SAFEGUARD

Conceptualisation and stakeholder validation of the Integrated Assessment Framework (IAF) for pollinators for different policy sectors and scales.

Deliverable D5.3

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Safeguard
Safeguarding European wild pollinators

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List of abbreviations

BioAgora	**Biodiversity Knowledge Agora: Developing the Science Service for European Research and Biodiversity Policymaking (HE project)**
DG Env	**Directorate General Environment**
DPSIR	**Driver-Pressure-State-Impact-Response model**
EU	**European Union**
EC	**European Commission**
IAF	**Integrated Assessment Framework**
IPBES	**Intergovernmental Platform for Biodiversity and Ecosystem Services**
MS	**Member State**

Preface

This deliverable integrates the work from Safeguard Task 5.1 *[Conceptualise an integrated assessment framework (IAF) of the separate and combined effects of DPSIR components on wild pollinators and pollination]* with that of Task 5.3 *[Test, validate and adapt the IAF for different scales of governance (local to international) and sectors (agriculture, urban)]*. The logic of integrating these two tasks into a single deliverable report is that the science-stakeholder co-conception and validation of the IAF (as described in the Safeguard DoA) was interdependent and conducted in an iterative way (ongoing into 2025) [Note: Task 5.1 did not have a specific deliverable attached to it in the DoA].

This deliverable report describes:

- The conceptualisation of the Safeguard Integrated Assessment framework, including scoping and methodology.
- Results of an expert elicitation exercise to score the importance (Pressure-State-Impact) or effectiveness (Responses) of the linkages in the (D)PSIR framework at the European scale.
- Various stakeholder consultations and workshop activities to inform the conceptualization and to establish the acceptability of Responses (ongoing) identified by experts as being effective in alleviating pressures on pollinators or directly improving the State.

Two versions of this deliverable 5.3 were produced. Version 1 described the state-of play up to December 2024 (the original due date). Version 2 (final) took advantage of the project extension to ensure the D5.3 can be as complete as possible with a final data visualization of the expert elicitation and a revision of the serous game with which stakeholders could engage with this IAF.

Summary

To conceptualise the IAF we used the DPSIR model (Drivers-Pressures-State-Impacts-Responses) as the overarching framework to assess wild pollinators (and the benefits they provide to humanity and nature) in Europe.

We conceptualised the issues and integrated knowledge on wild pollinators for different policy relevant environments (agriculture, urban and semi-natural) sources using an expert-elicitation (modified Delphi approach). We also ran dialogue within the Safeguard consortium and with key stakeholder groups to validate the IAF conceptualisation and to understand the acceptability of different response (policy or practices) options to different stakeholders.

Our overall objectives were to assess the evidence up to 2024 to establish:

1) the importance of different Pressures to the State of wild pollinators and to various Impacts on the benefits to nature and human society that pollinators can provide.
2) the effectiveness of Responses (policy) in mitigating these Pressures or improving the State.

We also asked the experts to project forward over the next decade (2025-2035) by giving an opinion on the likely direction of trends in importance for Pressure-State and State-Impact links. We also elicited the level of certainty experts had about this knowledge using the widely recognised IPBES 4-box model.

The IAF concept was presented to multiple stakeholders in different European and international forums to obtain co-development feedback. For stakeholder validation we used a workshop approach where stakeholders used an interactive serious game application – a digital game designed to educate, inform, train or influence behaviour (developed by University of Stirling through a collaboration with the BioAgora project). This game allowed a diversity of decision-makers to implement a set of potential EU-scale policies in a virtual landscape (agricultural, urban or semi-natural). Workshop deliberations and data from the decision-taking on pollinator-friendly policies will provide a stakeholder validation of the 'acceptability' of RESPONSES identified as most effective by the expert elicitation to be reported in a subsequent deliverable (contingent on data and results).

In this Deliverable 5.3 we present our conceptualisation and scoping of the IAF, the methodologies used, and a visualisation of results from an expert elicitation using the developed framework. We also describe here the approach taken for stakeholder engagement and validation steps involving a serous game approach.

1. Introduction

An Integrated Assessment Framework (IAF) is defined as a systematic approach for gathering and evaluating knowledge in ways that can assist decision making. It requires integrating multiple disciplines or perspectives to frame and evaluate a complex environmental and/or social-economic problem or issue. This can include a systematic analysis of the interrelationships, costs-benefits & trade-offs between various factors and their impacts. An IAF can be flexible in terms of drawing on multiple knowledge sources (e.g., data, models, scenarios, expert-based evaluations and stakeholder knowledge). The ultimate purpose of an IAF is to provide to experts and decision-makers a method for a establishing a general and integrated view of a multidimensional problem & potential solutions.

The overarching framework of our IAF was taken to be the **DPSIR model (Drivers-Pressures-State-Impacts-Responses)**[1]. This model allows us to frame the specific issues around pollinators and pollination in different policy relevant environments (agriculture, urban and semi-natural). Within this framework we followed three principles to creating a general IAF for safeguarding wild pollinators. The first was to accurately **conceptualise** the issues around wild pollinators for areas of the contemporary European-scale landscape that were predominantly under agricultural, urban or semi-natural habitat. The second was to integrate different knowledge sources (e.g., scientific literature and reports, Safeguard data/analyses and stakeholder and expert knowledge) through knowledge synthesis approaches, namely a **rapid evidence assessment** using an **expert-elicitation** approach (and dialogue within the Safeguard consortium and with key stakeholder groups e.g., EC, Eurocities, Promote Pollinators). The third step was to **validate** the IAF and test the **acceptability** of different response options (policy or practice options deemed effective by scientific experts) to and with actors from different sectors.

This last stakeholder validation step is ongoing (starting in December 2024 and continuing in the first half of 2025). Accordingly, this deliverable is version 1 and it will be updated (by 09/2025) with the definitive feedback and validation information from stakeholders through planned workshops and online survey. In sum, we are overall conducting a two-stage process to the conceptualisation (Task 5.1) and validation (Task 5.4) of the IAF.

A series of consortium workshops and consultative meetings/workshops with stakeholder groups (e.g., EC DG Env-European Pollinators Initiative, Promote Pollinators, Eurocities) helped to refine the approach to be taken in conceptualising the IAF (T5.1) and in validating its utility for stakeholders (T5.4). Furthermore, we developed **an inter-project collaboration** with the Pollination Demonstration Case of the Horizon Europe BioAgora project https://bioagora.eu/knowledge-exchange-networks. This collaboration assisted in leveraging expert participation beyond the Safeguard consortium and assisted the engagement of the stakeholder community in the co-development of the IAF.

1.1 Conceptualise an integrated assessment framework (IAF) of the separate and combined effects of DPSIR components on wild pollinators and pollination

The first stage (Task 5.1) was to conceptualise the IAF by drawing on existing knowledge to develop a socio-ecological DPSIR framework (Box 1) that could be used to assess the multiple interactions between combinations of (drivers), pressures, status, impacts and responses affecting pollinators and their values. The aim was to develop a common assessment framework that can be applied and

[1] Smeets, E., and R. Weterings. 1999. Environmental indicators: Typology and overview.

adapted to different policy scales (local to international) and that would reflect different landscape elements (agriculture, urban and semi-natural systems), and therefore policy sectors.

We used an expert elicitation process inspired by the modified Delphi process[2] that has been used to assess the pressures on pollinators in different world regions (Dicks et al, 2021[3]). This method allowed rapid assessment of the evidence concerning the **linkages in the DPSIR model.** More precisely, this assessment established the level of *importance* of different human-caused **pressures** causing changes to the **state** of wild pollinators and pollination and, in turn, **impacts** on the values or benefits wild pollinators provide to nature and human well-being. Furthermore, our assessment established the *effectiveness* of different **responses** in either alleviating pressures or directly improving the state. This expert elicitation exercise was done considering evidence at the European level. The final purpose of the exercise was to communicate to policymakers the key messages around the (D)PSIR, the level of uncertainties and identify any knowledge gaps arising.

For this expert elicitation approach, we used the collective knowledge of the members of the Safeguard consortium together with that of a selection of invited external experts to broaden the expertise base. Experts were tasked to base their scores on the body of evidence that they were aware of up to the present day (2024). Experts were advised to use the IPBES 2016 assessment, which contained a wealth of peer-reviewed information from a 2-year assessment of the evidence up to 2016 by over 70 international experts as a baseline. Building on that assessment's key findings, the experts were asked to consider the more recent published evidence since 2016 when formulating their scores. Experts were encouraged, where they wished, to supplement their scores by pointing to key references or any exceptions or context dependencies pertaining to their scores.

The final analysis and visualisation of the expert elicitation will lead to a production of a paper and a associated policy brief in autumn-winter 2025/26. Below we outline the scope and methodology taken during 2024 and results on the median expert scores (plus confidence ranking) together with a forward projection (2025-2035).

1.2. DPSIR framing of the expert elicitation assessment

We used the DPSIR framework (Figure 1) as the conceptual model of the Safeguard IAF. In the DPSIR model these 5 components (Drivers, Pressures, States, Impacts, Responses) are linked by a causal chain. **Drivers** (indirect drivers) are the economic, social and institutional systems (e.g. global market forces, economic consumption patterns) that cause environmental **Pressures** (direct drivers), such as landscape simplification, land-use change or climate change, which in turn affect the environmental **State,** in our case pollinator diversity, abundance and pollination services. These causal chains lead to **Impact**, namely changes in environmental functions that affect social, economic and environmental benefits (e.g. crop yields, supply of healthy human diets, economic livelihoods, cultural values). The perception of these impacts triggers **Responses** that are the changes in policies or management practices that attempt to limit Drivers, alleviate Pressures and/or directly improve the State. Such Responses include new policies or regulations, collective initiatives, preventive actions or practices. In our expert elicitation we decided that the *Drivers* were accepted as the conclusions of the IPBES 2019 global assessment and so they were not directly re-assessed in this exercise.

[2] Mukherjee, N., J. Hugé, W. J. Sutherland, J. McNeill, M. Van Opstal, F. Dahdouh-Guebas, and N. Koedam. 2015. The Delphi technique in ecology and biological conservation: applications and guidelines. Methods in Ecology and Evolution 6:1097-1109.

[3] Dicks, L. V., T. D. Breeze, H. T. Ngo, D. Senapathi, J. An, M. A. Aizen, P. Basu, D. Buchori, L. Galetto, L. A. Garibaldi, B. Gemmill-Herren, B. G. Howlett, V. L. Imperatriz-Fonseca, S. D. Johnson, A. Kovács-Hostyánszki, Y. J. Kwon, H. M. G. Lattorff, T. Lungharwo, C. L. Seymour, A. J. Vanbergen, and S. G. Potts. 2021. A global-scale expert assessment of drivers and risks associated with pollinator decline. Nature Ecology & Evolution.

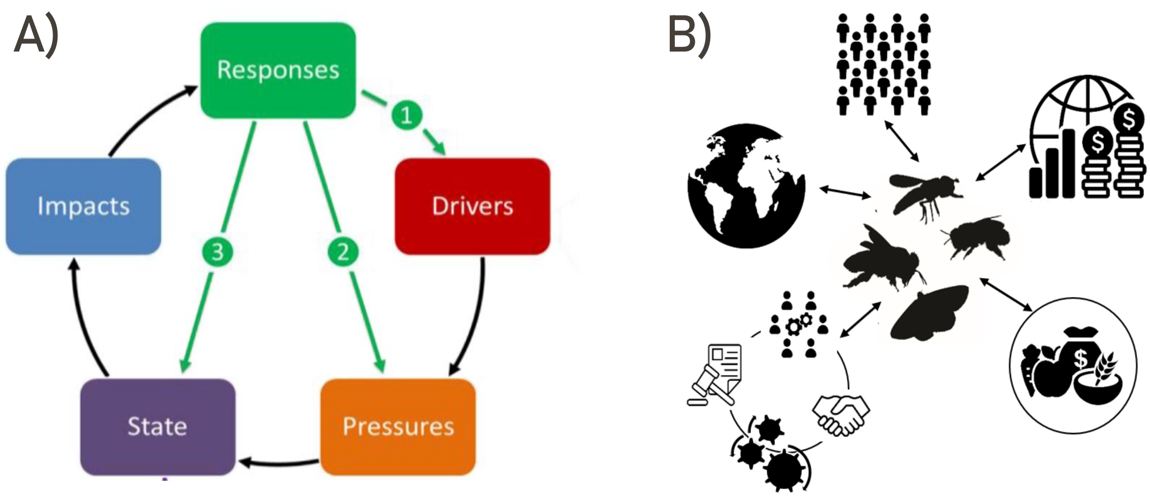

Figure 1 (A) Key elements and linkages in the socio-environmental DPSIR framework used by Safeguard. Numbers refer to the three pathways through which scientific, technical and societal responses can influence trends in Drivers, (❶), Pressures (❷) or the State (❸) of the system. **(B)** Pollinators and pollination services have ecological, socio-economic and cultural values to human societies that require multi-actor and multi-sector agreement to conserve them.

1.3 Objectives of the expert elicitation assessment

Our overall objectives were to assess the evidence for:

3) The **importance** of different **Pressures** to the **State** of wild pollinators and to various **Impacts** on the benefits to nature and human society that pollinators can provide.
4) The **effectiveness** of **Responses** (policy) in mitigating these **Pressures** or improving the **State**.

In both cases, we also elicited the level of certainty experts had about this knowledge using the IPBES 4-box model (see below).

Ultimately, a final objective is to identify knowledge gaps and future research priorities. This was anticipated to emerge from the assessment of evidence and expert confidence in that evidence.

2. Methodological approach

2.1 Scope of the expert elicitation assessment

2.1.1. Spatial scale

The scoring was done at the spatial scale of Europe. This was defined for this exercise as the totality of the EU member states, non-EU EEA member states (Iceland, Liechtenstein, Norway), candidate countries (Albania, Bosnia and Herzegovina, Moldova, Montenegro, North Macedonia, Serbia, Turkey, Ukraine) and the United Kingdom and Switzerland. Although the selection of experts (see below) took into account the desire for a geographical representation (North-South-East-West) of expert scorers, the focus of this specific exercise was to consider and score the general 'on average' picture for this European scale and not regional specific contexts. We acknowledge that this required making some general assumptions and acknowledging limits or loss of precision in certain situations.

2.1.2 Temporal scale

The evidence assessment and scoring were carried out for the period up to 2024 (Section 2.2.1). Then experts were tasked with reflecting on that evidence base and the resulting scores and give a subjective opinion on the direction of trend in the near future (2025-2035) for each Pressure-State and State-Impact. The experts were asked to decide if for 2025-2035 the various links in the P-S-I would become more important/effective than the situation up to 2024; not change or become less important/effective than the situation up to 2024 (Section 2.2.2). No evidence-based confidence terms could be associated with this forward projection as it was a subjective judgement. We also decided not to project forward for Responses over the period of 2025-2035 because the uncertainty was too great for experts to make a reliable judgement in the context of this type of scoring exercise.

2.1.3 Definitions of Agricultural, Urban and Semi-Natural Areas

To ensure that all experts understood what context they should be thinking of when scoring, we provided definitions of the agricultural, urban and semi-natural areas and the elements from which they are composed. For the purpose of this exercise, we also specified that when scoring the **importance** and **effectiveness of P-S-I-R**, that the experts should think in terms of the relationship **<u>within</u> the specified scope of the defined agricultural, urban or semi-natural area**. That is to say, when assigning a score experts were instructed to not consider the landscape-scale effects or processes that may spill-over at the interface of these areas. As an illustration, when scoring the importance of intensive land management in semi-natural areas, they were instructed not to take into account the contributing effects of a surrounding agricultural area. In addition, there was a specific Pressure parameter to be scored: '**Landscape Simplification'** (= homogenisation of landscape structure) that takes into account the landscape-scale spatial processes affecting wild pollinators.

Figure 2 *Photos of pollinator forage habitat in (A) agricultural, (B) semi-natural and (C) urban areas. Photo credit: A. Vanbergen*.

2.1.3.1 Definition of Agricultural area

Landscapes dominated (at least 75%) by conventional intensive agricultural monocultures (cereals, mass flowering crops, species-poor fertilised intensive grassland predominate). When it is present in an agricultural zone >75% of the human population are living in rural grid cells with low population densities (< 300 inhabitants per km^2).

A typical or representative farmed area with the following general characteristics (specific habitat examples are provided following EUNIS habitat classification):

- The farm is around 15ha in area (the mean in the EU in 2016, EC 2021[4])

[4] EC 2021 European food chain https://ec.europa.eu/eurostat/documents/3217494/13957877/KS-FK-21-001-EN-N.pdf/dcf8d423-fa1c-5544-0813-b8e5cde92b59?t=1645018342178

- About 70% of the land is used for arable agriculture (V11 : Intensive unmixed crops ; V311 : Dry or moist agriculturally-improved grassland), 25% for permanent grassland (R2 : Mesic grasslands) and 5% for permanent crops such as olives, nuts, grapes, top fruit (V62 : Evergreen orchards and groves V61 : Broadleaved fruit and nut tree orchards) or horticulture (V121 : Large-scale market gardens and horticulture) . (EC 2021)
- The farm focuses primarily on high yield production through conventional production methods (91.5% of farms were not organic in 2019, EC 2021);
- Conventional use of synthetic pesticides (including insecticides, herbicides, fungicides), and inorganic fertilisers allowed under current EU regulations, are applied at manufacturer recommended rates. Full IPM is not practised on the farm, but some general IPM principles have been adopted (e.g., in some cases targeted pesticide applications are used for specific pests rather than broad-spectrum pesticides).
- There is modest investment in the environment in cultivated areas; always meeting minimum legal requirements (e.g. Cross Compliance and Greening under CAP Pillar 1) and with some agri-environmental and climate measures being implemented to deliver public goods and services (CAP Pillar 2); In 2018, 80% of EU farm land was subject to at least one of the CAP greening obligations (https://copa-cogeca.eu/europeanfarming).
- There are small areas (no more than 5-10%) of uncultivated land of the farm area spared for nature on the farm. These comprise elements of **semi-natural habitats – see below definition and categories** – and may include small areas of high nature value woodlands, permanent grasslands, hedgerows (V43 : Species-rich hedgerows of native species) and wetlands.

