effect sizes (Hedges' *d* or *g*, log response ratio or Pearson's r) together with their 95% confidence intervals (CI) from all meta-analyses, mostly from forest plots with PlotDigitizer 2023, but a few cases from text or tables. We converted standardised mean differences (Hedges' *d* or *g*) to Pearson's r correlation coefficient (Borenstein et al. 2009). We then calculated R^2 from r and multiplied it by 100 to get the percentage of explained variance. We provide Cohen's benchmarks for Person's r and the corresponding percentage of explained variance below for interpreting effect sizes: $r < 0.1$ (<1%) -- very small effect; $0.1 \leq r < 0.3$ (1-9%) — small effect; $0.3 \leq r < 0.5$ (9-25%) moderate effect and $r \geq 0.5$ (>25%) large effect (Cohen 1988). Finally, in the case of the log response ratio, we calculated the percentage of change by taking the exponential of this effect size, from which we subtracted one, and then multiplied by 100 to get the percentage of change (Pustejovsky 2018).

We extracted 75 effect sizes altogether from the 25 summarised meta-analyses. We classified them based on population two-fold. First, which taxonomic or functional groups were studied, i.e. arthropods in general or pests, natural enemies, pollinators or detritivores. Second, which agroecosystems were studied, i.e. croplands, grasslands, permanent crops (agroforestry, vineyard) or a mixture of them (typically without differentiating cropland and grassland). We also classified studies based on outcome terms, i.e. species richness, abundance, biodiversity (considering species richness, abundance or even biomass together), yield or profit. Finally, we grouped all studies into three major groups based on intervention into so-called intensification or extensification comparisons, organic farming, which is often a main focus of many meta-analyses, and remaining specific measures in the often specific agroecosystem, such as grazing, reduced tillage or vineyard vegetation management.

2.3 Results and Discussion

In general, extensification measures showed positive effects on species richness and abundance of arthropods with varying effects depending on population, intervention type and outcome (Fig. 2.1). Organic farming also showed positive effects on arthropod species richness, but with a substantial loss of yield (Fig. 2.2). Finally, specific measures showed varying effects on arthropods dependent on the measure in the different agroecosystems (Fig. 2.3).

2.3.1 Extensification meta-analyses

Investigating the extensification meta-analyses in detail, Attwood et al. (2008) performed one of the earliest agroecological meta-analyses and highlighted that the type of agroecosystem can moderate the effectiveness of different measures. They found strong effects of extensification on grassland arthropods when they compared natural grasslands with the probably strongly impoverished fauna of improved grasslands. A similar comparison of reduced input cropping vs. conventional cropping turned out to be less effective with weaker effects, but later meta-analyses often showed similar effects (see below). In contrast, Shackelford et al. (2013) did not differentiate agroecosystems, but instead investigated local and landscape scale complexity together on species richness vs. abundance. They found that effects on species richness of arthropods and also natural enemy arthropods are more expressed (10% increase) than on abundance (2-3% increase). Another comparison was performed by Batáry et al. (2011) with the authorship of Teja, who tested his well-known landscape complexity hypothesis (Tscharntke et al. 2005a), which expected in a qualitative review that agri-environment management (AEM) is moderated by landscape complexity (often measured as a share of cropland or semi-natural area). Indeed, Batáry et al. (2011) could demonstrate that AEM effective supports species richness (also that of arthropods) in simple landscapes, but not in complex landscapes, which was only valid in croplands, but not in grasslands. The mechanism behind this is the spillover of organisms among habitats for resource complementation, often studied by Teja (Rand et al. 2006; Tscharntke et al. 2012). After this meta-analysis, a few follow-up meta-analyses also partly tested landscape moderation effects. For example, Scheper et al. (2013) confirmed this finding in the case of pollinating insects with a more expressed effect in simple landscapes of this mobile functional group (although they also found a small increase in complex landscapes). In addition, they also considered extremely simplified, so-called cleared landscapes, where agri-environment schemes were not at all effective due to the largely absent species pool (see landscape species pool hypothesis in Tscharntke et al. 2012). Furthermore, Gonthier et al. (2014, with Teja as co-author) showed a stronger local extensification effect on abundance than local extensification or landscape scale complexity effects on species richness or landscape-scale complexity effect on abundance. This was further investigated by Marja et al. (2022, also with Teja as co-author) with paired data design, who could show that increasing landscape complexity enhances species richness of farmland arthropods, whereas AES also enhances their abundance.

