EKLIPSE

Knowledge & Learning Mechanism
on Biodiversity & Ecosystem Services

What do we currently know about the impacts of pesticide and fertiliser use in farmland on the effectiveness of adjacent pollinator conservation measures such as flower strips and hedgerows, and what additional research is needed?

An EKLIPSE Expert Working Group report

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Glossary of Key Terms

Term	Definition
Conservation measures	Set of measures designated to support the effective conservation of a specific natural or semi natural resource.
Pollinators	Animals, primarily insects but also avian or mammalian species that pollinate and fertilize plants. In the context of this report, the term refers to insect pollinators.
Pollinator services	These are the direct and indirect contributions from pollination to human wellbeing as well as to maintain natural systems. Examples of pollinator services are the contribution to food security, food diversity, human nutrition, among others.
EU Common Agricultural Policy (CAP)	The CAP is a common policy for all EU countries. It is managed and funded at European level from the resources of the EU's budget. It aims to: a) support farmers and improve agricultural productivity, ensuring a stable supply of affordable food; b) safeguard European Union farmers to make a reasonable living; c) help tackle climate change and the sustainable management of natural resources; d) maintain rural areas and landscapes across the EU; e) keep the rural economy alive by promoting jobs in farming, agri-foods industries and associated sectors (EU Commission).
EU Pollinators' Initiative	On 1 June 2018, the European Commission (EC) adopted the Pollinator Initiative which sets strategic objectives and a set of actions to be taken by the EU and its Member States to address the decline of pollinators in the EU and contribute to global conservation efforts (EU Commission).
Pollinator conservation	Conservation interventions targeted towards supporting pollinator populations and diversity (e.g. planting flower strips in field margins, conserving hedges).
Multi-stakeholder consultation	The process of gathering perceptions and feedback from different stakeholder groups through a variety of established methods.
Stakeholder assessment	Stakeholder assessment is the process of gathering and analysing information on the interests and perceptions from relevant groups (stakeholders). This knowledge can be used to design and modify a project plan, policy, program, or other action.
Woody structures	Type of conservation measure that includes woody elements in the landscape. In this report, three types of woody structures were considered: hedges, adding trees and maintaining trees.

Term	Definition
Nest boxes	Type of conservation measure, represented by above ground bee hotel, that provides nesting place for solitary bees to support their populations
Semi natural habitat	An ecosystem with most of its processes and biodiversity intact, though altered by human activity in strength or abundance relative to the *natural* state (IPBES).
Herbaceous strips	A narrow strip of land in an agricultural field, planted with different types of multi-annual flowering plants
Wetland buffering	"A wetland buffer is a setback area between a stream, river, or wetland and any upland development. It maintains the natural vegetation cover along the waterway, which is an essential part of the aquatic ecosystem." [http://planportsmouth.com/wetlandbuffer.pdf]
Glyphosate	Glyphosate is a broad-spectrum systemic herbicide and crop desiccant. Glyphosate is used for killing weeds (especially annual broadleaf weeds) and grasses that compete with crops.
Neonicotinoids	Neonicotinoids (often referred to as neonics) are a class of neuro-active insecticides chemically similar to nicotine. The neonicotinoid family of chemicals include acetamiprid, clothianidin, imidacloprid, nitenpyram, nithiazine, thiacloprid and thiamethoxam.
Fipronil	Fipronil is a broad-spectrum insecticide belonging to the phenylpyrazole chemical family.
Non-systemic insecticides	A non-systemic pesticide is any formulation applied to a plant directly onto its foliage, flowers, buds, stems, branches, roots, or seeds that is intended to control pests or diseases by making direct contact with them.
Sustainable use directive	"The Sustainable Use of Pesticides Directive (SUD) establishes a framework for European Community action to achieve the sustainable use of pesticides by setting minimum rules to reduce the risks to human health and the environment that are associated with pesticide use. It also promotes the use of integrated pest management. The Directive is designed to further enhance the high level of protection achieved through the entire regulatory system for pesticides." [Source: http://www.pcs.agriculture.gov.ie/sud/]

Executive Summary

EKLIPSE received a request by Pollinis on the 30th of June 2018, to produce an overview of the current knowledge and research gaps related to the impacts of pesticide and fertilizer use in farmland on the effectiveness of adjacent pollinator conservation measures. The call was answered through a Joint Fact Finding approach, including a workshop on the 9-10th Jan, 2020 at the Helmholtz Association, Brussels. This report documents the preparatory steps leading to the workshop, the deliberations during the workshop, as well as a summary of the main results and conclusions.

A team of knowledge-holders, representing various perspectives, sectors and disciplines, was selected and invited to collate and share their trusted sources of knowledge on the topic. These sources could be reports, scientific papers, articles or online resources, and may not have previously been available to all parties. This body of information was evaluated for relevance to produce the preliminary document that was used as a basis for discussions during the workshop in Brussels. The workshop brought together a team of experts from academia, NGOs, beekeeper organisations, industry, and the requester organisation (Pollinis). The participants discussed the key findings from the identified evidence and knowledge gaps during the first day and identified a list of key research needs and policy recommendations during the second day.

In addition to the research needs related to specific conservation measures, several cross-cutting themes emerged during the deliberations. The list of knowledge gaps were scored by the participants based on importance, feasibility and policy impact. Finally a list of policy recommendations were produced based on the outputs of the workshop.

1. Introduction and context

1.1 Organisers

The EKLIPSE project (funded by Horizon 2020) intends to create a self-sustaining EU support mechanism for evidence-informed policy on biodiversity and ecosystem services. One of the major roles of EKLIPSE is to identify and prioritize research needs through responding to knowledge requests from policy makers, civil society and the scientific community. Depending upon the context of the request, the process usually involves evidence synthesis, prioritization of research needs, and societal engagement activities among others.

This workshop and preparatory process was initiated as a response to a request initially put to EKLIPSE in its third call for requests (CfR.3/2018) by Pollinis. Pollinis is a European NGO based in France, which campaigns for the protection and conservation of pollinators, notably bees, and promotes the transition towards alternative agricultural practices, and away from the systematic use of pesticides in Europe.

1.2 Context

A number of policy actions at the European level are now in place that may support populations of pollinators and ensure the sustainable provision of pollination services. These include different measures under the EU Common Agricultural Policy (CAP): voluntary agri-environment and climate adaptation/mitigation measures under the rural development policy, as well as cross compliance and the three mandatory "Greening" measures under Pillar 1 (crop diversification, maintenance of permanent grassland and 5% of arable land dedicated to Ecological Focus Areas (EFA), for example trees and hedges).

The recent "EU Pollinators' Initiative" sets strategic objectives and a set of actions to be taken by the EU and its Members States to address threats to pollinators. One action under this EU Pollinators' Initiative is the development of a guidance document on land management practices that benefit pollinators, which is aimed at managing authorities, advisory services and farmers.

Part of this guidance will cover pollinator conservation measures, such as management of field margins, hedgerows or other non-cropped habitat. There remains, however, a need to understand the impact of actions in the wider environment on these pollinator conservation measures. In particular, there is a need to determine the impact of pesticides and fertilisers in farmland on adjacent (farm) land where pollinator conservation measures are implemented. Understanding whether and, if so, how pesticides and fertilisers reduce the efficacy of nearby implemented pollinator conservation measures is imperative in order to develop an effective pollinator-friendly agro-infrastructure.

The initial request stated: "There exist few information about how to manage or cultivate hedgerows in order to effectively increase pollinator population. There requires a study to investigate the importance of the hedgerows and its relationship to the wild pollinators." The scope was subsequently expanded by the Strategic Advisory Board (SAB) of EKLIPSE to include agricultural landscapes (not just hedgerows) and all pollinators (as opposed to only wild).

After the scoping meeting, the focus shifted to “the interactions between conservation actions aimed at pollinator conservation, and pesticides and how they affect pollinators”. The revised research questions were:

1. What are the interactions between conservation actions aimed at pollinators, and pesticides.
2. What are the effects of pesticides and fertilizers on conservation actions and how does this affect pollinators.

A Call for Knowledge related to this request was carried out and opened from the 21st of May until the 20th of June 2019. The Call for Knowledge was hosted on the EKLIPSE KNOCK Forum and resulted in 10 contributions from experts as well as the identification of relevant publications (Annex 2, EKLIPSE Document of Work). The call for knowledge revealed the number of available peer-reviewed studies on the specific topic to be rather limited. The Joint Fact Finding (JFF) method was therefore considered to address the request as it suits a situation where there is little published evidence available, but relevant evidence may be held by the private sector or NGOs; where there are likely to be different viewpoints and beliefs among stakeholder groups; and where there is potential for controversy in both the evidence and public opinion (Dicks et al. 2017). However, due to time and resource constraints, the process focused only on the initial steps in a JFF approach where research needs are identified based on existing knowledge among the stakeholders.

1.3 A Joint Fact Finding (JFF) approach

A multi-stakeholder consultation was proposed based on the first phase of a Joint Fact Finding activity, and focused on identifying research priorities. This involved representatives of all perspectives and opposing positions, including experts from relevant disciplines and non-experts, to ensure a participative process that balances all views.

In the Joint Fact Finding (JFF) method described in Dicks et al. (2017), separate coalitions of scientists, policy-makers and other stakeholders with differing viewpoints and interests work together to develop data and information, analyse facts and forecasts, and develop common assumptions and informed opinions. Finally, they use the information they have developed to reach decisions together. Our process used the same type of multi-stakeholder committee and the same principle of focusing on available data and information to mitigate conflict, but the ultimate objective was to jointly identify research needs and priorities (stage 1 in JFF). We call this truncated process 'Joint Research Priority Finding’ (JRPF).

A key step in the process is the initial stakeholder assessment and the identification of members of the Expert Working Group (EWG) that tries to balance the team in terms of perspective, gender, expertise and sector (NGOs, private sector, academia, policy, etc.).

An open call for experts was launched in October 2019 to invite relevant actors (including experts and non-experts, NGOs, private sectors, policy, etc.) to join the JRPF and a group of about 18-20 experts were selected to ensure balance in disciplines and sectors (List of members and workshop participants in Appendix I). In addition, targeted invitations were sent to ensure some of the interest groups were aware of the call for experts. Despite several invitations to participate, farming organisations were not represented.

2. Preparatory work

2.1 Objectives

The process included two phases, a preparatory phase between November 21st 2019 and January 7th of 2020 and a one and a half day workshop on the 9th and 10th of January 2020 at the Helmholtz Association, Brussels. The aim was to highlight the key findings from the current evidence and available data, to identify knowledge gaps related to the impacts on pollinators, and to identify and prioritize key research needs and potentially provide policy recommendations based on key consensual findings from the available evidence.

The co-creation of research needs based on discussions among different stakeholder groups were one of the major objectives of the workshop. The ambition was to go beyond the published evidence and identify the future research needs (based on expert knowledge) to meet policy demands.

2.2 Preparatory work: collation and screening of the evidence

The EWG met virtually twice through a zoom platform to frame the work on available evidence. The initial task was to decide on the conservation measures that would be included in the review. The following conservation measures were agreed upon and grouped into three main categories (adding flowers, explicitly adding nest boxes, and protecting water bodies) and 11 subcategories. These were further grouped into the following five categories for the purposes of the workshop:

- Woody structures:
    - hedges
    - adding trees
    - maintaining trees
- Herbaceous strips
    - pollen and nectar
    - grass
    - wild bird seed
- Semi-natural habitat
    - extensive
    - whole field
    - grassland
- Provision of nest boxes
- Wetland buffering efficacy

Evidence gathering: Experts were requested to submit key sources of evidence that they trusted and thought to be relevant for the research questions, on an online platform (Owncloud). Given the time constraints, the total number of documents was limited to 100. Evidence consisted of both peer reviewed and grey literature. These were categorised into:

- Academic- Thesis, conference proceedings
- Academic- Peer reviewed

- Book chapters
- Policy documents (Government)
- Reports
- Others

Only literature published in English or translated into English was accepted for the database (Appendix II).

Screening of the evidence: These documents were then screened for the selected timeframe (1999-2019) by the EKLIPSE team and the collated database was made freely accessible to the experts in a google spreadsheet. Experts were invited to mention the key findings, link the document to the 11 categories in the intervention list and provide an explanation of the perceived relevance for each of the documents that they had submitted. The aim was to score each document by three independent reviewers on a binary scale of 1/0 (where 1= relevant) (Appendix III- online only).

Criteria for rejection: Based on inputs from the experts, the criteria for rejection of the documents were decided as follows:

- Out of timeframe (1999-2019)
- Out of scope
- No translation available in English
- Out of geographic scope (i.e. not based in Europe, UK or North America)
- Methodology is not sound (e.g. no multi-annual field trials)
- Evidence is not reliable

Grouping: Experts were asked to self-assign themselves to 15 documents such that each document in the database was scored by three experts. Experts could also provide comments in the comment boxes for each document. Prior to the workshop, each document was scored by at least two experts, while most documents were scored by three. A traffic light system was used to categorise them into three blocks: green (at least 2 experts out of 3 scored the document and found it to be relevant for the workshop), red (all experts scored it as not relevant), orange ("controversial evidence" where there was no consensus or not enough reviewers). The documents grouped as red were not used for the deliberations in the workshop. There were 33 "green" papers, 24 "red" papers and 29 "orange" papers (total= 86).

The documents were also mapped to the respective interventions using the same traffic light system with bold font used to highlight the papers that had been scored thrice (Appendix IV).

3. Format of the workshop

Fourteen members of the EWG attended the workshop with an adequate balance of sectors and expertise (Appendix I: List of participants for the workshop). The format of the workshop was highly collaborative and organised in eight sessions spread over one and a half days (cf. Appendix V – Agenda of the workshop).