2.1.3.2 Definition of urban area

Landscapes dominated by intermediate or densely populated (peri-)urban areas. Minimum human population at a density of >300 inhabitants per km^2 e.g., a population of ≥5000 people and so the scale of a large town or city.

- Urban areas can be defined as a zone where the majority of the land area (70-80%) covered, continuously or nearly continuously, by buildings, roads and other impermeable surfaces. The remaining ≤ 30-20% of the area can include various forms of "green space". These are variable and can include combinations of: waste lands and brownfield sites, woodland, public parks and other amenity spaces, public and private gardens, allotments for growing fruits and vegetables, cemeteries, ruderal vegetation alongside rivers and canals, rail and road infrastructure and in industrial zones.
- Associated EUNIS habitats: V2 : Cultivated areas of gardens and parks V122 : Small-scale market gardens and horticulture, including allotments V313 : Turf sports fields V314 : Park lawns V315 : Small-scale lawns V37 : Annual **anthropogenic** herbaceous vegetation V38 : Dry perennial **anthropogenic** herbaceous vegetation V39 : Mesic perennial **anthropogenic** herbaceous vegetation ; V41 : Hedgerows of non-native species V42 : Highly-managed hedgerows of native species ; V63 : Lines of planted trees ; T1H : Broadleaved deciduous **plantation** of non site-native trees T1K : Broadleaved deciduous **plantation** of site-native trees T2A : Broadleaved evergreen **plantation** of site-native trees T29 : Broadleaved evergreen **plantation** of non site-native trees

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Distribution_of_EU_farms_and_utilised_agricultural_area_according_to_farm_size,_2016_(%25).png

2.1.3.3 Definition of semi-natural area

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services defines semi-natural habitats as: "An ecosystem with most of its processes and biodiversity intact, though altered by human activity in strength or abundance relative to the natural state". This definition allowed us to include the fact that in Europe such semi-natural areas still tend to be managed (e.g., grazing, selective and minimal logging, hunting) for production, exploitation or conservation purposes. They are affected by wider human activities (recreation) or anthropogenic pollution from nearby or distant sources. These areas may (in certain situations, but not always) have a level of legal protection (e.g., Habitats Directive; Natura 2000) that governs their conservation and management (type and intensity).

Based on the EUNIS (habitat classification), we referred to the following four categories to define what can be included in the assessment of a semi-natural area:

- **R : Grasslands and lands dominated by forbs, mosses or lichens**
- **S : Heathland, scrub and tundra**
- **N : Coastal habitats**
- **T : Forest and other wooded land** (**including only** T1 : Deciduous broadleaved forest T2 : Broadleaved evergreen forest T3 : Coniferous forest T41 : Early-stage natural and semi-natural forest and regrowth). Note we **excluded here all highly managed anthropogenic forest plantings** (T1H : Broadleaved deciduous plantation of non site-native trees T1K : Broadleaved deciduous plantation of site-native trees T2A : Broadleaved evergreen plantation of site-native trees T29 : Broadleaved evergreen plantation of non site-native trees T3M : Coniferous plantation of non site-native trees T3N : Coniferous plantation of site-native trees V6 : Tree dominated man-made habitats T42 : Coppice and early stage plantations T43 : Recently felled areas)

When scoring semi-natural areas, experts were asked to think as broadly as possible about the contribution of the semi-natural habitat types (1-4) to wild pollinators and pollination, again thinking about the overall European picture. But if an expert was drawing on and framing their score around a particular type of semi-natural habitat, then they were asked to specify which type in the comments box provided in the scoring sheet.

2.2 Expert panel convened to score the links in the (D)PSIR model

In January 2024, 51 pollinator experts were invited to participate in the expert elicitation exercise and 42 accepted to carry out the individual-based assessments during 2024. We made efforts to balance the composition of the expert panel and achieved the participation of 30 experts from within the Safeguard consortium and 12 experts from other Horizon Europe or other projects. This resulted in 17 female and 25 male participants, with 29 in permanent research positions and 13 in non-permanent, post-doctoral research positions (**Table 1**). In terms of regional balance across Europe, we obtained contributions from northern (6, 14%), Western (16, 38%), Southern (10, 24%) and Central (8, 19%) experts, according to their host institution and not their individual nationality (**Figure 3**).

Table 1. *List of pollinator experts (anonymised), the country of the institution, whether they are part of the Safeguard consortium, the balance of gender (male or female – no one identified as non-binary), career stage (SNR = permanent position; ECR = non-permanent post-PhD) and their coverage of expertise according to ecosystem type (✓).*

No.	Country	Safeguard expert (Y/N)	Gender	Career stage	Agriculture	Urban	Semi-natural
1	SE	YES	M	SNR	✓		✓
2	DE	YES	M	SNR	✓	✓	✓
3	RS	YES	M	SNR	✓	✓	✓
4	UK	YES	M	SNR	✓		✓
5	BE	YES	M	SNR	✓	✓	✓
6	FR	NO	F	SNR	✓		✓
7	SE	YES	M	SNR	✓		
8	BE	YES	F	ECR	✓		
9	UK	YES	M	SNR	✓		✓
10	IE	NO	F	SNR	✓		✓
11	IT	YES	M	SNR	✓	✓	✓
12	UK	NO	F	SNR	✓	✓	✓
13	FR	NO	F	SNR	✓	✓	✓
14	UK	NO	M	SNR	✓		✓
15	UK	YES	F	SNR	✓	✓	✓
16	SE	YES	F	ECR			✓
17	PL	NO	F	SNR	✓	✓	✓
18	RS	YES	F	ECR	✓	✓	✓
19	IT	YES	F	ECR	✓		✓
20	UK	YES	M	SNR	✓	✓	✓
21	IT	YES	F	ECR	✓	✓	✓
22	SE	YES	M	SNR	✓		✓
23	FR	YES	M	ECR	✓	✓	✓
24	ES	YES	M	SNR	✓		✓
25	CH	YES	M	SNR	✓	✓	✓
26	SE	YES	M	SNR	✓		
27	FR	YES	M	SNR	✓	✓	✓
28	NL	YES	M	SNR	✓		✓
29	CH	YES	F	ECR	✓	✓	✓
30	DE	YES	F	SNR	✓	✓	✓
31	IT	YES	F	ECR	✓		✓
32	HU	YES	M	ECR	✓	✓	✓
33	ES	YES	F	SNR	✓		✓
34	GR	NO	M	SNR	✓		✓
35	RS	YES	F	ECR	✓		✓
36	BE	YES	F	ECR	✓		✓
37	UK	YES	M	SNR	✓		✓
38	DE	NO	M	ECR	✓		✓
39	DE	NO	M	SNR	✓	✓	✓
40	NL	NO	M	SNR	✓		✓

41	HU	NO	M	ECR	✓		✓
42	BE	NO	M	SNR	✓	✓	✓

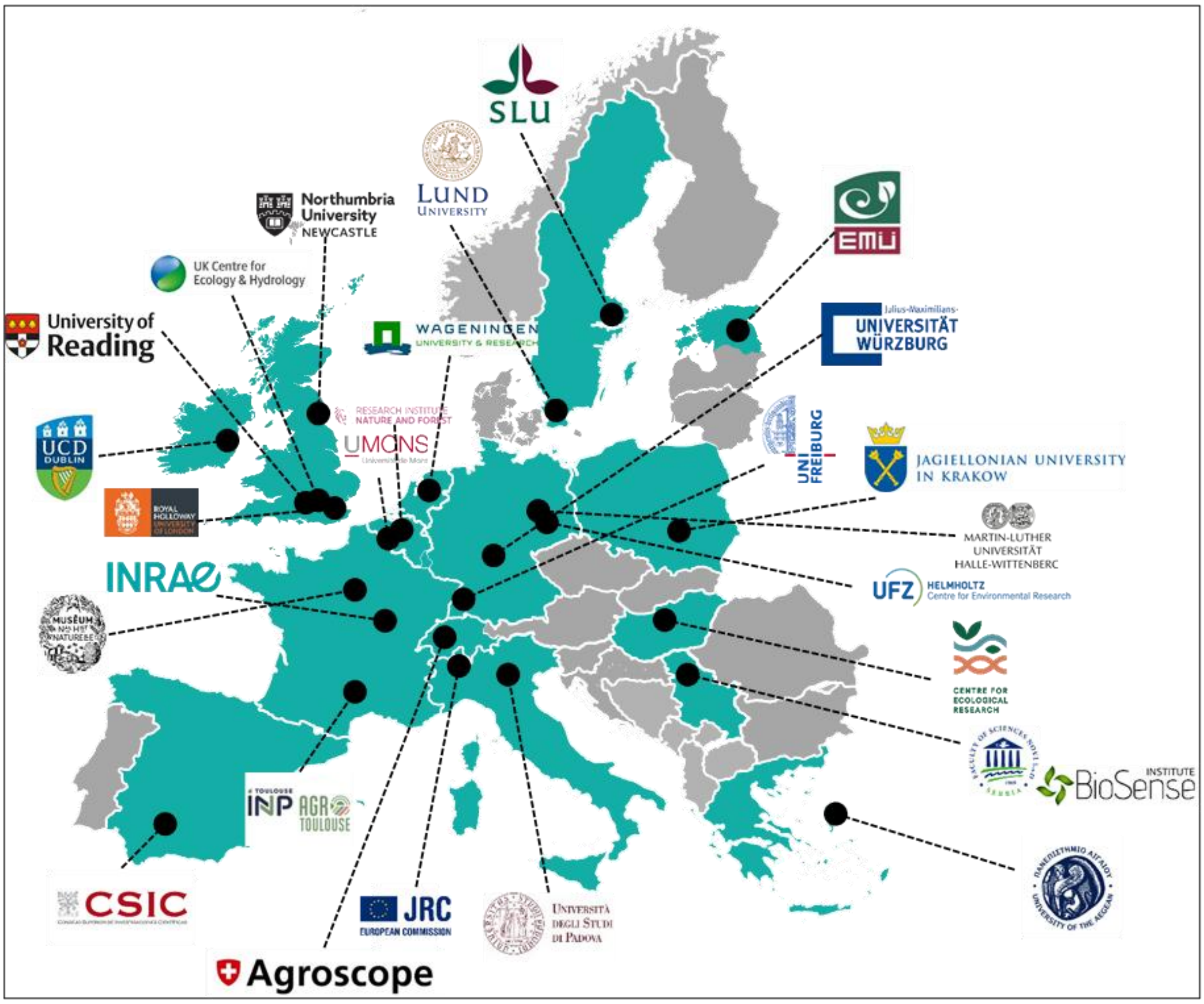

Figure 3. *Distribution of European research and higher education institutions that provided experts who participated in the Safeguard expert elicitation of the DPSIR framework for agricultural, urban and semi-natural ecosystems.*

2.2 Scoring approach and methodology

Using a predefined protocol and parameters the experts were to independently assign a score to the <u>importance</u> of (predefined by dialogue within the Safeguard consortium) parameters that form **the causal links between Pressures - State** and **State – Impact** and to score the **<u>effectiveness</u> of the links from Responses** (policy) in affecting change in the level of Pressure or the State of the system.

Experts were asked to consider the range of **direct or indirect effects that can be logically linked to the end point of "Wild Pollinators (and the functions/services they provide**)". We clearly pre-defined where effects are **direct** on wild pollinators (and their functions/services) or affect them **indirectly** (mediated via effects on floral resources, for example). They were also asked to consider the effects on **a single co-benefit (Wider biodiversity) and a single potential disservice (Pests & Weeds)**. This co-benefit and disservice were there to provide a parallel outcome that can arise from pressures or responses or effects on impacts. The reason being to provide possible downsides or perverse effects alongside the benefits of changing a system towards benefiting wild pollinator biodiversity, an important consideration in later discussions and validation steps with stakeholders.

At the same time as scoring the evidence the experts were tasked to rank their individual confidence in that evidence using the IPBES 4-box model terms up to 2024 (**Section 2.2.3**).

Following pre-testing of the method at INRAE, each expert was provided with a scoring template (Excel file) and separate guidance documents on the Scope (**Section 2.1**) and a Glossary for the complete listing and definitions of the parameters within each box of the framework so that all understood what was meant.

INRAE ran two online briefings and recorded these, which were circulated to the participants. Experts were able to contact the INRAE team coordinating the exercise with any specific questions. This individual and collective deliberative phase allowed the protocol to be revised and adapted to increase precision following feedback during the protocol development and after the first round of scoring. Scorers were free to carry out two rounds of scoring according to their personal schedule, but subject to the below timetable between March-September 2024.

Scorers were asked to each participate in:

1. A zoom briefing (x1 of 30 minutes) on the protocol and scoring sheet for groups of experts to hear about the study and to ask any questions. This was not compulsory, but recommended and the recording of the video briefing was supplied to all afterwards to help absentees.

2. Scoring 1: experts carried out an independent, desk-based scoring of PSIR using the protocol and scoring sheet, comments in support of scores are encouraged (especially where there is variability, such as idiosyncratic positive or negatives relationships). About 4 hours to complete the scoring was estimated based on testing.

3. A debriefing meeting by zoom (2-hours) for the presentation of round 1 initial results & to provide the opportunity for collective deliberative discussion about results, areas of convergence or divergence, and issues around the interpretation of the protocol. This was not compulsory, but recommended and the recording of the video briefing was supplied to all afterwards to help absentees.

4. Scoring 2: experts carried out an independent re-scoring of the PSIR based on the deliberative reflection on their original scores, modifications to definitions of parameters and refinements of the protocol.

2.2.1 Scoring protocol for the evidence up to 2024

At the **European scale**, for **each ecosystem type** (agricultural, urban and semi-natural areas) and over the period **up to 2024**, experts were asked to score each of the links between the various parameters in the PSIR framework in terms of the level of *importance* (magnitude of the effect), *effectiveness* (efficacy of a practice or a policy in creating a desired change) and the associated certainty (the level of confidence or certainty based on my knowledge of the available quality and quantity of the evidence).

We provided a series of framing questions to the scorers within the template and protocol:

1. Pressure-State How **important** is each **PRESSURE** likely to be in terms of <u>altering</u> the various **STATE** variables of wild pollinators and pollination?

2. State-Impact: How **important** is a particular **STATE** of wild pollinators and pollination going to be for the various environmental or socio-economic **IMPACT**s (affecting ecosystem function and human well-being)?

3.Response-Pressure: How **effective** is each **RESPONSE** likely to be in directly alleviating the **PRESSURE**s on wild pollinators and pollination?

4.Response-State: How **effective** is each **RESPONSE** likely to be in directly improving the **STATE** of wild pollinators and pollination?

The experts used a **5 point-Likert-like scale** for scoring either importance or effectiveness of above PSIR links.

For scoring the **importance** of **Pressure on State** and the later **State** consequences for **Impacts** the following scoring classification system was used:

> 1.P-S and 2.S-I**:** (0) neutral or no impact; (1) not important; (2) a little important; (3) important; (4) very important and (5) the most important.

For scoring **Response effectiveness** on **Pressure and State** the following scoring system was used:

> 3.R-P and 4.R-S**:** (0) neutral or no effect; (1) little effect; (2) slightly effective; (3) effective; (4) highly effective; (5) extremely effective.

Note: a score of the effectiveness or importance equal to 0 (zero) means that it has a neutral or no effect. But this also means there must be a level of evidence associated with it and hence a confidence can be attached to that evidence according to the IPBES 4 box model (Section 2.2.3). This distinguishes a score of zero from NL or IDK (see below).

Although the coordinating team tried to foresee all possibilities, the experts were also allowed to assign a **categorical 'score' of No Link (NL)** where they thought there was no possible direct or (significant) indirect linkage. **A category of 'IDK'** (I Don't Know) was also available where the individual expert had no knowledge to support a ranking of importance/effectiveness or confidence in the evidence. Experts were encouraged to use this statement only where they were completely unaware of any evidence/knowledge to assign a score and a level of confidence.

2.2.2 Scoring protocol for forward projection for 2025-2035

For 2025-2035, experts were asked to provide a subjective opinion on the direction of trend in the near future for each **Pressure-State** and **State-Impact** relationship. Linkages between Responses and Pressures or States were not scored over the period of 2025-2035 because the uncertainty was too great for experts to make a reliable judgement. Experts were asked to repeat the scoring exercise focussed on the next 10 years and provide a rescoring of each link according to their judgement on how the P-S and S-I links might change. The experts applied the following three categories to their original scoring matrix:

- **More** = more important/effective than situation up to 2024;
- **Same** = no change to situation up to 2024
- **Less** = less important/effective than the situation up to 2024.

