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A critical analysis of the potential for EU Common Agricultural Policy measures to support wild pollinators on farmland

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Abstract

1. Agricultural intensification and associated loss of high-quality habitats are key drivers of insect pollinator declines. With the aim of decreasing the environmental impact of agriculture, the 2014 EU Common Agricultural Policy (CAP) defined a set of habitat and landscape features (Ecological Focus Areas: EFAs) farmers could select from as a requirement to receive basic farm payments. To inform the

post-2020 CAP, we performed a European-scale evaluation to determine how different EFA options vary in their potential to support insect pollinators under standard and pollinator-friendly management, as well as the extent of farmer uptake.

2. A structured Delphi elicitation process engaged 22 experts from 18 European countries to evaluate EFAs options. By considering life cycle requirements of key pollinating *taxa* (i.e. bumble bees, solitary bees and hoverflies), each option was evaluated for its potential to provide forage, bee nesting sites and hoverfly larval resources.

3. EFA options varied substantially in the resources they were perceived to provide and their effectiveness varied geographically and temporally. For example, field margins provide relatively good forage throughout the season in Southern and Eastern Europe but lacked early-season forage in Northern and Western Europe. Under standard management, no single EFA option achieved high scores across resource categories and a scarcity of late season forage was perceived.

4. Experts identified substantial opportunities to improve habitat quality by adopting pollinator-friendly management. Improving management alone was, however, unlikely to ensure that all pollinator resource requirements were met. Our analyses suggest that a combination of poor management, differences in the inherent pollinator habitat quality and uptake bias towards catch crops and nitrogen-fixing crops severely limit the potential of EFAs to support pollinators in European agricultural landscapes.

5. *Policy Implications*. To conserve pollinators and help protect pollination services, our expert elicitation highlights the need to create a variety of interconnected, well-managed habitats that complement each other in the resources they offer. To achieve this the Common Agricultural Policy post-2020 should take a holistic view to implementation that integrates the different delivery vehicles aimed at protecting biodiversity (e.g. enhanced conditionality, eco-schemes and agri-environment and climate measures). To improve habitat quality we recommend an effective monitoring framework with target-orientated indicators and to facilitate the spatial targeting of options collaboration between land managers should be incentivised.

KEYWORDS

agri-environment schemes, bees, CAP Green Architecture, Common Agricultural Policy, Ecological Focus Areas, habitat complementarity, pollination services, pollinator conservation

1 | INTRODUCTION

Since the 1950s, agricultural biodiversity has undergone significant declines globally (Benton, Vickery, & Wilson, 2003). The intensification of agricultural practices and associated loss of high-quality habitats, both within the crop and adjacent (semi)-natural land, are amongst the primary drivers of biodiversity loss (Benton et al., 2003; IPBES, 2019). Farmland biodiversity underpins a range of ecosystem services vital to both natural and farmed ecosystems, including nutrient cycling, natural pest regulation and pollination, with losses indirectly constraining agricultural productivity (Deguines et al., 2014) and impacting on (semi)-natural habitats (Ollerton, Winfree, & Tarrant, 2011; Potts et al., 2016).

To mitigate adverse environmental impacts of intensive agriculture, the European Union's Common Agricultural Policy (CAP) introduced agri-environment schemes in 1992 to financially support environmentally friendly farming practices (EEC Regulation No 2078/92). Unfortunately, the success and cost-effectiveness of such schemes at halting biodiversity declines remains debatable

(Batáry, Dicks, Kleijn, & Sutherland, 2015; Pe'er, Lakner, et al., 2017). Consequently, to improve environmental sustainability, the 2014 CAP reform linked basic farm payments (i.e. 'direct payments' and 'market-related expenditures') to compulsory greening measures (EU Regulation No 1307/2013). Three greening measures were introduced: maintenance of permanent pastures, crop diversification and Ecological Focus Areas (EFAs; European Commission, 2017). EFAs specifically aimed to provide ecologically beneficial areas within arable cropping systems to *safeguard and improve biodiversity on farms* (European Commission, 2017).

Proposals for the post-2020 CAP (budget period: 2021–2027) outline plans to abandon EFAs in their current format (European Commission, 2019). Instead, it is proposed that Member States set a *minimum share of agricultural area devoted to non-productive features or areas* as part of obligatory standards for good agricultural and environmental condition of the land, with the threshold area and available landscape/habitat options being set by Member States. In principle, this proposition is similar to current EFA requirements; however, with implementation being determined by individual Member States, recommendations on the minimum area, management and relative environmental and conservation value of different options are lacking.

Pollinators provide key services to insect-pollinated crops and wild plants across Europe, yet they are vulnerable to agricultural intensification and habitat loss (Potts et al., 2016). Indeed, a pan-European study of pollination potential indicated a deficit for large parts of northern Europe (Zulian, Maes, & Paracchini, 2013). Pollinators may forage in crop habitats during the short period when crops flower, but the rest of the year they rely on surrounding semi-natural habitats for vital resources: food, shelter, nesting, breeding and dormancy/overwintering sites (Baude et al., 2016; Kovács-Hostyánszki et al., 2017). Local and landscape structures influence the abundance and diversity of insects visiting pollinator-dependent crops, directly impacting yield (Blaauw & Isaacs, 2014; Garibaldi et al., 2016). With animal pollinators benefitting production in approximately 75% of major crops world-wide (Klein et al., 2007), maintaining healthy pollinator communities is critical to food security. Furthermore, with an estimated >87.5% of flowering plant species benefitting from animal pollination world-wide, pollinator conservation is fundamental to the preservation of wider biodiversity (Ollerton et al., 2011).

Through providing habitats and enhancing landscape heterogeneity, EFAs have the potential to increase the abundance, diversity and spatio-temporal continuity of vital resources for pollinators in agricultural landscapes. However, the success of EFAs at meeting biodiversity goals has been fiercely challenged, largely as a result of high proportion of farms being exempt and uptake bias towards more production-orientated EFAs (European Court of Auditors, 2017; Hart et al., 2017; Pe'er, Zinngrebe, et al., 2017). EFA options vary greatly in their effects, and, because their environmental efficacy is largely dependent on the way in which they are implemented and managed, these effects can differ geographically

(Alliance Environment & Thünen Institute, 2017). The post-2020 CAP reform provides an opportunity to improve implementation of non-productive features/areas and to outline management recommendations targeted to farm or regional requirements (e.g. diffuse pollution mitigation, pollinator conservation).

Here we provide a critical evaluation of how different EFA options can support pollinators by considering their inherent potential to provide key resources, their management and their uptake. We focus on important pollinators, specifically bees (Hymenoptera: Apiformes) and hoverflies (Diptera: Syrphidae). For each EFA option, we identify standard and 'pollinator-friendly' (i.e. enhanced actions specifically designed to increase the availability of resources for pollinators) management practices. With comprehensive empirical data on the relative value of EFA options to provide pollinator resources (i.e. forage, bee nesting and hoverfly larval resources) lacking, we use a Delphi expert elicitation process to evaluate EFAs (Mukherjee et al., 2015). Our European-scale evaluation aims to answer the following questions to inform the CAP post-2020 on key measures to promote pollinator conservation on farmland:

1. How do EFA options differ in their potential to provide pollinator resources and how does this vary temporally (through the year) and geographically (across Europe)?
2. To what extent does improving the management of EFAs enhance their quality in terms of the range and quantity of resources offered?
3. Do different EFAs complement each other in the type and spatio-temporal distribution of resources they offer, and could this complementarity be exploited by encouraging farmers to take up particular combinations of options?

Through answering these key questions, and subsequent analyses, we derive implications for EFAs, for Agri-Environment Schemes and for the 'Green Architecture' of the CAP.