The workshop participatory format was supported by a team of facilitators including lead facilitators Estelle Balian and Saskia Van Crugten and group facilitators from EKLIPSE (Allan Watt, Flore Jeanmart, Nibedita Mukherjee and Lynn Dicks). During the workshop, group work was organised around conservation measures as follows:

- Woody structures and nest boxes
- Semi-natural habitats and water and crop buffers
- Herbaceous strips

Figure 1 Participants at the workshop

Day 1

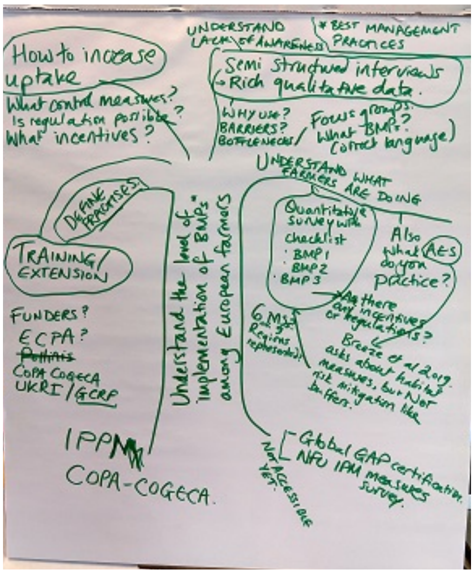
- First session (13.15 – 15.15): In the first session, the trusted evidence (i.e. "green" documents) were discussed. The aim was to identify the key findings and knowledge gaps with respect to the intervention category. Participants were initially provided the time to familiarize themselves with the trusted evidence and subsequently a "tour de table" was used to clarify if there was still a strong doubt about the relevance of some proposed evidence. Following this, experts were asked to list the key findings from each of the documents and identify the knowledge gaps. An interesting output that emerged from the deliberations was the cross-cutting issues that touched upon several conservation measures and across the three broad themes.
- Second session (15.30 – 17.30): In the second session, the controversial evidence was discussed (i.e. "orange" documents). The focus was on the identification of the knowledge gaps and emergent cross-cutting issues rather than on assessing the quality of the evidence. Participants could change groups if they wished.

Day 2

- Third session (9.15 – 9.45): This session focussed on discussing the generic papers that were not specifically linked to any intervention but rather to the research questions in general. Participants were asked to work in pairs and look at two papers in each pair to identify if there were any additional knowledge gaps or key findings from these papers that could be added to the four themes (three groups on conservation measures and the additional cross-cutting group). These were added to the appropriate group posters at the end of the session.
- Fourth session (9.45 – 12.30): The previous day's key findings and knowledge gaps related to each conservation measure were reported by the facilitators and brainstormed by the

participants. The participants moved from one group to another. The knowledge gaps were reformulated, merged or new ones added based on the brainstorming within the group. The additional knowledge gaps from the earlier session on generic papers were also merged during the discussion. This led to a final list of knowledge gaps on all four themes.

- Fifth session (12.40 – 13.00): The participants were asked to score the knowledge gaps (n=34) based on three criteria (feasibility, cost-benefit, relevance to policy) on a scale of 1 – 4 (1= low, 4= very high). The results show a matrix of knowledge needs/prioritise depending on the chosen criteria.
- Sixth session (14.00 – 15.00): This session was an open discussion on the evidence that was missing from the preparatory phase and that could be identified and listed into three topics in section 4.3.
- Seventh session (15.00 – 16.00): The aim of this session was to unfold some research priorities into more detailed research questions and enabling conditions. The participants were asked to self-organize into three groups.



They were invited to choose a knowledge need as identified during the morning and build a "research action" tree where:

- trunk: the knowledge need
- roots: enabling conditions/What key resources are needed (data, geographical cover, interdisciplinarity, etc.)
- branches: What research questions should be tackled
- leaves: actions/activities

Figure 2 Example of a research action tree produced by the group

- Eighth session (16.00 – 17.00): The results of the scoring of the knowledge gaps were reported back to the participants by the EKLIPSE team. This led to a discussion about the implications for policy and the need for more accessible data. Finally, the participants were asked to fill in an evaluation form and a short debrief session ensued where the group provided critical feedback on the JRPF methodology and the workshop process.

4. Results

4.1 Key findings

The key findings are presented according to the broad themes/conservation measure categories for the workshop (woody structures, nest boxes, semi natural habitat and herbaceous strips) as well as the cross-cutting themes. The numbers at the end refer to the document numbers in the preliminary document (See Appendix II). In case the finding arose based on the discussion among experts rather than a specific paper, this has been indicated in square brackets. There were no key findings or knowledge gaps identified specifically for the conservation measure category "wetland buffering".

4.1.1 Woody structures

Table 1 Key findings on Woody structures

Woody structures	Key findings
Generic- woody structures	Residues of neonicotinoids in pollen are lower in trees and hedges compared to herbaceous plants in field edges #68 Woody plants (non-crop) tend to have lower concentrations of pesticides than non-crop herbaceous plants #6 Pollinators rely on crop and wild plant pollen over the course of a season. A landscape study showed wide agricultural and non-agricultural pesticide contamination of pollen from weeds, shrubs, meadows and trees in natural areas. #34
Hedgerows	Contamination of wild plant pollen represents a route of exposure and a risk of toxicity to pollinators #6 Negative effects of pesticides, herbicides and fungicides on hedgerow plant communities can be reduced to zero with an unsprayed buffer of 2.25m and application of 'best practice' #13 Spray drift reduction nozzles limit the drift of insecticides #13
Adding trees	There is some evidence to suggest that crop trees do not represent nutritional bottlenecks for bee diversity #83
Maintaining trees	The more semi-natural habitat (including deciduous forest) in the agricultural landscape (e.g. annual crops, pasture or fallow fields and apple orchards), the lower the negative impact of pesticide use on wild bee abundance and richness in the agricultural system (i.e. in apple orchards) #44 Both social and solitary bee abundance increases with a greater amount of semi-natural area in the landscape #44

4.1.2 Nest boxes

Table 2 Key findings on nest boxes

Nest boxes	Key findings
	Combination of conservation measures that include nest boxes do work to support pollinator biodiversity (#73) It is known that pathogens may accumulate in large nesting boxes supporting high densities of solitary bees [Discussion] Nest boxes a are one of the measurements that farmers can implement within the IPM guidelines [Discussion]

4.1.3 Herbaceous strips

Table 3 Key findings on herbaceous strips

Herbaceous strips	Key findings
Exposure risk in field margin habitats	Exposure route: Several studies have shown and measured the pesticide residues in field margin flowering species #4,5,6,12 This includes neonicotinoids and fipronil from study #4 These pesticides are found in nectar, pollen and foliage Pollinator exposure: While honey bee exposure to pesticides can come from foraging on treated flowering crops, another route of exposure comes from their consumption of pollen from agricultural weeds contaminated by pesticide residues #68 Contamination of honey bee collected pollen shows how they are exposed throughout the season to many pesticide types, including fungicides #34 Impacts on pollinators (and other non-target invertebrates): Neonicotinoids in field margin vegetation affect honey bee nutritional status (glycogen stores and lipids in workers). This can be interpreted as a disruption of physiology and therefore health. #39 A correlation between pesticide spray drift and impacts on insects (not major pollinators) has been observed #33 Impacts of conventional farming practices on Collembola in margins are less severe and not persistent in the long-term #19 Experimentally simulated insecticide drift into field margins reduced caterpillar abundance (single study, 'no control') #25

Plant community change in response to pesticide and fertilizer drift	Herbicide and fertilizer drift have impacts on plant community composition and structure #13,15, 17 One study showed reduced flower visitation by pollinators and reduced seed set in a focal wild plant (*Tanecetum species*) in response to glyphosate application #17 Herbicides, fertilizers and insecticides affect plant community structure and reproduction (including bee forage plants) #48 Plant diversity is reduced, formation of flowers is suppressed, and seed set is reduced #48,49 When the best practices such as buffer distance with herbicides are applied, the risk can be reduced to zero #13, 15, 19 and 57 Not shown for fertilizers #17,19 Plant losses can be linked indirectly to local bee extinctions, in the Netherlands #83 In Europe, herbaceous plants have been lost to extinction, but not woody plant species #83
Effects of field margins/herbaceous strips in the landscape on pollinator populations	One study shows that high quality flower-rich habitat (particularly flower margins) in the landscape improved the survival of bumblebee lineages between years (i.e. a population level effect). This fieldwork was conducted when neonicotinoids were in wide use in central England. Hence in this landscape, the benefits of increased floral resources outweigh any negative impacts of pesticides. #69 Many studies show that pollinator densities or activity increase in response to flower strips. A meta-analysis (#73) showed that 10 % of a landscape with ecological enhancement measures led to significantly greater activity density and species richness of pollinators. #70, 73, 77, 89, 90, 91, 93

4.1.4 Semi-natural habitats

Table 4 Key findings on semi-natural habitats

Semi-natural habitats (SNH)	Key findings
Generic- SNH	Pollen diversity and quantity of semi natural areas promote the diversity of pollinators #69 In temperate zones, plant diversity and flower availability are particularly important during summer and autumn #69 When pollen producing field crops were abundant in the landscape, bees still preferred to collect pollen from non-crop plants #34
SNH/pesticide related	Fertilizers can drastically restrict weed species richness, reducing pollinator diet breath, yet a varied diet is essential for pollinator health #47 The application of highly toxic insecticide (Fenitrothion) was linked to a reduction in pollinator diversity/species richness, especially bumblebees and butterflies at the landscape level #7 Pollen collected from non-cultivated plants is heavily contaminated with pesticides mainly in late season #34,68 Residues from crop pollen were an order of magnitude higher than those from pollen collected in non-agricultural areas and field margins (untreated) #34 Across landscapes, wild herbaceous plants are widely contaminated with pesticides #68 Mixtures of pesticides are typically found in honey bee matrices (cells in hives for storing food and raising brood), which raises the likelihood of synergetic/antagonistic effects of different pesticides on social bee health) #34 One study questions whether conservation measures should be implemented in heavily intensified agriculture (if farming practices remain as they are) #68

4.1.5 Cross cutting topics

Table 5 Key findings on cross cutting topics

Cross cutting topics	Key findings
Type of agrichemicals tested	Physio-chemical characteristics and level of use of pesticides determine the distribution and fate of their residues in the environment #4
Testing design and conditions for conservation measures	European Food Safety Authority (EFSA) guidance provides a methodological framework for assessing the pesticide drift to off-field, subsequent crops and water, and their direct effects on biota #61
New technologies to reduce risk from spraying/best practices/ risk mitigation measures	There is an inventory of existing risk mitigation measures (e.g. drift reduction technologies) implemented in EU countries #57
Design of conservation measures	There is an inventory of conservation measures and their benefits to wildlife (from 2015) #57 Some pollinators are highly specialised on particular plant species. This has implications for the effectiveness of conservation measures at providing suitable habitat and food resources to all pollinators #83 Conservation measures need to be designed according to the purpose i.e. cropping system and expected pollinator species (e.g. ground-nesting bees and bumblebees will need more or less the same measures) [discussion; #57] Inventory available on the ecosystem services that conservation measures provide in addition to pollination and biodiversity. Useful knowledge on benefits and enhancement #89 Herbicide and fertilisers alter the composition, diversity and dynamics of field margin floral communities, and so their spill over may disrupt the efficacy of agricultural environmental schemes #77
In field management	Occurrence of weeds in different crops at early crop stages is <10% coverage. Current European Food Safety Authority guidance #64 suggests that the risk to pollinators is accordingly low. But this fails to account for the accumulation of pesticides in floral resources later in the season as a potential exposure route for pollinators. Cessation of pesticide use within crop edges led to increased insect abundance (non-pollinators), albeit this effect varied among taxa #20 Drift matters. #7 [Discussion]

4.1.6 Summary of Key findings

Pollinators forage across fields, habitats and landscapes for pollen and nectar from a diverse range of wild and crop plants. Access to these resources is crucial to assure their nutrition and health, in particular a diversity of pollen that provides their only source of protein (Filipiak and Rader 2019, Muth, Francis and Leonard 2016, Requier et al. 2015). The addition of diverse and abundant floral resources within agricultural landscapes often helps to increase populations sizes, and increase the local activity and species richness of pollinators (#44, 69, 70, 73, 77, 89, 90, 91, 93). There is now direct evidence that this can increase bumble bee population sizes by increasing colony survival and reproduction (#69)

Herbaceous strips planted as a conservation measure in arable field margins may present an exposure risk for pollinators because pesticides and fertilizers applied to arable crops do not remain solely on the target plant, but can leach, runoff and/or drift into the surrounding environment on slopes or when best management practices are not being implemented. This risk is also likely to occur in other semi-natural or natural landscape features in close proximity to the point of agro-chemical application, e.g. hedgerows. Pesticide residues of various concentrations have been detected in the nectar, pollen and foliage of field margin flowering plant species (#4, 5, 6, 12). Residues in trees and hedges are lower compared to herbaceous plants (#68).

Pollinators are potentially exposed to these chemicals when they forage in field margin habitats and other semi-natural habitats that have been unintentionally contaminated with these products. For example, pollen collected by honey bees throughout the season contains many pesticide types, including fungicides, and the greatest acute exposure comes from agricultural weeds (#34, 68). Such exposure can have negative impacts on pollinators, e.g. neonicotinoids present in field margin vegetation can negatively affect honeybee nutritional status by reducing glycogen stores and lipids in worker bees, thus disrupting the physiology that underpins health (#39).