Subsequently the data were coded as 1 (More) / 0 (Same) / -1 (Less) and summed over all scores provided to derive the expected future trend, defined as the number of experts expecting an increase minus the numbers of experts expecting a decrease.

2.2.3 Assigning and communicating the level of confidence in scores: the IPBES four box model.

The four-box model **(Figure 4)** of the qualitative communication of confidence in an evidence base was employed in this assessment exercise.

For each score, experts were asked to **assign a level of confidence** (or certainty) in the quality and the quantity of the evidence underpinning each score (P-S /S-I / R-P /R-S) on **a categorical scale** as follows:

(I) Inconclusive: existing as or based on a suggestion or speculation; no or limited evidence

(U) Unresolved: multiple independent studies exist but conclusions do not agree

(EI) Established but Incomplete: general agreement although only a limited number of studies exist but with no comprehensive synthesis, or the studies that do exist imprecisely address the question

(WE) Well established: comprehensive meta-analysis or other syntheses and/or multiple independent studies that agree

This 4-box model has become well established in expert-based assessments by the IPBES since 2012. Its advantage is that it allows a synthesis of the quantity & quality of the evidence and the level of agreement (consistency) in that evidence through four statements that are simple to convey and understand. These statements are well used in the policy community (national, EU, international).

Note: Confidence increases towards the top-right corner as suggested by the increasing strength of shading. 'Well-established' can be further subdivided into 'very well established' and 'virtually certain'.
Source: IPBES, 2016.

Figure 4 *The four-box model for the communication of confidence in scientific evidence* - after IPBES 2016.

2.2.4 PSIR parameters scored by the experts.

Using the protocol, the experts independently scored the importance of parameters that form the causal links between Pressures - State and State – Impact and scored the effectiveness of the links from Responses (policy) in affecting change in the level of Pressure or the State of the system. State parameters were pre-defined as effects that are direct on wild pollinators (and their functions/services) or affect them indirectly mediated via a third party. The parameters to be scored in the expert elicitation were predefined by the INRAE and LUND teams and are listed in **Table 2** definitions are provided in **Annex 1.**

Table 2. *List of PSIR parameters scored by 42 pollinator experts that can be logically linked to the end point of "Wild Pollinators and the functions/services they provide. Responses: Green = applicable to agricultural, urban and semi-natural areas; Violet = applicable to applicable to agricultural and urban areas; Blue = urban areas only; Orange = agricultural areas only.*

Pressures	State	Impact	Response
1.Landscape simplification [i]	1.Wild pollinator abundance & diversity (DIRECT effect)	1.Crop pollination & production (amount, yield stability)	1. Recreation or restoration of ecological zones
2.Intensive land management	2. Effects of managed bee abundance on wild pollinators (INDIRECT effect)	2.Economic value chain (farm-to-fork) [iv]	2. Biodiversity Strategies and Initiatives
3.Pesticides (use & high frequency) [ii]	3.Effects of floral resource diversity & abundance on wild pollinators (INDIRECT effect)	3.Nutritional diversity (e.g. vitamin A)	3. Nature Protection Regulations
4.Bee Management (competitive pressure)	4. Effects of Habitat resources (nest sites, water) on wild pollinators (INDIRECT effect)	4.Wild plant pollination services	4. Integrated Pest Management (IPM)
5.Pollinator parasites and pathogens (including spillover)	5.Wider biodiversity (birds, mammals etc) (DIRECT CO-BENEFIT)	5.Aesthetic values	5. Regulation of plant protection products (= pesticides)
6.Invasive alien species	6. Pest & Weed abundances (DIRECT DISSERVICE)	6.Cultural values	6. Certification Schemes
7.Climate change [iii]	7.Effects of weed diversity & abundance on wild pollinators (INDIRECT effect)	7.Honey production	7. Urban Greening Plans
		8.Ecosystem functioning (e.g., web of life)	8. Sustainable Intensification of Agriculture (SIA)
			9. Organic farming
			10. Ecological Intensification of Agriculture (EIA)

			11. Diversified farming systems (DFS)
			12. Conservation or Regenerative agriculture
			13. Economic incentives for Agri-Environmental Schemes

i Sole landscape process scored, i.e. the consequences for each variable considered of the process of landscape simplification beyond the focal habitat itself.
ii Assuming no pesticide use within SNH itself.
iii Climate change occurs at global to regional scales, but here we considered only effects within the designated habitat areas
iv Assuming no direct economic values from wild pollinators within semi-natural habitat

3. Results of the expert elicitation

We report and visualise below the median scores of 42 scientific experts for the importance of parameters that form the causal links between Pressures – State (**Section 3.1**) and State – Impact (**Section 3.2**) and for the effectiveness of the links from Responses (policy) in affecting change in the level of Pressure (**Section 3.3**) on or the State (**Section 3.4**) of wild pollinators (and their functions/services). The scores refer to the level of importance/effectiveness of each factor in turn, and do not necessarily constitute a relative ranking, e.g., more than one factor might be scored as a 'most important' factor. Our below description of the expert elicitation focuses solely on parameters that, according to the experts, attained a minimum median score of 3 (= 'important' or 'effective') or above (4 = very important or highly effective; 5 = most important or extremely effective). Definitions of pressures, states, impacts and responses are found in Annex 1.

3.1 The importance of multiple Pressures affecting the State of pollinators

Landscape simplification and intensive land management were scored as either the **'most important'** or **'very important'** pressures on wild pollinator biodiversity and their floral resources *[Well established]* in agricultural, urban and semi-natural areas (**Figure 5**). These pressures were also either the '**most important**' or '**very important**' pressures on other habitat resources needed by wild pollinators in agricultural *[Well established]*, urban, and semi-natural areas *[Established but Incomplete]* (**Figure 5**).

Pesticide use was scored as a '**very important**' pressure on wild pollinators in both agricultural and urban areas *[Established but Incomplete]* and on floral resources in agricultural *[Well Established]* and urban areas *[Established but Incomplete]* (**Figure 5**).

Intensive land management and pesticide use were ranked as '**very important**' in affecting the floral offer to wild pollinators from weed diversity *[Established but incomplete]* and disservices from pests and weeds *[Well Established]* in both agricultural and urban ecosystems (**Figure 5**). Landscape simplification and intensive land management were judged to be a '**most important**' or '**very important'** pressure on wider biodiversity in agricultural *[Well Established]*, urban *[Established but Incomplete]*, and semi-natural *[Well Established]* areas (**Figure 5**).

Compared to the above pressures, climate change was ranked in all three ecosystems as currently a lesser, but nonetheless **'important'** pressure for wild pollinators and their floral resources, and also for wider biodiversity and pest and weed disservices *[Established but incomplete]*. Climate change also ranked as being **'important'** in affecting other habitat resources and weed diversity [Unresolved] (**Figure 5**).

Invasive alien species were '**important'** in directly affecting wild pollinator biodiversity in urban *[Unresolved]* and semi-natural *[Established but incomplete]* ecosystems, while in all three ecosystems, they indirectly affected pollinators through effects on floral resources and weed diversity *[Established but incomplete]* (**Figure 5**). Invasive alien species were also an '**important'** factor influencing wider biodiversity and the disservice of pests and weed abundance in all three ecosystems *[Established but incomplete]* (**Figure 5**).

Bee management was scored as **'very important'** in urban or semi-natural ecosystems or among the '**most important'** pressures in agricultural areas in affecting managed bee effects on wild pollinators via resource competition in all environments *[Established but incomplete]* (**Figure 5**). Parasites and pathogens were ranked as a **'very important'** pressure in all environments, via managed bee abundance and corresponding chances of pathogen spill-over *[Established but incomplete]* (**Figure 5**).

3.2 The importance of multiple States to Impacts on the benefits pollinators provide to ecosystems and people

Wild pollinator biodiversity was ranked as the '**most important**' factor in wild plant pollination and ecosystem functioning in agricultural and semi-natural environments *[Well Established]* (**Figure 6**), and as **'very important'** in urban areas *[Established but Incomplete]* (**Figure 6**). Wild pollinators were also scored as **'very important'** to crop pollination services in agricultural *[Well Established]* and urban environments *[Established but Incomplete]* (**Figure 6**). Wild pollinators were correspondingly ranked as '**very important'** and **'important'** to creating economic value linked to cropping in agricultural and urban areas *[Established but Incomplete]*, respectively (**Figure 6**). They equally held '**very important'** (agricultural, semi-natural) or **'important'** (urban) contributions to human nutritional diversity from cropped or wild growing plants *[Established but Incomplete]* (**Figure 6**). Wild pollinators were deemed to create cultural and aesthetic values ranging from '**important'** to **'very important'** in all three environmental contexts *[Unresolved]* (**Figure 6**).

Floral resources of pollinators were a key indirect influence on most Impacts linked to wild pollinators (**Figure 6**). They were scored as **'very important'** to wild plant pollination [all, *Established but Incomplete]*, ecosystem functioning [agricultural & semi-natural: *Well established*; urban: *Established but Incomplete*], crop pollination [agricultural & urban: *Established but Incomplete*], and honey production [all, *Established but Incomplete*] (**Figure 6**). They were also a **'most important'** (agricultural & urban) or **'very important'** (semi-natural) influence on aesthetic values *[Established but Incomplete]* and a **'very important'** influence on cultural values *[all, Established but Incomplete]* (**Figure 6**).

The specific effect of weed diversity on pollinators was scored as **'important'** for wild plant pollination *[agricultural & urban: Unresolved; semi-natural: Established but Incomplete]*, ecosystem functioning *[agricultural & semi-natural: Established but Incomplete; urban: Unresolved]*, crop pollination *[agricultural: Established but Incomplete; urban: Unresolved]* and associated economic value *[Unresolved]* in agricultural systems (**Figure 6**).

Other habitat resources by providing nesting sites, fresh water etc to wild pollinators were also scored as being '**very important'** to ecosystem functioning *[all, Established but Incomplete]* and wild plant pollination in agricultural & semi-natural areas *[Established but Incomplete]* and **'important'** to wild plant pollination in urban areas *[Unresolved]* (**Figure 6**).

The potential competition from managed bee abundance on wild pollinators was important in influencing Impacts linked to wild pollinators. Managed bee abundance was obviously the **'most important'** direct influence on honey production *[agricultural& semi-natural: Well Established; urban: Established but Incomplete]*. Managed bees were also ranked as **'very important'** *[agricultural: Established but incomplete]* or **'important'** *[urban: Established but incomplete]* in affecting the crop pollination services provided by wild insects, with **'important'** consequences for economic values in agricultural areas *[Established but incomplete]* (**Figure 6**). In all three environments, the effect of managed bee abundance was ranked as **'important'** in affecting the role of wild insects in ecosystem functioning *[Established but Incomplete]* and wild plant pollination specifically *[agricultural & semi-natural: Established but Incomplete; urban: Unresolved]* (**Figure 6**).

In terms of the benefits of wider biodiversity that interact directly or indirectly with pollinators, it was determined that this was among the **'most important'** *[semi-natural Well established]* or **'very important'** *[agricultural & urban Established but Incomplete]* factors affecting ecosystem function (**Figure 6**). In addition, wider biodiversity had a 'very important' effect on aesthetic and cultural values in all three environments *[Established but Incomplete]* (**Figure 6**).

Disservices from weeds and pests were considered **'important'** impacts on ecosystem function in all environments *[Established but Incomplete]*. They were ranked as **'very important'** and **'important'** to crop pollination in agricultural environments and urban areas, respectively [Established but Incomplete] and **'important'** to economic values in both settings *[Established but Incomplete]* (**Figure 6**).

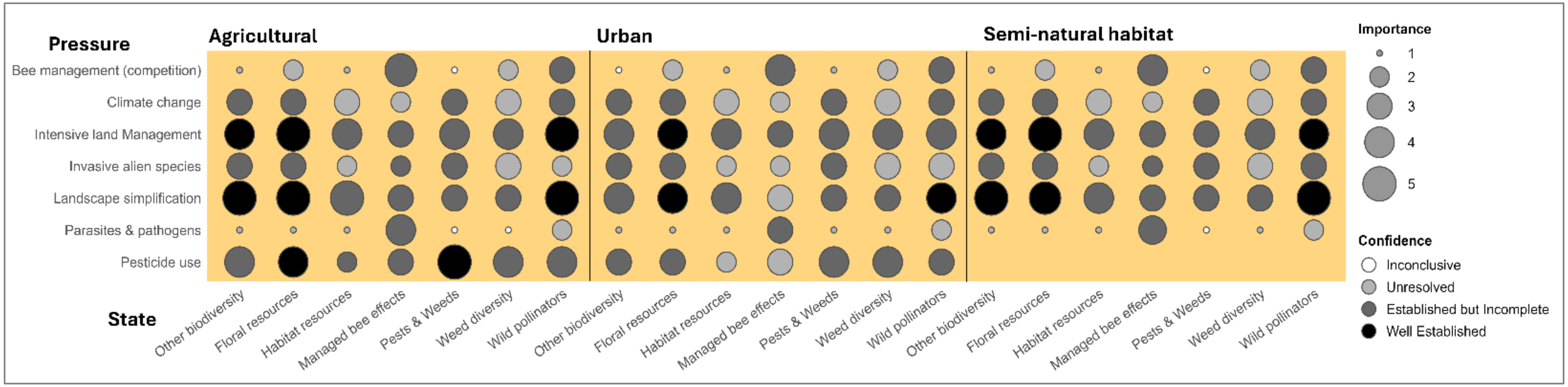

Figure 5. *The importance (median score of 42 experts) of **PRESSURES** in terms of altering various **STATE** variables linked to wild pollinators and pollination in each ecosystem type (agricultural, urban and seminatural - see 2.1.3 for definitions). Size of circles indicates degree of importance: (0) neutral or no impact; (1) not important; (2) a little important; (3) important; (4) very important and (5) the most important. The shading of the circle indicates the median level of expert confidence in the evidence underpinning the scores of importance (see Fig.4). Blank columns in the panel for semi-natural habitat (pesticide use) indicate parameters that were considered not applicable and unscored due to their logical absence according to the scope of the expert elicitation i.e., scores only considered effects <u>within</u> the specified agricultural, urban or semi-natural area with the exception of landscape simplification (see section 2.1)*

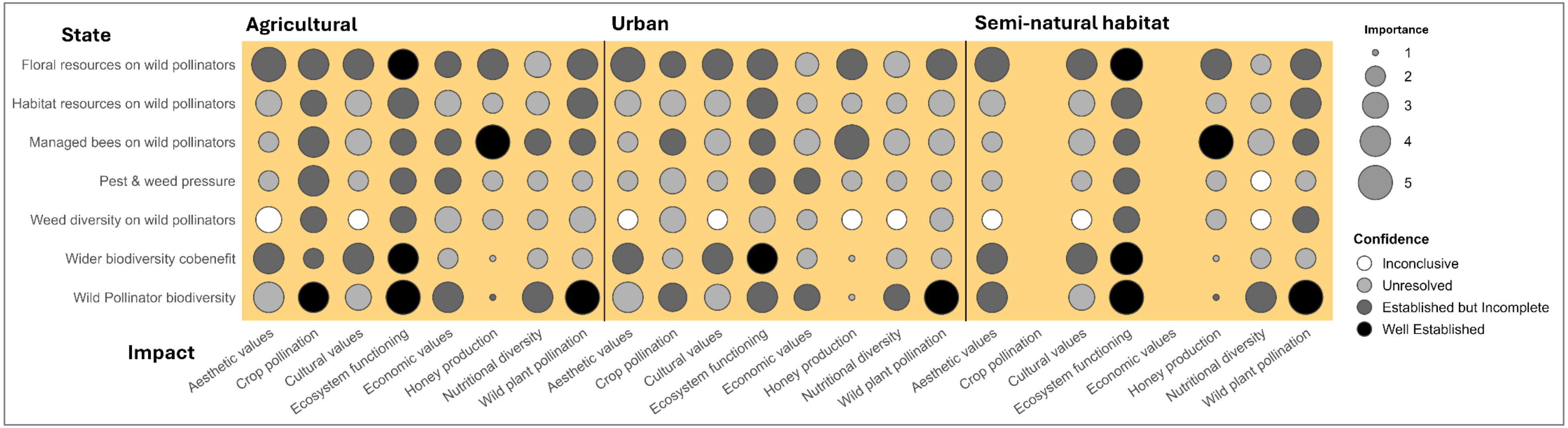

Figure 6. *The importance (median score of 42 experts) of each ecosystem* ***STATE*** *variable linked to wild pollinators and pollination for environmental or socio-economic* ***IMPACTs****, affecting ecosystem function and human well-being. Size of circles indicates degree of importance: (0) neutral or no impact; (1) not important; (2) a little important; (3) important; (4) very important and (5) the most important. The shading of the circle indicates the median level of expert confidence in the evidence underpinning the scores of importance (see Figure 4). Blank columns in the panel for semi-natural habitat (Crop pollination & Economic values) indicate parameters that were not applicable and unscored due to their logical absence according to the scope of the expert elicitation i.e., scores only considered effects within the specified scope of agricultural, urban or semi-natural area with the exception of landscape simplification (see section 2.1). Note: we considered direct economic values only, which is why there are no scores for semi-natural habitats (which might offer through their effects on pollinators indirect economic values.*

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3.3 The effectiveness of multiple Responses (policy and practice) in alleviating Pressures on pollinators

The recreation or restoration of ecological zones (habitats, landscapes, ecosystems) was ranked as an **'extremely effective'** policy response to easing the effects on wild pollinators of landscape simplification *[semi-natural Well established; urban and agricultural: Established but Incomplete]* and **'highly effective'** for mitigating intensive land management in all areas *[Established but Incomplete]* (**Figure 7**). This policy response was also scored as **'effective'** in addressing the pressure from climate change *[Established but Incomplete]* and invasive alien species *[Unresolved]* on wild pollinators in all three environments (**Figure 7**).

