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Transition pathways and policy recommendations

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Table of Contents

Table of Contents **4**

List of Figures **6**

List of Tables **6**

List of Boxes **6**

List of Abbreviations **7**

Clarification of Terms **8**

Executive summary **9**

A. Introduction **12**

A.1. Background 12

A.2. Aim and objectives of the report 13

A.3. Structure of the report 13

B. Visions and Transition Pathways **15**

B.1. Context 15

B.2. Methodology 16

B.3. Results 21

B.3.1. Starting contexts for transitions 22

B.3.2. Values 24

B.3.3. Visions 26

B.3.4. Pathways 29

B.4. Discussion 39

B.4.1. Legitimacy and uptake: feedback, values, and visioning 39

B.4.2. From visioning to action: strategic challenges 41

B.4.3. From pathways to policies: linking co-created actions to systemic change 42

B.5. Policy recommendations to enable transition pathways 44

B.5.1. Boost on-farm innovation and biodiversity 44

B.5.2. Support fair value chains and markets 46

B.5.3. Reform governance for systemic change 47

B.5.4. Transparency and public engagement 48

B.5.5. Strengthen knowledge and advisory systems 50

B.5.6. Align financial and economic incentives with agroecology 51

C. Pre and post market policy recommendations **54**

C.1. Context 54

C.2. Methodology 56

C.3. SPRINT Overall Approach and Key Findings 57
C.4. Pre-Market Risk Assessment 57
C.4.1. Background 57
C.4.2. Environmental Risk Assessment 59
C.4.3. Human Health Risk Assessment 63
C.5. Post-Market Monitoring and Targeted Risk Reduction 68
C.5.1. Pesticide Monitoring in Environment and Food 69
C.5.2. Human Biomonitoring 71
C.5.3. Scaling up the Impact – Targeted Risk Reduction and Prioritisation 73
D. CAP appraisal and specific recommendations 76
D.1. Context 76
D.2. Methodology 78
D.3. Results 79
D.3.1. Conditionality (GAECs) 79
D.3.2. Eco-schemes and ENVCLIM interventions 80
D.3.3. Complementary instruments 82
D.3.4. Alignment of instruments and interventions 85
D.4. Discussion and recommendations 85
D.4.1. Strengthen the GAECs to establish a strong environmental baseline 86
D.4.2. Enhance eco-schemes and ENVCLIM interventions as levers of practice change 86
D.4.3. Integrate knowledge exchange and sectoral support into broader incentive architectures 87
D.4.4. Strategically align instruments and interventions to drive systemic change 87
E. Summary of Policy Recommendations 89
F. Bibliography 96
G. Annex 106
Annex 1: Workshop agenda and exercise instructions 106
Annex 2: SPRINT Case Studies and farming systems 107
Annex 3: Visions for 2050 by Case Study 107
Annex 4: Pathway Tables by Case Studies 111
Annex 5: Detailed Recommendations for Improvement to Ecotoxicology Section 122
Annex 6: Research Agenda: Reducing the Risk of and Reliance on Pesticides 124

List of Figures

Figure 1: Overview of the sequential process from earlier project tasks to context-specific analysis to stakeholder validation and final policy recommendations under T7.3 17
Figure 2: SPRINT pathway logic 20
Figure 3: Total share of stakeholder types in the final stakeholder workshops 20
Figure 4: Average ranking of values across workshops 25
Figure 5: Average scoring of vision's dimensions 27
Figure 6: Key policies regulating and supporting pre-market authorisation and post-market surveillance of active substances and plant protection products (PPPs). 55
Figure 7: Share of eco-scheme interventions and corresponding share of budget allocations dedicated to farm practices relevant to sustainable pesticide management 81
Figure 8: Share of ENVCLIM interventions and corresponding share of budget allocations dedicated to farm practices relevant to sustainable pesticide management 81
Figure 10: Number of interventions linked to result indicators (R1, R2, and/or R28), disaggregated by type of intervention. 84

List of Tables

Table 1: Comparison of incremental vs. systemic change vision 18
Table 2: Dimensions of change 19
Table 3: Starting points: where do case study farming systems stand today? 23
Table 4: What values are the most important for me in the transition? 24
Table 5: Average scoring of vision dimensions 27
Table 6: Pathways: Indicative timeline of transition activities across vision dimensions 29
Table 7 Mapping transformation levels to policy levers for pesticide-free agriculture 43
Table : Regulations for Uniform Principles of Evaluation (Reg. (EU) No 546/2011) and Data Requirement for Pesticide Pre-Market Approval. Reg. (EU) 283/2013 covers the approval or basics substances. Reg. (EU) 284/2013 covers PPP registrations. 58
Table 10: Overview of CAP instruments particularly relevant for supporting more sustainable pesticide management. 77
Table 11: Mapping of Farming Practices 78
Table 11 Summary of SPRINT policy recommendations 89

List of Boxes

Box 1: Vision for 2050 pesticide-free olive growing in Croatia 26
Box 2: The Danish Whole Grain Partnership 31
Box 3: CUMA Cooperatives in France 32
Box 4: Copenhagen's food strategy 34
Box 5: Landfiles Platform 36
Box 6: Agri-environmental collectives in the Netherlands 38
Box 7: SPRINT Goals for Risk Assessment 59

List of Abbreviations

Abbreviation	Full name
AKIS	Agricultural Knowledge and Innovation Systems
BGV	Biological Guidance Value
BLV	Biological Limits Value
CAP	The Common Agricultural Policy
CSP	CAP Strategic Plan
CSS	Case Study Site
EEA	The European Environment Agency
EFSA	The European Food Safety Agency
EIP AGRI	European Innovation Partnership 'Agricultural Productivity and Sustainability'
ENVCLIM	Environment-Climate Commitments
EQS	Environmental Quality Standards
ERA	Environmental Risk Assessment
EU	The European Union
F2F	Farm to Fork Strategy
FSDN	Farm Sustainability Data Network
GAEC	Good Agricultural and Environmental Condition
HBM	Human Biomonitoring
HRI	Harmonised Risks Indicators
IPM	Integrated Pest Management
MS	Member State
PARC	Partnership for the Assessment of Risks from Chemicals
PEC	Predicted Environmental Concentration
PPP(s)	Plant Protection Product(s)
RI	Result Indicator
SO	Specific Objective
SUD	The Sustainable Use Directive
TER	Toxicity to Exposure Ratio

Clarification of Terms

The terminology for pesticides is not applied consistently across contexts. In EU legislation, precise definitions are laid down to guide risk assessment and authorisation procedures. In contrast, in scientific literature and public debate, the same terms are often used more broadly or inconsistently. For instance, in EU policy strategies and public communication, "pesticide" may be used to describe any active substance or plant protection product (PPP) in agricultural use, whereas in scientific discussions it typically refers to any product intended to control harmful organisms, including biocides (Reg. (EC) 1107/2009).