2 | MATERIALS AND METHODS

2.1 | Evaluation process

EFA options were evaluated following the Delphi technique (see Figure S1) which seeks consensus of expert opinion via anonymous, iterative rounds of evaluations and reduces bias that can accompany expert judgement (e.g. subjectivity, overconfidence, social pressure, group-thinking and dominance: Mukherjee et al., 2015). First, a workshop was held to bring pollinator experts from across Europe together. Participants discussed 'standard' (i.e. typical of EFAs across regions) and 'pollinator-friendly' (i.e. enhanced management designed to increase pollinator resources) management practices, identified nine important resources for key pollinator *taxa* (i.e. hoverflies, bumble bees and solitary bees: Table 1) and provided feedback on the proposed scoring document (an evaluation

Pollinator resource	Resource description
Floral	
Early season	Flowers that provide nectar and/or pollen resources early in the year (i.e. European spring)
Mid-season	Flowers that provide nectar and/or pollen resources towards the middle of the year (i.e. early summer/mid-summer depending on region)
Late season	Flowers that provide nectar and/or pollen resources late in the year (i.e. late summer/autumn depending on region)
Open flowers easily accessible	Flowers that are easily accessible to most pollinator species including those with short mouthparts (e.g. *Crataegus monogyna* and *Valeriana officinalis*)
Tubular flowers accessible by long-tongued species	Flowers that are complex in structure with deep corollae where access is restricted to long-tongued pollinators (e.g. *Symphytum officinale* and *Vicia faba*)
Bee nesting	
Solitary bees	Suitable nesting sites for solitary bees, such as bare ground, cavities in trees, plants or man-made structures
Bumble bees	Suitable nesting sites for bumble bees, such as tussocky grasses, old mammal burrows
Hoverfly larvae	
Insectivorous larvae	Suitable prey items (particularly aphids) for insectivorous hoverfly larvae such as *Syrphus* spp. and *Episyrphus* spp.
Saprophytic larvae	Damp, decaying organic matter that provides a food source for hoverflies with saprophytic larvae such as *Helophilus* spp. and *Eristalis* spp.

TABLE 1 Description of insect pollinator resources included in the evaluation process

spreadsheet). A scientific literature review was then undertaken to provide detailed descriptions of EFA options (Table S1), summarize what is known about each option's potential to provide pollinator resources and refine the definitions of pollinator-friendly and standard management (Table S2 outlines standard and pollinator-friendly management including, for each EFA, comprehensive recommendations for pollinator-friendly management).

The formal Delphi process engaged 22 experts from 18 European countries which were divided into three broad Köppen-Geiger Climate Regions specifically: Northern and Western (N&W), Southern (S) and Eastern (E) Europe (Figure 1; Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). To provide sufficient replication each Köppen-Geiger region was represented by a minimum of five countries. To ensure anonymity of responses, evaluation spreadsheets were distributed and collated via email by a central administrator not involved in the scoring exercise. Experts were requested to evaluate all EFA habitats physically present in their country (i.e. irrespective of whether the habitat was a permitted EFA option in that country). As Switzerland is not in the EU, our Swiss evaluator was only requested to score agri-environment habitats comparable to European EFAs.

For each EFA option, experts scored its potential to provide the selected pollinator resources under standard and under pollinator-friendly management, with these practices outlined in the evaluation spreadsheet to ensure standardization between evaluators (Table S2). Values were selected from an ordinal scale ranging from 0 (no resource provided) to 3 (high resource availability). To reduce the

risk of low confidence in a given score, experts could decline to score where they felt they had insufficient knowledge. Within each geographical region, we aimed to reach a threshold consensus of >66% of scorers selecting the mode. Percentage agreement is the most common definition for consensus, with our 66% criterion being comparable to other studies (i.e. ranging from 50% to 97%) (Diamond et al., 2014).

Following the first round of scoring, mean scores for each region were calculated (i.e. per EFA option, management and resource). These means were included in the second scoring round and experts were invited to revise their initial score in light of the group response, giving justification of their choice. Following calculation of summary statistics from the second scoring round, EFA options not reaching consensus were put forward to a third scoring round, where participants were presented with mean scores derived from round two alongside the rationale/evidence provided by experts in their region. Experts were requested to revise their scores and provide reasoning/evidence behind their chosen score. At this point, deviation between scores was considered to represent true inter-country variation and/or differences in opinion between experts and scoring was terminated (Appendix S1).

Following evaluations, scores were verified by reviewing comments/evidence provided and validating against information collated in the literature review (Appendix S2). Expert scores typically agreed with the literature, or where significant departures occurred these could generally be attributed to geographical differences in the habitat itself or its management. We note that
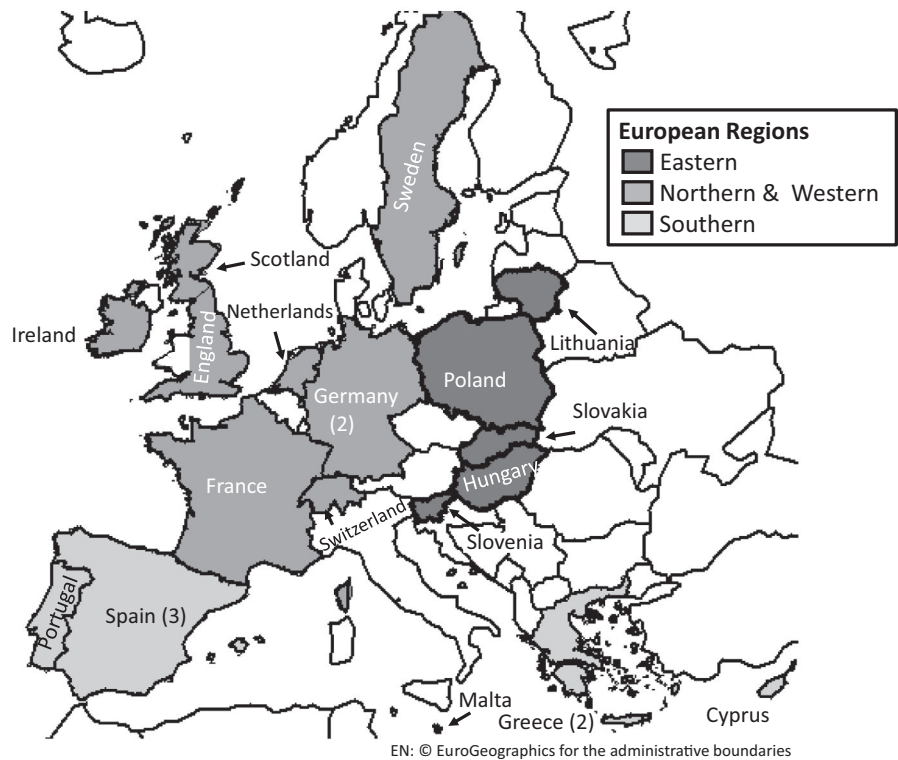
FIGURE 1 Overview of our three European geographical regions and countries represented in each region. Geographical regions were based on Köppen-Geiger Climate Regions (Kottek et al., 2006). For countries where more than one expert scored the number of scorers is represented in brackets

there was ambiguity in interpretation of the EFA option 'strips along forest edges', with some respondents scoring the area adjacent to forest edges (the actual EFA), while others scored the forest edge itself (not an EFA). This EFA option was therefore omitted from the dataset.