Nature protection regulations were considered to be **'highly effective'** in semi-natural areas and 'effective' in agricultural and urban zones at alleviating the pressures from landscape simplification [Established but Incomplete] and intensive land management *[Established but Incomplete]* (**Figure 7**). These regulations were also ranked as being potentially **'effective'** against effects of pesticides on wild pollinators in agricultural and urban areas *[Unresolved]* and pressure from climate change and invasive alien species in all three environments *[Unresolved]* (**Figure 7**). Biodiversity strategies were ranked as potentially **'highly effective'** and **'effective'** at reducing the effects of landscape simplification and intensive land management respectively in semi-natural systems, and **'effective'** in urban and agricultural zones *[Unresolved]* (**Figure 7**). Such strategies were also deemed potentially '**effective'** against climate change effects in the three ecosystems *[Unresolved]* (**Figure 7**).

Regulation of plant protection products was ranked as **'highly effective'** at reducing the pressure from pesticide use [agricultural *Well established; urban Established but Incomplete]* and **'effective'** at alleviating the effects of intensive land management *[*agricultural *Established but Incomplete;* urban *Unresolved]* (**Figure 7**). Certification schemes such as voluntary, market-oriented schemes or standards were ranked as **'effective'** at minimising the pressure from pesticide use *[agricultural & urban Unresolved]* and intensive land management *[*agricultural *Unresolved]* (**Figure 7**).

Urban greening was evaluated as **'highly effective'** against effects of landscape simplification and **'effective'** in alleviating pressure from climate change and intensive land management inhuman settlements *[Established but Incomplete]* (**Figure 7**).

Different farming systems and practices have the potential to contribute to alleviating multiple pressures in agricultural systems. Sustainable agriculture (defined as technological precision farming to increase efficiency) was ranked as **'effective'** at reducing the pressure from pesticide use *[Established but Incomplete]* and intensive land management *[Unresolved]* (**Figure 7**). Organic farming was scored as being **'highly effective'** at reducing pesticide pressure *[Well Established]* and **'effective'** in reducing the intensity of land management *[Established but Incomplete]* (**Figure 7**). Economic incentives for agri-environmental schemes (AES) were ranked as **'effective'** against the pressures of landscape simplification, intensive land management and pesticide use *[Established but Incomplete]* (**Figure 7**). Integrated pest management as a practice was ranked as **'highly effective'** against pesticide use *[agricultural & urban Established but Incomplete]* and **'effective'** at reducing effects of intensive land management *[*agricultural *Established but Incomplete;* urban *Unresolved]* on pollinators. Diversification of farming systems (e.g., mixed systems with complex crop rotations) were scored as **'highly effective'** against landscape simplification and **'effective'** at reducing the pressure from pesticide use and intensive land management *[Established but Incomplete]* (**Figure 7**). Conservation or regenerative agriculture was scored as **'effective'** against landscape simplification, intensive land management *[Established but Incomplete]* and also pesticide use and climate change *[Unresolved]* (**Figure 7**). Ecological intensification of agriculture ranked overall most highly among farming systems being **'highly effective'** at reducing pressure from landscape simplification, intensive land management, pesticide use *[Established but Incomplete]* and also **'effective'** against climate change *[Unresolved]* effects on wild pollinators (**Figure 7**).

3.4 The effectiveness of multiple Responses (policy and practice) in directly improving the State of pollinators and their functions or services

Recreating or restoring ecological zones was scored as an **'extremely effective'** response to directly improving the state of wild pollinators, floral resources and wider biodiversity in agricultural and semi-natural areas *[Well established]* and **'highly effective'** for wild pollinators *[Well established]*, floral resources and wider biodiversity *[Established but Incomplete]* in urban zones. Nature restoration also was determined at being **'highly effective'** in providing other habitat resources to pollinators in all environments *[Established but Incomplete]* (**Figure 8**).

Nature protection regulations were ranked as **'highly effective'** at improving the state of wild pollinators and floral resources in semi-natural and agricultural areas and **'effective'** in urban areas *[Established but Incomplete]* (**Figure 8**). They were also scored as **'highly effective'** or **'effective'** in improving the state of wider biodiversity [agricultural and semi-natural *Well established*; urban *Established but Incomplete*] and habitat resources *[Established but Incomplete]* in all three areas (**Figure 8**). Biodiversity strategies were ranked as **'effective'** at improving the state of the ecosystem for wild pollinators, floral and other habitat resources and wider biodiversity in all three environments *[Established but Incomplete]* (**Figure 8**).

Regulation of plant protection products was ranked as **'highly effective'** and **'effective'** at improving the state of wild pollinator biodiversity in agricultural and urban areas, respectively *[Established but Incomplete]* (**Figure 8**). This regulation as also scored as **'effective'** in improving the state of floral resources in both urban and agricultural zones, and weed diversity and reducing the competitive effect of managed bee abundance on wild insects in agricultural areas *[Established but Incomplete]* (**Figure 8**). Regulation of plant protection products was also deemed **'effective'** at improving wider biodiversity and ameliorating disservices from pests or weeds in agricultural and urban areas *[Established but Incomplete]* (**Figure 8**).

In terms of different farming systems, diversified farming was scored as **'highly effective'** *[Established but Incomplete]* at improving the state of wild pollinator biodiversity, while ecological intensification *[Established but Incomplete],* economic incentives for agri-environmental schemes *[Established but Incomplete]*, conservation or regenerative agriculture *[Unresolved]*, IPM *[Unresolved]*, and sustainable(precision) agriculture *[Unresolved]* were ranked as **'effective'** (**Figure 8**).

For floral and other habitat resources, agri-environmental schemes [floral & habitat: *Established but Incomplete*], ecological intensification [floral: *Established but Incomplete*; habitat: *Unresolved*] and diversified farming [floral: *Established but Incomplete*; habitat: *Unresolved*] and conservation/regenerative agriculture [floral & habitat: *Unresolved*] were scored as **'effective'** in improving for pollinating insects (**Figure 8**). Ecological intensification, diversified farming *[Unresolved]* and IPM *[Established but Incomplete]* were considered **'effective'** in affecting weed diversity that can provide floral nutrients to pollinators, while ecological intensification and diversified farming *[Unresolved]* also can reduce the competitive effect of managed bee abundance on wild insects (**Figure 8**).

Ecological intensification, diversified farming *[Established but Incomplete]* and conservation/regenerative agriculture *[Unresolved]* were scored as **'effective'** in influencing wider biodiversity and disservices from pests and weeds (**Figure 8**). IPM was scored as **'highly effective'** [agriculture & urban: *Established but Incomplete*] and sustainable (precision) agriculture as **'effective'** in limiting pest and weed disservices *[Unresolved]* (**Figure 8**).

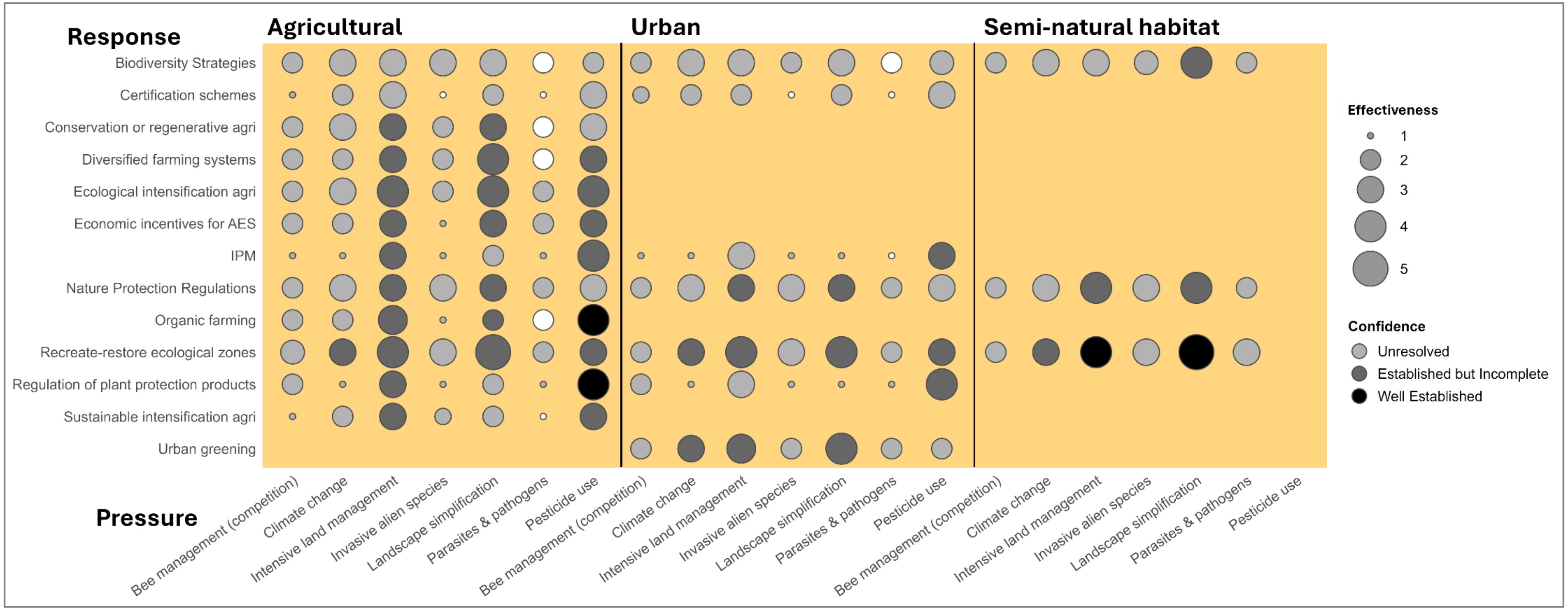

Figure 7. *The effectiveness (median score of 42 experts) of each policy* ***RESPONSE (****if implemented) in terms of alleviating various* ***PRESSURES*** *affecting wild pollinators (and the services/functions they provide). Also shown are the effects on a single co-benefit (Wider biodiversity) and a single potential disservice (Pests & Weeds). Size of circles indicates degree of effectiveness: (0) neutral or no effect; (1) little effect; (2) slightly effective; (3) effective; (4) highly effective; (5) extremely effective. The shading of the circle indicates the median level of expert confidence in the evidence underpinning the scores of importance (see Figure 4). Blank columns in the panels indicate parameters that were not applicable and unscored due to their logical absence according to the scope of the expert elicitation i.e., scores only considered effects* <u>*within*</u> *the specified scope of agricultural, urban or semi-natural areas with the exception of landscape simplification (see section 2.1)*

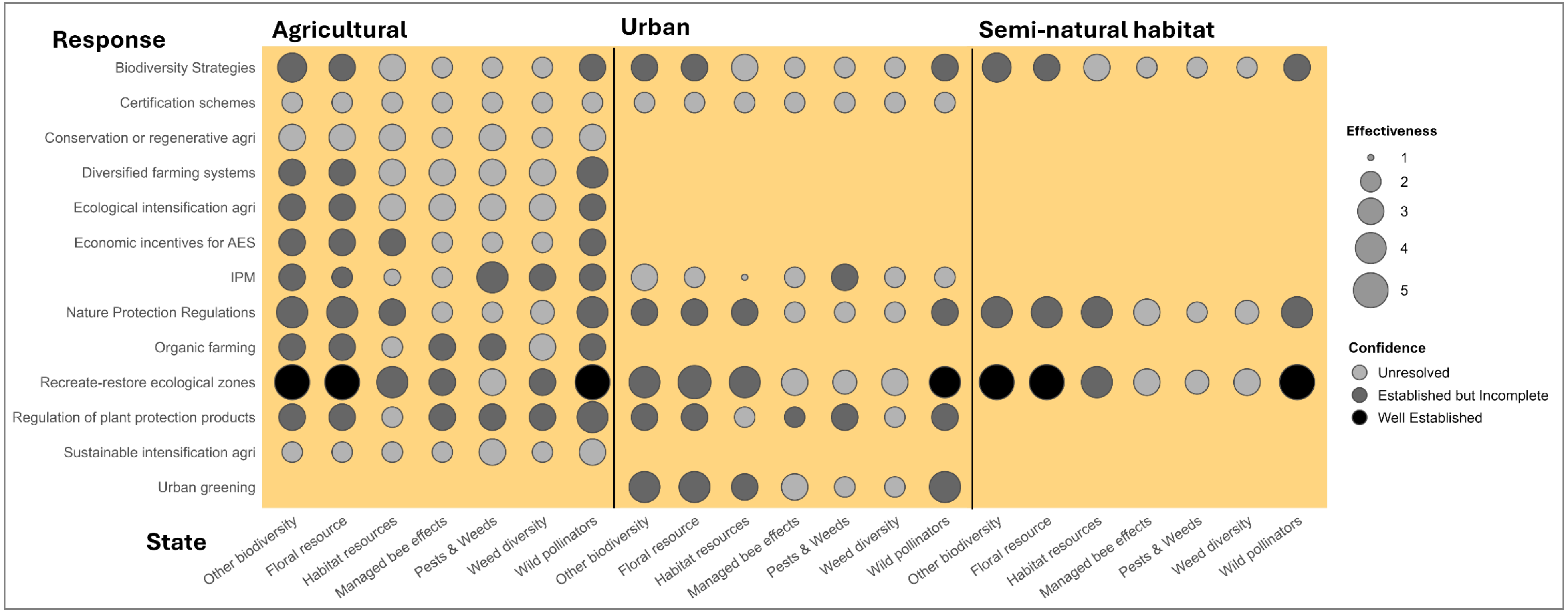

Figure 8. *The effectiveness (median score of 42 experts) of each policy* ***RESPONSE*** *(if implemented) in improving ecosystem* ***STATE*** *variables linked to wild pollinators (and the services/functions they provide). Also shown are the effects on a single co-benefit (Other biodiversity) and a single potential disservice (Pests & Weeds). Size of circles indicates degree of effectiveness: (0) neutral or no effect; (1) little effect; (2) slightly effective; (3) effective; (4) highly effective; (5) extremely effective. The shading of the circle indicates the median level of expert confidence in the evidence underpinning the scores of importance (see Figure 4). Blank columns in the panels indicate parameters that were not applicable and unscored due to their logical absence according to the scope of the expert elicitation i.e., scores only considered effects* <u>*within*</u> *the specified scope of agricultural, urban or semi-natural area with the exception of landscape simplification (see section 2.1)*

3.5 Expert-based projections of trends in links between Pressures, States and Impacts for 2025-2035.

A majority of the pressures were anticipated to increase in importance over the next 10 years with regard to their influence on the state of wild pollinators and related ecosystem attributes. There was a large degree of consensus among the experts that **climate change** and **invasive alien species** will increase in importance relative to the period up to 2024 in all ecosystem types, in line with ongoing climate change and, often associated, spread of invasive alien species (IAS) **(Figure 9)**. **Parasites and pathogens** were also rated by the experts as being likely to grow in importance as a problem in the near future, this projection will be related to the chance that changing climate and spread of non-native species may lead to emerging pest and pathogen problems in the European continent **(Figure 9)**. **Landscape simplification** effects on wild pollinator 'States' were expected to increase in importance, albeit to a lower degree than projections for climate change, IAS and pests and pathogens **(Figure 9)**. This might be indicative of the fact that a predominant amount of the European land surface has already become increasingly structurally simple (low habitat diversity or heterogeneity) over the 20-21st century due to large-scale conventional intensive land management (see Annex 1 for definition) coupled to spread of artificial surfaces (urbanization). It is likely that perceptions concerning food security or sovereignty may maintain the land surface under conventional intensive agriculture, or even extend it to areas previously considered uneconomic or marginal for food production. Political and socio-economic reasons may therefore continue to lead to landscape simplification continuing as a notable pressure in Europe.

Only a few pressures were projected by experts to decrease in importance to wild pollinators and linked ecosystem attributes over the period 2025-2035. The importance of **pesticide-use** as an influencing factor on wild pollinator biodiversity and other state variables was overall expected to be reduced in agricultural and especially in urban areas **(Figure 9)**. Even with recent (2024-2025) push-back by some parts of the agricultural industry and political implications, the scientific evidence for non-target effects, together with wider societal non-acceptance on environmental or human health grounds, makes it more likely that efforts will continue to grow to minimize pesticide use via combinations of precision applications, other (bio)technologies and use of alternative systems of pest and weed control (e.g., sustainable farming systems, mechanical control).