To avoid ambiguity and ensure readability, this report adopts working definitions that are both consistent with other SPRINT deliverables and accessible across disciplinary and policy contexts. Consistent with other SPRINT scientific deliverables, the term ***pesticides*** is used here to refer to active ingredients of PPPs also including any other uses next to plant protection including biocide use or use as veterinary medicine. In addition, the term *'pesticides'* will be used to cover products as applied in practice by farmers.

The term ***synthetic pesticides*** is used to describe active substances produced through chemical synthesis, formulated into plant protection or biocidal products to control harmful organisms. In this report, the term is used to distinguish these chemically derived substances from biopesticides or naturally derived compounds. SPRINT targets the reduction of reliance on synthetic chemical pesticides, excluding a focus on copper-based metal fungicides, biological pesticides or micro-organisms.

Specific technical terminology will be applied where necessary, following definitions from Table 1.

Table 1. Technical terminology for pesticide products and ingredients, adapted from EU legislation.

Term	**Definition**
Active Substance (AS)	A single substance approved at the EU level as a pesticide for use in agriculture (approved by EFSA for use in PPPs) or other uses (approved by ECHA for use in biocidal products). (Reg. (EC) 1107/2009, Reg. (EU) No 528/2012)
Plant Protection Product (PPP)	A formulated and marketed product which includes at least one active substance for use in plant protection (along with co-formulants, safeners, and synergists – other substances that support the efficacy and stability of the active ingredient). (Reg. (EC) 1107/2009)
Biocidal Products	A formulated and marketed product which includes at least one active substance for use outside of agricultural settings, such as to treat rodent infestations and domestic pet infection. (Reg. (EU) No 528/2012)
Pesticide Residues	One or more substances present in or on plants or plant products, edible animal products, drinking water or elsewhere in the environment and resulting from the use of a plant protection product, including their metabolites, breakdown or reaction products (Reg. (EC) 1107/2009)

Executive summary

Evidence from the European Environment Agency shows that pesticide residues are widespread in soils, water, and even human bodies, raising significant concerns for health and biodiversity. Public awareness and consumer demand for safer food are growing, while debates on the withdrawn Sustainable Use Regulation and 2024 farmer protests highlight the contested nature of pesticide use reduction. Achieving the EU's target of halving pesticide use and risk by 2030 will not be possible through incremental adjustments alone. Systemic change across farming practices, markets, governance, and institutions is required.

This report provides transition pathways and policy recommendations for reducing Europe's reliance on Plant Protection Products (PPPs). It is distinctive in combining the comprehensive empirical evidence carried out in the SPRINT project — including measurement of 209 pesticide residues in environmental and human samples — with **stakeholder-driven foresight and back-casting across ten European case study regions**. By bridging science and governance, it translates knowledge into timely, actionable strategies for EU and national policymakers.

Visions and transition pathways for pesticide-free farming

SPRINT engaged stakeholders across ten European case study regions to co-create visions of pesticide-free farming systems in 2050 and identify transition pathways to achieve them. These visions emphasised five transformation dimensions: agronomic practices, economic structures, social values, governance systems, and institutional frameworks.

Findings:

- Stakeholders across diverse regions emphasised common values: environmental stewardship, human health protection, and fairness in food systems.
- Incremental measures such as efficiency gains or substitution were widely regarded as insufficient.
- Systemic change is needed, addressing farming practices, markets, governance, and knowledge systems in an integrated way.
- The participatory process revealed both strong ambition and persistent barriers linked to economic and institutional lock-ins, while also building legitimacy and ownership of transition pathways.

Key policy recommendations:

- **Set binding reduction and accountability frameworks**: Establish EU-wide pesticide reduction targets with clear national reporting and enforcement and reorient CAP funding to reward delivery of public goods such as biodiversity and ecosystem services.
- **Align economic incentives with sustainability**: Design CAP eco-schemes, taxation, and risk-sharing instruments to support diverse farming systems and provide competitive advantages for low-input practices. Use public procurement to build stable markets for pesticide-free products.
- **Strengthen knowledge and advisory systems**: Reinvest in independent advisory services, expand Living Labs and demonstration farms, and embed agroecology and systems thinking in agricultural and veterinary education.
- **Correct market imbalances**: Enforce rules against unfair trading practices, support producer cooperation and regional value chains, and enable fairer value distribution across supply chains.
- **Integrate pesticide reduction into governance frameworks**: Embed pesticide reduction and resilience goals across food, biodiversity, and climate policies, and institutionalise participatory governance through food councils and territorial transition platforms.

Strengthening Pre- and Post-Market Regulation of Pesticides

EU policies for pre-market risk assessment are intended to prevent harm to human health and the environment, while post-market surveillance seeks to detect risks once pesticides are in wide use. However, SPRINT results suggest that both pre and post market assessments have critical shortcomings. Pre-market assessments largely focus on individual active substances and controlled scenarios, overlooking the reality of pesticide mixtures, cumulative exposures, and sensitive groups. Safety thresholds are often based on limited indicators and precautionary margins may not account for important gaps in pesticides safety data. Post-market monitoring is fragmented, with inconsistent coverage across environmental media and Member States, and lacks legally binding limits for most residues in soils, air, and many surface waters. Human biomonitoring is scarcely implemented, and registries of pesticide use remain incomplete and inconsistent.

SPRINT addressed these gaps through extensive sampling of 209 pesticide residues across environmental and human samples in 10 European countries (plus Argentina), assessing the risk of realistic exposures on human health and ecosystems and developing new methodologies such as the SPRINT Toolbox to identify high-risk pesticide–crop–region combinations. These insights underline the need for a more precautionary and harmonised EU framework.

Key policy recommendations:

- **Better integrate mixture and cumulative exposure assessment** into pre-market procedures, ensuring that authorisations reflect the real-world combinations of pesticides applied by farmers and already present in the environment.
- **Expand testing requirements** to cover more sensitive indicators (including sublethal and chronic effects) and realistic exposure scenarios, so that risk assessments better capture long-term and systemic impacts.
- **Apply stronger precautionary safety margins** (higher assessment factors) when setting thresholds, to account for uncertainties and unknown risks that remain in the scientific evidence base.
- **Introduce legally binding environmental quality standards (EQS)** for soils, air, and a wider range of surface waters, ensuring that risks beyond residues in food and drinking water are systematically addressed.
- **Require the establishment of human Biological Guidance Values** (safety thresholds in human matrices) to allow for the post-market monitoring of aggregate human exposure.
- **Establish EU-wide human biomonitoring programmes** across all Member States to detect and compare pesticide exposure in populations, enabling more consistent protection of public health.
- **Mandate harmonised national PPP registries and use inventories**, with sufficient spatial and temporal resolution to make pesticide applications transparent, comparable, and useful for risk management.
- **Link monitoring to targeted risk reduction** by using science-based prioritisation of active substances and combining use data with spatial indicators such as crop distribution and population density, building on tools like the SPRINT Toolbox.

Unlocking the CAP's potential for PPP reduction

The CAP is the EU's main policy instrument shaping farm-level practices, with both budgetary and regulatory power to influence sustainability transitions. Its potential to reduce pesticide reliance is significant, but under current conditions it remains underutilised. In the new delivery model, Member States design national Strategic Plans within an EU-wide framework, yet ambition depends heavily on

how instruments are operationalised at national level. Key environmental objectives and indicators measuring the impact of the CAP are directly linked to sustainable pesticide use.