2.2 | Data analyses

For each respondent, three broad resource scores were calculated (i.e. floral, bee nesting and hoverfly larval resources) per EFA option and management. Broad resource scores were calculated as follows: floral resources (mean of early season, mid-season, late season, open and tubular flowers), bee nesting sites (mean of bumble bee and solitary bee nest sites) and hoverfly larval resources (mean of insectivorous and saprophytic larval resources: Table 1). Although data were collected on an ordinal scale, means were calculated rather than medians to give equal weighting to all resources constituting a broad resource category. The resultant broad resource data allowed the fitting of linear mixed models (LMMs), with EFA option nested in country as random effects to fully capture the hierarchical structure of the data. Preliminary analyses revealed significant three- and four-way interactions between EFA option, management, broad resource type and geographic region (Table S3). To ease interpretation, separate analyses were therefore performed for each of our three geographical regions (i.e. E, N&W and S Europe) and broad resource-types. Models included EFA option, management and their interaction as fixed factors to enable us to explore whether:

1. Experts perceived current EFA options to differ in their potential to provide resources for pollinators (i.e. fixed effect EFA option).
2. Experts perceived that pollinator-friendly management promoted pollinator resource value (i.e. fixed effect management).
3. Effects of pollinator-friendly management on pollinator resource value was perceived to differ among EFA options (i.e. interaction between EFA and management).

LMMs also explored whether EFAs showed seasonal differences in floral resource value. Again a significant three-way interaction was detected between EFA option, season and geographic region (Table S3). To ease interpretation, separate analyses were therefore conducted for each region under standard management. Here the response variable was the floral resource score with fixed effects EFA option and season (i.e. early, mid and late season), and their interaction. Again, EFA option nested within country were included as random effects.

All analyses were performed in R version 3.5.0 (R Core Team, 2018) using the package NMLE (Pinheiro, Bates, DebRoy, & Sarkar, 2018). EFA options were omitted from analyses when scores were obtained from fewer than three countries in a geographic region. In Germany, Greece and Spain, evaluations were provided by more than one expert. To avoid over-representation bias, scores were averaged over respondents to provide a single score per country, broad resource-type, EFA and management. Homoscedasticity and normality of residuals were validated by visual inspection of diagnostic plots, with no major departures from normality and equality of variances detected.

3 | RESULTS

3.1 | Overall trends

Heat maps of the mean scores achieved by each option highlighted substantial differences in the resources different EFAs provided, and that these changed across geographical regions, seasonally and with management (Figure 2; Table S3). Inter-country variation was also detected, with hoverfly larval resources in E Europe and nesting resources in E and S Europe showing the greatest variation. Lower inter-country variation in N&W Europe may reflect the greater availability of research in this region. See Figure S2 for detailed country-level results for each broad resource category. It is important to note that the Delphi evaluation process may have reduced inter-country variation within a geographical region due to the process of seeking consensus between scorers (Supporting Information: Delphi Technique).

Heatmaps indicate that under standard management, no single EFA option scored over medium (i.e. >2) for all resources; however, in E Europe, trees in groups/lines only lacked late season floral resources (score = 2). Across EFAs under standard management, perceived resource values tended to be lowest in N&W Europe. This geographical trend was not, however, apparent under pollinator-friendly management, where N&W resource scores were comparable to other regions.

The bias in EFA uptake towards nitrogen-fixing crops, fallow land and catch crops (accounting for 97% of total EFA area; European Commission, 2017) is reflected across our three geographical regions (Figure 2; Table S4). Resource scores indicated that even under pollinator-friendly management, these three EFAs (two EFAs in S Europe where catch crops were not an option) in combination would fail to deliver all necessary resources at good levels (i.e. >2). In E Europe, bee nesting sites received low scores (i.e. ≤2) across these three EFAs, with bumble bee nesting sites also scoring low in the south. Hoverfly larval resources scored low across dominant EFAs in our N&W region, with resources for insectivorous hoverflies also scoring low in S Europe.

3.2 | EFA options and management across regions

3.2.1 | Eastern Europe

In E Europe, EFA options differed in their perceived potential to provide resources (Table 2, Figure 3). Under standard management, floral resource scores were lowest for fallows, ponds, afforested areas and short-rotation coppices, and highest for ditches, field margins and trees in groups/lines. Alongside catch and nitrogen-fixing crops, ponds and fallows also received the lowest scores for nesting sites. Afforested areas, while scoring low with respect to floral resources, achieved one of the highest scores for nesting sites. Hoverfly larval resource data were lacking for several EFA options, highlighting a knowledge gap in this region.

Experts indicated that ditches and ponds provided most hoverfly larval resources, while fallows, catch crops and isolated trees provided the least.

For all EFA options, enhanced pollinator-friendly management improved the perceived value across resource categories. For hoverfly larval resources and bee nesting sites, pollinator-friendly management in all EFA options was perceived to increase resources to a similar extent (i.e. no significant EFA × management interaction, Table 2). For floral resources, however, the capacity for management to improve resources differed between EFA options (significant EFA × management interaction; Table 2 and Figure 3). Pollinator-friendly management had a greater capacity to improve floral resources in afforested areas, fallows, field margins and nitrogen-fixing crops than in catch crops, isolated trees and trees in a line/group.

3.2.2 | Northern and Western Europe

EFA options in N&W Europe showed the greatest differences in pollinator resource scores (Table 2). Under standard management, ponds and catch crops had the lowest floral resource scores, while field margins and hedges had the highest (Figure 3). Ponds and catch crops, together with nitrogen-fixing crops, also had the lowest scores for bee nesting sites under standard management. Under standard management, nesting site scores were highest for agroforestry, hedges and trees in groups/lines. Under standard management, scores for hoverfly larval resources were lowest for catch crops and highest for trees in groups.

Across the three broad resource options, pollinator-friendly management improved resource scores, with the magnitude differing between EFA options (Table 2 and Figure 3). Under pollinator-friendly management, the greatest perceived increase in floral resources occurred in fallows and ponds, while the increase was only marginal in catch crops, isolated trees and nitrogen-fixing crops. Pollinator-friendly management did not influence nesting scores of nitrogen-fixing crops, but did substantially improve nesting scores for fallows and stone walls. Effects of pollinator-friendly management on hoverfly larval resource scores were most pronounced for ponds and least pronounced for field margins (Figure 3).