Intensive land management in urban areas was also expected to be a pressure that reduced in importance compared to the situation up to 2024 **(Figure 9)**. This assessment reflects societal actions across Europe (e.g., arising from the EU Green Deal, local governmental and citizen initiatives etc.) leading to national and municipal governments formalizing various actions to adapt to climate change and address the biodiversity crisis by recreating habitats/green infrastructure and reducing the levels of management intensity of public lands (e.g., reduced chemical use, reduced frequency of mowing). Intensive land management can have a great impact on wild pollinators, floral resources and other biodiversity (**Figure 5**), but nature protection regulation and habitat restoration can reduce such negative effects (**Figure 7-8**). The adoption of the NRR into European law (the first such continental-scale law worldwide) may be reflected in the a relatively optimistic perspective of experts in projecting overall an attenuation of negative land management effects in agricultural and, particularly, semi-natural areas **(Figure 9)**.

The effects of potential competition from managed bees (mostly honeybees) on wild pollinators was overall considered to be only a relatively minor concern, compared to other factors, in the coming decade **(Figure 9)**.

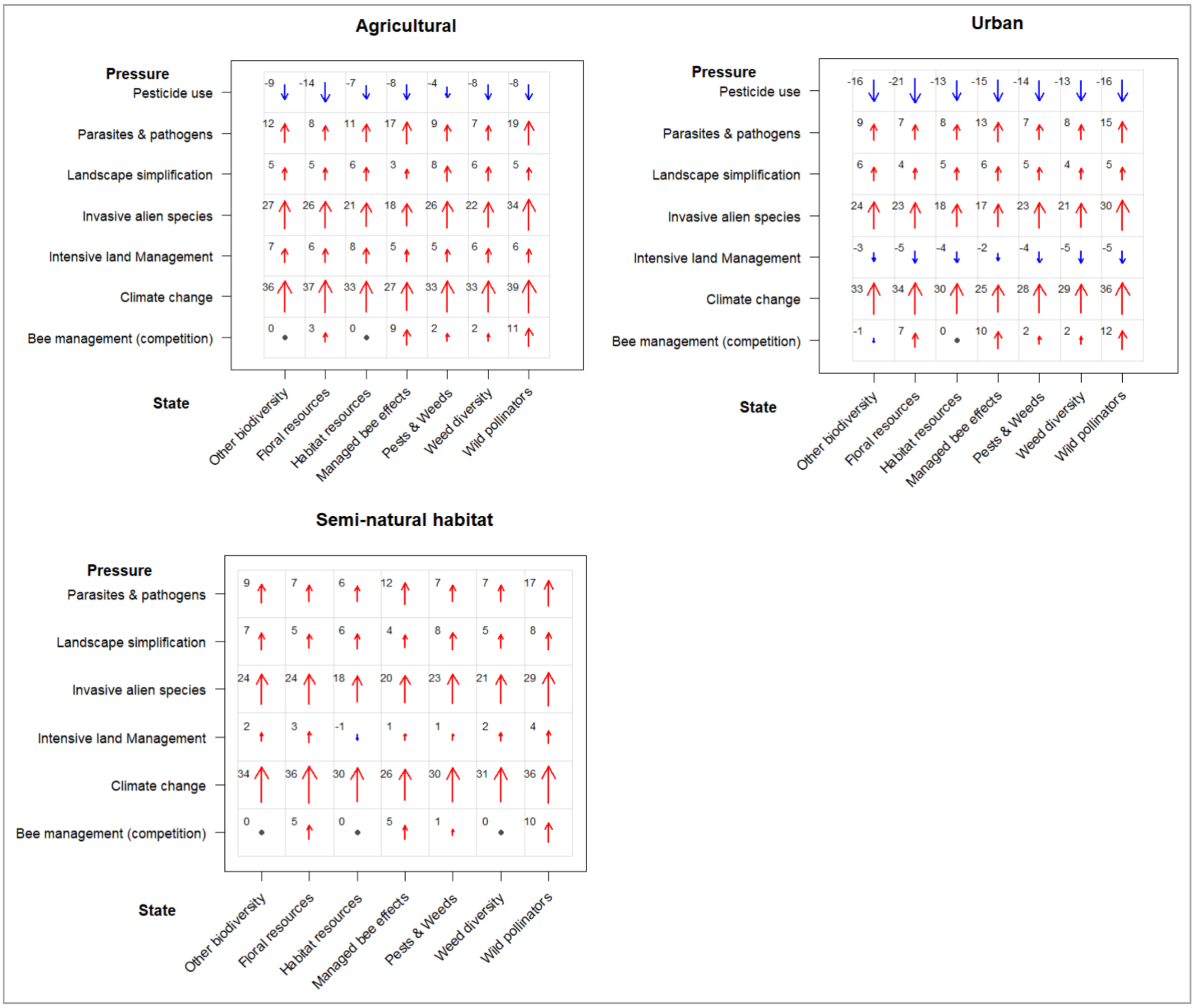

Figure 9 *Expert-based judgement of whether the importance of **PRESSURES** in terms of altering various **STATES** linked to wild pollinators and pollination in each ecosystem type (see 2.1.3 for definitions) will remain the same, diminish or increase over the period 2025-2035. Red arrows show increases, blue arrows decreases and no change to the period up to 2024 is shown by a point. Numbers indicate the net number of experts expecting a future increase (positive value) or decrease (negative value). Arrow length is proportional to the square root of the net number of experts expecting an increase/decrease.*

Regarding the relationship between states and impacts, experts projected that the well documented importance of wild pollinator biodiversity to different ecosystem and human well-being values would continue to be the case, with a slight projected tendency to increase over the coming period 2025-2035 in all environments (**Figure 10**). The net projected scores for all other parameters illustrated a general tendency for an increase in importance over the next decade, albeit with variability in the net expectation among experts (**Figure 10**). Apart from wild pollinators themselves, the largest projected increase was thought most likely to concern floral and other habitat resources in all environments (**Figure 10**). Effects of pests and weeds and weed diversity on various impacts was also forecast to grow over the next decade **(Figure 10)**, potentially reflecting the projected increase in importance of climate change and IAS (**Figure 9**).

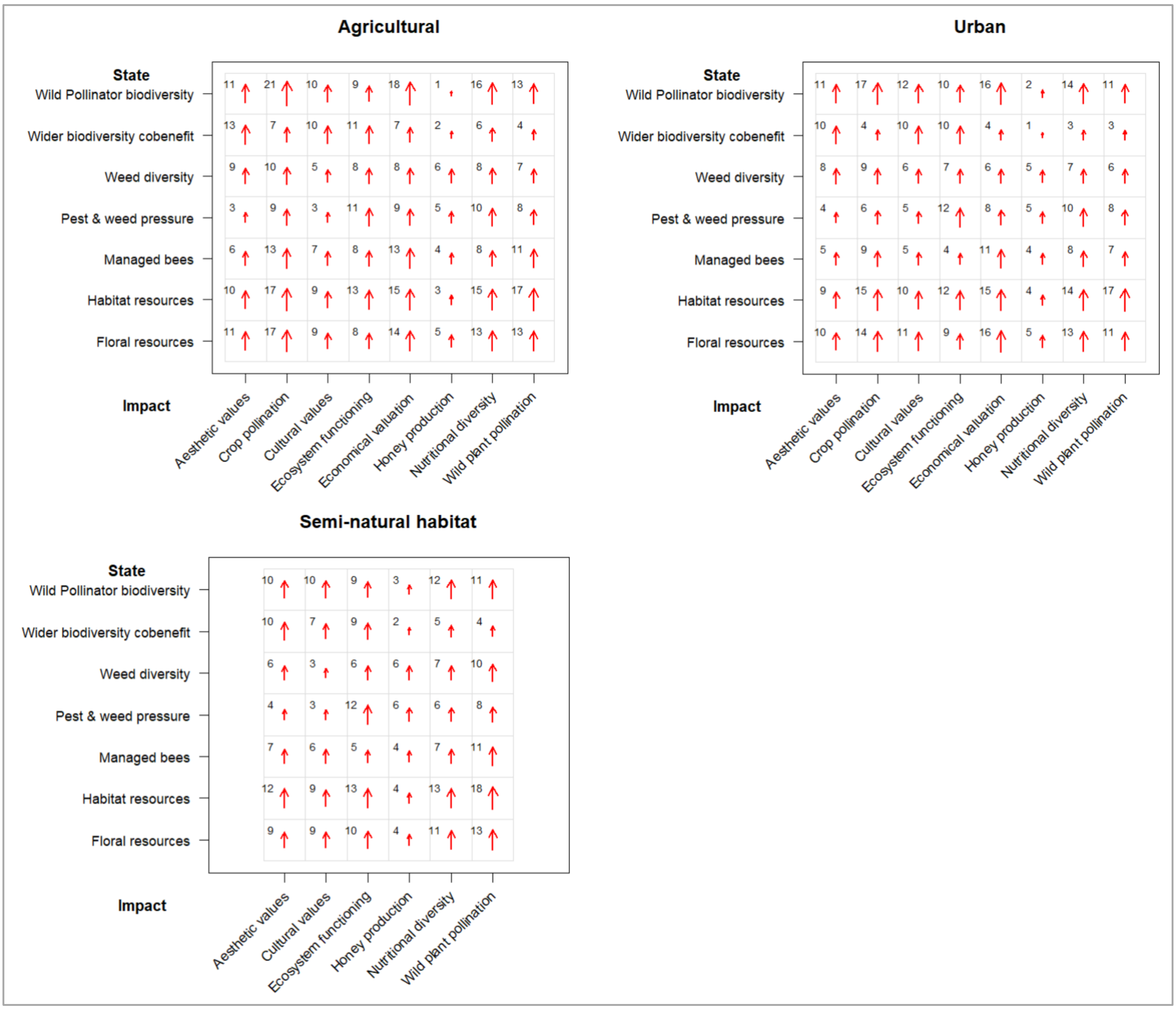

Figure 10. *Expert-based judgement of whether the importance (median score of 42 experts) of each ecosystem* ***STATE*** *variable linked to wild pollinators and pollination for environmental or socio-economic* ***IMPACTs*** *in each ecosystem type (see 2.1.3 for definitions) are projected to remain the same, diminish or increase over the period 2025-2035. Red arrows show increases, blue arrows decreases and no change to the period up to 2024 is shown by a point. Numbers indicate the net number of experts expecting a future increase (positive) or decrease (negative). Arrow length is proportional to the square root of the net number of experts expecting an increase/decrease.*

4. Stakeholder engagement to assess the IAF

Experts were able to use the IAF to evaluate the importance of Pressures-State-Impact and the effectiveness of Response-State and Responses-Impact connections (**Sections 2-3**). The coordinating Safeguard team and the assembled experts rapidly concluded that they were in no position to score the acceptability of various Responses within the IAF. This is because such a judgement requires the knowledge of the willingness of the end-user to take the action(s), which can be affected by their individual or collective socio-economic or cultural position or views, the level of difficulty of implementation or their level of or access to knowledge and know-how. Therefore, the experts concluded that any judgement on acceptability that they might form would lack validity in the absence of the perspective of end-users. The valid way to approach this facet of the IAF, judgements around the acceptability of Response options, therefore required the input of various societal actors. Despite their important role in in providing such judgements, it is extremely difficult (or nearly impossible) to obtain a dedication of unfunded time and effort from a balanced representation of societal actors to an (exhaustive) assessment exercise (as illustrated in Section 2-3).

Safeguard had the stated objective of testing and validating the IAF as an assessment and response tool with different stakeholders and piloting it with actors from different policy sectors (e.g., agriculture, nature conservation) and operating at different scales (EU, MS). This validation includes evaluating the IAF performance with potential end-users to understand whether the casual links identified in the (D)PSIR model by our evaluation are accurate, relevant or realistic according to their perspectives. Furthermore, this engagement allowed us to raise the specific question of 'acceptability' to end-users of different policy Responses (and associated practices) if implemented, and thereby complete and complement the expert elicitation done during 2024.

This stakeholder engagement took place over a series of presentations, consultations and workshops between 2022 and 2025 to obtain feedback on the proposed IAF in the initial stage, and in the case of workshops, use of a serious game approach to pilot a potential tool (virtual landscapes) for testing aspects of the IAF and in particular visualizing the consequences of different policy Response options.

4.1 Initial stakeholder consultations on the IAF (2022-2024)

This testing with stakeholders started from late 2022 in the conceptualization phase of the IAF (Task 5.1) with presentations, consultations and workshop activity with stakeholders (**Table 3**) to obtain their initial feedback on the IAF (Task 5.4). These activities helped to validate the conceptual framework being developed by Safeguard and to identify strengths and weaknesses of the approach including on how stakeholders could engage with the IAF and its use.

Table 3. *Engagement activities with governmental and non-governmental stakeholders by invitation to present the development of the IAF (Task 5.1) and to obtain stakeholder feedback to assist its co-development and validation. EU: European Union; MS: Member State; INT: International.*

Speaker	Title	Event	Stakeholder
A.J. Vanbergen, E. Underwood et al.	"Pollinators & Cities": framing the issue for evidence informed decisions. (*Online workshop*)	*Eurocities Urban greening for pollinators: from policy to practice. Nov. 2022*	Municipal authorities, ICLEI, NGOs (EU, MS)

A.J. Vanbergen	Urban greening for pollinators: from policy to practice. (*Presentation*)	*Side Event at the UN Biodiversity COP15, Dec 2022, Montréal*	MS of Promote Pollinators.org (INT)
J. Settele & A.J. Vanbergen.	An expert-elicitation and stakeholder assessment of wild pollinators and pollination in Europe: a Safeguard-BioAgora collaboration (*Presentation*)	*EU Biodiversity Platform Working Group on Pollinators 26 June 2024*	Representatives of EU MS, NGOs (EU, MS)
A.J. Vanbergen	Towards an integrated assessment framework for pollinators in agricultural, semi-natural and urban areas *(Presentation, workshop and panel discussion)*	*22nd European Week of Regions and Cities Buzzworthy solutions for pollinator conservation in cities and regions*	DG Env, Municipal authorities, Statutory agencies, NGOs (EU, MS)

4.2 Stakeholder validation of the acceptability of pollinator-friendly response options (2024-2025)

Two science-stakeholder workshops were performed in Brussels that had three overall aims. **Aim 1)** To present the IAF concept and initial results of the expert elicitation to a diverse stakeholder audience spanning different policy sectors. **Aim 2)** To obtain stakeholder views on the 'acceptability' according to end-user perspectives of the RESPONSES identified as most effective in the expert elicitation exercise**. Aim 3)** To obtain co-development feedback on the game as a decision support tool and ideas for its evolution.

To realise and organise these Brussels-based science-stakeholder workshops (December 10 2024 & September 10 2025), Safeguard (INRAE/UFZ/ELO/IUCN/LUND) collaborated with the pollination knowledge exchange network (KEN) of the BioAgora project - a CSA that aims to orchestrate collaborations between projects aiming to improve the European science-policy and science-society interface. The Safeguard-BioAgora collaboration allowed us to bring together different stakeholders from across sectors and enlist the expertise and services of an academic team from the University of Stirling (UK) experienced in using game theory to develop applications to simulate and visualise decision taking in different scenarios. The University of Stirling researchers worked closely with the INRAE team in the development of the game application from June 2024.

A representative set of stakeholders were invited to these game-based deliberative workshops to explore how policy and practice in responding to the pressures facing pollinators may improve the state of pollinator biodiversity and their benefits (**Figure 11**). Through interactive online game scenarios played out in virtual agricultural to urban landscapes, the stakeholders chose and evaluated different policies or strategies affecting the management of wild pollinators, examining their impacts on aspects of biodiversity, ecosystem services and human well-being. The workshop brought together stakeholders from policy, business and NGOs with researchers (**Tables 4-5**). The stakeholders, individually and collectively, explored how the game functions as a deliberative tool (designed to stimulate dialogue and foster shared understanding).