Findings:

- Conditionality (GAECs) provides the mandatory baseline, but exemptions, national flexibility, and diluted requirements undermine its effectiveness.
- Eco-schemes and ENVLCIM interventions are designed to incentivise sustainable practices, including organic farming, yet their impact is constrained by weak design, short-term orientation, and limited support for innovative or result-based practices.
- Complementary instruments (e.g. knowledge exchange and innovation programmes under AKIS, Farm Advisory Services, programmes for specific agricultural sectors) are critical for knowledge transfer and collective action, but ambition varies widely between Member States, implementation is fragmented, and contributions to pesticide reduction are difficult to track.
- Alignment of instruments is weak: they are often designed in parallel rather than strategically integrated, reducing synergies and transformative potential.

Key policy recommendations:

- **Strengthen GAEC standards** to establish a robust and uniform baseline for environmental performance across Member States, limiting exemptions and ensuring that mandatory requirements provide effective safeguards for pesticide reduction.
- **Redesign eco-schemes and environmental interventions** to shift from short-term, action-based payments to longer-term and results-based incentives, with payment levels sufficient to make low-input and pesticide-free practices economically attractive.
- **Integrate complementary instruments for knowledge exchange, training, advisory services and specific sectors** more explicitly with pesticide-reduction objectives
- **Adopt a more strategic approach in the design of CAP instruments (its 'Green Architecture') for sustainable use of pesticides** by ensuring coherence and continuity of support enabling the large scale transition towards Integrated Pest Management and organic farming.

By linking robust exposure data and transition pathways, SPRINT delivers a new basis for decision-making at EU and national levels. The next EU's Multi-Annual Funding Framework 2028-2034 provides the opportunity to realign regulation, CAP instruments, and governance frameworks so that pesticide reduction becomes a credible and achievable objective. A consolidated list of all policy recommendations can be found in the final part E of this report: **Summary of Policy Recommendations** (pp. 89-94, Table 11).

A. Introduction

A.1. Background

Plant Protection Products (PPPs) remain widely used across European agriculture to safeguard yields against pests, weeds, and diseases. While effective in securing production, their extensive application carries well-documented risks for human health, ecosystems, and biodiversity. The European Environment Agency (EEA, 2023) has highlighted the pervasive presence of pesticide residues in surface water, groundwater, soils, and even human biomonitoring samples. These findings confirm that exposure extends beyond agricultural settings into everyday life. Epidemiological evidence links pesticide exposure to cancers, respiratory and cardiovascular diseases, and neurological disorders, while ecological studies associate it with pollinator decline, biodiversity loss, and disruptions to ecosystem functioning. Significant knowledge gaps persist regarding mixture toxicity, cumulative exposures, and long-term effects, reinforcing scientific uncertainty and raising concerns about the adequacy of current safeguards.

Public awareness of these risks has grown, and consumer demand for safer, more sustainable food systems is increasing. Civil society organisations and NGOs have amplified these concerns through advocacy and litigation, creating heightened pressure on policymakers to reduce pesticide dependence and accelerate the uptake of alternatives.

In response, the European Union has established one of the world's most comprehensive regulatory frameworks. Regulation (EC) 1107/2009 and its implementing principles (Reg. (EC) 546/2011) apply strict approval criteria and embody the precautionary principle, while a suite of directives and monitoring frameworks aims to manage post-market risks. Yet important shortcomings remain. Current instruments lack binding standards for residues in soils and air, monitoring remains uneven across Member States, and regulatory science has been slow to integrate emerging evidence on complex exposure pathways.

Strategic EU policy initiatives such as the Farm to Fork Strategy, the Biodiversity Strategy, and the Zero Pollution Action Plan have set the ambitious objective of halving pesticide use and risk by 2030. However, progress has been contested. Farmer protests, political polarisation around the proposed Sustainable Use Regulation, and calls for regulatory simplification reflect the social, economic, and institutional tensions surrounding this agenda. The Common Agricultural Policy (CAP), as the EU's most significant agricultural instrument, has substantial leverage to support systemic change. Yet its transformative potential remains underutilised, with fragmented implementation and limited alignment of instruments constraining its effectiveness.

Analyses within SPRINT WP7 (D 7.1 & D7.2) have shown that pesticide dependence is not merely the product of individual farm choices or regulatory gaps, but the outcome of systemic "lock-ins." Monocultures and high pest pressures reinforce agronomic reliance on chemical inputs; economic models and market standards prioritise yield and cosmetic quality over ecological resilience; fragmented CAP instruments and rigid authorisation procedures limit flexibility; and research and innovation agendas continue to privilege chemical solutions. These technical, economic, institutional, and cognitive factors interact to stabilise the current paradigm, making incremental reforms insufficient. Meaningful change requires systemic transitions that simultaneously reconfigure farming practices, market incentives, governance structures, and societal expectations.

The SPRINT project positions itself within this context by generating both new evidence and new methodologies. It has conducted large-scale monitoring of over 200 pesticide residues in environmental and human samples, assessed ecological and health impacts under realistic exposure conditions, and developed tools for spatial prioritisation of risks. Beyond empirical contributions, SPRINT has applied participatory foresight and back-casting approaches, co-creating long-term visions for pesticide-free farming with stakeholders across ten European case study regions. These methods move beyond

incremental Integrated Pest Management (IPM) approaches and instead articulate systemic pathways, linking short-term measures with medium-term scaling and long-term institutional reforms.

Deliverables 7.1 and 7.2 provided the foundation by identifying barriers to transition, highlighting stakeholder hesitations, and testing back-casting as a means of overcoming cognitive lock-ins. Building on this groundwork plus all other work packages results, Deliverable 7.3 synthesises these insights into concrete transition pathways and policy recommendations. By bridging local stakeholder visions with EU-level policy frameworks, notably PPP regulation and the CAP, it aims to provide decision-makers with actionable strategies for accelerating Europe's transition towards pesticide-free agriculture.

A.2. Aim and objectives of the report

The overall aim of this report is to develop concrete proposals for how Europe can reduce its reliance on Plant Protection Products and move towards more sustainable plant production systems. To achieve this aim, the report focuses on two main areas.

The first concerns **the reform of the regulatory framework governing PPPs**. The objective in this domain is to generate recommendations for strengthening the processes of approval, post-market monitoring, and risk assessment. A particular emphasis is placed on ensuring that the latest scientific evidence on pesticide risks is systematically integrated into regulatory decision-making, thereby reinforcing the precautionary principle and improving public confidence in the system.

The second area addresses **the development of transition pathways within farming systems**. The objective here is to co-develop visions of pesticide-free agriculture and to chart realistic pathways that connect present conditions with long-term goals. This involves identifying the economic, social, and policy conditions that make such transitions possible, with particular attention to the role of the CAP as a central framework for shaping farming practices and incentives.

Taken together, these two areas also inform a third objective: to **outline future research priorities.** These recommendations build on the outcomes of the SPRINT project and align them with evolving policy needs, ensuring that research agendas contribute directly to supporting systemic change across European agriculture.