3.2.3 | Southern Europe

Again, EFA options differed in their potential to provide pollinator resources (Table 2 and Figure 3). Under standard management, fallows, nitrogen-fixing crops and field margins were evaluated as providing most floral resources, and short-rotation coppices the least. Bee nesting site scores were highest in terraces and stone walls, and lowest in catch crops and ponds. Hoverfly larval resource scores were highest in afforested areas, agroforestry, buffer strips and ditches, and lowest in hedges and trees in a line.
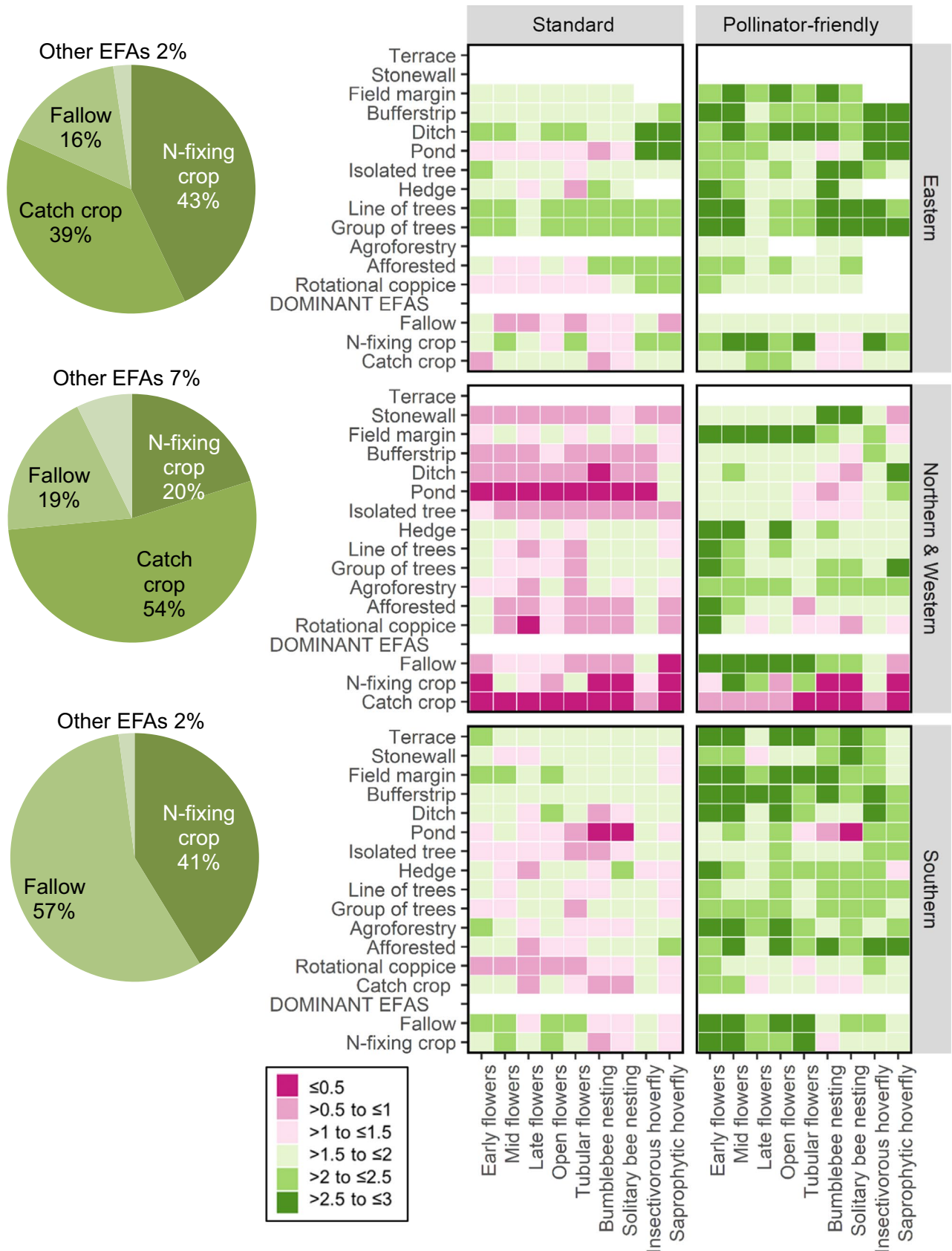
FIGURE 2 Heat maps illustrating the perceived mean value of Ecological Focus Areas (EFA) options under standard and pollinator-friendly management for our three European geographical regions. Heat maps are based on the score for each resource type averaged across countries within a region. Missing data represent options with insufficient scores. Pie charts reflect the % area (before applying weighting factors) of EFA options for each region based on the countries in this study (see Table S4 for more detailed information)

	East		North-West		South	
	χ^2 (df)	p	χ^2 (df)	p	χ^2 (df)	p
Floral resources						
EFA	45.98 (12)	<.001	159.31 (14)	<.001	89.76 (15)	<.001
Management	68.05 (1)	<.001	192.26 (1)	<.001	121.80 (1)	<.001
EFA × management	16.41 (12)	<.001	90.91 (14)	<.001	16.41 (12)	<.001
Bee nest resources						
EFA	65.54 (12)	<.001	210.23 (14)	<.001	64.82 (15)	<.001
Management	35.49 (1)	<.001	66.62 (1)	<.001	85.53 (1)	<.001
EFA × management	20.40 (12)	.060	107.09 (14)	<.001	15.59 (15)	.410
Syrphid larval resources						
EFA	30.21 (8)	<.001	153.59 (14)	<.001	49.76 (15)	<.001
Management	15.24 (1)	<.001	91.68 (1)	<.001	75.34 (1)	<.001
EFA × management	4.97 (8)	.761	50.99 (14)	<.001	22.66 (15)	.092

Note: Direction and magnitude of effects are presented in Figure 3.

Across broad resource categories and EFA options, there was an increase in perceived resource quality with pollinator-friendly management. As in E Europe, effects of management on pollinator resources only varied amongst EFA options for floral resources (significant EFA × management interaction; Table 2). Impacts of management on floral resources were most noticeable in agroforestry and afforested areas, and least pronounced in stone walls and catch crops.

3.3 | Temporal variation in floral resources across geographical regions

In all three regions, under standard management, seasonal trends in flowering typically differed across EFA options (i.e. significant EFA × season interaction: Table 3 and Figure 4). In N&W Europe, 'woody habitat' EFAs (e.g. afforested areas, hedges and trees in lines/groups) were perceived to provide rich, early-season forage with the resource value typically decreasing as the season progressed. Hedges and afforested areas also scored highly for early-season forage in S and E Europe, with hedges in E Europe and afforested areas in S Europe continuing to be valuable mid-season. Fallows scored highly for early-season resources in S and E Europe, with scores remaining high for this habitat though mid-season in S Europe.

Across geographical regions, field margins were perceived to provide high floral resources; however, temporal trends differed. In S and E Europe, field margins were one of the highest scoring EFA options throughout the pollinator activity period (although clear peaks in value were observed early to mid-season in S Europe). In N&W Europe, however, they lacked early-season floral resources.

Irrespective of the region, under standard management no EFA had a late-season floral resource score >2. This was particularly

notable in N&W Europe, where no EFA scored >1.5. Late season peaks in floral resources were only detected in catch crops in E Europe and groups of trees in S Europe.

4 | DISCUSSION

Twenty-two experts from across Europe evaluated the potential of EFAs (representing a range of habitats and landscape features) under standard and pollinator-friendly management to support wild pollinators. By considering the seasonal dynamics of floral resources and taxon-specific life-cycle requirements, this study expands beyond previous assessments that simply focus on bee floral and nesting resources (Koh et al., 2016; Zulian et al., 2013). With EFA habitats displaying inherent differences in the resources they offer (Baude et al., 2016; Cole, Brocklehurst, Robertson, Harrison, & McCracken, 2017) and these differences varying across Europe, our evaluation provides baseline data to enable Member States to consider pollinator requirements when designing their own choices of options.