Batáry et al. (2015), in their review paper about the European AESs classified the various AEM based on whether they are applied in actively managed agricultural land as in production AEM, such as low-input farming vs. if they are applied on land taken out-of-production as out of production AEM, such as flower strips or hedgerows. They showed that out of production AEM, as a greener measure, supports species richness (also that of arthropods) more than in production AEM. Nevertheless, there might be a scale issue, as the out-of-production AEM is typically limited to a small area of the original

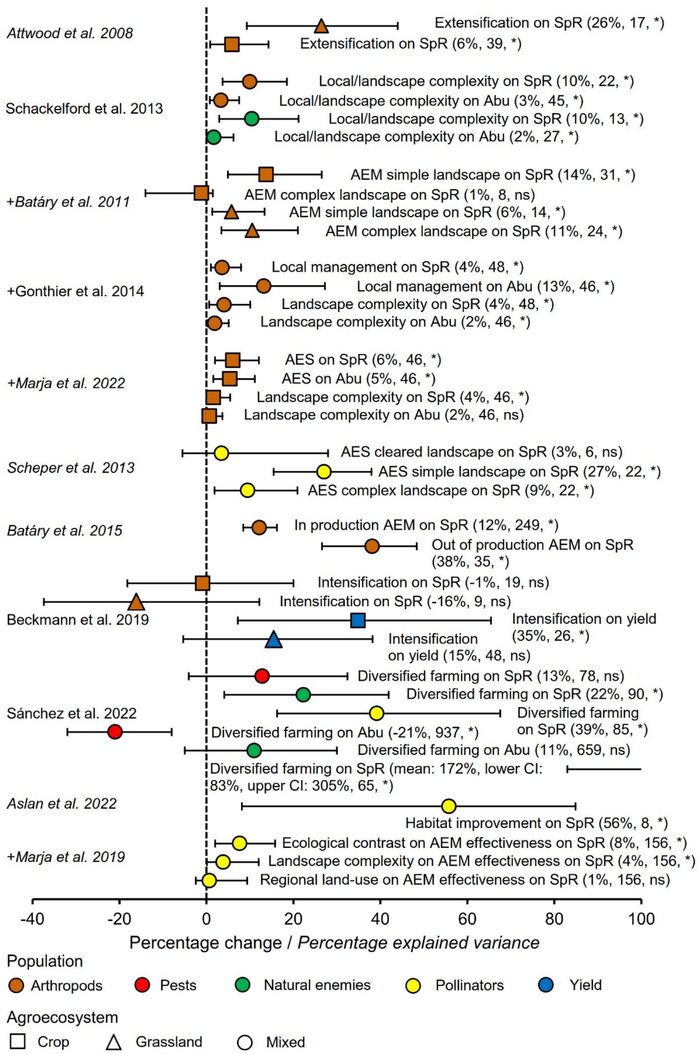

Fig. 2.1: Forest plot showing the main findings of meta-analyses testing different extensification measures on arthropod diversity (or yield) expressed as percentage change/percentage explained variance (reference in italics). Numbers in parentheses show the mean change, number of observations (i.e. effect sizes), and significance *: $p < 0.05$ and ns (if 95% CIs bracket zero the effect is not significant). AES: agri-environment scheme, AEM: agri-environmental management, SpR: species richness, Abu: abundance. Note: In contrast to all meta-analyses, Beckmann et al. (2019) tested intensification as intervention against lower land-use intensity as control. Effect size and Cis for pollinator abundance of Sánchez et al. (2022) is presented as text in the figure given the large effect. + indicates co-authorship of Teja.