A.3. Structure of the report

The report is structured in three interlinked parts. Part B of this deliverable sets out the analysis of visions and transition pathways toward pesticide-free farming. It begins with the contextual framework (B.1), based on Deliverable 7.1, which identified interconnected barriers sustaining pesticide reliance across agronomic practices, research agendas, economic models, cognitive norms, knowledge infrastructures, and regulatory systems. The methodology (B.2) draws on how draft visions for 2050 were constructed and subsequently refined through national workshops in year 5. Chapter B.3. summarises the results of the national workshops in year 5. It examines the starting contexts in the ten case study sites, the values prioritised by stakeholders, and the visions of pesticide-free farming systems in 2050. It then details the transition pathways, structured across five dimensions and sequenced over short-, medium-, and long-term horizons. The discussion (B.4) reflects on the reasoning process, uptake of the visioning exercises, and the strategic challenges of moving from foresight to action. Finally, the part concludes with policy recommendations (B.5), which synthesise stakeholder inputs and research findings into six thematic clusters. These recommendations are explicitly linked to existing or potential EU regulatory frameworks, financial instruments, and governance structures, providing a structured basis for embedding transition pathways into policy processes.

Part C sets out the pre- and post-market policy recommendations developed within SPRINT. The context (C.1) provides an overview of the current EU regulatory and legislative framework governing pesticides, clarifying the baseline against which improvements are proposed. The methodology (C.2) explains how

recommendations were generated, drawing on findings from across SPRINT work packages (WP2–WP6) and refined through a structured process of mapping, drafting, and review in close collaboration with external experts. This ensured both scientific robustness and consortium consensus. The part then summarises overall key findings and policy messages (C.3), before addressing in detail recommendations for the pre-market authorisation process (C.4), as well as environmental and human health risk assessment procedures (C.5). The analysis continues with post-market monitoring and risk reduction (C.6), covering pesticide monitoring in the environment and food, human biomonitoring, and approaches to scaling up targeted risk reduction. Each subsection combines background analysis with SPRINT's findings and recommendations, linking scientific evidence to concrete proposals for regulatory improvement.

Part D of this deliverable examines the CAP as the EU's main budgetary and regulatory framework for farming, with its significant implications. The context (D.1) outlines the objectives and functioning of the CAP architecture, with particular attention to instruments relevant for supporting more sustainable pesticide management. The methodology (D.2) describes the analytical approach, which drew primarily on data from the Agri-Food Data Portal and was complemented by insights from ongoing policy debates and related scholarly work. The chapter D.3 investigates the extent to which the current CAP supports interventions promoting sustainable pesticide use. The results show that, while the CAP already incorporates a variety of potentially useful instruments, their transformative potential is only partly realised. Subsections address the role of conditionality (GAECs) as a structural baseline, the contribution of eco-schemes and ENVCLIM interventions in incentivising practice change, the limited evidence on complementary instruments such as AKIS, FAS, and sectoral programmes, and the overall lack of alignment across instruments within national CSPs. Finally, concrete adaptations to strengthen CAP support for sustainable pesticide management are discussed (D.4).

The report concludes with a synthesis of recommendations that link the findings to current policy debates and provide orientation for future research and implementation.

B. Visions and Transition Pathways

B.1. Context

In the SPRINT project, sustainability transitions are understood as comprehensive, co-evolutionary shifts that unfold across multiple dimensions over extended timeframes (Markard et al., 2012). Our foundational analysis (D7.1) identified an interlocking system of barriers that sustain PPP reliance. These barriers span agronomic practices, research and innovation agendas, economic models, cognitive norms, knowledge infrastructures, and regulatory frameworks. These findings align with broader understandings of socio-technical lock-ins, which involve the interplay of multiple transformation domains, including power relations, cultural norms, and institutional inertia, that collectively reinforce the existing system (see Geels, 2019; Klitkou et al., 2015; Bene & Abdulai 2024).

Assessing the trajectory of pesticide dependence in the EU is not straightforward. Eurostat reports that total pesticide sales were about 292,000 tonnes in 2023 — the lowest level since 2011 (Eurostat, 2024). Yet these statistics cover both agricultural and non-agricultural uses (e.g. forestry, private gardening, green infrastructure, and infrastructure maintenance) and are therefore only a partial proxy for farm-level reliance. Data on actual agricultural use are collected only every five years and are not harmonised across Member States. This opacity itself reflects one of the systemic barriers identified in SPRINT: limited transparency and knowledge infrastructures that obscure the true extent of PPP dependency.

Rather than treating pesticides simply as a necessary risk to be minimised, SPRINT builds on a growing body of research that positions pesticide-free agriculture as both a normative goal and a heuristic device to unlock creative, systemic thinking (Jacques et al., 2022). In line with recent European initiatives (Jacques et al., 2022), pesticide-free agriculture is defined here as the complete avoidance of PPP, while permitting the use of mineral fertilisers (Dueri & Mack, 2024; Finger & Mohring, 2024). This framing challenges the focus on strategies like integrated pest management (IPM), which aim to reduce PPP use but still rely on chemicals. While these approaches are useful, research shows they rarely lead to deeper changes in how farming works. In some cases, they can even make it harder to move away from PPP use completely (Padel et al., 2019).

To guide this transformation, SPRINT draws conceptually from a five-level framework adapted from Gliessman (2015) and Jones et al. (2022), distinguishing between:

1. Improving input[1] efficiency,
2. Substituting with less harmful inputs,
3. Redesigning the agricultural system,
4. Reconnecting food producers and consumers, and
5. Rebuilding food system governance and equity.

While Levels 1 and 2 offer important early steps, Levels 3 to 5 reflect a paradigm shift in agricultural systems thinking, challenging the incrementalist tendencies of input-efficiency models (Tang et al., 2021) and aligning with new research visions of synthetic pesticide-free agriculture (Jacques et al., 2022). The focus of SPRINT lies in Levels 3 to 5, particularly in co-developing context-specific strategies for system redesign, reconnection, and institutional realignment. Recognising the urgency of transitioning towards pesticide-free agriculture, this report identifies practical pathways embedded within current and potential policy frameworks.

Building on these foundations, our early research stages (D7.1) revealed the role of cognitive and institutional inertia, as well as the fragmentation of knowledge systems that limit experimentation.

[1] In this context, "input" refers to external resources used in agricultural production, such as PPP, mineral fertilisers, water, energy, and other material resources. The term is commonly used in agroecology and farming systems research to denote substances and materials that are brought into the farming system, as opposed to those generated within it.

National workshops conducted under D7.2 surfaced both the transformative ambitions of stakeholders and their hesitation to imagine pesticide-free futures. The use of back-casting methodologies (i.e. working backwards from a desirable long-term vision to identify the steps needed to get there, e.g. Vergragt & Quist, 2011, e.g. Vergragt & Quist, 2011) often confronted cognitive lock-in, as some participants found it difficult to believe that such systemic change was possible. As Jacques et al. (2022) note, continued framing of PPPs as part of the solution may limit transformative thinking. This resonates with SPRINT's findings, where even back-casting exercises revealed hesitation to envision pesticide-free trajectories (see D7.2). Nevertheless, these moments of tension catalysed reflection and refinement, laying the groundwork for more pragmatic, regionally grounded co-creation in the final workshop phase.