4.1 | Landscape features and floral resources

EFAs varied considerably in their forage value. Across Europe ponds were perceived to provide little in the way of forage while field margins provided particularly rich foraging habitats. Field margins are also perceived as one of the best EFA options for wider biodiversity (Pe'er, Zinngrebe, et al., 2017). The forage value of floristically diverse field margins is well documented (Mendoza-García, Blanco-Moreno, Chamorro, José-María, & Sans, 2018; Sutter, Jeanneret, Bartual, Bocci, & Albrecht, 2017); however, margin mixes are facing criticism for being targeted towards bumble bees, limiting their potential to support other pollinating *taxa* (Campbell, Biesmeijer, Varma, &
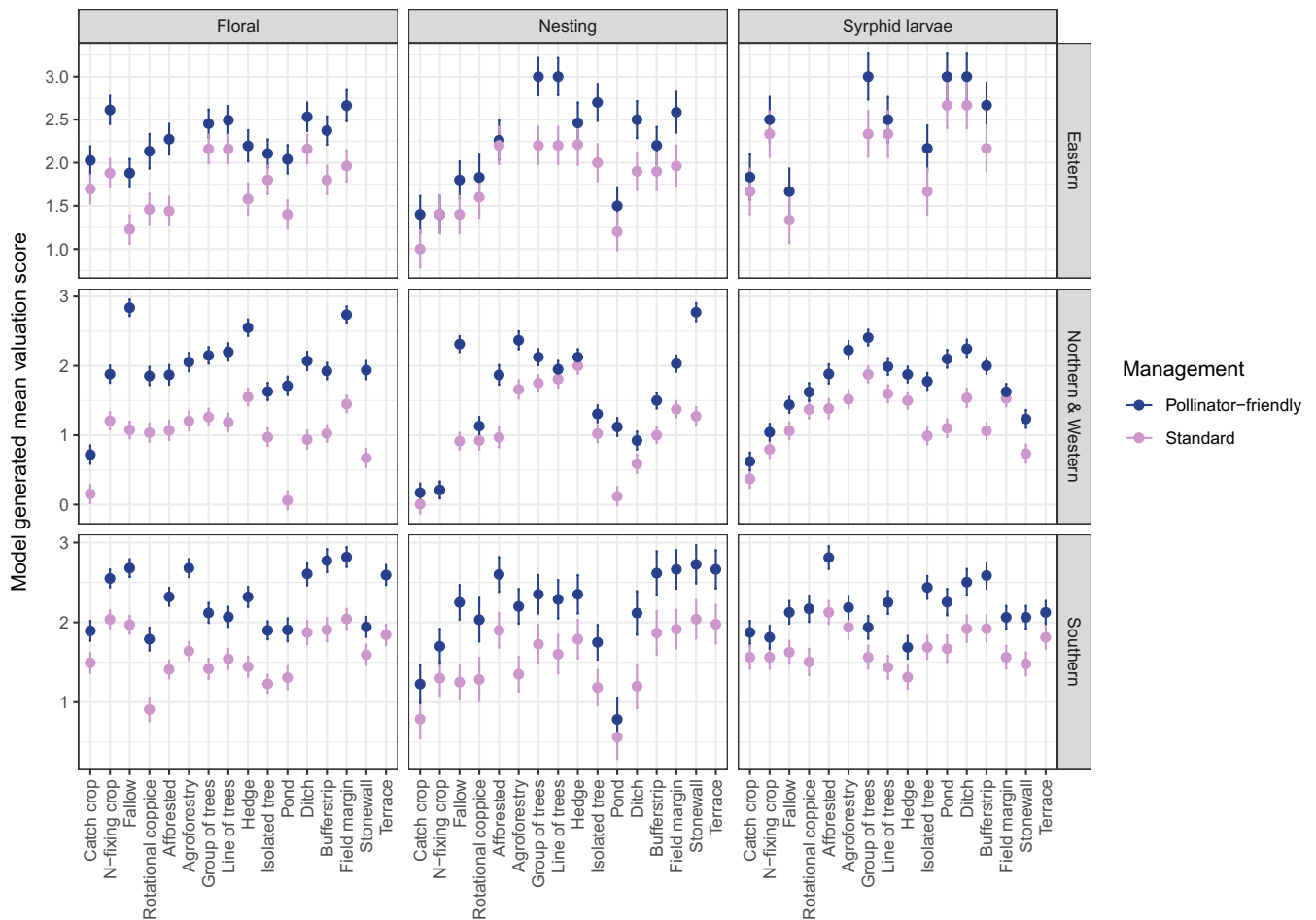
FIGURE 3 Linear mixed model estimated mean resource scores of different Ecological Focus Areas (EFA) options in the three geographical locations and under standard and pollinator-friendly management. Error bars indicate ±1 *SE* reflecting variation between countries within a geographical region. Models included EFA, Management and EFA × Management as fixed effects for the following response variables: floral resources, bee nesting sites and hoverfly larval resources. Missing data reflect EFA options with insufficient scores

Wäckers, 2012; Wood, Holland, & Goulson, 2015). Naturally regenerated margins or multi-functional native species mixes can improve the functional diversity of flowers by increasing the abundance of species with accessible nectaries (e.g. Asteraceae and Apiaceae), favouring a greater diversity of beneficial insects, including parasitic wasps and hoverflies, and thereby improve ecosystem services (pest control; Campbell et al., 2012; Wood et al., 2015).

Pe'er, Zinngrebe, et al. (2017) indicated that nitrogen-fixing crops provided limited benefits to biodiversity. Our evaluation, however, highlights their potential to provide forage for pollinators, with their protein-rich pollen being critical for bee reproduction (Scheper et al., 2014). Their forage value, however, varies considerably across Europe, with regional differences driven by both the species grown and the management (e.g. the use of plant protection products and, for fodder crops, the timing and frequency of cutting/grazing). Dominance of field beans, *Vicia faba*, in N&W Europe (particularly in the UK and Netherlands) limits forage value, with deep corolla tubes limiting access by short-tongued species, and the constrained flowering period reducing the duration of forage availability (Suso et al., 2016). Furthermore,

our evaluation was conducted before the use of plant protection products was restricted in EFAs and consequently applications of insecticides and herbicides in *V. faba* were expected to be high, further limiting their value (Underwood & Tucker, 2016). Although worth noting is that this was not the case in the Netherlands where a ban was in place at the time of the evaluation. Within an intensive arable matrix, the value of nitrogen-fixing crops, particularly forage legumes, in providing protein-rich pollen should, however, not be underestimated. To capitalize on this potential, cutting/grazing regimes should permit flowering and a diversity of species selected to increase functional diversity, prolonging the flowering period and providing forage for a wider suite of species.

EFA options showed clear seasonal differences in their potential to deliver floral resources, with temporal patterns differing geographically. Field margins were perceived to provide a continuous source of forage in E and S Europe but lacked early season forage in N&W Europe, where woody habitats (e.g. hedgerows and groups of trees) were important in spring instead. With mobile pollinators tracking resources at the landscape

TABLE 3 Results of linear mixed models examining the effects of Ecological Focus Area (EFA) option, season and their interaction on floral resource value scores

Floral resources (standard management)	East		North-West		South	
	χ^2 (df)	p	χ^2(df)	p	χ^2(df)	p
EFA	34.89 (12)	<.001	124.94 (14)	<.001	55.45 (15)	<.001
Season	5.47 (2)	.065	19.57 (2)	<.001	29.08 (2)	<.001
EFA × season	62.20 (24)	<.001	173.05 (28)	<.001	61.50 (30)	<.001

Note: Results are based on EFA options under standard management. Direction and magnitude of effects are presented in Figure 4.
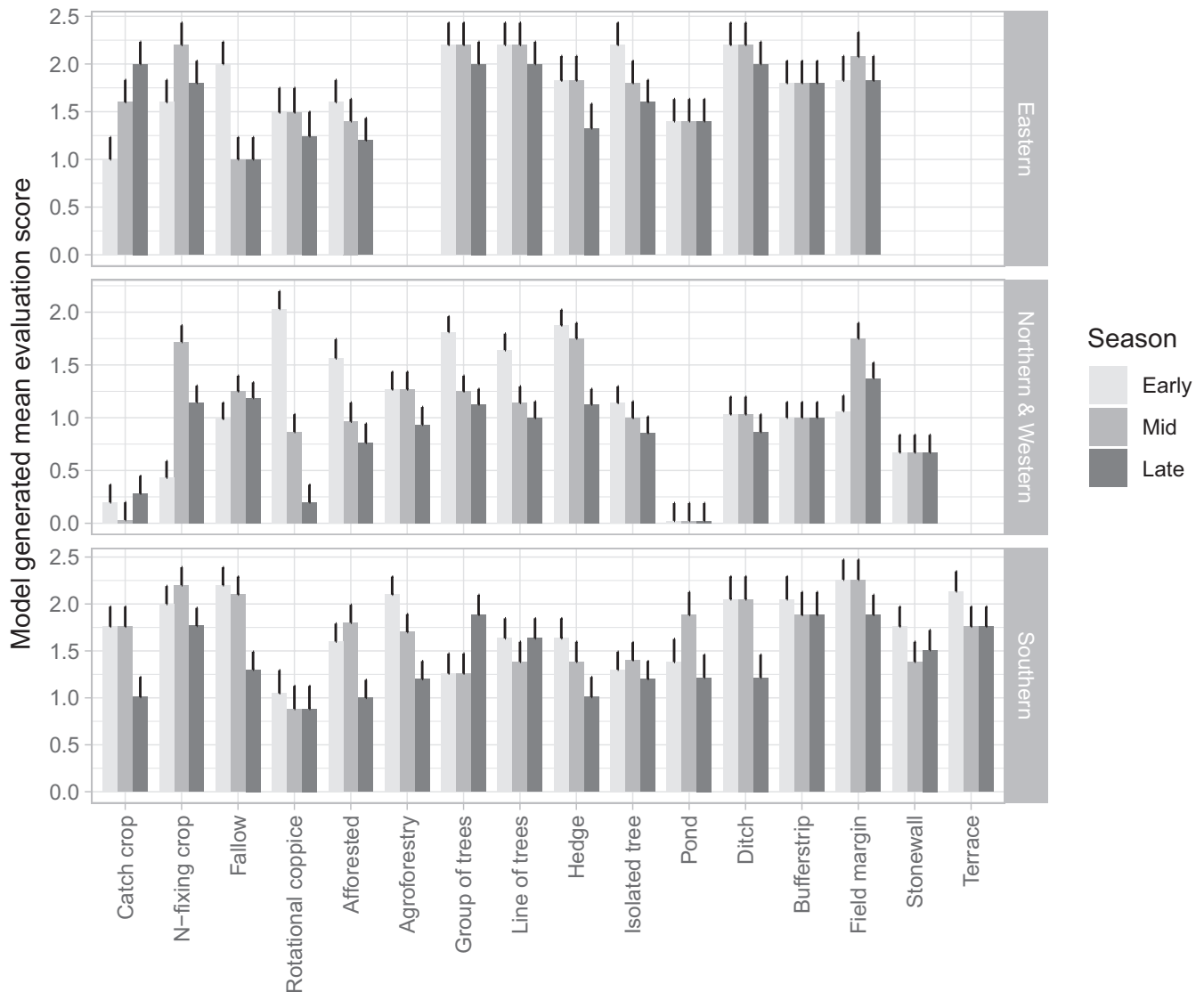
FIGURE 4 Seasonal variation in floral resource provisioning across different Ecological Focus Areas (EFA) under standard management. Linear mixed model estimated means are presented alongside error bars (±1 *SE*) reflecting variation between countries within a geographical region. Missing data reflect EFA options with insufficient scores