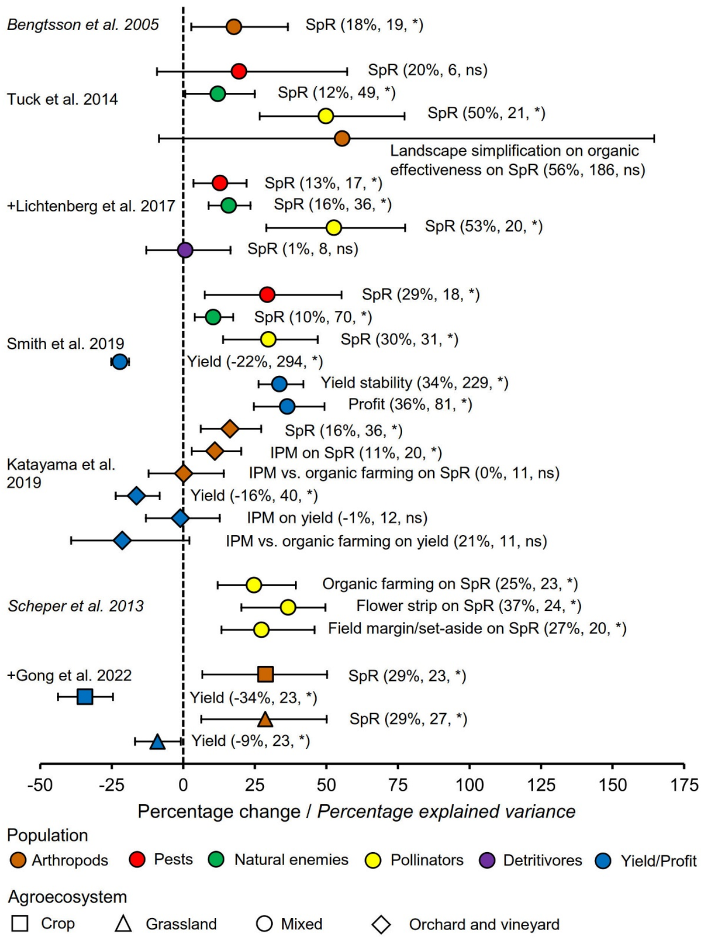

Fig. 2.2: Forest plot showing the main findings of meta-analyses testing organic farming on arthropod diversity (or yield and profit) expressed as percentage change/percentage explained variance (italics). See Fig. 2.1 for explanations.

field, whereas the in production AEM to the whole field, which complicates the outcomes dependent on which scale (transect, field, farm or even yield amount) is considered (Batáry and Tscharntke 2022).

Beckmann et al. (2019) considered intensification a bit unusual as an intervention and compared it to extensive systems as control. Nevertheless, their finding can also be interpreted as the opposite of extensification, and these largely confirm former meta-analyses. Intensification decreased the richness of arthropods, especially in grassland ecosystems (cf. with the finding of Attwood et al. 2008), but yield could be increased more in crops than in grasslands. This suggests that grasslands are probably more sensitive to intensification, and also that yield is hard to improve there. In a related meta-analysis, Sánchez et al. (2022)

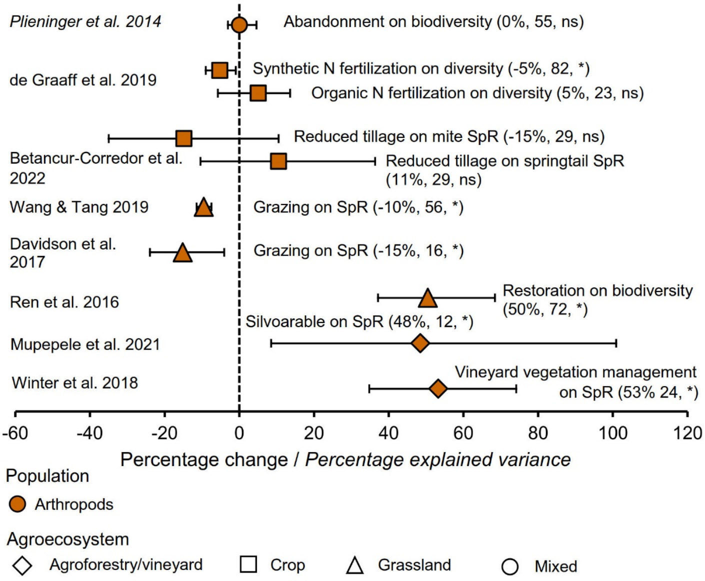

Fig. 2.3: Forest plot showing the main findings of meta-analyses testing specific farming measures on arthropod diversity expressed as percentage change/percentage explained variance (italics). See Fig. 2.1 for explanations.

studied diversified farming (also a mixture of all kinds of extensification measures, such as intercropping, and agroforestry) on different functional groups of arthropods. They showed a strong negative effect (−21%) on pest abundance, but a non-significant increase (11%) in natural enemy abundance (their species richness increased by 22%). Furthermore, they found that diversified farming increased pollinator richness by 39% (Aslan et al. 2022) also showed a large effect), and their abundance extremely by 172%. This latter surprising finding should be investigated further by a future meta-analysis by testing different agroecosystems and measures as moderators. Nevertheless, this meta-analysis also highlights that extensification or diversification schemes can have more expressed effects on more mobile organism groups, such as pollinators, and that these measures can shape biological control by suppressing pests and/or supporting their natural enemies. This cannot function well in given cases, as hypothesised by Teja (Tscharntke et al. 2016), which needs to be tested in future meta-analyses too. Finally, Marja et al. (2019, with Teja as co-author) studied the effects of European AEM on only pollinator richness. Besides the known landscape moderation effect, regional land-use intensity does not moderate AEM effectiveness, but the ecological contrast between the studied intervention and control measures is the most important in moderating this effectiveness. Large contrast cases, e.g. flower strip vs. conventionally managed field, showed somewhat stronger, but in general weak effect than low contrast cases, e.g. grassy field margin vs. conventional farming.