The drift of herbicides and fertilizers can also alter the composition and structure of plant communities (#13, 15, 17, 48, 47, 49), which may then indirectly affect pollinators seeking floral rewards and, in turn, wild plant pollination. Indeed, application of glyphosate has been shown to reduce flower visitation by pollinators and reduced seed set of *Tanacetum vulgare* by its indirect effect on flowering phenology and floral density (#17). Other studies have shown that herbicides and fertilizers reduce plant diversity, suppress the formation of flowers and reduce seed set (#48, 49). Future studies need to verify if this is an ongoing risk as and when farming practices are modified.

European Food Safety Authority (EFSA) guidance provides a methodological framework for assessing the pesticide drift off-field, to subsequent crops and water, and their direct effects on biota #61. When the best practices are applied, such as using technologies that minimise drift or establishing herbicide/pesticide buffer strips, mitigating effects can be seen (#13, 15, 57,19) and the risk can be reduced to zero (#13),although this effect is less clear for fertilizers (#17,19).

Although this study was not designed to evaluate this, anecdotal evidence suggests that enhancement of bumble bee colony reproduction (and hence population size) was achieved by the addition of flower-rich habitats (#69) during a period when there was widespread use of neonicotinoids on oilseed rape crops. This finding implies that provision of high quality habitats can outweigh negative impacts of pesticides that may accidentally contaminate off-crop habitats utilised by bees, at least in some cases. It should be noted that this study did not quantify residues of neonicotinoids in off-crop habitats such as field margins. However, this conclusion is further supported by another study showing that a greater amount of semi-natural forest habitat in a landscape mitigated effects of pesticide applied to a crop (apple) use on wild pollinator abundance and species richness (#44). The interpretation of these studies need to be caveated within the limitations of both the limited number of agricultural systems and chemicals that were considered, as well as the resolution both spatially and taxonomically that they consider.

4.2 Knowledge gaps

The knowledge gaps were scored by the participants from 1 (low) to 4 (high) for 3 criteria (Feasibility, Cost benefit ratio, Policy relevance). The criteria are defined as follows:

1. Feasibility: capacity to address the knowledge gap including in terms of resources, infrastructure availability, scope, environmental constraints, timing among others.
2. Cost-Benefit ratio: the ratio between investment to address the knowledge gap and expected results and outcomes. A high ratio means the investment is high but the expected outcomes will be limited, while a low ratio means the investment is low for a high expected outcome or that a high investment is going to generate an important expected outcome.
3. Policy relevance: Connection and relevance to current EU policy agenda including all relevant policy sectors.

The scores were averaged across all the 14 participants and are presented in the table below.

Table 6 Knowledge gaps

Theme	Knowledge gaps	Feasibility	Cost-benefit ratio	Policy relevance	Total score
WOODY STRUCTURES					
Generic	Lack of expertise within the group on forestry and agronomy so we could not get the relevant literature and expertise on the impact of woody structures and the impact of fertilizers on plant composition respectively [Discussion]	1.4	1.3	1.5	1.4
	Studies can highlight evidence of exposure in areas where pesticides are not directly applied, but there are no measurement of effects	2.8	2.8	3.2	2.9

	on the conservation measure #34				
	Assessments of quantitative pollen collection by wild bees needs to be done at the plant-species level (and not just at the family level) #83	3.4	2.3	2.3	2.7
	We need to identify a threshold of pesticide use (given different levels of surrounding habitat), under which orchards could have a net positive effect on bee populations owing to the mass bloom #44	2.1	1.7	2.1	2.0
Hedge rows	We need to measure the actual toxicity in the field for hedgerow flowers #6	2.6	2.7	2.7	2.6
	Difficulty to find real controls for field trials due to the wide distribution of pesticide residues [Discussion]	1.1	1.3	2.2	1.6
	Quantify/assess the gain in safety from the exposure reduction of the use of drift reduction technology [Discussion]	3.4	2.9	3.3	3.2
Adding trees	The possible buffering effects of tree planting on off-site pesticide exposure have not been quantified #44	3.1	2.3	2.3	2.5
	Very few studies assessing conservation benefits to pollinators of adding woody structures. Therefore, it is very difficult to assess whether	2.2	2.1	2.7	2.3

	pesticide/fertilizer use impacts their efficacy. [Discussion]				
NEST BOXES					
	Determine the effects of pesticides (drift) on the efficacy of nest boxes in supporting bee reproduction [Discussion]	3.7	2.9	2.6	3.1
HERBACEOUS STRIPS					
Exposure risk in field margin habitats	Exposure route: No link to pollinator population size or health. What is the impact of these levels of exposure on foraging behaviour and reproduction? One exception – effects of honey bee physiology #39. Otherwise, not clearly documented in field studies.	3.0	2.9	3.5	3.1
	Impacts on pollinators: What are the spatial scales at which pesticides/fertilisers affect pollinators in field margins? #7	2.5	2.7	3.5	2.9
	Impacts on pollinators: Have practices changed since the 2008 study #33?	1.9	1.7	2.1	1.9
Plant community change in response to pesticide and fertilizer drift	What are the trophic effects of changes in plant community and associated microbial communities on pollinator diversity and populations [13,15,17]	3.1	2.9	2.5	2.8
	How do best practices in agrochemical usage affect the impacts on pollinator communities and	2.8	2.5	3.2	2.8

	populations, including cascading trophic effects?				
	We need replicated studies following best practice recommendations (17).	2.8	2.0	2.7	2.5
Effects of field margins/herbaceous strips in the landscape on pollinator populations	Would the flower strips work even better without pesticides?	2.2	1.9	2.2	2.1
	What would be the efficiency/efficacy of these conservation measures without any pesticides or fertilizers?	1.9	2.2	2.5	2.2
	What is the trade-off between the risks from agrochemical exposure and the benefits of additional floral resources?	2.5	2.7	2.9	2.7
SEMI-NATURAL HABITAT (SNH)					
SNH/pesticide related	What is the impact of fertilisers on plant composition of conservation measures? #83	3.7	3.1	3.2	3.4
	How much semi natural habitat do we need at landscape scale to mitigate adverse effects of agrochemical use? #44, 69	2.3	3.2	3.5	3.0
	How does increasing crop diversity and reducing field size help mitigate agrochemicals impact? #7	2.4	2.6	3.0	2.7

	How does agro chemical use change evolution/adaptation of plants and pollinators (over the long-term)? To help predicting future. #83 (discussion --> not cross cutting, but apply to woody structures and mostly to SNH)	2.0	1.8	2.0	1.9
	Does drift occur at landscape scales to shift plant communities, floral resources and pollinators foraging in semi natural habitats?	2.4	2.4	2.8	2.5
	What is the impact of livestock on conservation measurements? 1. Biocides/veterinary products; 2. livestock pressure. #65 [Discussion]	2.9	2.5	2.7	2.7
CROSSCUTTING TOPICS					
Type of agrichemicals tested	Not all types of pesticide and fertilizer are represented. A lot of papers focus on neonicotinoids. Non-systemic insecticides are particularly missing (except 34). 34 looks at a wider range of agrichemicals in honey bee collected pollen, but we still don't know where they're coming from or what impact they have.	3.0	2.6	3.1	2.9
	Bee Impact Quotients (BIQ) for fertilizers are not available. Authors assume that it is not relevant, but are they? [44]	2.7	2.5	2.8	2.7

Testing design and conditions for conservation measures	What would be the efficiency/efficacy of conservation measures with and without pesticide or fertilizer use in adjacent fields?	2.1	2.6	3.6	2.8
	It is hard to implement an experiment to test the efficacy of the conservation measures with and without pesticides, due to the complexity of interacting/confounding effects. Some crops can't be grown organically yet (without pesticides e.g. maize, at least not in comparable field sizes); organic and conventional farms are often in different landscapes; difficulty of finding real controls for field trials due to the wide distribution of pesticide residues.	1.7	1.9	2.7	2.1
	Pesticide impacts are tested in one way, and conservation measures are tested in another way	2.2	2.3	2.2	2.3
	Farmers need to be paid for several years to make observations about the efficacy of the conservation measure (with and without pesticides)	2.5	2.4	2.7	2.5
	Effects of environmental conditions, soil type and organic matter content are poorly understood [68]	3.2	2.9	2.8	3.0

New technologies to reduce risk from spraying/best practices/ risk mitigation measures	There have been developments in nozzle technology. Papers before 2010/2011 may not reflect this change [13]	2.1	2.5	2.6	2.4
	We need studies that test the impact of new technologies, particularly new nozzle types (e.g. one side sprayers for inward spraying) on the efficacy of conservation measures [13, 57].	3.7	3.1	3.3	3.4
	Are best practices (nozzle technology, unsprayed buffer zones) really implemented by the farmers? Social science research needed.	3.6	3.3	3.6	3.5
	Level of implementation of the Sustainable Use Directive in the different Member States and regions is missing, including its efficacy in reducing pesticide exposure.	2.7	3.4	3.5	3.2
Design of conservation measures	In field management: Data on presence of weeds at later crop growth stages are missing [64]	3.4	2.8	2.7	2.9
	In field management: What is the trade-off between crop productivity and benefits to pollinator of allowing increased in-field weed abundance? [64]	3.1	2.5	2.7	2.7
	In field management: Characterisation of attractiveness of weeds for pollinators, depending	3.1	2.6	2.3	2.7

	on species, weather and soil conditions [64]				
	In field management: More work is needed to understand how buffer strips in the crop (i.e. no-sprayed crop edges) can reduce agrochemical drift into semi-natural habitat. [20]	3.2	2.8	3.1	3.0
	Availability of evidence/data: Less evidence on nest boxes and woody structures compared to herbaceous strips	3.4	2.9	3.1	3.1
	Availability of evidence/data: EFSA GD Document does not recognise such agri-environment measures. The GD document [60] identifies data gaps [61]	2.1	1.7	1.9	1.9

The summary table of the knowledge gaps, which had a total score of 3.0 or higher are shown below in Table 7.

Table 7 Summary of knowledge gaps

Intervention type	Knowledge gaps: Research is needed on	Feasibility	Cost Benefit	Policy relevance	Average score
Woody structures- Hedge rows	Quantifying the gain in safety from the exposure reduction of the use of drift reduction technology.	3.4	2.9	3.3	3.2
Nest boxes	Determining the effects of pesticides (drift) on the efficacy of nest boxes in supporting bee reproduction.	3.7	2.9	2.6	3.1
Herbaceous strips- [Exposure risk in field margin habitats- Exposure route]	Studying the link between exposure and pollinator diversity, population size or health. More specifically on the impact of these levels of exposure on foraging behaviour and reproduction.	3.0	2.9	3.5	3.1
Semi-natural habitat- pesticide related	Studying the impact of fertilisers on plant composition of conservation measures	3.7	3.1	3.2	3.4
	Studying the role of semi natural habitat at landscape scale in mitigating adverse effects of agrochemical use on pollinators	2.3	3.2	3.5	3.0
Crosscutting- New technologies to reduce risk from spraying/best practices/ risk mitigation measures	Studying and testing the impact of new technologies, particularly new nozzle types (e.g. anti-drift nozzles, one side sprayers for inward spraying) on the efficacy of conservation measures.	3.7	3.1	3.3	3.4

	Better understanding if and how best practices (nozzle technology, unsprayed buffer zones) are implemented by the farmers	3.6	3.3	3.6	3.5
	Assessing the level of implementation of the Sustainable Use Directive in the different Member States and regions is missing, including its efficacy in reducing pesticide exposure	2.7	3.4	3.5	3.2
	Better understanding how buffer strips in the crop (i.e. no-sprayed crop edges) can reduce agrochemical drift into semi-natural habitat	3.2	2.8	3.1	3.0
Crosscutting-Availability of evidence/data	Studying the effect of pesticides and fertilisers on nest boxes and woody structures as conservation measures for pollinators	3.4	2.9	3.1	3.1

4.3 Research action trees

Participants chose some knowledge gaps to further develop them prior to having results of the scoring. Hence, these knowledge gaps should not be considered as the ones emerging as priorities from the scoring criteria. The experts developed these gaps as research action trees. The research action trees, which emerged from the discussions among the participants, were as follows:

Group 1: Linking exposure to insecticides in herbaceous strips /wildflowers to pollinator population level processes

One of the core limitations to identifying risks to wild pollinators utilising herbaceous or wildflower strips is the currently restricted evidence base on which to make wider inferences of the consequences. In the majority of cases there exist only a few directly relevant studies (e.g. Botias et al. (2015)) with these typically focused on one or a few agrochemicals. This typically reflects funding preferences at the time of the study, for example the evidence for neonicotinoids is particularly prevalent. However, for the majority of plant protection products that could pose a risk, there are no studies conducted taking into account today's farming practices. Other studies are very general in the nature of their responses, although these are often informative in giving context to the wider risks posed by these agricultural management practices. For example, studies looking at knock on impacts of fertilizer application on the plant communities identify direct consequences for the resources in herbaceous strips that bees will use (e.g. Schmitz, Schäfer and Brühl (2014)), but typically do not extend this to population level process effects on the bees utilizing these flowers. This limitation means that while we can define a framework for interpreting the risk resulting from the use of widely used plant protection products in association with adjoining herbaceous strips there remains a considerable degree of uncertainty associated with this. Given the current state of the evidence base, intuitive leaps were required to link different component studies. For example, fertiliser drift reduces flowering plant occurrence linked to an unconnected study showing bees depend on the density of flowering plants for population growth (Carvell et al. 2017). There is absence of joined up research that integrates this whole process from agrochemical drift, to direct or indirect (mediated by plants) risks to bees, to population level consequences for those bees. In the following text we highlight the key areas where new research would be required to achieve this.