scale (Cole et al., 2017; Mandelik, Winfree, Neeson, & Kremen, 2012), habitats that differ in peak flowering time complement each other, stabilizing forage at the landscape scale. For less mobile pollinators (e.g. many species of solitary bees), dispersal between different habitats is less feasible. For such species, the focus should be on improving management in habitats with the potential to provide continuous floral resources (e.g. field margins throughout Europe and fallow land in N&W and S Europe).

Across Europe experts identified a scarcity of late-season forage, which has been implicated in the decline of late-active bee species

(Scheper et al., 2014). This highlights the importance of management actions that increase late season resources (e.g. including late flowering species in seed mixtures, and staggering and/or more lenient mowing/grazing of nitrogen-fixing crops).

4.2 | Landscape features and bee nesting sites

Bees predominantly nest in (semi-)natural habitats, and the abundance and diversity of bumble bees in farmland indeed increases with proximity to such habitats (Öckinger & Smith, 2007). Bumble bees prefer to nest in areas of dense tussocky grass, embankments and woodland edges, often reusing small mammal nests (Kells & Goulson, 2003). Solitary bees can be broadly divided into ground and cavity-nesting species, with the availability of bare ground and suitable nesting cavities (e.g. in wood, stonework or pithy plant stems) driving nest site availability (Potts et al., 2005). Habitats perceived to provide the greatest potential for nesting bees (e.g. trees in groups/line and hedgerows in N&W and E Europe and stone walls, afforested areas and terraces in S Europe) offered nesting opportunities for both solitary and bumble bees. In areas where they occur, drystone walls and terraces provide particularly valuable solitary bee nesting sites (Petanidou & Ellis, 1993).

Bees rarely nest in productive crops due to disturbance by infield management (e.g. tillage, harvest, agro-chemical applications: Scheper et al., 2013), exemplified by the lack of nesting opportunities in catch crops and nitrogen-fixing crops. With these productive EFA options constituting over 73% of EFAs area, current uptake bias limits the capacity of EFAs to provide bee nesting sites. Habitats typically failed to provide both continuous forage and nesting sites and it is therefore important to consider the spatial configuration of habitats with complementary resources. For example, ensuring flower-rich habitats such as field margins are in close proximity to good nesting habitats such as hedgerows and stone walls. Such spatial targeting would be particularly beneficial for species with limited dispersal powers (e.g. solitary bees).

4.3 | Landscape features and hoverfly larval resources

Broadly speaking, hoverfly larval resources were perceived to be most abundant in woody (e.g. agroforestry, afforested areas; Schirmel et al., 2018) and damp habitats (e.g. ditches and ponds), reflecting their diversity of feeding guilds (Jauker, Diekötter, Schwarzbach, & Wolters, 2009; Speight, 2017). Pollinator research is largely biased towards bees and resource requirements of other *taxa* (e.g. hoverflies and parasitic wasps) are often overlooked (Jauker et al., 2009). Our findings indicate that habitats deemed not valuable for bees (i.e. ponds) provide important resources for hoverflies. With hoverflies supplementing pollination in a wide variety of crops (Rader et al., 2016), and many species having predatory larvae that suppress pests (Tschumi et al., 2016), such habitats should not be under-valued in agroecosystems. Hoverflies are an ecologically diverse group with

different species showing habitat specialization towards woody, open and aquatic habitats, highlighting the importance of promoting a diversity of green and blue landscape elements to support them (Schirmel et al., 2018).

4.4 | Policy implications

With approximately 40% of the EU under agricultural management (European Commission, 2018a), the CAP remains a key policy instrument to tackle pollinator declines. The European Commission proposes to include a pollinator performance indicator within the post-2020 CAP monitoring framework, highlighting its commitment to conserve pollinators (European Commission, 2018b). The post-2020 CAP will streamline how it meets environmental objectives under Pillar I (i.e. direct income support) by integrating greening and cross-compliance regulations through enhanced conditionality (i.e. baseline requirements that must be met to obtain direct income support: European Commission, 2019). Conditionality will see EFAs being replaced by 'a minimum share of agricultural area devoted to non-productive features or areas' under Good Agricultural and Environmental Condition obligations (i.e. GAEC 9). More targeted conservation action will be achieved by continuation of Pillar II rural development vehicles (e.g. agri-environment and climate measures AECM), and the introduction of eco-schemes (Pillar I: European Commission, 2019). Eco-schemes, if implemented effectively, will enable Member States to direct Pillar I funding to address specific regional challenges whilst providing the flexibility to adapt to changing circumstances. Member States will have greater ownership on how they integrate and implement these Green Architecture elements, allowing regional tailoring to local farming systems and conditions. With implementation left largely to the discretion of Member States, however, the CAP post-2020 lacks clearly defined options and guidelines on the implementation and management of these options. This could weaken environmental outcomes (Pe'er, 2019). Our evaluation provides a baseline to assist Member States consider pollinator requirements when designing their national strategic plans.

Pollinator-friendly management increases the likelihood that habitats will provide abundant and diverse resources for wild pollinators, potentially also benefiting honeybees (Requier et al., 2015) and other beneficial invertebrates including natural predators (Tschumi et al., 2016). To optimize the benefits derived, the CAP post-2020 should focus on improving habitat quality, for example incentivizing positive management via result-based payments. To achieve this, we recommend an effective monitoring framework alongside appropriate target-orientated indicators (e.g. a specific pollinator indicator in addition to other indicators of ecosystem health such as the EU Butterfly Grassland Indicator; Pe'er et al., 2019). Even under pollinator-friendly management, however, only ditches in E Europe and buffer strips (especially of perennial shrubs) in S Europe were perceived to provide all necessary resources at sufficient quantities. This highlights that measures to simply improve habitat quality may not be sufficient. Furthermore, as a result of current uptake bias towards

nitrogen-fixing crops, fallow land and catch crops (i.e. 97% of EFA area: European Commission, 2017) experts perceived shortages in bee nesting sites, late season forage and hoverfly larval resources. Restricting eligible landscape elements to non-productive features/ areas could address this uptake bias; however, this clearly depends on implementation.