By Year 5, SPRINT had moved beyond abstract visions to articulate detailed, stakeholder-led transition pathways tailored to ten distinct case study regions. These pathways were shaped through iterative learning, grounded in the practical realities of diverse farming systems, e.g. from Swiss orchards to Croatian olive groves, and informed by shared values, such as environmental stewardship, public health, and fairness. The project's methodological design combined a systemic visioning approach with multi-level stakeholder engagement, aligned with the growing European research momentum toward pesticide-free futures (e.g. the INRAE-ZALF-JKI alliance or Pe'er et al., 2023). SPRINT's visioning and co-creation processes were explicitly designed to foster imaginative exploration, acknowledging that transformative futures require creativity beyond current constraints.

Recognising agriculture as embedded within broader food networks, SPRINT emphasises that transitioning to pesticide-free systems also entails reconfiguring market structures, institutional support, and consumer engagement. Consequently, part B presents an analysis of the outcomes and insights gathered from the recent workshops, highlighting the critical interconnections essential for transitioning towards pesticide-free agricultural systems. It begins with a description of the methodological approach employed during the research, followed by an in-depth examination of the findings. Subsequently, feedback on the co-creation process and methodological limitations are explored, leading to a comprehensive discussion of the general implications for policies of these findings. Consistent with existing research (Kern & Markard, 2016), the analysis underscores the pivotal role of public policy as a key facilitator in achieving effective sustainability transitions, with further elaboration provided in Section B.5.

While many research initiatives on pesticide reduction focus primarily on input efficiency or substitution, SPRINT deliberately advances the debate in three ways. First, it integrates back-casting methods with multi-level stakeholder co-creation, enabling participants to collectively imagine pesticide-free futures and then translate these into actionable pathways. Second, it ensures that local visions are systematically linked to EU and national policy frameworks, bridging the gap between regional realities and institutional agendas. Third, it explicitly prioritises transformation at Levels 3–5 of system change—redesigning farming systems, reconnecting producers and consumers, and rebuilding governance—rather than stopping at incremental efficiency gains. Together, these elements distinguish SPRINT's approach as both methodologically innovative and policy-relevant, providing insights into how systemic agricultural transitions can be envisioned and enacted across diverse European contexts.

B.2. Methodology

The methodology followed a stepwise process that combined analytical and participatory elements to progressively refine visions and transition pathways (see Figure 1). First, insights from Deliverable 7.1 on systemic barriers and lock-ins were revisited and translated into case-specific contexts through targeted literature reviews and feedback from case study leaders. Building on the foundation of successful examples and transition building blocks presented in Deliverable 7.2, narrative draft visions and policy pathways of pesticide-free farming systems in 2050 were developed. These draft visions were then expanded and refined through engagement with stakeholders during the final stakeholder workshops, where visions were validated, shared values were prioritised, and detailed transition pathways were

constructed. In parallel, a structured process synthesised policy recommendations from research findings and stakeholder inputs, ensuring that the pathways were directly linked to EU policy debates and instruments.

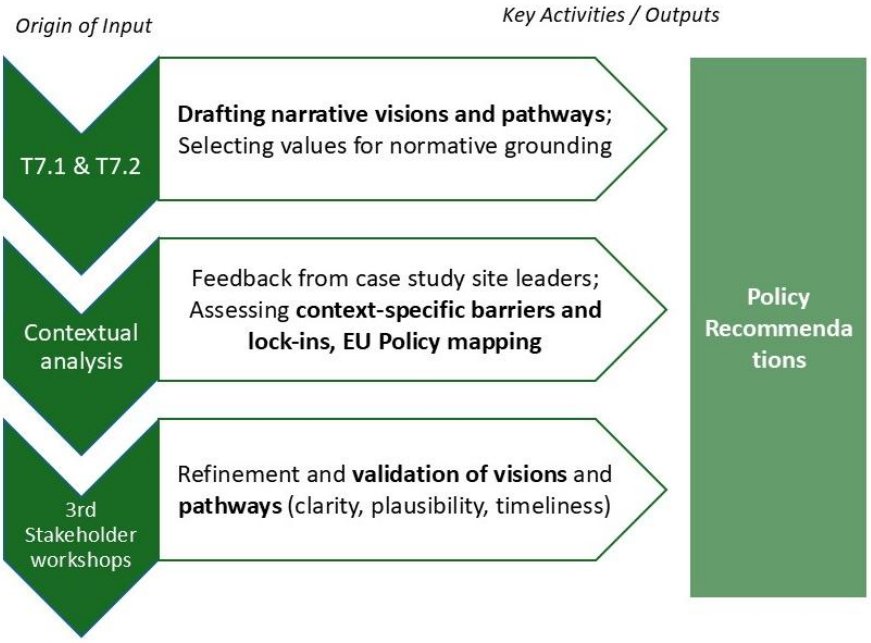

Figure 1: Overview of the sequential process from earlier project tasks to context-specific analysis to stakeholder validation and final policy recommendations under T7.3

Revisiting context specific barriers and lock-ins: starting context for transition

Deliverable 7.1 provided an EU-level typology of systemic barriers. In Task 7.3, these general insights were translated into context-specific barriers by examining the structural, agronomic, and institutional conditions of each case study site. This step drew on targeted literature reviews covering pest pressures, cropping systems, climate implications, and institutional contexts, complemented by the empirical baselines of pest and disease challenges from D2.6 and the farm-level economic analyses of PPP use from D6.3. Draft summaries were then reviewed by case study site leaders to ensure contextual accuracy. This process helped clarify the mechanisms that keep current systems in place and informed a more grounded understanding of what change would require in practice. It revealed not only what constrains change in theory, but also how these constraints play out in different farming systems and regions.

Developing case-specific visions

The draft visions were constructed by combining analytical findings from D7.1 and D7.2 with case-specific contextual analyses. This included literature reviews and feedback from site leaders to capture local agronomic, climatic, and institutional conditions. These elements provided the foundation for ten preliminary visions of pesticide-free farming systems in 2050, which were later refined through iterative stakeholder engagement.

The methodology for the French case study differs, as unlike the other sites, it did not host a dedicated stakeholder workshop in Year 4 for T7.2. Instead, site leaders chose to build on existing national and regional initiatives to avoid duplication, such as the "European Pesticide-Free Agriculture in 2050" initiative and processes led by research institutions like INRAE and IFV. Insights from these exchanges, complemented by analysis of French stakeholder publications and feedback from the case study leader,

were used to draft the initial visions for T7.3 then presented in their final workshop in Year 5. This approach allowed the French case study to leverage existing momentum, remain efficient, and align closely with both local expertise and national transition priorities. This alternative approach also produced materials that remain compatible with the overall project framework and usable for comparative analysis across cases.