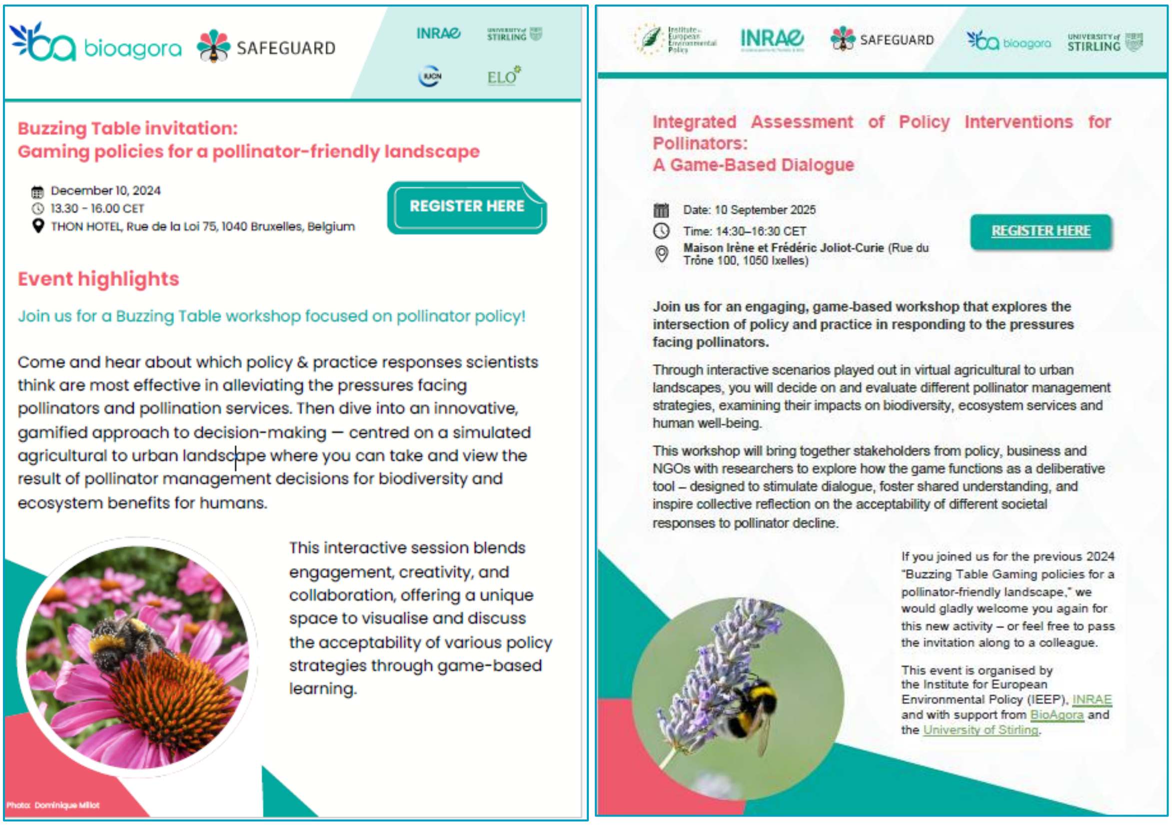

Figure 11 *Workshop flyer front page inviting stakeholder organisations to participate in the Buzzing table event: '**Gaming policies for a pollinator-friendly landscape'**, 10 December 2024 in Brussels and the follow-up workshop: **Integrated Assessment of policy Interventions for Pollinators: a Game Based-Dialogue**.*

Table 4 *Stakeholder and research organisations that participated in the Buzzing table event: **Gaming policies for a pollinator-friendly landscape, 10 December 2024 in Brussels**. A total of 16 individuals from 12 stakeholder organisations participated as individual players in the decision-making game. EU: European Union; MS: Member State; ST: non-EU State; INT: International.*

Organisation	Type	Sector/Scale
DG Agriculture	European Commission	Agriculture/EU
DG Environment	European Commission	Environment/EU
Copa-Cogeca	Farming organisation	Agriculture and farming/EU & MS
IEEP	Policy think tank	Environment/EU
ELO	Landowners, land managers, rural business	Agriculture, Forestry/EU
Promote Pollinators	International governments	Agriculture, Forestry Environment/INT & MS
IFOAM-Organics Europe	Farming organisation	Agriculture & farming /EU
IUCN	NGO	Environment /EU & INT
Butterfly Conservation Europe	NGO	Environment /EU
TU Delft	University	Research & Education MS
The Pollinators.org	NGO	Environment/MS
University of Reading	University	Research & Education/ST

***Table 5** Stakeholder and research organisations that participated in the workshop: **Integrated Assessment of Policy Interventions for Pollinators: a Game Based-Dialogue**, 10 September 2025 in Brussels. A total of 20 individuals from 16 stakeholder organisations participated as individual players in the version 2 of the decision-making game. EU: European Union; MS: Member State; ST: non-EU State; INT: International.*

Organisation	Type	Sector/Scale
DG Agriculture	European Commission	Agriculture/EU
Corteva Agriscience	Agribusiness	Business & Industry/INT
IEEP	Policy think tank	Environment/EU
Bayer Cropscience	Agribusiness	Business & Industry/INT
Promote Pollinators	International governments	Agriculture, Forestry Environment/ INT & MS
EEA	European Commission Agency	Environment/EU
IUCN	NGO	Environment /EU & International
BeeLife	NGO	Environment /EU
NFU-England & Wales	Farming organisation	Agriculture/UK
City of Rotterdam	Government	Municipality/MS
FACE European Federation for Hunting and Conservation	NGO	Natural Resources & Environment/EU
BugLife	NGO	Environment /UK
BBCT	NGO	Environment /UK
INBO-Flanders	Research organisation	Research & Education/MS
Teagasc	Government	Agriculture, Food/MS
Sweco	Business & Sustainability	Business & Industry/EU

4.2.1 'Gaming policies for a pollinator-friendly landscape': a Buzzing table event, December 10 2024

The game is designed as a tool to assist deliberation and decision making about managing wild pollinator biodiversity and the benefits they may bring to ecosystems and humankind. For simplicity of comprehension, operation and utility we had to reduce the games complexity to a subset of the parameters (**Table 6**) that were evaluated by a panel of 42 pollinator experts from 15 European countries in the expert elicitation (see **sections 2-3**). The choice of these Responses was based on them being identified as at least effective, but preferably highly or extremely effective, options (if implemented) at alleviating pressures and improving state. It was also governed by the desire to cover Responses that could be common to all environments, with specific options for agricultural and urban areas. The final limitation on choice was the need to keep the complexity of the serious game to a manageable level for non-experts to use. This means that the game represented an exemplar subset of all possible options, and it does not exclude other choices or combinations being valid options in reality.

Prior to the workshop, the Stirling group and the INRAE team worked together to use the scores (average effect sizes and variability) from the expert elicitation to parameterise the game (the effects of Responses on the States and the subsequent Impacts). In addition, to add realism and present a simulation of natural spatial-temporal variation the team assigned a degree of background variability to these parameters in different parts of the landscape. This was, for example, to reflect the reality in nature that the effect of a Response in one part of a landscape does not always result in an identical outcome in another part, due to complex physical and biological conditions in different habitats or microclimates. In the simulation therefore there was programmed a degree of variation to reflect such spatial variability in outcomes. In addition, the team devised for each ecosystem type two scenarios: one a situation of highly-degraded biodiversity and the other with a moderately good level of biodiversity. This was done to explore the effect and trajectory of policy Responses when starting from different baseline states.

Table 6. Subset of Responses, States and Impacts used in the simulation game for the first workshop 'Gaming policies for a pollinator-friendly landscape': a Buzzing table event, December 10 2024.

Responses	States	Impacts
Recreating/restoring ecological zones *(agricultural, urban and semi-natural zones)*	Wild pollinator abundance and diversity Floral resource diversity and abundance Habitat resources (e.g. nest sites)	Crop pollination Economic value chain Wild plant pollination Aesthetic values
Nature protection regulations (*agricultural, urban and semi-natural zones)*	Wild pollinator abundance and diversity Floral resource diversity and abundance Habitat resources (e.g. nest sites)	
Ecological intensification of agriculture (*agricultural zones only)*	Wild pollinator abundance and diversity Floral resource diversity and abundance Habitat resources (e.g. nest sites)	
Urban greening (*urban zones only*)	Wild pollinator abundance and diversity Floral resource diversity and abundance Habitat resources (e.g. nest sites)	

During the workshop, participants were able to take real time decisions on implementing the most <u>effective</u> responses (policies and linked practices) and see how their decisions played out year-to-year on a 5-year cycle (**Table 6, Figure 12**). Participants were divided into small groups to play the game individually but allowing discussion and deliberations among the players and sometimes working together on forming the decisions. The simulation allowed total freedom to take decisions in the virtual landscape as many times (5-year cycles for different combinations) as the player wished to try. This gamification of decisions in the application allowed the participants to explore the complex issues around landscape management of pollinators.

These response options can be applied uniformly across the entire landscape of 16 parcels of land or they can be applied (ticking) or disapplied (unticking) in individual areas (sub-rectangles corresponding to intensive agriculture, urban or semi-natural) of the virtual landscape (large rectangle) **(Figure 12)**. Once the player was content with their selection of responses, they advanced time by a year and visualised the **changes to the state** of each part of the landscape (sub-rectangles) and the overall level of **change in landscape-scale impacts (Figure 12)**. This provided instant feedback (seconds) on the decisions that participants made regarding the different policy options and their combinations.

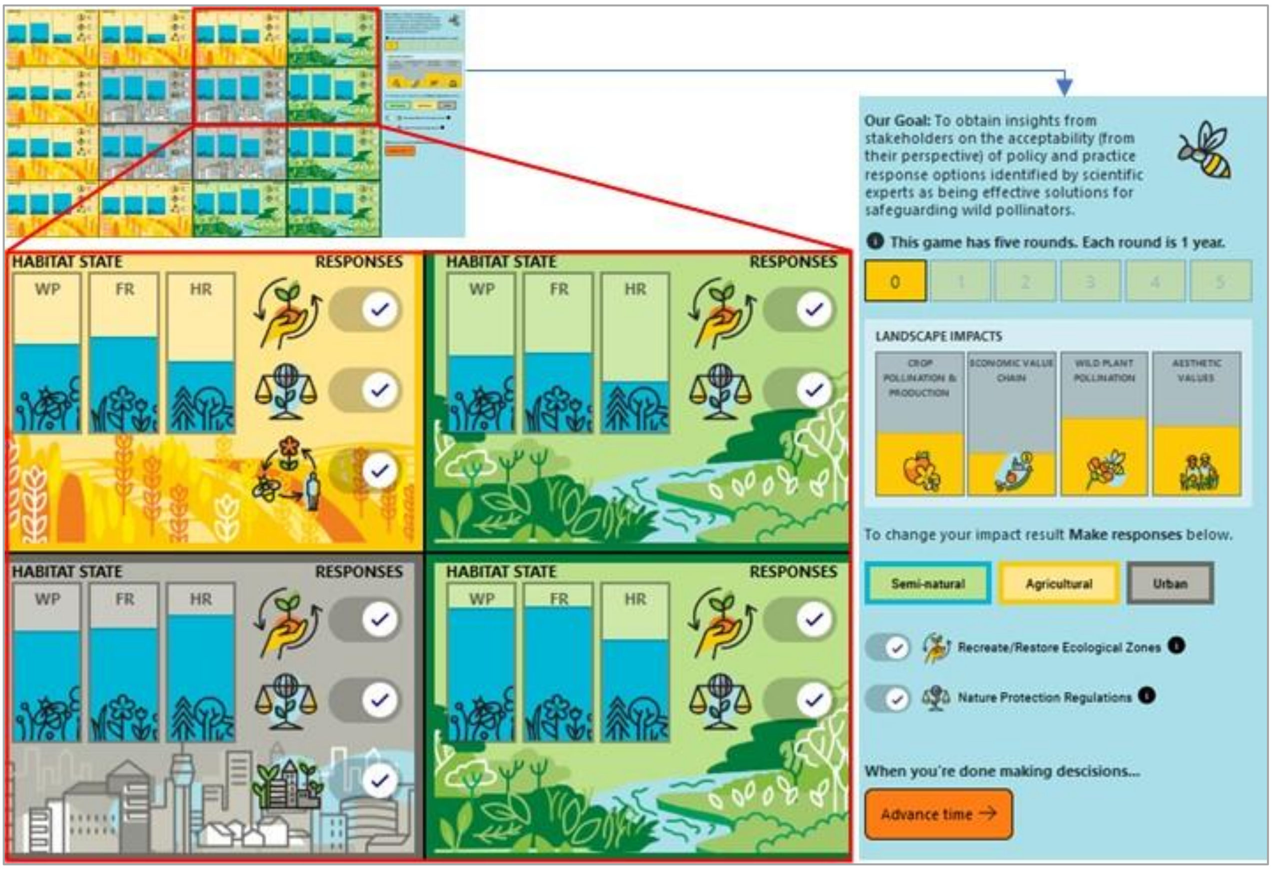

Figure 12 *Screen capture of the application 'Gaming policies for a pollinator-friendly landscape' showing the agricultural (yellow), urban (grey) and seminatural (green) zones in a common landscape. Responses could be implemented or not (ticked/unticked) in separate zones (sub-rectangles) or implemented across all zones of a particular habitat type (intensive agriculture, urban or semi-natural). Then the player advances time by a year and visualised the changes to the state of each part of the landscape (sub-rectangles) and the overall level of change in landscape-scale impacts.*

4.2.2 Stakeholder group feedback on 'Gaming policies for a pollinator-friendly landscape': a Buzzing table event, December 10 2024

Deliberative feedback was obtained during three break-out discussion groups following the gaming sessions. A report was compiled and sent to the participants that summarised the groups perspectives and insights on the game's strengths, weaknesses, and areas for potential improvement. Below we summarise some key points from that report:

● Group 1 emphasised the need for a more comprehensive simulation that incorporates the costs and constraints associated with implementing conservation actions, recognising the crucial role of these factors in real-world policymaking. They also highlighted the importance of explicitly demonstrating how different conservation measures may interact and potentially conflict with one another, as well as how these interactions are modelled within the game.

● Group 2 found the game's complexity to be somewhat challenging, expressing a desire for a more intuitive and user-friendly interface with clearer oversight of actions. They also expressed a need for greater transparency in the model, particularly in understanding the underlying mechanisms that drive specific outcomes. Furthermore, they emphasised the importance of presenting the game from the perspective of local decision-makers, considering economic and aesthetic factors as primary concerns.

● Group 3 observed a consistent trend: restoring and recreating habitats were frequently identified as the most effective strategies across all habitat types. They also noted the relatively limited impact of natural protected areas on the overall landscape and highlighted the significant economic benefits associated with actions that directly benefit pollinators. They also offered several valuable suggestions for game improvement:

- Linking the different landscape elements (sub-rectangles in the virtual landscape) to accommodate the fact that pollinators are mobile. For example, enhancing agricultural practices in one landscape parcel to benefit pollinators might be expected to spill-over to a neighbouring area producing a degree of improvement there. Therefore, enactment of policies through management responses in agriculture, urban, or semi-natural areas should have reciprocal positive effects on improving overall landscape quality for pollinators.

- Incorporating a historical perspective: Improving the in-game visualisation of the history of cause-effect arising from choices taken would better allow players to view and learn from previous decisions and would enable them to refine their strategies more effectively. This could be achieved through timeline graphs that show the in-game state variables over the course of the game play.

- Including cost and information gaps: This would provide a more realistic and practical experience, helping players understand the trade-offs involved in decision-making.

A subsequent plenary discussion involving the three groups highlighted the need to incorporate a broader range of potential outcomes, including negative effects, to create a more realistic simulation of real-world challenges. Participants emphasised the game's potential for evolution and adaptation at the EU level, recognising its relevance to member states. They explored how the game could facilitate diverse approaches to decision-making, making it easier to ask questions and explore potential solutions.

The discussion also touched upon several crucial areas for further potential development and ambition:

● Connecting the game to real-world monitoring data: This would allow players to apply their knowledge and work towards implementing the EU's Nature Restoration Law and Article 10.

● Improving the clarity and transparency of the game's variables and their interactions.

● While the current game mechanics may not fully capture the nuanced impact of policy interventions, it's important to acknowledge the significant role that policy plays in real-world conservation efforts. Further development of the game should aim to more accurately reflect this crucial aspect, to be able to be an effective tool for policymakers.

Overall, the decision makers from policy and NGO institutions present in these sessions demonstrated a positive attitude towards the development of new tools that can facilitate informed and effective policymaking. They also recognised the potential to educate and learn as powerful tools for promoting conservation efforts and the positive impact such a tool can have in building trust within and across stakeholder communities and actively engaging them in conservation decision-making processes. The new pollinator-friendly landscapes game holds promise for raising awareness and helping a decision-making process for those in charge of protecting pollinators.

4.2.2 Evolution of the game deployed in the workshop: Integrated Assessment of Policy Interventions for Pollinators: a Game Based-Dialogue, 10 September 2025 in Brussels

Following the piloting of the game in the 'Buzzing table' workshop in December 2024, the team followed the stakeholder advice wherever possible and produced a revised game that has been tested in September 2025. Key changes were:

1) To create greater 'player' confidence and understanding of the simulation we produced a more detailed and improved presentation of the results of the expert elicitation that underpinned the game parameterisation. This was achieved through the advancement of the data visualisation between December 2024 and September 2025 and the production of an information note provided to participants before the workshop and accompanied by a brief presentation during the workshop itself and explanation of the data and how it was used to create the game.
2) We reduced the visual and compositional complexity of the game by moving away from a virtual landscape comprising a mixture of the three ecosystems (agricultural, urban, semi-natural) to three separate landscapes, one of each type. This also helped to reduce the user perception that different ecosystem types were being traded-off against one another in terms of relative value (**Figure 13** for the example of the agricultural landscape).
3) We clearly specified in the revised game the spatial scale of each sub-rectangle corresponded to a dimension of 2 km x 1.5 km. This meant that the players operated knowing that most of the pollinator activity and movement was contained within each sub-rectangle (e.g., at the scale of an individual farm or a city quarter). This practical definition step meant that the potential issue of the implementation of a Response in one area spilling-over to cause effects in an adjacent area could be discounted. This step also brought the game in line with the expert elicitation where experts were instructed not to consider spill-over effects, with the single exception of the pressure of landscape simplification, which is a landscape-scale process by definition.
4) The cumulative history of Impacts over the entire landscape was better visualised so the player could see the progress in the individual bars. Wild pollinator biodiversity and floral resources were highly positively correlated (in real-world ecology and in expert scores), so the latter was dropped and replaced with the ecosystem disservice of pests and weeds to answer the request from some costs to be visualised (**Table 7)**.