2.3.2 Meta-analyses on organic farming

Organic farming is a widely tested management measure in agroecology, with a lot of studies originating from the Agroecology group of Teja (e.g. Schmidt and Tscharntke 2005; Holzschuh et al. 2008; Batáry et al. 2012), which are often considered in different meta-analyses as a primary source. Organic farming, with its relatively clear local management extensification by mostly abolishing agrochemicals, is in the EU a common AES measure (Batáry et al. 2015). Even though organic farming can increase species richness, quite probably due to more individuals registered there, compared to conventional farming, this comes with a cost of lower yield, as detailed below. Therefore, Teja and his alumni recently emphasised the importance of landscape scale measures and relativised the importance of organic farming (Tscharntke et al. 2021). The meta-analysis studies start with Bengtsson et al. (2005), who found a moderately positive effect on arthropod richness. Its updated and amended meta-analysis by Tuck et al. (2014) showed 12% increase for natural enemies and a much stronger (50%) increase for pollinators, while a non-significant increase for pest richness. They also showed a strong landscape moderation effect on organic farming effectiveness, with higher effects in simpler landscapes, but this effect was not significant. Lichtenberg et al. (2017), with co-authorship of Teja) showed that organic farming effects also depend on the functional group considered, with no effects on detritivores, and increases for pests (13%), natural enemies (16%) and again especially for pollinators (53%). In contrast, Smith et al. (2019) found a stronger effect on pests (29%) than on natural enemies (10%), highlighting the fact that both groups are attracted by organic farming with variable diversity in contrast to the conventionally managed systems. While here not summarized, the global synthesis of Dainese et al. (2019) showed that increased richness of natural enemies resulted in a improved biocontrol (see results by crop diversification in the second-order meta-analysis of Beillouin et al. (2021), and similarly higher diversity of pollinators results in increased pollination success (but see Kleijn et al. 2015).

Smith et al. (2019) also tested the effects on yield and showed a 22% decrease in organic farming, but with higher yield stability (34%) and an increased profit (36%). Katayama et al. (2019), who studied orchards and vineyards, showed a 16% decrease in yield for organic farming, but basically, no yield loss in IPM compared to conventional farming. Both alternative measures increased arthropod richness, organic by 16%, IPM by 11%. Interestingly, when they compared organic farming directly with IPM, they showed no change in species richness, but the yield was still 12% lower (not significantly) in organic farming than in IPM. Thus we agree with their conclusion that integrated farming may be a crucial component of regional conservation planning in orchard/vineyard landscapes.

The earlier discussed Scheper et al. (2013) also tested the effects of other extensification measures besides organic farming on pollinator richness. They showed that organic farming, as well as, field margins and set-asides increased species richness by ca. 25-27%, but flower strips boosted them more with an increase of 37%. Nevertheless, as emphasised earlier, this greener measure might have less expressed impact at larger scales, therefore, combining these different measures is desirable (Grass et al. 2019). Finally, Gong et al. (2022), with Teja as co-author) also tested yield and species richness outcomes of organic farming and showed that organic farming increases species richness by 29% in crop and grass agroecosystems, but there is a stronger yield loss in crops (34%) than in grasslands

(9%). This study also highlights a similar yield-biodiversity trade-off in crops, but with a smaller intensification for closing the yield gap in grassland ecosystems, we might lose more species.