The vision framework was informed not only by project outputs but also by established academic research. It draws on socio-technical systems theory (Klitkou et al., 2015 cited in Geels, 2019) and studies on agroecological transitions (Niggli et al., 2023; Bene & Abdulai 2024). Together, these strands informed the identification of five transformation domains:

- **Cognitive and social norms** – perceptions, awareness, and cultural attitudes around agriculture and PPP use.
- **Agricultural practices and innovation** – agronomic techniques and configurations of future farming systems.
- **Economics and value chains** – market structures, economic relations, and distribution of costs and benefits.
- **Knowledge systems and research** – how knowledge is generated, shared, and applied in the advisory and farming landscape.
- **Governance, policy, and institutions** – the regulatory environment, support mechanisms, and institutional coordination.

For developing robust pathways, a systemic change vision was prioritised. Incremental strategies, such as efficiency improvements or substitution, offer short-term gains, but they fail to dismantle structural lock-ins (D7.1). These measures leave the deeper economic, policy, and cognitive barriers intact and in some cases reinforce existing dependencies (Padel, 2019; Mohring et al., 2020). In contrast, the system change vision directly tackles these interlinked barriers and aligns with calls in the sustainability transitions literature for transformative rather than incremental governance responses (Patterson et al., 2017). For this reason, and consistent with the ambition of WP7, SPRINT has chosen to focus exclusively on the system change vision. Table 1 contrasts incremental and systemic visions, highlighting why SPRINT chose to focus exclusively on systemic change

Table 1: Comparison of incremental vs. systemic change vision

Incremental change vision (50% reduction in PPP use by 2035)	**Systemic change vision** (100% reduction towards a pesticide-free agriculture by 2050)
• Prioritising curative rather than preventive strategies. • Increasing adoption of biocontrol solutions. • Utilising mechanical and digital control techniques. • Cultivating adaptability to novel crops and varieties. • Improving input efficiency and minimising harmful practices. • Transitioning conventional practices towards agroecological alternatives.	• Integrated and resilient farming systems enhancing biodiversity and ecological balance. • Farms operating as sustainable ecosystems harmonising agriculture with natural environments. • Empowered farmers driving innovation, autonomy, and collaborative knowledge exchange. • Robust local economies supported by cooperative models and shortened supply chains. • Policies guaranteeing equitable compensation and limiting corporate dominance. • A society deeply valuing ecological responsibility and sustainable agricultural practices.

Constructing transition pathways

Draft transition pathways were built on the prioritisation of vision building blocks from Task 7.2, insights from good practice case studies, cross-case comparison, and expert input from the SPRINT research team. While the visions articulated desirable futures, the pathways translated these into concrete, time-

bound sequences of action. The design logic linked building blocks to enabling measures, mapped dependencies, and situated actions within short- (0–5 years), medium- (6–11 years), and long-term (12–20 years) horizons. Stakeholder priorities identified in earlier workshops informed this sequencing, while expert assessment ensured thematic coherence across cases. Each pathway was structured along the five transformation dimensions (see Table 2), highlighting common leverage points for systemic change.

Table 2: Dimensions of change

Dimension	Strategic Focus	Core Elements of the Dimension
Cognitive and Social Norms	Transforming Cultural Attitudes	Perceptions, values, and attitudes influencing agriculture and food systems.
Agricultural Practices and Innovation	Sustainable Agricultural Innovation	Strategies and innovative techniques influencing the sustainability and resilience of farming systems.
Economics and Value Chain	Equitable Market Structures	Economic relationships, market structures, and distribution mechanisms within food and agricultural sectors.
Knowledge Systems and Research	Collaborative Knowledge Generation	The generation, sharing, and application of knowledge within farming and advisory communities.
Governance, Policy and Institutional Frameworks	Regulatory and Institutional Enhancement	Frameworks, policies, and institutional arrangements guiding agricultural practices and governance.

This categorisation underscored that transition requires coordinated progress across multiple domains. In the short term, actions focused on raising awareness and embedding alternatives in institutions and society. In the medium term, promising solutions were scaled and institutional support strengthened. In the long term, systemic change was consolidated, with new norms and practices embedded in markets, governance, education, and farm-level routines (see Figure 2).

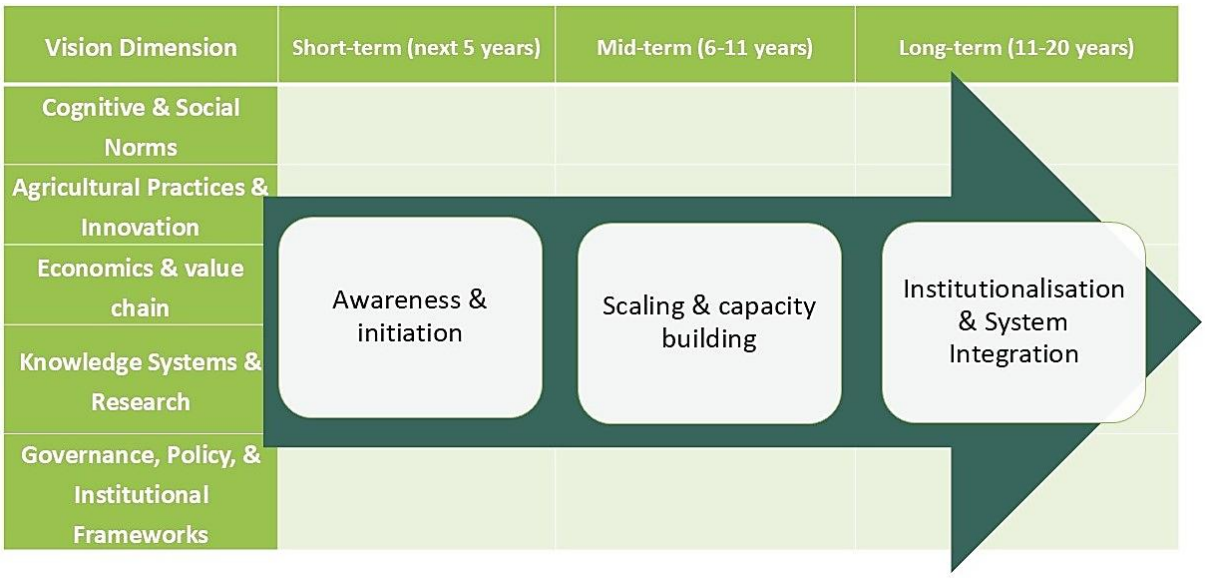

Figure 2: SPRINT pathway logic

Refinement and validation of visions and pathways

The third and final round of Case Study Site (CSS) workshops, conducted between April and May 2025, was central to refining and validating both visions and pathways. The workshops were held as part of the final stakeholder event coordinated by WP1 (see D1.3 Minutes of multi-stakeholder workshop). In total, 245 stakeholders participated across the ten case study sites, around half of them being women. Participants included farmers, advisors, researchers, policy actors, and representatives from civil society and the private sector (see Figure 3).