To safeguard pollinators in agroecosystems, the post-2020 CAP needs to progress beyond simply improving habitat quantity to explore options that increase habitat quality, connectivity and complementarity to ensure that pollinators have access to all necessary resources in sufficient quantities. Fundamental to achieving this is a better understanding of the level of resources required to sustain healthy populations, and also the level of resources currently present in a landscape. Robust scientific data in this field is, however, largely lacking, highlighting the need for targeted research in this area. While our evaluation provides a comprehensive baseline evaluation of the resource potential of non-productive habitats across Europe, we recommend Member States work directly with pollinator experts in their region to ensure that pollinator requirements are taken into account. In addition, an effective participatory monitoring framework, backed with scientific knowledge, will help to keep track of effectiveness and identify where refinement is required to improve outcomes.

Our evaluation indicates that as a result of the inherent capacity of habitats to provide different resources, inadequate management and uptake bias, EFAs are largely failing to deliver all necessary pollinator resources at sufficient quantities in European agricultural landscapes. Targeted pollinator-friendly management, can help address this shortfall in resources. Beyond this, the post-2020 CAP could deliver further benefits through landscape-level initiatives that support combinations of options targeted to provide complementary pollinator resources. Effective delivery would require the integration of Pillar I (conditionality and eco-schemes) and Pillar II (AECM and support for organic/high nature value farming) vehicles with means of incentiviszng collaboration between farmers and other stakeholders to spatially target measures (Bartomeus & Dicks, 2019). For example, eco-schemes and AECM could be regionally targeted to complement habitats delivered under conditionality, thus fulfilling shortfalls in resources. A more joined-up approach to the implementation of the post-2020 CAP will not only benefit pollinators but also wider biodiversity (Nilsson et al., 2019; Pe'er et al., 2019).

As we approach the CAP post-2020, our European-scale evaluation highlights that to effectively conserve pollinators and help protect pollination services, there is a need to improve habitat quality and exploit habitat complementarity. Through adopting an integrated approach to Green Architecture, it is our vision for the post-2020 CAP to deliver a diversity of interconnected, high-quality habitats tailored across Europe to local farming systems and conditions. Such pollinator-friendly landscapes would not only help conserve pollinators within intensive agricultural matrices, but also help connect isolated areas of high nature value farmland and protected sites, often critical for species of conservation concern.

AUTHORS' CONTRIBUTIONS
L.J.C., L.V.D., D.K., J.C.S. and S.G.P. conceived the idea and designed methodology. L.J.C. and J.S. formulated and analysed the data. L.J.C., D.K. and J.S. wrote the initial draft. All authors contributed to the writing the manuscript, the evaluation process/formulation of pollinator-friendly management options and gave approval for final publication.

DATA AVAILABILITY STATEMENT
Data are available via the Dryad Digital Repository https://doi.org/10.5061/dryad.ht76hdrbn (Cole et al., 2020).

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REFERENCES
Alliance Environment & Thünen Institute. (2017). *Evaluation study of the payment for agricultural practices beneficial for the climate and the environment*. Luxembourg: European Commission.
Bartomeus, I., & Dicks, L. V. (2019). The need for coordinated transdisciplinary research infrastructures for pollinator conservation and crop

pollination resilience. *Environmental Research Letters*, *14*(4), 045017. https://doi.org/10.1088/1748-9326/ab0cb5

Batáry, P., Dicks, L. V., Kleijn, D., & Sutherland, W. J. (2015). The role of agri-environment schemes in conservation and environmental management. *Conservation Biology*, *29*(4), 1006–1016. https://doi.org/10.1111/cobi.12536

Baude, M., Kunin, W. E., Boatman, N. D., Conyers, S., Davies, N., Gillespie, M. A. K., ... Memmott, J. (2016). Historical nectar assessment reveals the fall and rise of floral resources in Britain. *Nature*, *530*(7588), 85–88. https://doi.org/10.1038/nature16532

Benton, T. G., Vickery, J. A., & Wilson, J. D. (2003). Farmland biodiversity: Is habitat heterogeneity the key? *Trends in Ecology & Evolution*, *18*(4), 182–188. https://doi.org/10.1016/S0169-5347(03)00011-9

Blaauw, B. R., & Isaacs, R. (2014). Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. *Journal of Applied Ecology*, *51*(4), 890–898. https://doi.org/10.1111/1365-2664.12257

Campbell, A. J., Biesmeijer, J. C., Varma, V., & Wäckers, F. L. (2012). Realising multiple ecosystem services based on the response of three beneficial insect groups to floral traits and trait diversity. *Basic and Applied Ecology*, *13*(4), 363–370. https://doi.org/10.1016/j.baae.2012.04.003

Cole, L. J., Brocklehurst, S., Robertson, D., Harrison, W., & McCracken, D. I. (2017). Exploring the interactions between resource availability and the utilisation of semi-natural habitats by insect pollinators in an intensive agricultural landscape. *Agriculture, Ecosystems and Environment*, *246*, 157–167. https://doi.org/10.1016/j.agee.2017.05.007

Cole, L. J., Kleijn, D., Dicks, L. V., Stout, J. C., Potts, S. G., & Scheper, J. (2020). Resource evaluation scores for insect pollinators. Data to accompany: A critical analysis of the potential for EU Common Agricultural Policy measures to support wild pollinators on farmland. *Dryad Digital Repository*, https://doi.org/10.5061/dryad.ht76hdrbn

Deguines, N., Jono, C., Baude, M., Henry, M., Julliard, R., & Fontaine, C. (2014). Large-scale trade-off between agricultural intensification and crop pollination services. *Frontiers in Ecology and the Environment*, *12*(4), 212–217. https://doi.org/10.1890/130054

Diamond, I. R., Grant, R. C., Feldman, B. M., Pencharz, P. B., Ling, S. C., Moore, A. M., & Wales, P. W. (2014). Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *Journal of Clinical Epidemiology*, *67*(4), 401–409. https://doi.org/10.1016/j.jclinepi.2013.12.002

European Commission. (2017). *Report from the commission to the European Parliament and the council on the implementation of the ecological focus area obligation under the direct payment scheme*. Brussels: Author.

European Commission. (2018a). *Eurostat regional yearbook: 2018 edition*. Brussels: Author.

European Commission. (2018b). *Communication from the commission to the European Parliament, the council, the European economic and social committee and the committee of the regions: EU pollinators initiative*. Brussels: Author.

European Commission. (2019). *The post-2020 common agricultural policy: Environmental benefits and simplification*. Brussels: Author.

European Court of Auditors. (2017). *Greening: A more complex income support scheme, not yet environmentally effective*. Luxembourg: Author.

Garibaldi, L. A., Carvalheiro, L. G., Vaissiere, B. E., Gemmill-Herren, B., Hipolito, J., Freitas, B. M., ... Zhang, H. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*, *351*, 388–391. https://doi.org/10.1126/science.aac7287

Hart, K., Mottershead, D., Tucker, G., Underwood, E., Maréchal, A., Menet, L., & Klages, S. (2017). *Evaluation study of the payment for agricultural practices beneficial for the climate and the environment*. Luxembourg: Publications Office of the European Union.

IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (J. Agard, A. Arneth, P. Balvanera, K. Brauman, S. Butchart, K. Chan, ... C. Zayas, Eds.). Bonn, Germany: IPBES Secretariat.