- More types of pesticides: Current evidence is limited to a restricted number of agrochemical including insecticides, herbicides, fungicides and fertilisers. While the huge number of agrochemicals in use makes a comprehensive assessment of all risks impractical, more detailed risk assessments on a wider range of widely used chemicals would help to address this problem.
- Better spatial quantification or spatial/ temporal variation of residues within strips: The majority of studies fail to take into account detoxification rates of compounds or the likely spatial pattern of effects, in particular how quickly the risk of residue build up dissipates from the edge of the crop into the herbaceous strip. This information is crucial to understand the likely net area of a given herbaceous strip that may pose a risk of contamination to foraging bees.
- Realistic exposure rates: It is important for field and semi-field studies (e.g. caged bee experiments) that artificially simulate exposure to agrochemical drift include realistic field exposure rates, such as median reported residue values. This needs to be included in studies to set a realistic parameter space for interpreting risks posed by field based agrochemical exposure.
- True population level assessments: To promote linked up studies that move from exposure risk to population level processes there needs to be increased use of directly controllable model systems. This can include the use of common model species, including the application of commercially available *Bombus* sp. colonies or *Osmia bicornis* cocoons released in association with trap nests within which they can breed (Rundlof et al. 2015, Woodcock 2017). Trap nests may be used to monitor populations of wild cavity nesting bees in general, while there is an opportunity to develop new systems with mining bees.
- Definition of appropriate controls: The decision for what is an appropriate control to compare exposure risk may require greater consideration. Some studies simply do not have controls and only aim to quantify risk in association to treated crops. For others, additional controls may be needed, for example where a crop not grown with one chemical is always treated with another under normal agricultural conditions. Specifically, this is needed to introduce agronomic realism to inferences made from the conclusions. Other experimental limitations may also need to be accounted for, or acknowledged, for example where a product is so widespread no insecticide control can be achieved. This issue may be particularly problematic for landscape scale studies.
- Impact of historical agrochemical management: Agrochemical drift may be only one potential mechanism of exposure within herbaceous strips. Another risk could be historical management using agrochemicals that persist in the soil. Such agrochemicals may have been applied directly

to the crop prior to the establishment of the herbaceous strip (Jones, Harrington and Turnbull 2014), used to clear existing vegetation before sowing strips or used directly to aid herbaceous strip establishment as part of ongoing management (Blake et al. 2012). These all pose potential risks of exposure to bees subsequently foraging on these herbaceous strips. Quantifying these risks, with particular consideration given to soil detoxification rates, needs to be undertaken.

- Mining bees occurring in natural aggregation in field corners: Many mining bees (e.g. *Andrena* spp, *Lasioglossum* spp) will make nests in the corners of fields. These areas are important for local populations, but may be particularly at risk to exposure. While strictly not an herbaceous strip, this area is effectively not cropped and its importance and associated risks following non-target contamination should be better quantified.
- Model species vs natural populations: One of the biggest opportunities of research undertaken in field conditions is to extend our understanding of impacts outside of the limited number of bee species used in regulatory studies (specifically *Apis mellifera, Bombus terrestris* and *Osmia bicornis*). While these model species inform the regulatory process, there is strong evidence to suggest that unique behavioural, habitat preference, toxicokinetic and toxicodynamic characteristics drive unique responses to agrochemicals (e.g. Woodcock et al. (2016)). The distinction between what is expected from the regulatory framework and what is actually observed needs to be developed in terms of the risk of agrochemical spill over into herbaceous strips.
- Epidemiological approach (correlative studies): While direct experimental evidence allows robust inferences about cause and effect, the role of correlative evidence should not be ruled out. Such studies have the potential to integrate long term time series information, allowing a post hoc application of a before and after control impact study (Mancini, Woodcock and Isaac 2019). The use of long term and large scale data sets also allows for national scale inferences about risks to bee populations outside the scope of small scale experimental work. These studies do need to be used with caution due to the absence of an experimental framework, without which they cannot robustly determine cause and effect.

Group 2: The effects of livestock in conservation measures

- Livestock can affect pollinator plantings, natural areas and hedgerows by two broad pathways; by grazing actions and by the dung they produce. Grazing impacts can be obvious via the overgrazing on specific plants that prevents them from flowering and or kills them outright. A knowledge of the preferences of livestock for specific plants is needed and or means to prevent overgrazing on target plant species. With dung deposition in conservation areas, the dung can be viewed in at least three ways: 1) positive impacts via added natural fertilizers that may shape plant communities, 2) negative impacts via dung contamination with antibiotics, pesticides etc. when animals are treated, if these residues lead to risks to exposed organisms. Bees and other pollinators visit dung and or puddles in fields to take in water and the contamination can leach into the soil and be taken up by plants and expressed in nectar; 3) lastly there can be some combination of positive and negative effects if livestock are treated for parasites and diseases. The effects of antibiotics and veterinary medicines that pass through livestock and end up in dung is poorly understood. The effects that these products have on soil heath, and the microorganisms vital for plant growth, are also little studied.

- To avoid unwanted consequences of livestock on conservation areas, broad expertise should be included in the planning of pollinator conservation efforts. This consultation should include veterinarians, pasture management specialists, agronomists, ecologists, soil specialists and others to implement a balanced program of conservation to include livestock. It is possible to integrate livestock into farming and conservation areas but understanding the risks is the first step.

Group 3: Understanding the level of implementation of Best Management Practices among European farmers (research need)

Currently, there is a lack of information on the level of implementation of Best Management Practices (BMPs) that protect conservation measures. These include unsprayed crop edges, anti-drift nozzles, application standards), training of professional users, inspection of pesticide application equipment, Integrated pest management among others. The BMPs were deemed compulsory for Member States to be included in their National Action Plan as stated within the Sustainable Use Directive. Therefore, there is a need to investigate this at a European Union level.

The first research question is to understand what farmers are implementing. This can be assessed by a quantitative survey having a checklist on which best management practices are practiced (BMP1, BMP2, BMP3 etc.). In parallel, it is important to understand if these BMPs are being encouraged by agri-environmental schemes or national regulations through secondary questions. This research could be conducted covering a number of member states (e.g. six or nine) ideally representing southern, central and northern European regions to identify differences in adoption of Sustainable Use Directive.

The second question is about understanding the lack of awareness. This could be achieved through semi-structured interviews of key stakeholders to achieve rich qualitative data and understand the barriers and bottlenecks of implementation.

The third question (more policy relevant) is how to increase the uptake of BMPs that will protect conservation measures. Could BMPs be potentially included by the EC as requirements when a grower applies for a subsidy to establish conservation measures such as flower strips and hedgerows mitigating the risk of reducing the value of the measures due to pesticide drift?

Finally, after evaluating the status of implementation in member states under investigation, the level of support through training and extension could be determined and a strategic plan developed by the EC.

5. Evaluation and feedback

The participants provided verbal feedback at the end of day 1 and 2 and written feedback on day 2. In their written evaluation form, participants have scored the different aspects of the preparatory process and of the workshop organisation (see summary of scoring in the Figure 3 below).

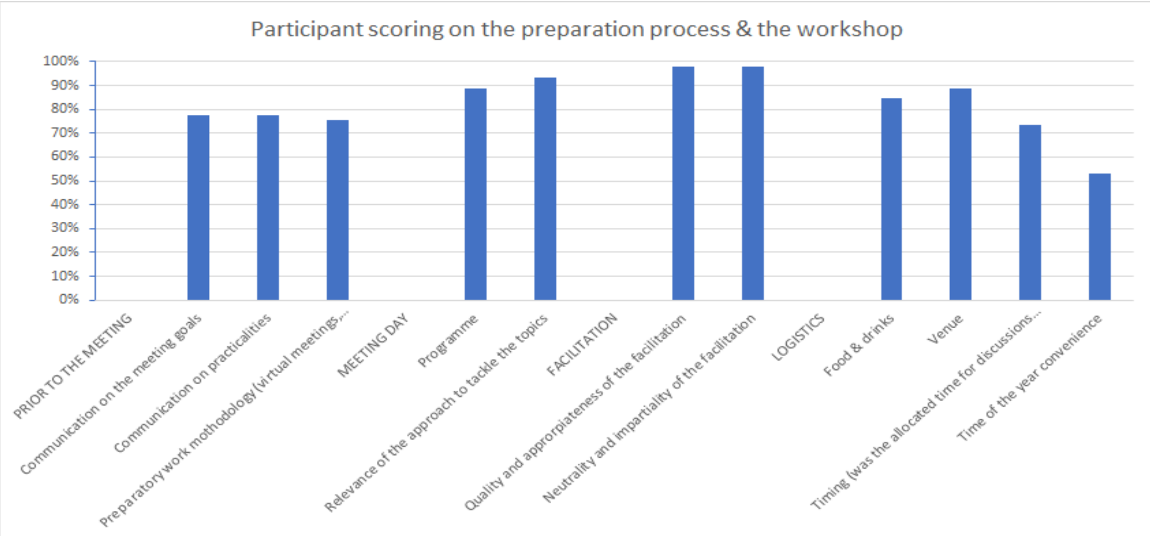


Figure 3 Feedback by the group of participants

The workshop was considered to be successful by the majority of the participants. All respondents mentioned that they found the meeting useful and they considered it to have been a good opportunity to meet and share ideas with people with different perspectives. As it can be seen on the histogram above, the preparatory process was judged as good (with 76 to 78% average scores), the facilitation and the content of the meeting day have been judged extremely positively (average scores between 89% and 98%). On logistical aspects, the venue and catering have been much appreciated (84 to 89% in average), but the timing allocated to discussion was considered a bit short (73% as average satisfaction score) and the time of the year for the process is the parameter for which participants have expressed dissatisfaction (average score of 53%).

The few critical points for reflection for future exercises are summarized as follows:

- Preparation and timing of the workshop: Some participants felt overwhelmed with the volume of engagement requested within a very short time. This perception was further accentuated by an insufficient clarity and framing on definitions and terminology and description of the whole process within which the paper review was taking place. There was very little time allocated to discussion of the preparatory material and explanation of the process of the workshop prior to the meeting. Many participants felt that the timing of the workshop (during Christmas holiday season) further accentuated the workload.
- Involvement of the donor organisations: Pollinis felt that they would have preferred to be kept in the loop of the preparatory documents shared prior to the workshop (as an observer). This would have enabled them to contribute more meaningfully to the discussions at the workshop.

- Diversity of participant profiles: some identified the need to have more diversified knowledge in the group in the field of agronomy, agro-forestry and field practitioners (farmers and advisors), not only for more comprehensive discussions in the workshop, but also for identifying relevant resource papers on a research topic for which multi-disciplinary perspective seems to be key.
- Time frame of the workshop: The total time allocated to the workshop was only one and a half days. Participants felt that at least a two-day or a three-day workshop would have allowed greater opportunities for collaboration and discussions.

The full scoring and comments from participant written feedback can be found in Appendix VI.

6. Conclusions & Policy recommendations

The process highlighted the restricted evidence available to the expert working group on the specific question of how pesticides and fertilisers use might affect conservation measures for pollinators. The conclusions presented in the current report reflect this evidence base. Consequently, while there remains the potential for non-target exposure of insect pollinators to agrochemicals when foraging in habitats adjoining crops, the limited amount of study of this topic meant that no conclusion could be drawn here. Therefore, these findings need to be considered within the scope of a wider body of research and evidence that was not submitted among the key sources of trusted evidence at the start of this process.

In particular, industry has a large set of drift and exposure studies depending on application technologies, crops and implementation of buffering measures. Most of this evidence was not included in this process as it was first considered out of scope of the key question. As part of the discussions during the workshop, it was decided that participants would send and share the relevant pieces of evidence that might have been overlooked in the preparatory phase. These are gathered in Appendix VII. Such anti-drift nozzle technologies and overall use of best practice spraying application techniques (i.e. boom height, drive speed, wind conditions etc.) could be considered as requirements for the Good Agricultural and Environmental Conditions standard no. 9 of the future CAP, for mitigating the risk of reducing the value of conservation measures due to pesticide drift.

The identified evidence in the preparatory phase was very limited on woody structures and semi-natural habitats as well as on nest boxes and wetland buffering. Since large nest boxes attract pathogens, it is recommended to install nest boxes that are smaller and distribute them along the area. However, based on the more extensive evidence available from herbaceous strips some cross-cutting knowledge needs could be identified to be considered by research policy at EU and national level:

- Research is needed to better understand how the "Sustainable use directive" is implemented at national level. In particular, studies would need to explore how best practices recommendations (nozzle technology, unsprayed buffer zones) on pesticide and fertiliser use are implemented by farmers. In addition, it is recommended to collect experience from farmers in different countries on the practical aspects of implementation of conservation measures through questionnaires.
- Some studies are available on drift and exposure routes but further research is needed on the impact of new technologies, particularly new nozzle types (e.g. anti-drift nozzles, one side sprayers for inward spraying) on the efficacy of conservation measures. In addition, research should further assess and quantify the gain in safety from the exposure reduction of the use of drift reduction technology.
- Research is urgently needed on the link between exposure and impact on pollinator diversity, populations, and health. In particular, research should explore the impact of various types of pesticides (not just neonicotinoids) and the resulting various levels of exposure in different landscapes or habitats on foraging behaviour and reproduction of pollinators.
- Research is needed to look at the impact of fertilisers on plant composition of conservation measures to understand the indirect impact on forage resources underpinning pollinator health and biodiversity.
- Additional research is needed to strengthen the understanding of drift, exposure and impact in woody structures and to further investigate the role of semi-natural habitats and nest boxes.