2.3.3 Meta-analyses focusing on specific interventions in different ecosystems

It is welcome that more and more meta-analyses pop up, which test specific agroecosystems, interventions or populations, and can respond to more detailed questions. Plieninger et al. (2014) highlighted the threats of land abandonment in the Mediterranean and found a slight increase in biodiversity (species richness and abundance, without differentiating among them), although not for arthropods. Therefore, they concluded that there is no one-size fits all solution for nature conservation, but there is a strong context dependency. Another specific meta-analysis by de Graaff et al. (2019) investigated the effects of fertilisation on cropland arthropods and found a 5% decrease in their richness due to artificial fertiliser, and a non-significant 5% increase due to organic fertilisers. The high amount of N fertilisers, often coupled with intensive pesticide use in conventional systems, resulted in a strongly reduced diversity and cover of arable wild plants Kleijn et al. (2009), which forms the basis of food webs for the arthropod fauna. Also, in croplands, Betancur-Corredor et al. (2022) showed a non-significant decrease (−15%) and increase (11%) of reduced tillage for mite and springtail richness, although positive effects on their abundances were more obvious (not presented). Thus, reduced tillage has great importance in soil conservation, especially in times of climate crisis.

Extensive grazing has enormous importance in the maintenance of natural and semi-natural grasslands Báldi et al. (2013), Kormann et al. (2015), and Torma et al. (2023), especially in Europe, where large megaherbivores are strongly missing on grasslands Pärtel et al. (2005). Wang and Tang (2019) showed in their global meta-analysis that increased grazing intensity (vs. enclosed control) negatively affected arthropod species richness resulting in a 10% decline. Similarly, Davidson et al. (2017) studying the grazing intensity on salt marshes showed a negative effect on arthropod richness (−15%). Furthermore, a meta-analysis on grassland restorations (including grazing exclusion as a passive method) in the Tibetan plateau, where overgrazing is a serious issue, found a positive effect on arthropod richness with 50% increase Ren et al. (2016). Future meta-analyses on grazing should focus on tipping points in grazing intensity and consider the contrast between grazed vs. control areas.

In silvo-arable systems, where crops are grown among trees, Mupepele et al. (2021) were able to show strong positive (48%), but highly variable effects on arthropod richness, where researchers compared this agroecosystem to temporary crops without trees. Thus the high variability made it hard to draw strong conclusions about these measures. Nevertheless, including trees and shrubs in the cropping systems might provide food resources, shelters, overwintering sites and, in general, habitats for many arthropods, as also suggested by Teja for small habitat fragments (Tscharntke et al. 2002). Finally, Winter et al. (2018) showed several ecosystem service benefits of vineyard inter-row vegetation management, which also supports biodiversity, including arthropod richness, by over 50% increase compared to conventionally managed (tilled, mulched, herbicide-controlled) vineyards. Furthermore, they found no trade-off between grape yield and quality vs. biodiversity or other ecosystem services highlighting the importance of establishing locally adapted diverse vegetation cover in vineyard inter-rows. This latter, specific meta-analysis is an exceptional example, which could provide a reasonably clear management and policy suggestion.

2.3.4 Knowledge gaps

Despite the remarkable progress in our understanding of measures promoting farmland biodiversity, in no small part due to the work of Teja and his colleagues, knowledge gaps remain. Much of our knowledge stems from the temperate agricultural landscapes of Europe and the US, including the meta-analyses considered in this book chapter (tremendous geographic bias). By contrast, we have little knowledge on the state of farmland biodiversity and ecosystem services in most tropical regions, where many studies still focus on conservation of natural habitats, especially forests (Gibson et al. 2011; Lewis et al. 2015; Barlow et al. 2018). This is despite the significant role of farmland biodiversity and associated ecosystem services (e.g., pollination, biological pest control) for tropical agriculture, and in particular smallholders, as emphasised by many studies of Teja's group (e.g. Klein et al. 2003; Hoehn et al. 2008; Maas et al. 2013; Li et al. 2022). In addition, recent research shows that agricultural land-uses in the tropics are much more biodiverse than previously assumed (e.g. Wurz et al. 2022). However, influential ecological theories developed by Teja and colleagues, such as the intermediate landscape complexity and the dominance of beta diversity hypotheses (Tscharntke et al. 2012), remain largely to be tested in tropical human-modified landscapes.

2.3.5 Future meta-analysis directions

The methodology of both systematic reviews and meta-analyses develops quickly (O'Dea et al. 2021). For instance, machine learning has been speeding up the screening process of systematic reviews (Farrell et al. 2022). Although, most (agro)ecological meta-analyses use univariate models, i.e. a single moderator, more and more complex models also testing interactions (e.g. Marja et al. 2019) are possible with the ever increasing number of primary studies and developing statistics. For example, second-order meta-analyses have recently appeared also in agroecology (Tamburini et al. 2020; Beillouin et al. 2021), but these might be biased by including partly overlapping primary meta-analyses. One criticism of meta-analyses, in general, might be that given their often simplistic design, they are less helpful in explaining mechanisms. Luckily, with more and more data from similarly designed studies, this can be achieved by path analyses, namely applying meta-analytic structural equation modelling (as summarized by Wang and Tang 2019). Hence, besides the still increasing number of meta-analyses, we expect more specific ones, which might improve our understanding more how spatial and temporal scale management diversification actions can maintain and support farmland biodiversity and their services to achieve societal and policy changes, ultimately a transformative change. Finally, we expect that the importance of increasing the temporal stability of meta-analyses will increase in the future, as accumulating new evidence (additional effect sizes) can change the magnitude or even the sign of the effects, but in general, increases its robustness (Koricheva and Kulinskaya