Through this gaming activity the algorithm obtains information on the 'acceptability' of different societal responses to pollinator decline (Aim 2 of these stakeholder validation exercises) through the choices made in the simulations and feedback forms. Individual gamer identity will be anonymized with choices ultimately linked only to broad stakeholder types: e.g., NGO, Business, Government…) in compliance with informed consent obtained from participants and in line with GDPR. The next goal will be to complete the expert elicitation exercise and analysis of stakeholder choice data for reporting in D5.5 of the Safeguard project and a scientific paper.

Table 7 Subset of Responses, States and Impacts used in the simulation game. Parameter in blue italics was dropped and replaced by that in bold type.

Responses	States	Impacts
Recreating/restoring ecological zones *(agricultural, urban and semi-natural zones)*	Wild pollinator abundance and diversity *Floral resource diversity and abundance* Habitat resources (e.g. nest sites) **Ecosystem disservice : Pests & weeds**	Crop pollination Economic value chain Wild plant pollination Aesthetic values
Nature protection regulations (*agricultural, urban and semi-natural zones)*	Wild pollinator abundance and diversity *Floral resource diversity and abundance* Habitat resources (e.g. nest sites) **Ecosystem disservice : Pests & weeds**	
Ecological intensification of agriculture (*agricultural zones only)*	Wild pollinator abundance and diversity *Floral resource diversity and abundance* Habitat resources (e.g. nest sites) **Ecosystem disservice : Pests & weeds**	
Urban greening (*urban zones only*)	Wild pollinator abundance and diversity *Floral resource diversity and abundance* Habitat resources (e.g. nest sites) **Ecosystem disservice : Pests & weeds**	

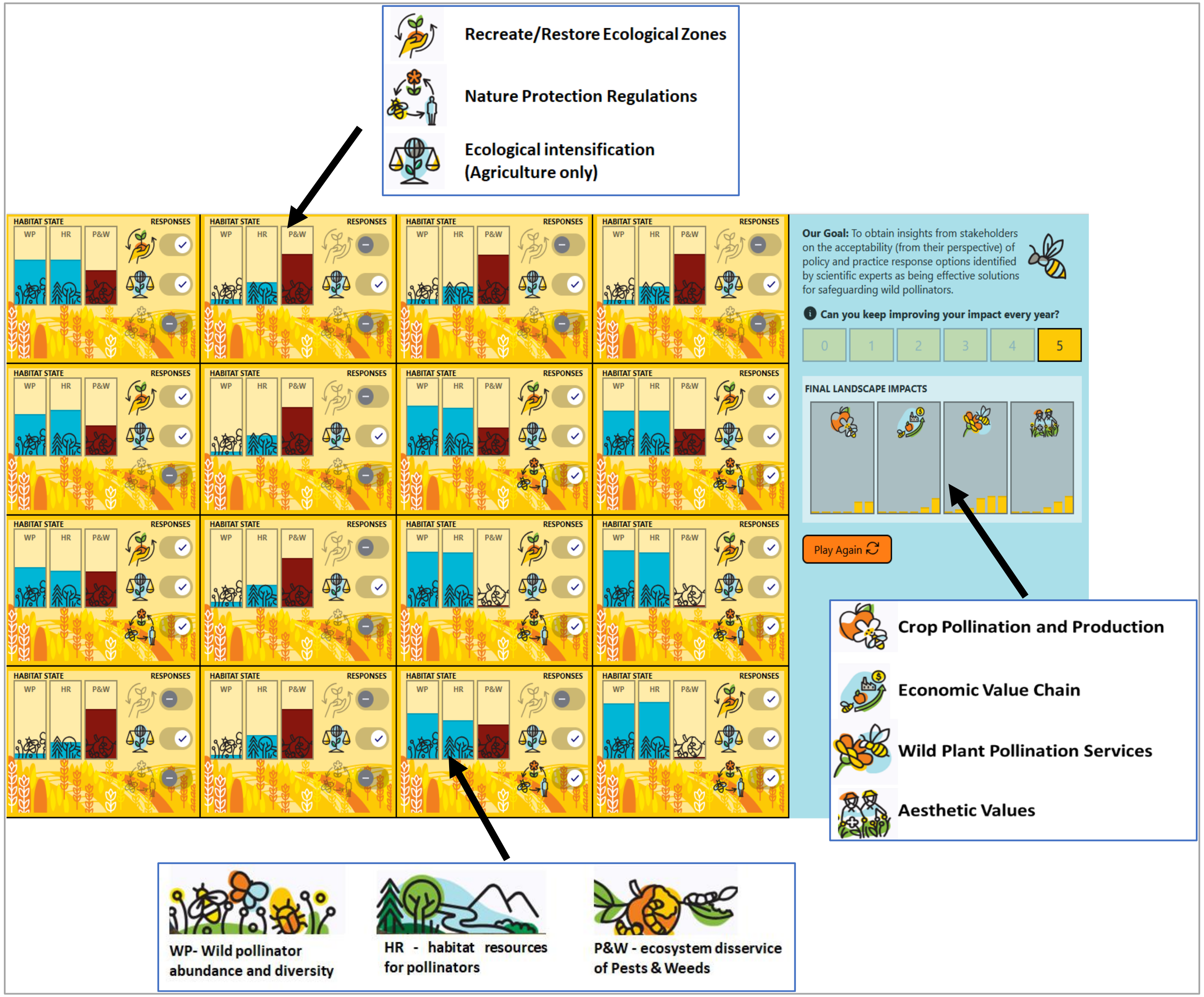

Figure 13 Screenshot providing a view of the final game: an example using an agriculture dominated landscape*.* *Different agricultural areas (yellow sub-rectangles) are shown that together make up a larger intensive agricultural landscape. The agricultural areas have been subjected to a selection of policy* ***Response*** *options (listed below) applied to the farmed area over a 5-year cycle and resulting in this end point. These response options can be applied uniformly across the entire landscape of 16 parcels of land or they can be applied (ticking) or disapplied (unticking) in individual areas (sub-rectangles) of the virtual landscape. Each sub-rectangle can be considered to be of 2 x 1.5 km in dimension, so might correspond to an individual farm or part of a large one. This spatial scale also means most of the pollinator movement and foraging takes place within a sub-rectangle.*

5. Perspectives on the performance of the IAF and expert elicitation exercise.

- This (D)PSIR model is a useful method for an Integrated Assessment Framework (IAF) on wild pollinators. It proved to be an informative and operational systematic approach to frame the complexity of environmental and social-economic aspects relating to wild pollinators and the services or values they provide.
- The framework was shown to be operational at the European political scale (EU++) and experts were able to relate to that scale in their individual assessment of evidence and scoring of the links among the various PSIR elements.
- The framework was flexible and readily adaptable to different ecosystems, which also correspond to distinct policy sectors (agricultural, urban or semi-natural areas). It is also flexible in terms of being comprehensible to multiple stakeholders (scientists, policymakers, industry, NGO).
- The method used to elicit expert knowledge was a modified Delphi approach (after Mukherjee et al 2015; Dicks et al. 2021), which proved to be an effective and robust approach for such a rapid assessment exercise. Feedback from the experts was the exercise was an intellectual challenge, but overall, an enjoyable one. The time taken for an expert to score the evidence took between several hours to a few days, depending on their experience with such rapid evidence assessment processes. The iterative nature of the method was satisfying to the experts in that it allowed for collective reflection and debate on the method, the relationship between different parameters, and on the scores themselves with their subsequent refinement as needed.
- Our protocol's confidence ranking was based on the use of the IPBES 4-box model to assign a level of certainty (according to the quantity and the quality of the evidence) to a score given by an expert to a linkage in the P-S-I-R framework. A caveat is that this type of rapid assessment based on expert elicitation depends on an individual's awareness of the literature, and no individual person is likely to know all the literature (every paper or report published on the subject in Europe will be of the order of 100-1000s per year). However, our guiding principle was that the experts assembled should be aware of the most comprehensive and robust papers and data, and keep that in the forefront of their thinking when forming the score and the related level of certainty. They were free to devote as much time they wished to supplement that knowledge via additional online searches.
- We replicated with >40 experts, and took into account, with our deliberative and reflective protocol, differences among them in their awareness of the evidence and their personal perspectives – a way of looking at things from an individual perspective and according to personality (e.g., a more or less pessimistic/optimistic personal lens). Our deliberative protocol aimed to counter this personal lens via an iterative approach that allowed an individual expert to compare their scores to the median/range of scores across all experts during the post-scoring briefings and to hear and participate in deliberations that allowed them to reflect and rescore, if they so decided. It should be acknowledged that this expert group comprised researchers from ecology, ecological economics & agronomy who held a collective pre-existing viewpoint on the need to improve the state of wild pollinator biodiversity. This collective 'bias', however reflected the practicalities of bringing in experts with sufficiently high-level knowledge to be able to meaningfully contribute to the exercise. Again, the nature of the modified Delphi method allowing collective scrutiny and reflection provides a means to ensure that the evidence and scores presented are carefully scrutinized.

- This IAF allowed scientific experts to contribute to an evaluation in a structured way. Importantly, if applied in a way that requires access to and synthesis of scientific knowledge, then the role of the expert in providing knowledge and evidence-based judgement is key to the IAF. Although the use of large language models/generative AI as a tool to rapidly synthesise evidence for an evaluation was not involved in our IAF exercise, it will almost certainly have a role in future evaluations – its growing power to distil and collate online information will be a useful tool in terms of speed. However, quality control must be paramount in any future integration of AI into such evaluation methods to ensure accurate attribution of synthetic statements to peer-reviewed or other legitimate evidence sources. Scientific (disciplinary) experts should therefore continue to have a crucial oversight and checking role to avoid erroneous or false conclusions being drawn in any future evaluations using AI tools.
- Experts were able to use the IAF to evaluate the importance of Pressures-State-Impact and the effectiveness of Response-State and Responses-Impact connections. Experts rapidly concluded that they were in no position to score the acceptability (e.g., feasibility, costs vs benefits, willingness to implement) of various Responses within the IAF. This represents a limitation to the utility of the IAF. Such judgements around the acceptability of Response options therefore require the input of various societal actors. Despite their important role in in providing such judgements, it is extremely difficult (or impossible) to obtain a dedication of time and effort from a balanced representation of societal actors to such an (exhaustive) assessment exercise. Other solutions are therefore required, which led us to adopt the serious game approach to elicit from stakeholders some of their knowledge but perhaps more importantly a space for discussion and reflection on the topic.
- The next immediate steps are to prepare a journal publication for submission in late 2025, an accompanying policy brief to the paper once published, and to present through the last deliverable of this WP5 (D5.5) the further development of the IAF (e.g., additional data visualisation to fill gaps, report and analysis of stakeholder choices through the serious game done during the September 2025 workshop).
- The gaming application itself has potential to be developed further to improve its scope, utility and interface, but this would require additional resources beyond the Safeguard project itself (e.g., public or private funds). Such a game could be a useful tool for education, training and piloting decisions.
- Overall, the IAF conceived and applied here comprising the (D)PSIR model, an expert elicitation approach and use of serious games represents a flexible and useful method to provide a general and integrated view of a multidimensionality of the issues around wild pollinators and potential response options to policy and other decision makers.

6. Acknowledgements

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8. Annex

Annex 1: Glossary of parameters and their definitions scored in the expert-elicitation and assessment

PRESSURES

- **Landscape simplification**

This is the process of the homogenization of landscape structure due to a reduction in the variety of habitats present caused by the dominance of one or few land-uses (e.g., large-scale monoculture of crop or silvicultural plantation, conversion to continuous cover of artificial surface) at the landscape scale (≥ 1 km^2). This process can result in the reduction in semi-natural habitat area and habitat diversity leading to greater fragmentation and isolation of remaining natural habitat patches. This process has consequences for pollinator biodiversity according to the scale or grain of the landscape homogenization and the ecology of the species concerned.

- **Intensive land management**

This refers to a set of practices and techniques employed to maximise productivity and efficiency in the use of land resources, such as an agricultural crop, plantation forest or an amenity area. The production of one or few products of high value to people tends to be the overall goal of this management process. It involves industrial-scale land management characterised by high levels of technological infrastructure (e.g., mechanisation, selected crop varieties or genetic lines bred for high yields) and extrinsic inputs (e.g., synthetic agrichemicals like NPK fertiliser and plant protection products: herbicides, insecticides, fungicides). It often produces a high demand for water resources in support of the production. An environmental outcome of intensive land management is a biologically homogenous area. When implemented at scale it can produce highly simplified landscapes (see above).

- **Pesticides use and frequency**

The application and frequency of application of chemical substances intended to control, repel, or eliminate pests such as insects, weeds, and plant diseases. The products are typically synthetic chemicals composed of industrially-manufactured formulations of molecules and chemical compounds, but they can also include biological products naturally occurring in or derived from plant metabolites, microbes or abiotic elements (e.g. metals) that possess antibiotic properties useful in mitigating pest impacts. Although formulated, designed or evolved to attack particular pests, these products can have unintended effects on non-target organisms. The risk posed by pesticides is driven by the toxicity (hazard) of the pesticide (active ingredient, metabolite or formulation), which will vary according to the species (or its developmental stage: larvae vs adult) or the environmental conditions. The risk is also dictated by the level and duration of exposure of the pollinator to the active ingredient, which depends on species' ecology and the level of application and frequency of use of the product.

- **Pollinator parasites and pathogens**

Pollinator parasites and pathogens are microorganisms that can negatively impact the health and populations of pollinating insects, including bees, butterflies, moths, and other species. Pathogens and parasites include species, populations and variants of viruses, bacteria, fungi, protozoan and invertebrates that infect or feed on insect pollinators, thereby causing disease or decreasing the performance/fitness of their insect pollinator hosts. Although these pathogens and parasites are naturally-occurring, their impact can be magnified by human activities. Pest and pathogen issues have arisen from intensive beekeeping and the translocation of managed bee species around the world allowing host shifts. Managed honey bees (see below), especially honey bees because of their high densities can harbour many pathogens or parasites and can be a source of pathogen spill-over to wild pollinator species. Future global changes (land-use, climate change) may affect vulnerability to pathogens or parasites by affecting pollinator habitat, nutrition and health.

- **Bee management**

This refers to human actions that exploit pollinator species. This can be through beekeeping (apiculture) to obtain hive products (i.e., honey, wax) or for the provision of crop pollination services. The objectives are to obtain economic, food and sociocultural benefits, individually or in combination. The western honey bee (*Apis mellifera* L.) is the most widespread species of bee due to its use in beekeeping and is exploited for both hive products and pollination services in Europe (and worldwide). There is trade in managed honey bees regionally, across the European continent and globally. Other species (e.g., bumble bees, *Bombus* spp.; mason bees, *Osmia* spp.) are produced commercially or locally to supplement natural pollination services in specific cropping systems to achieve crop yields. Managed bees can compete with wild pollinators for floral resources.

- **Invasive alien species**

Invasive alien species refer to non-native organisms that are introduced to new environments, where they establish and spread rapidly, at the expense of native ecosystems, species, and habitats. These species can include plants, animals, fungi, and microorganisms, and they are typically introduced through human activities such as trade, travel, horticulture and agriculture. Invasive alien species impacts on pollinators and pollination often vary according to their role in the food web.

- **Climate change**

Climate change refers to large-scale and long-term alterations in global or regional climate patterns due to increased concentration of greenhouse gases (GHGs) in the Earth's atmosphere arising from human activities. Climate change has (and will have) significant impacts on biodiversity (abundance, distribution, behaviour, and interactions) by causing changes in weather, phenology (timing of life cycle events) and habitats. Climate change is likely to create negative and positive effects on biodiversity, depending on the species concerned and the degree to which it interacts with other pressures.

STATE

- **Wild pollinators abundance & diversity**

The number of individuals (or biomass) and taxonomic (or functional) diversity of wild pollinators, including bees, flies, butterflies/moths, beetles and other insects in a specific time or place.

- **Managed bee abundance**

The abundance of managed bee (see above) individuals or colonies (for social species) in a specific time or place. Primarily the western honey bee (*Apis mellifera* L.) in Europe, but also in some instances other species (e.g., *Bombus terrestris* spp. *Osmia* spp.)

- **Floral resource diversity and abundance**

The variety and amount of flowering plant species available in a habitat or landscape over time, which provide to pollinators (and other insects) different sources of calories and macro- and micro-nutrients (e.g. lipids, amino acids) contained in pollen and nectar.

- **Habitat resources**

The various components (other than floral resources) within an ecosystem that provide essential elements for the survival, reproduction, and overall health of organisms within that habitat. This includes access to fresh water, nest sites (cavities in vegetation or soil, aquatic larval habitats) and alternative (non-floral) resources (e.g., insect prey for larvae of hoverfly (Syrphidae) or Empidae species, dung for certain fly species (e.g. Muscidae), larval host plants for Lepidoptera).

- **Wider biodiversity (birds, mammals)**

The abundance, health and diversity of populations of non-pollinator species that interact (sometimes directly or indirectly with pollinators) in trophic networks within their ecosystems.

- **Pests & Weeds**

Pests are organisms that cause harm or damage to crops, livestock, forests, structures, human health, or other desirable components of ecosystems or human environments. Weeds are plants that grow in locations where they are not wanted or are considered undesirable by humans due to their competitive ability, invasiveness, and negative impacts on agricultural or natural ecosystems. Many flowering weed species provide floral resources to pollinators and so we scored weed diversity and abundance separately in this regard.