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Rundlof, M., G. K. Andersson, R. Bommarco, I. Fries, V. Hederstrom, L. Herbertsson, O. Jonsson, B. K. Klatt, T. R. Pedersen, J. Yourstone & H. G. Smith (2015) Seed coating with a neonicotinoid insecticide negatively affects wild bees. *Nature,* 521**,** 77-80.

Schmitz, J., K. Schäfer & C. A. Brühl (2014) Agrochemicals in field margins—Field evaluation of plant reproduction effects. *Agriculture, Ecosystems & Environment,* 189**,** 82-91.

Woodcock, B. A., Bullock, J.M., Shore, R.F., Heard, M.S., Pereira, M.G., Redhead, J., Ridding, L., Dean, H., Sleep, D., Henrys, P. and Peyton, J (2017) Country-specific effects of neonicotinoid pesticides on honeybees and wild bees. *Science,* 356**,** 1393-1395.

Woodcock, B. A., N. J. Isaac, J. M. Bullock, D. B. Roy, D. G. Garthwaite, A. Crowe & R. F. Pywell (2016) Impacts of neonicotinoid use on long-term population changes in wild bees in England. *Nat Commun,* 7**,** 12459.

Appendix I: List of experts and participants at the workshop

EKLIPSE Workshop on:

"What do we currently know about the impacts of pesticide and fertilizer use in farmland on the effectiveness of adjacent pollinator conservation measures such as flower strips and hedgerows and what additional research would be needed?"

Date and location: 9-10 January 2020, at the Brussels Office of the Helmholtz Association, Brussels.

List of participants

Nr.	Participant	Institution	Participated in the workshop
1.	Daniele Alberoni	University of Bologna	Yes
2.	Anne Alix	Corteva Agrisciences	Yes
3.	Anke C. Dietzsch	Julius Kühn-Institut	No
4.	André Krahner	Julius Kühn-Institute (JKI)	Yes
5.	Stefan Kroder	ADAMA	Yes
6.	Sara Leonhardt	Technical University of Munich	Yes
7.	Veerle Mommaerts	Bayer	Yes
8.	Jeffery Pettis	Pettis and Assoc LLC	Yes
9.	Nigel Raine	University of Guelph	No
10.	Ana Paula Sançana	LOUSÃMEL - Beekepers Portuguese Cooperative	No
11.	Noa Simon Delso	CARI - Beekeeping Center for Research and Information	Yes
12.	Adam Vanbergen	Institut national de la recherche agronomique (INRA)	Yes
13.	Vasileios Vasileiadis	Syngenta Crop Protection AG	Yes
14.	Casper van der Kooi	University of Groningen	Yes

Nr.	Participant	Institution	Participated in the workshop
15.	Sara Villa	University of Milano Bicocca	Yes
16.	Penelope Whitehorn	Karlsruhe Institute of Technology	Yes
17.	Thomas Wood	Université de Mons	Yes
18.	Benjamin Woodcock	Center for Ecology & Hydrology	Yes
19.	Estelle Balian	Facilitator	Yes
20.	Lynn Dicks	EKLIPSE team	Yes
21.	Nibedita Mukherjee	EKLIPSE Research Assistant	Yes
22.	Saskia Van Crugten	Facilitator	Yes
23.	Allan Watt	EKLIPSE team	Yes
24.	Juliette Young	EKLIPSE team	No
25.	Flore Jeanmart	EKLIPSE team	Yes

Joann Sy from Pollinis (requester of the project) was also in attendance at the workshop.

Appendix II: –List of documents along with reference numbers

Ref ID	Title	Citation
1	Bumblebee (Bombus terrestris) versus honey bee (Apis mellifera) acute sensitivity – Final results of an ECPA data evaluation	Dinter, A., Lückmann, J., Becker, R., Miles, M., Pilling, E., Ruddle, N., . . . Oger, L. (2019). Bumblebee (Bombus terrestris) versus honey bee (Apis mellifera) acute sensitivity – Final results of an ECPA data evaluation. Paper presented at the 14th International Symposium Bee protection group.
2	The wild flora biodiversity in pesticide free bufferzones along old hedgerows	Andresen, L. C., Nothlev, J., Kristensen, K., Navntoft, S., & Johnsen, I. (2012). The wild flora biodiversity in pesticide free bufferzones along old hedgerows. Journal of Environmental Biology, 33, 565-572.
3	Analysis of pollen loads in a wild bee community (Hymenoptera: Apidae) – a method for elucidating habitat use and foraging distances	Beil, M., Horn, H., & Schwabe, A. (2008). Analysis of pollen loads in a wild bee community (Hymenoptera: Apidae) – a method for elucidating habitat use and foraging distances. Apidologie, 39(4), 456-467. doi:10.1051/apido:2008021
4	Environmental fate and exposure; neonicotinoids and fipronil	Bonmatin, J. M., Giorio, C., Girolami, V., Goulson, D., Kreutzweiser, D. P., Krupke, C., . . . Tapparo, A. (2015). Environmental fate and exposure; neonicotinoids and fipronil. Environ Sci Pollut Res Int, 22(1), 35-67. doi:10.1007/s11356-014-3332-7
5	Neonicotinoid Residues in Wildflowers, a Potential Route of Chronic Exposure for Bees	Botias, C., David, A., Horwood, J., Abdul-Sada, A., Nicholls, E., Hill, E., & Goulson, D. (2015). Neonicotinoid Residues in Wildflowers, a Potential Route of Chronic Exposure for Bees. Environ Sci Technol, 49(21), 12731-12740. doi:10.1021/acs.est.5b03459
6	Contamination of wild plants near neonicotinoid seed-treated crops, and implications for non-target insects	Botias, C., David, A., Hill, E. M., & Goulson, D. (2016). Contamination of wild plants near neonicotinoid seed-treated crops, and implications for non-target insects. Sci Total Environ, 566-567, 269-278. doi:10.1016/j.scitotenv.2016.05.065
7	Impacts of a pesticide on pollinator species richness at different spatial scales	Brittain, C. A., Vighi, M., Bommarco, R., Settele, J., & Potts, S. G. (2010). Impacts of a pesticide on pollinator species richness at different spatial scales. Basic and Applied Ecology, 11(2), 106-115. doi:10.1016/j.baae.2009.11.007
8	Does insecticide drift adversely affect grasshoppers (Orthoptera: Saltatoria) in field margins? A case study combining laboratory acute toxicity testing with field monitoring data	Bundschuh, R., Schmitz, J., Bundschuh, M., & Bruhl, C. A. (2012). Does insecticide drift adversely affect grasshoppers (Orthoptera: Saltatoria) in field margins? A case study combining laboratory acute toxicity testing with field monitoring data. Environ Toxicol Chem, 31(8), 1874-1879. doi:10.1002/etc.1895
10	Living on the edge: Field boundary habitats, biodiversity and agriculture	Clark, R. G., Boutin, C., Jobin, B., Forsyth, D. J., Shutler, D., Leeson, J. Y., . . . Thomas, A. G. (2005). Living on the edge: Field boundary habitats, biodiversity and agriculture. In A. G. Thomas (Ed.), Field Boundary Habitats: Implications for

		Weed, Insect and Disease Management. Topics in Canadian Weed Science (Vol. 1, pp. 113-133). Sainte-Anne-de Bellevue, Québec: Canadian Weed Science Society – Société canadienne de malherbologie.
11	Honey bee-collected pollen in agro-ecosystems reveals diet diversity, diet quality, and pesticide exposure	Colwell, M. J., Williams, G. R., Evans, R. C., & Shutler, D. (2017). Honey bee-collected pollen in agro-ecosystems reveals diet diversity, diet quality, and pesticide exposure. Ecol Evol, 7(18), 7243-7253. doi:10.1002/ece3.3178
12	Widespread contamination of wildflower and bee-collected pollen with complex mixtures of neonicotinoids and fungicides commonly applied to crops	David, A., Botias, C., Abdul-Sada, A., Nicholls, E., Rotheray, E. L., Hill, E. M., & Goulson, D. (2016). Widespread contamination of wildflower and bee-collected pollen with complex mixtures of neonicotinoids and fungicides commonly applied to crops. Environ Int, 88, 169-178. doi:10.1016/j.envint.2015.12.011
13	Estimated nationwide effects of pesticide spray drift on terrestrial habitats in the Netherlands	De Jong, F. M., de Snoo, G. R., & van de Zande, J. C. (2008). Estimated nationwide effects of pesticide spray drift on terrestrial habitats in the Netherlands. J Environ Manage, 86(4), 721-730. doi:10.1016/j.jenvman.2006.12.031
15	Effect of herbicide drift on adjacent boundary vegetation	Snoo, G. R. d., & Poll, R. J. v. d. (1999). Effect of herbicide drift on adjacent boundary vegetation. Agriculture, Ecosystems and Environment, 73, 1-6.
16	Effects of landscape structure and land-use intensity on similarity of plant and animal communities (THIS TITLE and Citation does not correspond to the abstract and the comments (which match)- Adam	Dormann, C. F., Schweiger, O., Augenstein, I., Bailey, D., Billeter, R., de Blust, G., . . . Zobel, M. (2007). Effects of landscape structure and land-use intensity on similarity of plant and animal communities. Global Ecology and Biogeography, 16(6), 774-787. doi:10.1111/j.1466-8238.2007.00344.x
17	Effects of herbicide and nitrogen fertilizer on non-target plant reproduction and indirect effects on pollination in Tanacetum vulgare (Asteraceae)	Dupont, Y. L., Strandberg, B., & Damgaard, C. (2018). Effects of herbicide and nitrogen fertilizer on non-target plant reproduction and indirect effects on pollination in Tanacetum vulgare (Asteraceae). Agriculture, Ecosystems & Environment, 262, 76-82. doi:10.1016/j.agee.2018.04.014
18	Generalist foraging of pollinators: diet expansion at high density	Fontaine, C., Collin, C. L., & Dajoz, I. (2008). Generalist foraging of pollinators: diet expansion at high density. Journal of Ecology, 96(5), 1002-1010. doi:10.1111/j.1365-2745.2008.01405.x
19	Long-term impacts of an organophosphate-based regime of pesticides on field and field-edge Collembola communities	Frampton, G. K. (2002). Long-term impacts of an organophosphate-based regime of pesticides on field and field-edge Collembola communities. Pest Manag Sci, 58(10), 991-1001. doi:10.1002/ps.580
20	The effects on terrestrial invertebrates of reducing pesticide inputs in arable crop edges: a meta-analysis	Frampton, G. K., & Dorne, J. L. C. M. (2007). The effects on terrestrial invertebrates of reducing pesticide inputs in arable crop edges: a meta-analysis. Journal of Applied Ecology, 44(2), 362-373. doi:10.1111/j.1365-2664.2007.01277.x

21	Foraging ranges of solitary bees	Gathmann, A., & Tscharntke, T. (2002). Foraging ranges of solitary bees. The Journal of Animal Ecology, 71(5), 757-764.
22	A restatement of recent advances in the natural science evidence base concerning neonicotinoid insecticides and insect pollinators	Godfray, H. C., Blacquiere, T., Field, L. M., Hails, R. S., Potts, S. G., Raine, N. E., . . . McLean, A. R. (2015). A restatement of recent advances in the natural science evidence base concerning neonicotinoid insecticides and insect pollinators. Proc Biol Sci, 282(1818), 20151821. doi:10.1098/rspb.2015.1821 [Annotated bibliography]
23	A restatement of the natural science evidence base concerning neonicotinoid insecticides and insect pollinators	Godfray, H. C., Blacquiere, T., Field, L. M., Hails, R. S., Petrokofsky, G., Potts, S. G., . . . McLean, A. R. (2014). A restatement of the natural science evidence base concerning neonicotinoid insecticides and insect pollinators. Proc Biol Sci, 281(1786). doi:10.1098/rspb.2014.0558
24	Generalization vs. specialization in the pollination system of Hormathophylla spinosa (Cruciferae)	Gómez, J. M., & Zamora, R. (1999). Generalization vs. specialization in the pollination system of Hormathophylla spinosa (Cruciferae). Ecology, 80(3), 796-805.
25	The effects of agrochemicals on Lepidoptera, with a focus on moths, and their pollination service in field margin habitats	Hahn, M., Schotthöfer, A., Schmitz, J., Franke, L. A., & Brühl, C. A. (2015). The effects of agrochemicals on Lepidoptera, with a focus on moths, and their pollination service in field margin habitats. Agriculture, Ecosystems & Environment, 207, 153-162. doi:10.1016/j.agee.2015.04.002
26	Relationships between species' floral traits and pollinator visitation in a temperate grassland	Hegland, S. J., & Totland, O. (2005). Relationships between species' floral traits and pollinator visitation in a temperate grassland. Oecologia, 145(4), 586-594. doi:10.1007/s00442-005-0165-6
27	Microclimate and Individual Variation in Pollinators: Flowering Plants are More than Their Flowers	Herrera, C. M. (1999). Microclimate and Individual Variation in Pollinators: Flowering Plants are More than Their Flowers. Ecology, 76(5), 1516-1524.
28	Exposure of native bees foraging in an agricultural landscape to current-use pesticides	Hladik, M. L., Vandever, M., & Smalling, K. L. (2016). Exposure of native bees foraging in an agricultural landscape to current-use pesticides. Sci Total Environ, 542(Pt A), 469-477. doi:10.1016/j.scitotenv.2015.10.077
29	The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production	IPBES. (2016). The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. Retrieved from Bonn, Germany:
31	Multiple routes of pesticide exposure for honey bees living near agricultural fields	Krupke, C. H., Hunt, G. J., Eitzer, B. D., Andino, G., & Given, K. (2012). Multiple routes of pesticide exposure for honey bees living near agricultural fields. PLoS One, 7(1), e29268. doi:10.1371/journal.pone.0029268
32	Diversity and abundance of bees (Hymenoptera: Apiformes) in native and ruderal grasslands of agriculturally dominated landscapes	Kwaiser, K. S., & Hendrix, S. D. (2008). Diversity and abundance of bees (Hymenoptera: Apiformes) in native and ruderal grasslands of agriculturally dominated landscapes. Agriculture, Ecosystems & Environment, 124(3-4), 200-204. doi:10.1016/j.agee.2007.09.012