Jauker, F., Diekötter, T., Schwarzbach, F., & Wolters, V. (2009). Pollinator dispersal in an agricultural matrix: Opposing responses of wild bees and hoverflies to landscape structure and distance from main habitat. *Landscape Ecology*, *24*(4), 547–555. https://doi.org/10.1007/s10980-009-9331-2

Kells, A. R., & Goulson, D. (2003). Preferred nesting sites of bumblebee queens (Hymenoptera: Apidae) in agroecosystems in the UK. *Biological Conservation*, *109*(2), 165–174. https://doi.org/10.1016/S0006-3207(02)00131-3

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721

Koh, I., Lonsdorf, E. V., Williams, N. M., Brittain, C., Isaacs, R., Gibbs, J., & Ricketts, T. H. (2016). Modelling the status, trends, and impacts of wild bee abundance in the United States. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(1), 140–145. https://doi.org/10.1073/pnas.1517685113

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, *15*(3), 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Kovács-Hostyánszki, A., Espíndola, A., Vanbergen, A. J., Settele, J., Kremen, C., & Dicks, L. V. (2017). Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. *Ecology Letters*, *20*(5), 673–689. https://doi.org/10.1111/ele.12762

Mandelik, Y., Winfree, R., Neeson, T., & Kremen, C. (2012). Complementary habitat use by wild bees in agro-natural landscapes. *Ecological Applications*, *22*(5), 1535–1546. https://doi.org/10.1890/11-1299.1

Mendoza-García, M., Blanco-Moreno, J. M., Chamorro, L., José-María, L., & Sans, F. X. (2018). Patterns of flower visitor abundance and fruit set in a highly intensified cereal cropping system in a Mediterranean landscape. *Agriculture, Ecosystems & Environment*, *254*, 255–263. https://doi.org/10.1016/j.agee.2017.12.001

Mukherjee, N., Huge, J., Sutherland, W. J., McNeill, J., Van Opstal, M., DahdouhGuebas, F., & Koedam, N. (2015). The Delphi technique in ecology and biological conservation: Applications and guidelines. *Methods in Ecology and Evolution*, *6*(9), 1097–1109. https://doi.org/10.1111/2041-210X.12387

Nilsson, L., Clough, Y., Smith, H. G., Olsson, J. A., Brady, M. V., Hristov, J., ... Dänhardt, J. (2019). A suboptimal array of options erodes the value of CAP ecological focus areas. *Land Use Policy*, *85*, 407–418. https://doi.org/10.1016/j.landusepol.2019.04.005

Öckinger, E., & Smith, H. G. (2007). Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. *Journal of Applied Ecology*, *44*(1), 50–59. https://doi.org/10.1111/j.1365-2664.2006.01250.x

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*(3), 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Pe'er, G., Lakner, S., Müller, R., Passoni, G., Bontzorlos, V., Clough, D., ... Bonn, A. (2017). *Is the CAP Fit for purpose? An evidence-based fitness-check assessment*. German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig.

Pe'er, G., Zinngrebe, Y., Moreira, F., Sirami, C., Schindler, S., Müller, R., ... Lakner, S. (2019). A greener path needed for the EU Common Agricultural Policy. *Science*, *365*, 449–451.

Pe'er, G., Zinngrebe, Y., Hauck, J., Schindler, S., Dittrich, A., Zingg, S., ... Lakner, S. (2017). Adding some green to the greening: Improving the

EU's ecological focus areas for biodiversity and farmers. *Conservation Letters*, 10, 517–530. https://doi.org/10.1111/conl.12333

Petanidou, T., & Ellis, W. N. (1993). Pollinating fauna of a phryganic ecosystem: Composition and diversity. *Biodiversity Letters*, 1(1), 9–22. https://doi.org/10.2307/2999643

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & R Core Team. (2018). *nlme: Linear and nonlinear mixed effects models. R package version 3.1-137.* Retrieved from https://CRAN.R-project.org/package=nlme

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., … Vanbergen, A. J. (2016). Safeguarding pollinators and their values to human well-being. *Nature*, 540(7632), 220. https://doi.org/10.1038/nature20588

Potts, S. G., Vulliamy, B., Roberts, S., O'Toole, C., Dafni, A., Ne'eman, G., & Willmer, P. (2005). Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. *Ecological Entomology*, 30(1), 78–85. https://doi.org/10.1111/j.0307-6946.2005.00662.x

R Core Team. (2018). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Rader, R., Bartomeus, I., Garibaldi, L. A., Garratt, M. P. D., Howlett, B. G., Winfree, R., … Woyciechowski, M. (2016). Non-bee insects are important contributors to global crop pollination. *Proceedings of the National Academy of Sciences of the United States of America*, 113, 146–151. https://doi.org/10.1073/pnas.1517092112

Requier, F., Odoux, J. F., Tamic, T., Moreau, N., Henry, M., Decourtye, A., & Bretagnolle, V. (2015). Honey bee diet in intensive farmland habitats reveals an unexpectedly high flower richness and a major role of weeds. *Ecological Applications*, 25(4), 881–890. https://doi.org/10.1890/14-1011.1

Scheper, J., Holzschuh, A., Kuussaari, M., Potts, S. G., Rundlöf, M., Smith, H. G., & Kleijn, D. (2013). Environmental factors driving the effectiveness of European agri-environmental measures in mitigating pollinator loss - a meta-analysis. *Ecology Letters*, 16(7), 912–920. https://doi.org/10.1111/ele.12128

Scheper, J., Reemer, M., van Kats, R., Ozinga, W. A., van der Linden, G. T. J., Schaminée, J. H. J., … Kleijn, D. (2014). Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in The Netherlands. *Proceedings of the National Academy of Sciences of the United States of America*, 111(49), 17552–17557. https://doi.org/10.1073/pnas.1412973111

Schirmel, J., Albrecht, M., Bauer, P. M., Sutter, L., Pfister, S. C., & Entling, M. H. (2018). Landscape complexity promotes hoverflies across different types of semi-natural habitats in farmland. *Journal of Applied Ecology*, 55(4), 1747–1758. https://doi.org/10.1111/1365-2664.13095

Speight, M. C. D. (2017). Species accounts of European syrphidae, 2017. In M. C. D. Speight, E. Castella, J. P. Sarthou, & C. Vanappelghem (Eds.), *Syrph the net, the database of European syrphidae (diptera)* (Vol. 97). Dublin, Ireland: Syrph the Net Publications.

Suso, M. J., Bebeli, P. J., Christmann, S., Mateus, C., Negri, V., Pinheiro de Carvalho, M. A. A., … Veloso, M. M. (2016). Enhancing legume ecosystem services through an understanding of plant-pollinator interplay. *Frontiers in Plant Science*. 7(333): 1–18. https://doi.org/10.3389/fpls.2016.0033330

Sutter, L., Jeanneret, P., Bartual, A. M., Bocci, G., & Albrecht, M. (2017). Enhancing plant diversity in agricultural landscapes promotes both rare bees and dominant crop-pollinating bees through complementary increase in key floral resources. *Journal of Applied Ecology*, 54(6), 1856–1864. https://doi.org/10.1111/1365-2664.12907

Tschumi, M., Albrecht, M., Collatz, J., Dubsky, V., Entling, M. H., Najar-Rodriguez, A. J., & Jacot, K. (2016). Tailored flower strips promote natural enemy biodiversity and pest control in potato crops. *Journal of Applied Ecology*, 53(4), 1169–1176. https://doi.org/10.1111/1365-2664.12653

Underwood, E., & Tucker, G. (2016). *Ecological Focus Area choices and their potential impacts on biodiversity. Report for BirdLife Europe and the European Environmental Bureau*. London.

Wood, T. J., Holland, J. M., & Goulson, D. (2015). Pollinator-friendly management does not increase the diversity of farmland bees and wasps. *Biological Conservation*, 187, 120–126. https://doi.org/10.1016/j.biocon.2015.04.022

Zulian, G., Maes, J., & Paracchini, M. (2013). Linking land cover data and crop yields for mapping and assessment of pollination services in Europe. *Land*, 2(3), 472–492. https://doi.org/10.3390/land2030472

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.