2019). A promising solution is the maintenance of living systematic reviews already existing in health science (Elliott et al. 2017).

2.3.6 Recommendations for insect conservation in farmland

The analyses here highlight several emergent trends which may help guide insect conservation in farmland. Diversification practices focussing on increasing heterogeneity (structural, compositional, and temporal) at the local scale effective enhance arthropod diversity under most scenarios. Within-crop diversification practices such as mixed cropping, complex crop rotations, silvopasture and agroforestry improve arthropod resource diversity and continuity (Tamburini et al. 2020; Iverson et al. 2014), as do measures that focus on areas outside of the production fields such as flower strips, set-asides, field margins and hedgerows which show particular promise for boosting arthropods (Batáry et al. 2015). Despite substantial variation among systems and focal organisms, measures that focus on reducing management intensity in the production areas, such as organic farming, IPM, reduced tillage and low-intensity grazing soften the agricultural matrix for arthropods and may be especially effective in combination with diversification measures (Tscharntke et al. 2021). In addition, more hospitable crop fields may also facilitate greater arthropod dispersal across farming landscapes, with essential benefits for arthropod migration and adaption to climate change.

In the regions that were assessed, complexity at the landscape scale was less influential on farmland arthropod diversity than local-scale practices (Marja et al. 2022; Gonthier et al. 2014). Nonetheless, landscape-scale practices such as maintaining natural and semi-natural vegetation patches increase arthropod diversity in the species pool and are especially important for more mobile organisms (Gonthier et al. 2014), also bearing in mind that many species of conservation significance are supported in such areas (Tscharntke et al. 2002).

Our study highlights the variability among specific individual practices. An important focus area is to identify highly effective targeted practices that consistently enhance arthropods within certain agroecosystems, e.g. sensitive inter-row vegetation management in perennial crops such as vineyards (Winter et al. 2018).

2.4 Outlook

The evidence is more robust if the synthesised studies cover more systems (habitats, biogeographic regions, socio-economic environments, etc.). For example, the loss of farmland heterogeneity was suggested as the key factor behind bird population decline (Benton 2003), but this was based on West European experiences. Báldi and Batáry (2011) showed that the contrary might be valid in the semi-natural grasslands in Central Europe. Thus, the biogeographical coverage may modify the outcome, which policy makers may use. We recommend to be more comprehensive in research syntheses to reach higher relevance for policy, for example, with the more effective inclusion of non-English sources (Amano et al. 2023; Steigerwald et al. 2022). Another way is — what we applied in this study and demonstrated its usefulness – when results of several meta-analyses were synthesised, thus getting a more comprehensive and robust result than previous meta-analytical studies. Finally, we emphasize the temporal aspects of accumulating research evidence, which might change meta-analysis results (Koricheva and Kulinskaya 2019), with living systematic reviews providing a potential solution (Elliott et al. 2017).

However, all these meta-analyses are scientific publications, thus, not in the policy arena. Considering the robust nature of the evidence that a meta-analysis can hold, it is crucial that this evidence is guided through the science-policy interface for utilisation in policy developments. As farmland arthropods provide essential ecosystem services, such as pollination, pest control and soil fertility, this evidence could directly impact food security and sustainability of farming systems beyond the conservation of farmland biodiversity. Thus, the evidence may also contribute to the relevant European and global policies. For example, the EU's ambitious goals in the Biodiversity and Farm to Fork strategies are impossible to achieve without the application of knowledge on the effects of landscape and local scale factors on the functioning of arthropod groups. Acknowledging and including this in the Common Agricultural Policy may make the desired change to support transformative change in the European food system (European Commission: Directorate-General for Research and Innovation 2020). Therefore, a more effective interface to facilitate the flow of evidence from science to policy is badly needed to provide increased robust knowledge immediately to the hand of policymakers (Bertuol-Garcia et al. 2018).

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