33	Insecticide drift deposition on noncrop plant surfaces and its impact on two beneficial nontarget arthropods, Aphidius colemani viereck (hymenoptera, braconidae) and Coccinella septempunctata L. (coleoptera, coccinellidae)	Langhof, M., Gathmann, A., & Poehling, H. M. (2005). Insecticide drift deposition on noncrop plant surfaces and its impact on two beneficial nontarget arthropods, Aphidius colemani viereck (hymenoptera, braconidae) and Coccinella septempunctata L. (coleoptera, coccinellidae). Environmental Toxicology and Chemistry, 24(8), 2045-2054.
34	Non-cultivated plants present a season-long route of pesticide exposure for honey bees	Long, E. Y., & Krupke, C. H. (2016). Non-cultivated plants present a season-long route of pesticide exposure for honey bees. Nat Commun, 7, 11629. doi:10.1038/ncomms11629
38	Pollinator community structure and sources of spatial variation in plant--pollinator interactions in Clarkia xantiana ssp. xantiana	Moeller, D. A. (2005). Pollinator community structure and sources of spatial variation in plant--pollinator interactions in Clarkia xantiana ssp. xantiana. Oecologia, 142(1), 28-37. doi:10.1007/s00442-004-1693-1
39	Neonicotinoid-contaminated pollinator strips adjacent to cropland reduce honey bee nutritional status	Mogren, C. L., & Lundgren, J. G. (2016). Neonicotinoid-contaminated pollinator strips adjacent to cropland reduce honey bee nutritional status. Sci Rep, 6, 29608. doi:10.1038/srep29608
40	Flowering resources distract pollinators from crops: Model predictions from landscape simulations	Nicholson, C. C., Ricketts, T. H., Koh, I., Smith, H. G., Lonsdorf, E. V., Olsson, O., & Requier, F. (2019). Flowering resources distract pollinators from crops: Model predictions from landscape simulations. Journal of Applied Ecology, 56(3), 618-628. doi:10.1111/1365-2664.13333
41	Farm and landscape factors interact to affect the supply of pollination services	Nicholson, C. C., Koh, I., Richardson, L. L., Beauchemin, A., & Ricketts, T. H. (2017). Farm and landscape factors interact to affect the supply of pollination services. Agriculture, Ecosystems & Environment, 250, 113-122. doi:10.1016/j.agee.2017.08.030
42	The modularity of pollination networks	Olesen, J. M., Bascompte, J., Dupont, Y. L., & Jordano, P. (2007). The modularity of pollination networks. Proceedings of the National Academy of Sciences, 104(50), 19891-19896.
43	Temporal dynamics in a pollination network	Olesen, J. M., Bascompte, J., Elberling, H., & Jordano, P. (2008). Temporal dynamics in a pollination network. Ecology, 89(6), 1573-1582.
44	Negative effects of pesticides on wild bee communities can be buffered by landscape context	Park, M. G., Blitzer, E. J., Gibbs, J., Losey, J. E., & Danforth, B. N. (2015). Negative effects of pesticides on wild bee communities can be buffered by landscape context. Proc Biol Sci, 282(1809), 20150299. doi:10.1098/rspb.2015.0299
45	Long-term observation of a pollination network: fluctuation in species and interactions, relative invariance of network structure and implications for estimates of specialization	Petanidou, T., Kallimanis, A. S., Tzanopoulos, J., Sgardelis, S. P., & Pantis, J. D. (2008). Long-term observation of a pollination network: fluctuation in species and interactions, relative invariance of network structure and implications for estimates of specialization. Ecol Lett, 11(6), 564-575. doi:10.1111/j.1461-0248.2008.01170.x
46	Dominance of cropland reduces the pollen deposition from bumble bees	Pfister, S. C., Eckerter, P. W., Krebs, J., Cresswell, J. E., Schirmel, J., & Entling, M. H. (2018). Dominance of cropland

		reduces the pollen deposition from bumble bees. Sci Rep, 8(1), 13873. doi:10.1038/s41598-018-31826-3
47	Honey bee diet in intensive farmland habitats reveals an unexpectedly high flower richness and a major role of weeds	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.
48	Agrochemicals in field margins – An experimental field study to assess the impacts of pesticides and fertilizers on a natural plant community	Schmitz, J., Hahn, M., & Brühl, C. A. (2014). Agrochemicals in field margins – An experimental field study to assess the impacts of pesticides and fertilizers on a natural plant community. Agriculture, Ecosystems & Environment, 193, 60-69. doi:10.1016/j.agee.2014.04.025
49	Agrochemicals in field margins—Field evaluation of plant reproduction effects	Schmitz, J., Schäfer, K., & Brühl, C. A. (2014). Agrochemicals in field margins—Field evaluation of plant reproduction effects. Agriculture, Ecosystems & Environment, 189, 82-91. doi:10.1016/j.agee.2014.03.007
50	Agrochemicals in field margins--assessing the impacts of herbicides, insecticides, and fertilizer on the common buttercup (Ranunculus acris)	Schmitz, J., Schafer, K., & Bruhl, C. A. (2013). Agrochemicals in field margins--assessing the impacts of herbicides, insecticides, and fertilizer on the common buttercup (Ranunculus acris). Environ Toxicol Chem, 32(5), 1124-1131. doi:10.1002/etc.2138
51	Prospects for improved off-crop habitat management for pollen beetle control in oilseed rape	Skellern, M. P., & Cook, S. M. (2018). Prospects for improved off-crop habitat management for pollen beetle control in oilseed rape. Arthropod-Plant Interactions, 12(6), 849-866. doi:10.1007/s11829-018-9598-9
54	Chronic exposure to a neonicotinoid pesticide alters the interactions between bumblebees and wild plants	Stanley, D. A., & Raine, N. E. (2016). Chronic exposure to a neonicotinoid pesticide alters the interactions between bumblebees and wild plants. Funct Ecol, 30(7), 1132-1139. doi:10.1111/1365-2435.12644
55	Scale-dependent effects of landscape context on three pollinator guilds	Steffan-Dewenter, I., Münzenberg, U., Bürger, C., Thies, C., & Tscharntke, T. (2002). Scale-dependent effects of landscape context on three pollinator guilds. Ecology, 83(5), 1421-1432.
56	Resource distributions among habitats determine solitary bee offspring production in a mosaic landscape	Williams, N. M., & Kremen, C. (2007). Resource distributions among habitats determine solitary bee offspring production in a mosaic landscape. Ecological Applications, 17(3), 910-921.
57	Mitigating the Risks of Plant Protection Products in the Environment	SETAC. (2017). Mitigating the Risks of Plant Protection Products in the Environment. Paper presented at the SETAC Workshop Mitigating the Risk of Plant Production Products in the Environment, Rome, Italy.
58	Commission regulation (EU)	Commission regulation (EU), (2013).
59	Commission regulation (EU)	Commission regulation (EU) (2013).

60	Scientific Opinion on the science behind the development of a risk assessment of Plant Protection Products on bees (Apis mellifera,Bombusspp. and solitary bees)	Authority, E. F. S. (2012). Scientific Opinion on the science behind the development of a risk assessment of Plant Protection Products on bees (Apis mellifera,Bombusspp. and solitary bees). EFSA Journal, 10(5). doi:10.2903/j.efsa.2012.2668
61	Guidance on the risk assessment of plant protection products on bees (Apis mellifera, Bombus spp. and solitary bees)	Authority, E. F. S. (2013). Guidance on the risk assessment of plant protection products on bees (Apis mellifera, Bombus spp. and solitary bees). EFSA Journal, 11(7). doi:10.2903/j.efsa.2013.3295
62	Guidance for summarising and evaluating field studies with non-target arthropods. A guidance document of the Dutch Platform for the Assessment of Higher Tier Studies	Jong, F. M. W. d., Bakker, F. M., Brown, K., Jilesen, C. J. T. J., Posthuma-Doodeman, C. J. A. M., Smit, C. E., . . . Eekelen, G. M. A. v. (2010). Guidance for summarising and evaluating field studies with non-target arthropods. A guidance document of the Dutch Platform for the Assessment of Higher Tier Studies. Bilthoven, The Netherlands: National Institute for Public Health and the Environment.
63	Guidance Document on Terrestrial Ecotoxicology Under Council Directive 91/414/EEC	Guidance Document on Terrestrial Ecotoxicology Under Council Directive 91/414/EEC (2002).
64	Regulatory report on the occurrence of flowering weeds in agricultural fields	Last, G., Lewis, G., & Pap, G. (2019). Regulatory report on the occurrence of flowering weeds in agricultural fields. Retrieved from Brussels:
65	How pesticides used in livestock farming threaten bees	Zaninotto, V. (2018). How pesticides used in livestock farming threaten bees. Retrieved from
66	The challenges of predicting pesticide exposure of honey bees at landscape level	Simon-Delso, N., San Martin, G., Bruneau, E., Delcourt, C., & Hautier, L. (2017). The challenges of predicting pesticide exposure of honey bees at landscape level. Sci Rep, 7(1), 3801. doi:10.1038/s41598-017-03467-5
67	Assessment of the environmental exposure of honeybees to particulate matter containing neonicotinoid insecticides coming from corn coated seeds	Tapparo, A., Marton, D., Giorio, C., Zanella, A., Solda, L., Marzaro, M., . . . Girolami, V. (2012). Assessment of the environmental exposure of honeybees to particulate matter containing neonicotinoid insecticides coming from corn coated seeds. Environ Sci Technol, 46(5), 2592-2599. doi:10.1021/es2035152
68	Honeybee dietary neonicotinoid exposure is associated with pollen collection from agricultural weeds	Wood, T. J., Kaplan, I., Zhang, Y., & Szendrei, Z. (2019). Honeybee dietary neonicotinoid exposure is associated with pollen collection from agricultural weeds. Proc Biol Sci, 286(1905), 20190989. doi:10.1098/rspb.2019.0989
69	Bumblebee family lineage survival is enhanced in high-quality landscapes	Carvell, C., Bourke, A. F. G., Dreier, S., Freeman, S. N., Hulmes, S., Jordan, W. C., . . . Heard, M. S. (2017). Bumblebee family lineage survival is enhanced in high-quality landscapes. Nature, 543(7646), 547-549. doi:10.1038/nature21709
70	Comparing the efficacy of agri-environment schemes to enhance	Carvell, C., Meek, W. R., Pywell, R. F., Goulson, D., & Nowakowski, M. (2006). Comparing the efficacy of agri-

	bumble bee abundance and diversity on arable field margins	environment schemes to enhance bumble bee abundance and diversity on arable field margins. Journal of Applied Ecology, 44(1), 29-40. doi:10.1111/j.1365-2664.2006.01249.x
72	Landscape configurational heterogeneity by small-scale agriculture, not crop diversity, maintains pollinators and plant reproduction in western Europe	Hass, A. L., Kormann, U. G., Tscharntke, T., Clough, Y., Baillod, A. B., Sirami, C., . . . Batáry, P. (2018). Landscape configurational heterogeneity by small-scale agriculture, not crop diversity, maintains pollinators and plant reproduction in western Europe. Proceedings of the Royal Society B: Biological Sciences, 285(1872). doi:10.1098/rspb.2017.2242
73	Pollinator diversity in agriculture. Biodiversity project in Baden-Württemberg (Germany) Ecological enhancement measures prove beneficial for wild bee and butterfly biodiversity	IFAB, & Bayer. (2017). Pollinator diversity in agriculture. Biodiversity project in Baden-Württemberg (Germany) Ecological enhancement measures prove beneficial for wild bee and butterfly biodiversity. Retrieved from
74	Ground cover management with mixtures of flowering plants to enhance insect pollinators and natural enemies of pests in olive groves	Karamaouna, F., Kati, V., Volakakis, N., Varikou, K., Garantonakis, N., Economou, L., . . . Edwards, M. (2019). Ground cover management with mixtures of flowering plants to enhance insect pollinators and natural enemies of pests in olive groves. Agriculture, Ecosystems & Environment, 274, 76-89. doi:10.1016/j.agee.2019.01.004
75	Delivery of crop pollination services is an insufficient argument for wild pollinator conservation	Kleijn, D., Winfree, R., Bartomeus, I., Carvalheiro, L. G., Henry, M., Isaacs, R., . . . Potts, S. G. (2015). Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. Nature Communications, 6(1). doi:10.1038/ncomms8414
76	Effects of management by glyphosate or tillage on the weed vegetation in a field experiment	Koning, L. A., de Mol, F., & Gerowitt, B. (2019). Effects of management by glyphosate or tillage on the weed vegetation in a field experiment. Soil and Tillage Research, 186, 79-86. doi:10.1016/j.still.2018.10.012
77	Field margins in northern Europe: their functions and interactions with agriculture	Marshall, E. J. P., & Moonen, A. C. (2002). Field margins in northern Europe: their functions and interactions with agriculture. Agriculture, Ecosystems & Environment, 89(1-2), 5-21. doi:10.1016/s0167-8809(01)00315-2
78	Pollination service delivery for European crops: Challenges and opportunities	Nogué, S., Long, P. R., Eycott, A. E., de Nascimento, L., Fernández-Palacios, J. M., Petrokofsky, G., . . . Willis, K. J. (2016). Pollination service delivery for European crops: Challenges and opportunities. Ecological Economics, 128, 1-7. doi:10.1016/j.ecolecon.2016.03.023
79	The importance of the qualitative composition of floral margins to the maintenance of rich communities of bees	Pérez-Marcos, M., Ortiz-Sánchez, F. J., López-Gallego, E., Ramírez-Soria, M. J., & Sanchez, J. A. (2017). The importance of the qualitative composition of floral margins to the maintenance of rich communities of bees. Landscape management for functional biodiversity, 122, 83-87.