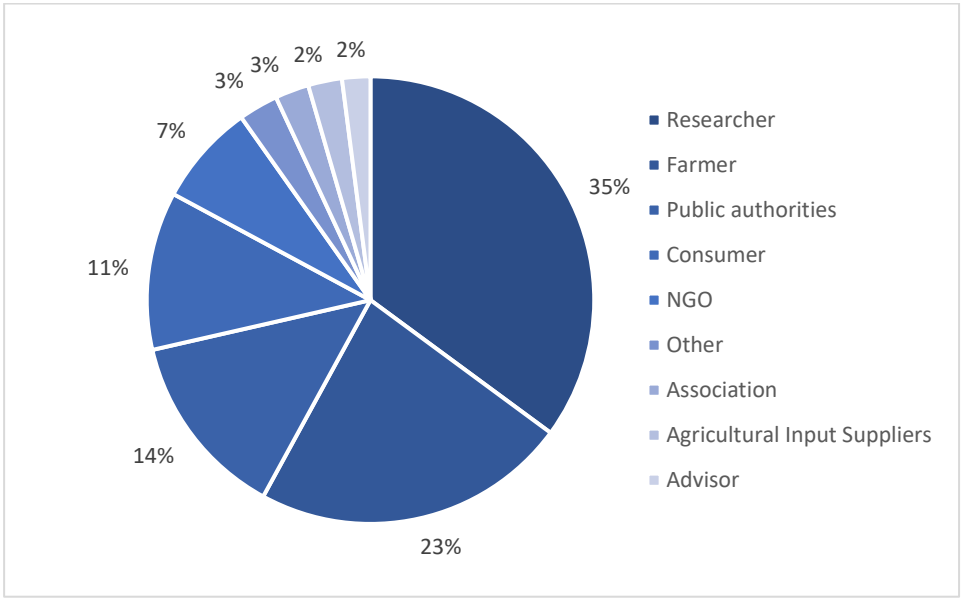

Figure 3: Total share of stakeholder types in the final stakeholder workshops

The sessions were designed as structured opportunities for validation and input. Stakeholders assessed the plausibility and clarity of draft visions, reflected on their alignment with local realities, indicated which of the five transformation dimensions they considered most critical for change, and reviewed proposed actions and timelines in the draft transition pathways. Discussions also addressed how trade-

offs in the pathways might be managed, for example, balancing local food networks with global market demands (see the workshop agenda in Annex 1: Workshop agenda and exercise instructions).

As part of the visioning exercise, participants were also asked to reflect on a shared set of values. These were presented as a series of short value-based statements relating to the agri-food future, for example, around fairness, public health, or care for nature. Stakeholders were asked to rank the statements in order of personal importance, beginning with the one they considered most significant when planning for the future of agriculture and food systems. This ranking exercise helped elicit which societal goals participants prioritised in transition thinking. Rather than treating values as abstract ideals, this exercise anchored the discussion in participant's lived concerns and ethical priorities. The ranked values served as a normative reference point during subsequent steps, particularly when evaluating whether proposed visions and transition pathways aligned with broader societal aspirations. In this way, the values exercise supported more grounded, inclusive, and reflective decision-making. This reflective process helped surface areas of consensus, identify tensions, and reinforce ethical and social dimensions alongside technical change. As a result, the final outputs were not only context-sensitive and feasible, but also normatively grounded and supported by those involved in shaping them.

Policy Recommendations

In parallel, SPRINT followed a structured process to generate policy recommendations aimed at enabling the transition towards pesticide-free agriculture. This process combined EU policy mapping, and synthesis of key activities identified in the visions, pathways and the stakeholder engagement. Feedback from policymakers and over 400 participants at the final policy event refined and prioritised six strategic areas for action: (1) on-farm innovation, (2) financial incentives, (3) fair markets, (4) governance reform, (5) transparency and engagement, and (6) knowledge systems. Framed around system change rather than incremental reform, these recommendations ensure that SPRINT's pathways are grounded in stakeholder realities while directly contributing to EU-level policy debates and instruments.

B.3. Results

This chapter presents the outcomes of the Year 5 national workshops, building on the iterative, multi-stakeholder research carried out throughout SPRINT. The results go beyond a descriptive account of workshop discussions. They demonstrate how SPRINT's methodological design—linking back-casting, stakeholder co-creation, and multi-case comparison—can generate concrete, policy-relevant transition pathways. By working systematically across ten diverse study regions, the project shows how local agronomic, cultural, and economic realities can be translated into structured strategies for systemic change. In this way, the findings not only capture stakeholder perspectives but also provide a scalable evidence base for European and national policymakers seeking to accelerate the transition toward pesticide-free agriculture.

The chapter is structured as follows. It begins with an analysis of the starting contexts across the ten case study sites (CSS), highlighting how transitions are shaped by entrenched economic, regulatory, and cultural dependencies on pesticides. It then synthesises the results of a values exercise, which identified a set of interdependent normative priorities considered central to shaping legitimate and desirable futures for pesticide-free farming. Building on this foundation, participants reviewed draft visions of farming systems in 2050, developed by the research team based on earlier deliverables and workshop insights. Finally, the chapter outlines the transition pathways, integrating stakeholder perspectives and practical measures across five transformation dimensions. These are sequenced over short-, medium-, and long-term horizons, with a focus on concrete actions critical for initiating, scaling, and institutionalising systemic change.

B.3.1. Starting contexts for transitions

Agricultural activities today are profoundly shaped by market prices and consumer preferences, which determine not only what crops are grown but also how they are produced. Farmers face strong price pressures from global commodity markets as well as stringent consumer and retailer demands for quality, appearance, and uniformity. These dynamics create powerful incentives for yield maximisation and cosmetic perfection, reinforcing chemical-dependent production systems and narrowing the perceived space for alternative approaches.

The ten CSS represent a wide range of farming systems including vegetables, vineyards, fruit orchards, cereals, oilseeds, olives, and mixed farms, each embedded within distinct ecological, economic, and social contexts. Despite this diversity, a shared characteristic cuts across all sites: they are embedded in agricultural models that have historically depended on synthetic PPPs. The transition does not begin from a neutral starting point but from within complex, often industrialised systems shaped by economic reliance on yield-maximising inputs, regulatory inertia, and cultural norms that prioritise risk aversion.

Across all crop groups, farming systems are characterised by persistent pest and disease pressures that reinforce reliance on PPPs. In fruits, fungal diseases such as apple scab and pests like codling moths and fruit flies can cause severe yield losses. Cereals are challenged by competitive weeds and fungal infections such as fusarium head blight and rusts, while maize remains vulnerable to insect pests like the European corn borer. Oilseeds face persistent problems with long-lived fungal pathogens such as sclerotinia and strong weed pressure in soybeans. Crop rotations, although generally beneficial, are undermined by herbicide-resistant weeds. Vegetable systems are particularly exposed, with potatoes and tomatoes threatened by late blight and viral diseases, alongside common insect pests such as aphids and whiteflies. In permanent crops such as grapevines and olives, long crop cycles and strict quality demands compound these pressures, reinforcing chemical dependency (see D2.6 for more detailed common pests and diseases by crop).