IMPACTS

- **Crop pollination & production**

Pollination is the process by which pollen is transferred from the male reproductive organs (anthers) to the female reproductive organs (stigma) of flowers, leading to fertilisation and the production of seeds and fruits. Many flowering crops depend on insects for the transport of pollen. This process within or between individual crop plants of the same species (autogamy/geitonogamy/xenogamy) can help to promote the amount, quality or stability over time of the crop yield produced. Pollination, is this respect of food production, provides a regulating ecosystem service to humankind.

- **Economic value chain (Farm2Fork)**

Linked to and downstream of the regulating ecosystem service of crop pollination underpinning crop yields, this encompasses a series of interconnected human activities starting with the crop cultivation and yield and leading to subsequent food processing, distribution, marketing and sales. This chain of events involves multiple economic values derived at each step by different actors ranging from agricultural industries (farmers and associated agribusiness) to food producers and retailers and ultimately consumers.

- **Nutritional diversity**

Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. A balanced diet includes a variety of foods from different food groups that provide essential nutrients, vitamins, minerals, and energy needed for optimal health and well-being. Pollinators through their pollination services to various fruit, seed, nut, oil and vegetable crops provide humans with access to a diversity of vitamins, minerals and energy contained in those foods.

- **Wild plant pollination**

Pollination is the process by which pollen is transferred from the male reproductive organs (anthers) to the female reproductive organs (stigma) of flowers, leading to fertilisation and the production of seeds and fruits. The majority of flowering plant species depend obligately or facultatively on insects for the transport of pollen in ways that support this sexual reproduction and production of seeds/fruits. In obligately or facultatively outcrossing flowering plant species, insect-mediated pollination is important in maintaining the long-term genetic fitness and health of their populations (e.g., avoidance of inbreeding and accumulation of deleterious alleles).

- **Aesthetic values**

The perceived benefits and enjoyment that people (individually or collectively) derive from the sensory and recreational qualities of (semi)natural landscapes, as well as specific habitats or other elements within those landscapes. Pollinators and pollination can play a direct contributory role in the creation of certain plant communities, habitats or landscapes that provide such aesthetic value. Pollinators themselves through their presence and visible or auditory behaviour may contribute to this sensory quality and the aesthetic value.

- **Cultural values**

This corresponds to a set of practices that encompasses a wide range of behaviours, customs, traditions, beliefs, rituals, and norms that characterise a particular society or cultural group. For example, in terms of pollinators and pollination, this may correspond to practices such as beekeeping, to a way of life connected to pollinators through particular landscapes of cultural importance, or to wider societal customs or traditions.

- **Honey production (and secondary hive products)**

The process by which beekeepers aim to harvest honey from their management of honey bee colonies (*Apis mellifera*) in order to provide a healthy food product (and secondary products like wax) for economic or personal benefit. Beekeepers maintain colonies in a hive or apiaries (collection of hives) and provide management practices to support healthy bee colonies, such as moving hives to locations near floral resources or treating diseases arising from pathogens or parasites.

- **Ecosystem functions (web of life support)**

Ecosystem functions are the processes within ecosystems arising from the activity and interactions among biotic and abiotic components of an ecosystem. These natural functions have evolved over geological time scales. Ecosystem functions exist independent of human needs or perceptions of their existence, but because they are part of the life-support system of the planet, they also support humankind by default. This parameter considers the impact on ecosystem functions of (change in) pollinator populations, communities and species interactions*. It does not consider ecosystem services*, which are the functions that are of direct, perceived value or benefit to sustaining human societies (e.g., the regulating service of crop pollination – see point 1).

RESPONSES

- **Sustainable Intensification of Agriculture (SIA) (APPLIES TO AGRICULTURE)**

Originally defined as increasing crop yields while improving ecological and social conditions using sustainable practices (e.g., agroforestry, conservation agriculture, and IPM). The current concept retains capital intensive and agri-technological approaches to conventional intensive agriculture (defined as a Pressure here in this exercise), but enhancing efficiencies, and precisely timed and targeted inputs (irrigation, fertiliser, pesticides) to high-yielding crop varieties and avoiding/minimising environmental impacts. On the spectrum of sustainable farming approaches, it targets improvements in **EFFICIENCY** (see Table S1°). Precision farming using AI and robots is one form of SIA. Deployment of ecological infrastructure (e.g., field margin treatments such as wildflower or grass-legume strips) to promote (functional) biodiversity and delivery of ecosystem services, is compatible with, but not a requisite for, SIA.

- **Organic farming (APPLIES TO AGRICULTURE)**

This aims to enhance soil fertility, water storage, and biocontrol of crop pests and diseases. It prohibits the use of most synthetic chemical inputs and GMOs while allowing organic fertilisers and certified biopesticides. It can be applied in both small-scale diversified systems and large-scale intensively-managed farming systems, in the latter case organic farms may in effect practice input substitution and resemble conventional intensive farms in that they are often high input, large-scale, and sustain low crop and non-crop diversity, but differing in that they use permitted organic products instead of synthetic fertilisers and pesticides. Overall, in Europe, organic farming is a practice that does not require a wholesale redesign of the management system but it represents the practice of SUBSTITUTION (Table S1) to avoid doing environmental harm through the use of synthetic chemical products.

- **Integrated Pest Management (IPM) (APPLIES TO AGRICULTURE & URBAN)**

IPM is a knowledge and monitoring intensive approach that emphasises the use of multiple pest control strategies, including biological, cultural, physical, and chemical methods. The goal is to minimise reliance on chemical pesticides by using alternative, less toxic products and/or substituting chemical control with a more sustainable set of pest management practices whenever possible. Pesticides are employed as a tactic only once an economic threshold of pest damage has passed; therefore, it requires monitoring by the land manager. Overall, in Europe, IPM is a practice that does not require a wholesale redesign of the management system, but it represents the practice of **SUBSTITUTION** of synthetic chemical products (Table S1) to mitigate environmental harm (e.g., non-target impacts) caused by their use.

- **Ecological Intensification of Agriculture (EIA) (APPLIES TO AGRICULTURE)**

A nature-based approach to agriculture requiring a redesign of the farming system. EIA aims to maintain or increase long-term agricultural productivity, while reducing reliance on synthetic inputs and the need for agricultural land expansion. This requires actively managing the cultivated and non-cultivated biodiversity in the farm system to enhance ecological processes and services that support agricultural crop performance (yield amount or stability). This management can include diversified crop planting (see Diversified farming systems below), restorative management of soil health, semi-natural habitat conservation, and creation of ecological infrastructures (e.g., perennial woody habitat, flower rich areas). This management aims to promote (functional) biodiversity, ecosystem functions and delivery of crop pollination and natural biocontrol services against crop pests, weeds and diseases. EIA can also provide wider benefits (e.g., system resilience to environmental stressors, promote soil carbon stocks, reduced pollution from agrochemical run-off) thereby reducing and responding to wider environmental impacts. EIA takes a more transformative approach to agriculture, which targets a **REDESIGN** of the farming system and a holistic approach to management of cultivated and semi-natural elements (see Table S1°). One specific form of EIA is **agroecological farming** (which can also include social elements such as justice, equality and sovereignty) (Table S1). Another similar approach in terms of the scale of the redesign and focus, is **Climate-smart agriculture,** which integrates economic, social and environmental aspects of sustainable development in a framework to achieve both sustainable food production and a mitigation of and adaptation to climate change effects (Table S1).

- **Diversified farming systems (DFS) (APPLIES TO AGRICULTURE)**

This emphasises integration of multiple crops and/or livestock across the farm and over time in more complex rotations than in conventional intensive management as the primary mechanism to achieve sustainable production and a corresponding reduction of external inputs. It can be thought of as an approach to spread risk to the farmer in market economic terms by diversifying income sources and also to reduce the undesirable environmental impacts (e.g., frequency of pest outbreaks, mitigate impact of adverse weather). It can be implemented alongside promotion of agrobiodiversity and ecosystem services and so it is compatible with the principles and practice of EIA, but as a practice in itself it is also implementable in conventional intensive and organic agricultural systems. Nonetheless, its implementation requires a **REDESIGN** of the farming system (Table S1) that embraces the management of a complexified cropping or mixed-farming system for sustainability gains (economic and environmental).

- **Conservation or Regenerative agriculture (APPLIES TO AGRICULTURE)**

These are closely-related sustainable crop production approaches that manage the type, timing, and rotations of crops with an emphasis on maintaining and improving soil structure, biodiversity, water holding capacity and nutrient levels. It does this by minimising physical soil disturbance (i.e., zero tillage approaches) and agrochemical inputs, maintaining permanent soil cover using crop residues or living mulches to increase soil carbon and fertility, and employing diversification of plant species through crop rotations, use of cover crops, or intercropping. Typically, these management approaches do not directly address non-soil biodiversity or other ecosystem services such as natural biocontrol and crop pollination but they may have indirect effects via changes to the vegetation. Implementation requires a **REDESIGN** of the farm management system and approaches (Table S1), but because of its narrower focus on soil health this can be more limited in scope than that which can occur under the implementation of agroecological farming, for example.

- **Recreation or restoration of ecological zones (APPLIES TO AGRICULTURE/URBAN/SEMI-NATURAL)**

The process of assisting the recovery of ecosystems that have been degraded, damaged, or destroyed. It involves restoring the structure, function, and biodiversity of ecosystems to a natural or semi-natural state. Habitat restoration is key to this process and can be achieved through plantings of natural vegetation, allowing ecological successional processes to take place, reintroducing species and returning geomorphology to more natural configurations. By definition the time required to restore an ecosystem element varies (e.g., annual vs perennial vegetation). The result of the restoration effort is often variable over space and time. The result tends to mimic and not necessarily equate to the exact natural habitat and community that was the product of evolutionary and ecological timescales. It can relate to restoration of specific elements as part of Natura 2000 site management guidance, or for a specific biodiversity conservation goal (e.g. rare species protection or re-introduction under Habitats Directive), improvement in a particular ecosystem service (e.g. urban water or carbon management or as part of agroecological farming practices) or a initiative to rewild an area to restore a biodiverse and resilient ecosystem. There are therefore various possible connections to policies and initiatives applicable to different environments, such as Nature Protection Regulations, Biodiversity Strategies and Urban greening plans.

- **Biodiversity Strategies and Initiatives (APPLIES TO AGRICULTURE/URBAN/SEMI-NATURAL)**

These are policy strategies aiming at promoting awareness and encouraging different societal actors, governmental or non-governmental, and citizens to engage with an issue around biodiversity conservation (or subsets thereof) and to facilitate or carry out direct activities to fulfil the strategic objectives. Strategies do not have legal force, but they indicate a policy priority and, in some cases, may contribute to the development of future legislation and regulation (e.g. Nature Restoration Law - See below). One example is the EU's Biodiversity Strategy for 2030 (in the framework of the EU Green Deal) which contains specific actions and commitments aiming to protect nature, reverse the degradation of ecosystems, and put Europe's biodiversity on a path to recovery by 2030. Integral to this overarching biodiversity strategy is the EU Pollinators Initiative , which has set specific objectives and 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. Such strategies and initiatives can stimulate and set the framework for public and private sector initiatives, e.g. EUROPARC Federation ; Business for Nature, with potential to assist biodiversity conservation and sustainability.

- **Nature Protection Regulations (APPLIES TO AGRICULTURE/URBAN/SEMI-NATURAL)**

Legal frameworks or directives enacted by governments to regulate and safeguard natural environments, ecosystems, and biodiversity. They typically encompass a range of provisions aimed at conserving and managing natural resources, protecting wildlife and their habitats, and promoting sustainable land use practices. The European Commission's Birds and Habitats Directives and Natura 2000 network are existing (interrelated) examples of these types of regulations in the EU. There is also the 2022-2024 proposal for a Nature Restoration Law (NRL), which is a key element of the EU Biodiversity Strategy. The NRL calls for binding targets to restore degraded ecosystems. The proposal aims to restore ecosystems, habitats and species across the EU's land and sea in order to enable the long-term and sustained recovery of biodiverse and resilient nature, contribute to achieving the EU's climate mitigation and climate adaptation objectives and to meet international commitments. Unlike the earlier Directives/Natura 2000, the NRL has a specific target of reversing pollinator decline by 2030 together with targets for improving habitat and biodiversity in urban, forest and agricultural zones. As of 03/2024, there remains considerable political resistance to the NRL and thus uncertainty about whether the NRL will be adopted by EU member states.

- **Economic incentives for Agri-Environmental Schemes (APPLIES TO AGRICULTURE)**

Economic incentives are essential components of Agri-Environmental Schemes (AES), designed to encourage farmers and landowners to adopt practices that enhance environmental protection and sustainability while maintaining agricultural productivity (e.g., direct payments, subsidies and grants, tax incentives). An example in the EU (non-EU European states often have similar measures, e.g. ELMS in England) are Eco-schemes, one of the new elements of the Common Agricultural Policy

(CAP) 2023-27. These are voluntary schemes available to support farmers in adopting practices that minimise the negative impact of agriculture on the environment and climate, and help them evolve towards more sustainable farming models (see above) and support practices such as restoring ecological zones or infrastructure, organic farming, agroecological or conservation agricultural practices, precision farming, agroforestry or carbon farming. CAP Strategic Plans at the level of EU countries allow national flexibility to customise the eco-schemes to specific national environmental and climate needs. There are various practices compliant with Ecoschemes: here.

- **Regulation of plant protection products (= pesticides) (APPLIES TO AGRICULTURE/URBAN)**

Regulation of plant protection products, also known as pesticides, typically involve laws, policies, and standards established by governments at national, regional, and international levels (e.g., registration and approval, risk assessment, ban and phase-out of hazardous pesticides) for ensuring the safety of human health, the environment, and agricultural production. In the EU there is legislation pertaining to the evaluation and authorisation to market of plant protection products. A proposal (since 2022) for a new Regulation on the Sustainable Use of Plant Protection Products, including EU wide targets to reduce by 50% the use and risk of chemical pesticides by 2030, in line with the EU's Farm to Fork and Biodiversity strategies was withdrawn by the EC (02/2024).

- **Urban Greening Plans (APPLIES TO URBAN)**

The EU Biodiversity Strategy 2030 calls upon cities with over 20.000 inhabitants to create Urban Greening Plans by the end of 2021. These plans aim to bring nature back into cities to support biodiversity and mitigate climate change. To help cities achieve this ambitious goal, the European Commission will create an EU Urban Greening Platform, under a new 'Green City Accord' with cities and mayors. Signatory cities are engaged in **making considerable progress in conserving and enhancing urban biodiversity**, including increasing the extent and quality of green areas in cities and halting the loss of and restoring urban ecosystems. There are organisations of cities and local government, e.g. EUROCITIES and ICLEI, working with communities and business, that are addressing issues around urban greening for multiple sustainability goals, including biodiversity.

- **Certification Schemes (APPLIES TO AGRICULTURE/URBAN)**

Certification schemes are voluntary, market-oriented schemes that indicate a certain standard involved in the production of a product. In the case of biodiversity certification, this is often applied to food products to indicate that they have been produced in a manner that is less environmentally impactful. Certified products often include a price premium to the consumer, which offsets costs or increases profitability for the producer. Examples include B-Corp, LEAF and Organic farming labels e.g. EU ; BIOSUISSE Switzerland. With the EU Sustainable Finance disclosure regulation coming into force, companies are increasingly interested in these schemes as a means to account for and reduce their impact on biodiversity.

Table S1 (from Vanbergen et al 2020, Transformation of agricultural landscapes in the Anthropocene: Nature's contributions to people, agriculture and food security Advances in Ecological Research. https://doi.org/10.1016/bs.aecr.2020.08.002 FULL TEXT

Table 1 Summary of properties of farm management systems along the continuum of efficiency-substitution-redesign.

	Goal	*Efficiency*		*Substitution*		*Redesign*				
	Farming system	CIA	SIA	IPM	OF	CA	DF	AF	EIA	CSA
System properties	Use of synthetic inputs	✓✓✓	✓✓✓	✓✓	×✓	×✓	×✓	×✓	×✓	✓
	Use of GMOs	✓✓	✓	×✓	×××	×✓	×✓	×××	×✓	✓
	Encourage non-farmed biodiversity	×✓	×✓	✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	High labour	×✓✓	✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Livestock integration	×✓	×✓	×××	✓✓	×✓	✓✓✓	✓✓	✓	✓✓✓
	Encourages spatial heterogeneity	×✓✓	✓	✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Uses nature-based solutions	×✓	✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Exploits ecological processes up to landscape scales	×✓	×✓	✓	×✓	✓	✓✓	✓✓	✓✓✓	✓✓✓
	Aims for resilience	×✓	✓	×✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Knowledge intensive	×✓	×✓✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Focus on ILK	×✓	×✓	×××	✓	✓	✓✓✓	✓✓✓	✓	✓✓✓
	Climate change mitigation/adaptation	×××	×✓	×××	×××	✓	×✓	✓✓	✓	✓✓✓

Never	×××
Rarely	×✓
Rarely sometimes	×✓✓
Sometimes	✓
Sometimes often	✓✓
Often	✓✓✓

CIA, conventional intensification of agriculture; SIA, sustainable intensification of agriculture; IPM, integrated pest management; OF, organic farming; CA, conservation agriculture; DF, diversified farming; AF, agroecological farming; EIA, ecological intensification; CSA, climate-smart agriculture.

Adapted from IPBES, 2016. The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo, (Eds.), Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.