80	Assessing habitat quality for butterflies on intensively managed arable farmland	Pywell, R. F., Warman, E. A., Sparks, T. H., Greatorex-Davies, J. N., Walker, K. J., Meek, W. R., . . . Firbank, L. G. (2004). Assessing habitat quality for butterflies on intensively managed arable farmland. Biological Conservation, 118(3), 313-325. doi:10.1016/j.biocon.2003.09.011
81	Wildlife-friendly farming increases crop yield: evidence for ecological intensification	Pywell, R. F., Heard, M. S., Woodcock, B. A., Hinsley, S., Ridding, L., Nowakowski, M., & Bullock, J. M. (2015). Wildlife-friendly farming increases crop yield: evidence for ecological intensification. Proc Biol Sci, 282(1816), 20151740. doi:10.1098/rspb.2015.1740
82	Long-Term Management Affects the Community Composition of Arable Soil Seedbanks	Rotchés-Ribalta, R., Armengot, L., Mäder, P., Mayer, J., & Sans, F. X. (2016). Long-Term Management Affects the Community Composition of Arable Soil Seedbanks. Weed Science, 65(1), 73-82. doi:10.1614/ws-d-16-00072.1
83	Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in The Netherlands	Scheper, J., Reemer, M., van Kats, R., Ozinga, W. A., van der Linden, G. T., Schaminee, J. H., . . . Kleijn, D. (2014). Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in The Netherlands. Proc Natl Acad Sci U S A, 111(49), 17552-17557. doi:10.1073/pnas.1412973111
84	Unpacking Pandora's Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing	Shackleton, C. M., Ruwanza, S., Sinasson Sanni, G. K., Bennett, S., De Lacy, P., Modipa, R., . . . Thondhlana, G. (2016). Unpacking Pandora's Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing. Ecosystems, 19(4), 587-600. doi:10.1007/s10021-015-9952-z
85	Ecosystem Services: Origins, Contributions, Pitfalls, and Alternatives	Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., & Dash, P. (2013). Ecosystem Services: Origins, Contributions, Pitfalls, and Alternatives. Conservation and Society, 11(4). doi:10.4103/0972-4923.125752
86	Landscape perspectives on agricultural intensification and biodiversity â" ecosystem service management	Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity "Ecosystem service management. Ecology Letters, 8(8), 857-874. doi:10.1111/j.1461-0248.2005.00782.x
87	Landscape Connectivity A call to action	WBSCD. (2017). Landscape Connectivity A call to action. Retrieved from
88	Crop flower visitation by honeybees, bumblebees and solitary bees: Behavioural differences and diversity responses to landscape	Woodcock, B. A., Edwards, M., Redhead, J., Meek, W. R., Nuttall, P., Falk, S., . . . Pywell, R. F. (2013). Crop flower visitation by honeybees, bumblebees and solitary bees: Behavioural differences and diversity responses to landscape. Agriculture, Ecosystems & Environment, 171, 1-8. doi:10.1016/j.agee.2013.03.005
89	Pollinator habitat enhancement: Benefits to other ecosystem services	Wratten, S. D., Gillespie, M., Decourtye, A., Mader, E., & Desneux, N. (2012). Pollinator habitat enhancement: Benefits to other ecosystem services. Agriculture,

		Ecosystems & Environment, 159, 112-122. doi:10.1016/j.agee.2012.06.020
90	Enhancement of Buffer Strips Can Improve Provision of Multiple Ecosystem Services	Blake, R. J., Westbury, D. B., Woodcock, B. A., Sutton, P., & Potts, S. G. (2012). Enhancement of Buffer Strips Can Improve Provision of Multiple Ecosystem Services. Outlooks on Pest Management, 23(6), 258-262. doi:10.1564/23dec05
91	Flower strip networks offer promising long term effects on pollinator species richness in intensively cultivated agricultural areas	Buhk, C., Oppermann, R., Schanowski, A., Bleil, R., Ludemann, J., & Maus, C. (2018). Flower strip networks offer promising long term effects on pollinator species richness in intensively cultivated agricultural areas. BMC Ecol, 18(1), 55. doi:10.1186/s12898-018-0210-z
92	Exploring the relationships between landscape complexity, wild bee species richness and reproduction, and pollination services along a complexity gradient in the Netherlands	Bukovinszky, T., Verheijen, J., Zwerver, S., Klop, E., Biesmeijer, J. C., Wäckers, F. L., . . . Kleijn, D. (2017). Exploring the relationships between landscape complexity, wild bee species richness and reproduction, and pollination services along a complexity gradient in the Netherlands. Biological Conservation, 214, 312-319. doi:10.1016/j.biocon.2017.08.027
93	Getting More Power from Your Flowers: Multi-Functional Flower Strips Enhance Pollinators and Pest Control Agents in Apple Orchards	Campbell, A. J., Wilby, A., Sutton, P., & Wackers, F. (2017). Getting More Power from Your Flowers: Multi-Functional Flower Strips Enhance Pollinators and Pest Control Agents in Apple Orchards. Insects, 8(3). doi:10.3390/insects8030101
94	Do sown flower strips boost wild pollinator abundance and pollination services in a spring-flowering crop? A case study from UK cider apple orchards	Campbell, A. J., Wilby, A., Sutton, P., & Wäckers, F. L. (2017). Do sown flower strips boost wild pollinator abundance and pollination services in a spring-flowering crop? A case study from UK cider apple orchards. Agriculture, Ecosystems & Environment, 239, 20-29. doi:10.1016/j.agee.2017.01.005
95	Insect pollinator conservation policy innovations at subnational levels: Lessons for lawmakers	Hall, D. M., & Steiner, R. (2019). Insect pollinator conservation policy innovations at subnational levels: Lessons for lawmakers. Environmental Science & Policy, 93, 118-128. doi:10.1016/j.envsci.2018.12.026
96	Reduced species richness of native bees in field margins associated with neonicotinoid concentrations in non-target soils	Main, A., Webb, E., Goyne, K., Mengel, D. (2020): Reduced species richness of native bees in field margins associated with neonicotinoid concentrations in non-target soils. Agriculture, Ecosystems & Environment 287: 106693.

Appendix III: Complete database of documents scores by the participants (only available online)

Appendix IV: Documents mapped to interventions (only available online)

Appendix V: Agenda of the workshop

EKLIPSE Pollinis Request

Knowledge on Impacts of pesticides and fertilizers on adjacent pollinators conservation measures

Brussels 9-10 January 2020

This workshop has two main goals

- *Identify current relevant and reliable knowledge on the issue*
- *Identify knowledge gaps and agree on research priorities*

SPECIFIC OBJECTIVES

- *Discuss currently available relevant evidence*
- *Summarize from this evidence current key outputs*
- *Identify knowledge gaps (either no available evidence or no jointly trusted evidence)*
- *Discuss and prioritize research needs to address these gaps.*

PROGRAM ACTIVITIES–

Day 1

TIME	Meeting process
10:30-11:30	**Briefing Facilitators**
11:30-12:30	**Session 1.1: Introduction:** - Context and objectives (EKLIPSE & Pollinis) Presentation of EKLIPSE Presentation of the request - Facilitation and process (E. Balian & S. van Crugten) - Icebreaker (E. Balian)
12:30-13:15	**LUNCH**
13:15 – 15:15	**Session 1.2: Available Knowledge from trusted evidence** **3 groups (6 persons each): each group will work on some types**

TIME	Meeting process
	4 of conservation measures/interventions 1. Woody structures and nest box (and General Aspects) (Saskia & Nibedita) 2. Semi-natural habitats and water and crop buffers (and General Aspects) (Allan & Flore) 3. Herbaceous strips (Estelle & Lynn) For each group, the list of evidence with strong support in relation to the conservation measures (papers included in the “trusted evidence batch” if at least 2 reviewers have found the evidence relevant 32 “green” Papers with 3 reviewers: 14 with 3 positive scores and 19 with 2 positive scores **Round 1 (30’) key findings from trusted evidence** 1-:- Give time for people to have a look at the summary of scoring and green papers 2- “tour de table” to clarify if there is still a strong doubt about relevance of some proposed evidence (these will be set aside) 3- Start listing the key findings from these trusted evidence **Round 2 (change group) (30’) Key findings and Knowledge Gaps** 1- Explain what was discussed in previous round and which papers if anywhere set aside 2- Complete the key findings 3- Start asking about knowledge gaps **Round 3 (change group) (30’) Knowledge gaps** 1- quick view on list of key findings and K gaps from previous gaps 2- Are there any additional K gaps? **Reporting in plenary (30’)**
15:15-15:30	Coffee & tea break
15:30-17:30	Session 1.3 on “controversial evidence” FOCUS ON KNOWLEDGE GAPS NOT ON ASSESSING QUALITY OF EVIDENCE We will work again in 3 groups based on same intervention groupings 1. Woody structures and nest box (and General Aspects) (Saskia & Nibedita) 2. Semi-natural habitats and water and crop buffers (and General Aspects) (Allan & Flore)

TIME	Meeting process
	3. Herbaceous strips (Estelle & Lynn) In each group people discuss the orange papers and identify knowledge gaps based on these People choose their group for starting with a maximum of 5 persons/group Round 1: Use the orange papers to identify knowledge gaps and complete the mindmap Gallery walk feedback of groups
17:30-18:00	Debriefing of the day Evaluation form Day 1 • Virtual line as a gradient of satisfaction

Day 2

TIME	Meeting process
09:00-09:15	**Summary day 1and agenda Day 2 (Estelle)**
9:15- 9:45	**Session 2.1 : Finalise with the last batch of papers nonspecific and only green ones** Plenary: work in pairs: 2 papers per pair. key findings and knowledge gaps on post its to be added to a specific measure or to cross-cutting
9:45-10:15 **Group 1** **10h15-10h45** **Group 2**	**Session 2.2: Reporting and complement with knowledge gaps/brainstorming** (all participants move from one group to the other) Group 1 on woody structure and nest boxes Reporting of day 1 results and brainstorming addition knowledge gaps Presenter Saskia Capture of knowledge gap: Nibedita

TIME	Meeting process
10;45-11:15 **Coffee break** **11:15-11:45** **Group 3** **11:45-12:15** **Group 4**	Group 2 on SNH and wetland buffering Reporting of day 1 results and brainstorming addition knowledge gaps Presenter Allan Capture of knowledge gap: Flore Group 3 on herbaceous strips Presenter Estelle Capture of knowledge gap: Lynn Group 4 on Cross-cutting aspects Reporting of day 1 results and brainstorming addition knowledge gaps Presenter: Saskia & Estelle Capture of knowledge gaps: Lynn
12:15-12:30	Introduction to the prioritisation and the afternoon research action tree process Participants are back at the table
12:30-13:00	**Session 2.4: Prioritisation of knowledge gaps into knowledge needs** *Individual scoring of knowledge gaps* *3 criteria :* - *Feasibility* - *Cost-benefit* - *Policy relevance* Each participants will be able to score each knowledge gap on a scale of 1 to 4 for each of the 3 criteria and add on a post-it justification for the score The results show a matrix of knowledge needs depending on the chosen criteria

TIME	Meeting process
13:00-13:30	**LUNCH**

13:30-15:00	**Session 2.5 : Unfolding knowledge needs into research actions/questions**
	
	Top 2 knowledge needs for each criteria: pick 4
	
	Working in trios:
	- participants in trios will be invited to choose a knowledge need as identified during the morning and build a "research action" tree :
	  - trunk: The knowledge need
	  - roots: enabling conditions/what key resources are needed (data, geographical cover, interdisciplinarity, etc.)
	  - Branches: What research questions should be tackled
	  - leaves: actions/activities
	
	This should results In a forest of "research action trees"

15:00-15:15	**Coffee & tea break:**
15:15-16:00	**Presentation of the "research action trees"**
16:00-17:00	**Evaluation of the workshop: debrief** **Evaluation Forms**

Appendix VI: Detailed information from participant feedback

Fifteen participants have filled out the feedback questionnaire which included a scoring (poor=0, acceptable=1, rather good=2, excellent=3). The average scores are expressed in percentage.

Pollinis-EKLIPSE workshop (Brussels 9-10 January 2020) - Feedback from participants

	Average (in%)	Average (/3)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Prior to the meeting																	
Communication on the goals of the meeting	78%	2,33	3	3	2	2	2	2	2	3	2	3	1	3	3	2	2
Communication on practicalities	78%	2,33	3	1	2	2	3	2	2	2	3	3	2	3	3	2	2
Preparatory work mothodology (virtual meetings, review, scoring...)	76%	2,27	2	2	2	2	3	3	3	2	3	3	2	3	2	1	1
Meeting day																	
Programme	89%	2,67	3	3	3	3	2	2	2	3	3	3	3	3	3	2	2
Relevance of the approach to tackle the topics	93%	2,80	3	3	3	2	3	3	3	3	3	3	3	3	3	1	3
Facilitation																	
Quality and approrpiateness of the facilitation	98%	2,93	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
Neutrality and impartiality of the facilitation	98%	2,93	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3
Logistics																	
Food & drinks	84%	2,53	2	2	3	2	3	3	3	3	2	2	3	1	3	3	3
Venue	89%	2,67	3	2	3	3	2	3	3	3	3	2	3	1	3	3	3
Timing (was the allocated time for discussions convenient?)	73%	2,20	1	2	3	2	2	3	3	2	3	1	3	2	2	2	2
Time of the year convenience	53%	1,60	1	0	3	2	1	2	2	2	2	1	2	1	2	2	1

Participants were also allowed to provide with their open comments as answers to some guiding questions on expectations, overall appreciation and critical feedback on what should be kept or changed in the process (preparation & workshop)

Appendix VII: Post workshop data sharing

TOPIC: Measurement of spray drift for plant protection products.

Source 1:

In Germany: the Julius Kuhn Institute (JKI) is a reference in spray drift measurement including in the field and has for example developed the standard drift values being used in risk assessment models (known as the Rautman et al values): https://www.julius-kuehn.de/en/application-techniques-in-plant-protection/fields-of-activity/drift-and-risk-reduction/drift-values/

In the Netherlands: Jan van Zande from the University of Wageningen is a referent person for his work on drift measurement in lab and field: https://research.wur.nl/en/persons/jan-van-de-zande

In Italy: Prof Paolo Balsari for his equivalent work at the University of Torino: https://www.disafa.unito.it/do/docenti.pl/Alias?paolo.balsari#tab-ricerca

In Spain/EU (in collaboration with Emilio Gil, project leader: INNOSETA https://www.disafa.unito.it/do/progetti.pl/Show?_id=gih2 and https://www.innoseta.eu/partners/upc/

In France: IRSTEA: Jean Paul Douzals at the IRSEA proposes methods to measure the efficacy of low drift nozzles in controlled conditions for standardization purposes https://itap.inrae.fr/?page_id=155

In the UK: Clare Butler Ellis at the Silsoe institute https://www.ssau.co.uk/

These institutes and contact experts are regularly involved in groups working on:

- the development of measurement methods for lan and field test designs;
- methods to develop low drift tools (nozzles, adjuvants)
- field measurements for research and regulatory purposes
- research on drift understanding and mechanism
- data generation for modelling purposes.

TOPIC: Risk assessment done in the context of the regulatory evaluation of active substances.

The European dossiers of each pesticide active substances are evaluated by EFSA and their conclusions are available here: https://www.efsa.europa.eu/en/publications/?f%5B0%5D=im_field_subject%3A62081

The full assessments and supporting documents are also available from the EFSA journal. Specific studies can be requested from the companies owning the substance (transparency initiative).
A dossier on an active substance contains typically ca 150 studies that will describe its fate in the environmental compartments and its ecotoxicological properties (out of a total of 400-500 studies that address also other safety points such as worker safety, consumer safety, analytical methods etc.). These studies are standardized (i.e. performed according to international guidelines) and are used derive “endpoints” i.e. reference values for degradation/dissipation (DT50, DT90), adsorption to

soils, stability in the air compartment, partition in water sediment systems, abiotic / biotic degradation, mineralization, degradation under different temperature and pH, and then intrinsic toxicity to a series of organisms (birds, mammals, bees, non-target arthropods, soil macro and micro-organisms, non-target plants and aquatic organisms. Studies are also conducted on all degradation products >5% in a compartment and on formulated products. They are all part of what we call a "core dossier" i.e. all of these are mandatory and generated on a systematic basis. The risks are then evaluated: exposure is estimated via calculations and models that reproduce the conditions of exposure for each specific use (e.g, exposure will be different from arable crops treatment and orchard treatment) and is calculated following worst case assumptions i.e. no buffer zones, lowest dissipation rate between applications etc. The most sensitive species within a group is used. If the ratio between no effects levels for that species and max exposure rates fulfils the requested safety margin (fixed by the regulation) then the risk assessment is completed. If the margin of safety is not achieved, the regulation requests to perform "high tier studies" i.e. field trials that assess the impact of the treatment under realistic conditions of use.

For non-target arthropods, risks must be acceptable in field and off field. For the assessment of off-field risks, a protocol has been developed to evaluate risks in the field margins.
An example of study summary is provided on page 35 of *Jong & Steen 2010*[1] (https://library.wur.nl/WebQuery/wurpubs/395399). Examples of off field studies have been performed e.g. for chlorpyrifos (insecticide). This type of study allows to measure potential effects of spray drift on populations and community of non-target arthropods present in the type of vegetation represented in the study. It is also possible to apply different rates and thus to evaluate impacts at different distances of the field. The outcome is used to provide conditions (on the label) for a safe use on non-target arthropods in the field margins. Pollinators being a subgroup of "non-target arthropods" be present as part of the samplings performed, however risks to pollinators are also evaluated and must be acceptable in the field margins as well, as part of the dossiers.

Additional resources:
Guidance document of the Italian Ministry of Health on "*Risk mitigation measures to reduce the drift and run-off contamination of surface water bodies*" actually used in the PPP registration procedure (National addenda: http://www.salute.gov.it/imgs/C_17_pubblicazioni_2644_allegato.pdf). In particular the efficacy of the single mitigation measure or their combinations are assessed.

Other literature is available not directly linked to pollinators but to knowledge gaps. Besides, this the regulatory process requires companies to provide a risk assessment for non-target plants and arthropods. The obtained data are translated into risk mitigation measures:

- For example there is a 4 year monitoring program that was conducted whereby the recovery of pesticide residues was monitored in surface water before and after anti-drift measures were

[1] Jong, F.M.W. de, Steen, J.J.M. van der. 2010. Guidance for summarising and evaluating field studies with non-target arthropods: a guidance document of the Dutch Platform for the Assessment of Higher Tier Studies. RIVM report / National Institute for Public Health and the Environment no. 6017120062010) - ISBN 9789069602455 - 73

implemented. This data was presented at the Symposium of the Ghent University and the article in attachment (Baets et al 2018[2]: Belgium-Ghent_2018)

- To bring a pesticide on the market the authorization process at European level asks that risk assessments are conducted towards non target arthropods and non-target plants (off-land) (https://ec.europa.eu/food/sites/food/files/plant/docs/pesticides_ppp_app-proc_guide_ecotox_terrestrial.pdf)
- In case the representative uses do not pass the risk assessment in the first step, then it will be checked if the risk is acceptable with the use of risk mitigation measures'. The implementation of risk mitigation measures is national: they include buffer zones and/or anti-drift nozzle (over the whole field a specific % needs to be applied). The European guidelines in attach and for example the local guidelines via guidance ecotox-be (https://fytoweb.be/sites/default/files/guide/attachments/guidance_ecotox_be_-_v2.1.pdf)
- In addition to this, the products and the data that was gathered for the regulatory process can be found this website: https://www.cropscience-transparency.bayer.com/

Table of drift values https://www.julius-kuehn.de/media/Institute/AT/PDF_RichtlinienListenPruefberichte/Abdrifteckwerte/Tabelle_der_Abdrifteckwerte_.xls updated in 2006 and obtained by using standard valves (e.g. by LU Lechler) but also to a table of drift-reducing application equipment https://www.julius-kuehn.de/media/Institute/AT/PDF_RichtlinienListenPruefberichte/Verlust_Geraete_Abdrift/Verzeichnis_Verlustmindernde_Geraete.xls

For any given equipment you reduce the percentage drift value by the percentage drift reduction (e.g. 50, 75, 90 or 95%). However, the drift values have been obtained by testing flat surfaces next to the application area to mimic surface water areas. AT has no published data on drift values in field-adjacent vegetation. I talked to Dirk Rautmann today and he told me that they did some experiments in the 1990s looking at drift and drift reduction in/of hedgerows. This data didn't get published but he promised to look in his archives and send me either some data or a kind of report with the results. He remembered that the hedgerows didn't act as a filter but rather redirected the wind with the spray drift. So they found similar drift on the other side of the hedgerow in accordance with the published drift values. Dirk Rautmann also mentioned the dust drift values that André certainly has reported about at the workshop and that we have data and some published materials on from work at our institute (I've already uploaded some of these into the cloud a while ago). As soon as Dirk Rautmann gets back to me, I'll let you know.

Topic: Soil quality and degradation

If we assume plants (with their flowers, nectars and nesting cavities) are the direct feed source and nesting sites for pollinators, what if those plants are naturally growing/or seeded in an inappropriate soil? In other words, what if the soil is not good enough to host plants of interest for pollinators, because it is degraded in terms of nutrients, structure, organic matter… therefore a sterile or compromised soil? Will any flower strips or initiative to improve plants biodiversity be actually long lasting if soil isn't properly supporting them?

[2] Baets, D, Sur. R., Krebber. R. Lembrich. D. 2018. High-resolution water monitoring prgram givers further insights on sources of residues from herbicides in surface waters. Comm. Appl. Biol. Sc. Ghent University 83/3

Source 1: https://www.eea.europa.eu/publications/92-9157-202-0/page306.html
"Sustainable management of soil as a natural resource, together with air and water, is one of the environmental challenges and priorities in the 5th Environmental Action Programme. But unlikely to the other two media, soil is not explicitly considered when specific objectives and targets are defined."…… omissis………."But, in general the policy measures are primarily aimed at combating pollution in other areas, and affect soils indirectly. Statutory soil monitoring is carried out as well in a number of Member States, but rarely for the purposes of soil protection per se; and comparability at the EU level remains weak. The development of an EU policy framework which recognises the role of soil, which takes account of the problems arising from the competition among its concurrent uses (ecological and socio-economic), and which is aimed towards the maintenance of its multiple function, would have multiple benefits and achieve a consistent improvement of Europe's environment as a whole."

There are plenty of evidence that address a number of environmental damages due to inappropriate management of soil:

- The lack of soil organic matter, due to a wide use of chemical fertilizers (and wrong agronomic practices) is surely linked to the loss of organic matter. And loss of organic matter can compromise productivity (and profitability):

Source 2: http://franklin.cce.cornell.edu/resources/soil-organic-matter-fact-sheet
"Biological Benefits of soil organic matter: 1-Provides food for the living organisms in the soil. 2-Enhances soil microbial biodiversity and activity which can help in the suppression of diseases and pests. 3- Enhances pore space through the actions of soil microorganisms. This helps to increase infiltration and reduce runoff."

"In Summary, with careful management the preservation and accumulation of soil organic matter can help to improve soil productivity resulting in greater farm profitability"

If a good content of soil organic matter, is linked with a greater farm profitability (usually it means a greater crops production), why the same concept isn't addressed for flowered strips? A good set of healthy plants for pollinators support can produce more nectar in a soil with high organic matter? Or bloom for a longer time? Or produce better seeds for the following year(s)?

- Soil organic matter is also an ecological niche for microorganisms. Microorganisms (like mycorrhiza, nitrogen fixing bacteria, etc…) can guarantee chelation of micronutrients useful for the plants, nitrogen fixation and solubilization of other nutrients (Phosphorus or Potassium). Weed killers have been shown to modify the microbial population or modify the gene expression of soil bacteria downregulation them.

Source 3: https://www.sciencedirect.com/science/article/pii/S0048969716302881
"Several transcripts involving nutrients, such as iron, nitrogen, phosphorus, and potassium, differed significantly in abundance between glyphosate-treated and untreated control rhizosphere soil samples. These results indicate an effect of glyphosate on nutrient uptake within the rhizosphere

bacterial community. Transcripts involved in acquisition of iron, ammonia assimilation, and phosphate metabolism were all downregulated in the rhizosphere of glyphosate-treated crops"

- Soil organic matter and soil structure (Bulk Density Management) are linked with water retention. Therefore, especially in south Europe, a longer storages of water resources in the soil can help in a more prolonged blooming of plants (and again in a better nectar production), before the dry season show up during summer.

Source 4:https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050936.pdf
Soil microorganisms (mainly growing on roots and organic matter) can change the Organic Volatiles Compounds (VOCs à perfume of the flower). Since the pollinators are mainly orientating on the feed sources driven by perfumes, microorganisms can positively or negatively influence the detection of those VOCs. Therefore it can be a major issue if the detection of the nectar source is compromised in this way.

Source 5: see attached document (Becklin et al 2011[3]) (https://doi.org/10.3732/ajb.1000450).
"Floral signals and rewards — Soil fungi impact many traits that function as signals to floral visitors. For example, mycorrhizal fungi increased flower production in a number of host species (Lu and Koide, 1994; Pendleton, 2000; Poulton et al., 2001a; Gange and Smith, 2005), but had no effect on flower production by *Lythrum salicaria* (Philip et al., 2001) and decreased flower production by *Campanula rotundifolia* (Nuortila et al., 2004). Other studies identified mycorrhizal fungal effects on flowering duration, flower size, and inflorescence number or structure, all of which may function as visual signals to insect visitors (Bryla and Koide, 1990; Lu and Koide, 1994; Pendleton, 2000; Gange and Smith, 2005). As with flower number, the effect of mycorrhizal fungi on these floral traits varies among host species (Bryla and Koide, 1990; Gange and Smith, 2005). Thus, although most studies indicate that mycorrhizal fungi positively impact floral signals, the magnitude and direction of these effects are generally context-dependent. In contrast to mycorrhizal fungi, there is surprisingly little information about soil pathogen effects on floral traits other than seed set (Marr and Marshall, 2006)."

[3] Becklin KM, Gamez G, Uelk B, Raguso RA, Galen C. Soil fungal effects on floral signals, rewards, and aboveground interactions in an alpine pollination web. *Am J Bot*. 2011; 98(8):1299–1308. doi:10.3732/ajb.1000450

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