Yet as D6.3 shows, these agronomic dynamics are deeply intertwined with economic ones: PPPs often represent a significant share of production costs, particularly in fruit and vegetable systems, while in lower-margin crops such as cereals or oilseeds, even moderate PPP expenditures weigh heavily on profitability. Farmers frequently justify PPP use as a form of risk management, both to secure yields against uncertainty and to meet strict market and contractual standards, where even minor cosmetic damage can lead to rejection. At the same time, the prospect of higher short-term costs and potential yield losses when adopting non-chemical practices acts as a barrier to change. Taken together, these findings underscore that PPP dependency is sustained by a combination of biological pressures and economic rationales, embedding it firmly within both farming practice and broader market structures (see D6.3 for details).

Moreover, farmers face growing difficulties in pest protection. Climatic changes are introducing new pests and diseases or intensifying existing pressures, while the range of available PPP is narrowing due to regulatory restrictions on active substances. High market and quality standards—particularly in fruit, grape, and olive production—reinforce reliance on chemical control, as even minor cosmetic damage can lead to rejection. Monocultures and simplified rotations further exacerbate pest vulnerability, leaving few options beyond chemical inputs. Economic reliance on stable yields, coupled with limited advisory support and entrenched cultural norms, creates additional barriers to adopting alternative strategies (see D7.1 for an analysis of barriers to transition). Together, these factors highlight that the transition away from synthetic PPPs is constrained not only by ecological conditions but also by structural, regulatory, and socio-economic contexts.

Nonetheless, signs of momentum toward change are visible. Organic and IPM have gained ground in several case studies, although they often remain limited in scale (e.g. IFOAM Organics Europe, 2021; Frelih Larsen et al., 2024). Stakeholder visions expressed during the workshops demonstrate both a

growing awareness of the urgent challenges facing these systems and a willingness to explore opportunities for transformative change (see D7.2). The following conditions in Table 3 describe the individual CSS farming systems specifications.

Table 3: Starting points: where do case study farming systems stand today?

Case Study	Farming System	Current Context
Spain (ES)	Horticulture systems	… particularly in Almería and Murcia, are technologically advanced yet heavily PPP-dependent due to dense cropping cycles and persistent pest pressures. Despite this, Spain is also a leader in biocontrol and greenhouse innovation, providing a solid base for transition. Further literature: Bielza 2014, Arnó et al. 2018, Desneaux et al. 2022, Espinosa et al. 2002
Portugal (PT)	Viticulture sector	… combines smallholder structures with high PPP use. Its strong reliance on native grape varieties and cultural wine heritage is seen as an asset for building resilient, place-based transition pathways. Further literature: Galindro et al. 2018, Neto et al. 2022, Sousa et al. 2024
France (FR)	Viticulture sector	… faces strong market pressures and quality demands. Though sustainability discourse is widespread, pesticide-free production remains limited, and entrenched input use patterns are still common. Further literature: Karimi et al. 2020, Litskas et al. 2020, Ugalde et al. 2016
Switzerland (CH)	Fruit orchards	… are among the most pesticide-intensive sectors, particularly for apple production. However, high public awareness, strong ecological movements, and political momentum around the ban of specific active substances have set the stage for broader change. Further literature: Zaller et al. 2023, Markó et al. 2017, Mathis et al., 2022
Italy (IT)	Horticulture systems	… face structural strain from climate extremes, invasive pests, and high-value market expectations. While diverse systems and growing organic areas exist, intensive open-field tomato production remains pesticide-reliant. Further literature: Pèrez-Hedo et al. 2017, Giorgini et al. 2018; Mancuso et al. 2024
Croatia (HR)	Olive farming	… is largely small-scale and traditional, with relatively low PPP use. However, climate change and pest outbreaks (e.g. olive fruit fly) are becoming more severe. There is strong potential for ecological diversification and cultural valorisation. Further literature: Šikić et al. 2023, EIP-Agri, 2020, Anđelić Dmitrović et al. 2023
Slovenia (SI)	Mixed farms	… are already low input by design, as they are integrating livestock and crops in mountainous areas. These systems are

		constrained more by market access, scale, and infrastructure than by agronomic barriers. Further literature: Jaklič et al. 2014, Slavič 2017, Schneider & Lysenkov 2022
Czech Republic (CZ)	Oilseed sector	… is industrial, dominated by monocultures of rapeseed. PPP use is structurally embedded, and organic alternatives are almost non-existent due to low economic and policy support. Further literature: Zumr 2023, Vašková & Saska 2024, Ortega-Ramos et al. 2022
The Netherlands (NL)	Potato sector	… is globally competitive and highly technological, but late blight management continues to drive heavy PPP use. The narrow genetic base and resistance challenges further complicate the starting point. Further literature: Wijnands et al. 2014; Ravensbergen et al. 2024, De Jong & De Snoo 2002
Denmark (DK)	Cereal systems	… are technologically advanced and embedded in large-scale, feed-oriented agriculture. PPP use is widespread, especially in larger farms, despite Denmark's strong regulatory leadership and organic food culture. Further literature: Jørgensen et al. 2019, Foodwatch 2024, Macholdt et al. 2020

B.3.2. Values

Building on the synthesis of stakeholder input from Tasks 7.1 and 7.2, a consolidated set of eight core values was developed to reflect the normative priorities underpinning the transition toward pesticide-free farming systems. These values capture both societal aspirations and systemic principles related to sustainability, fairness, safety, and innovation. These dimensions go beyond technical feasibility and frame what is considered desirable or legitimate in agri-food futures (see Table 4). They served not only as input for individual reflection during the third stakeholder workshop but also as normative reference points for assessing and refining the co-created visions.

Table 4: What values are the most important for me in the transition?

Value	Interpretation
Cultural Knowledge	Valuing and supporting traditional agricultural knowledge and practices that align with regional history and the environment.
Economic Resilience	Fostering economic resilience in agricultural markets in a changing world.
Environmental Stewardship	Caring for nature and the environment as a whole.
Farmer Empowerment	Empowering farmers in the market and strengthening trust and understanding between producers and consumers.
Food Justice	Ensuring that everyone has equitable access to safe, nutritious, and sufficient food.
Health & Safety	Enhancing and protecting the health and safety of individuals and communities.

Sustainable Innovation	Encouraging curiosity, research, and innovative solutions that align with ethical and sustainable practices.
Transparency	Ensuring transparency in supply chains, ethical trade, and accountability in labelling and pricing.

During the third round of stakeholder workshops, participants were asked to rank eight values from 1 (most relevant) to 8 (least relevant), in terms of their personal importance for shaping the agri-food system. This ranking exercise was conducted before the vision and pathway assessment exercises, offering a normative baseline to interpret how participants evaluated transition proposals. **Error! Reference source not found.** shows the aggregated results of this ranking exercise. The bullet points in the figure indicate the average ranking (mean score) of each value across all ten workshops. The bars indicate variation in stakeholder rankings, showing the full spread of responses. National workshops came to very different hierarchisations of the values, with most of the values receiving a wide range of scores (e.g. Sustainable Innovation was ranked most important in the Czech Republic but scored lowest in several other countries).

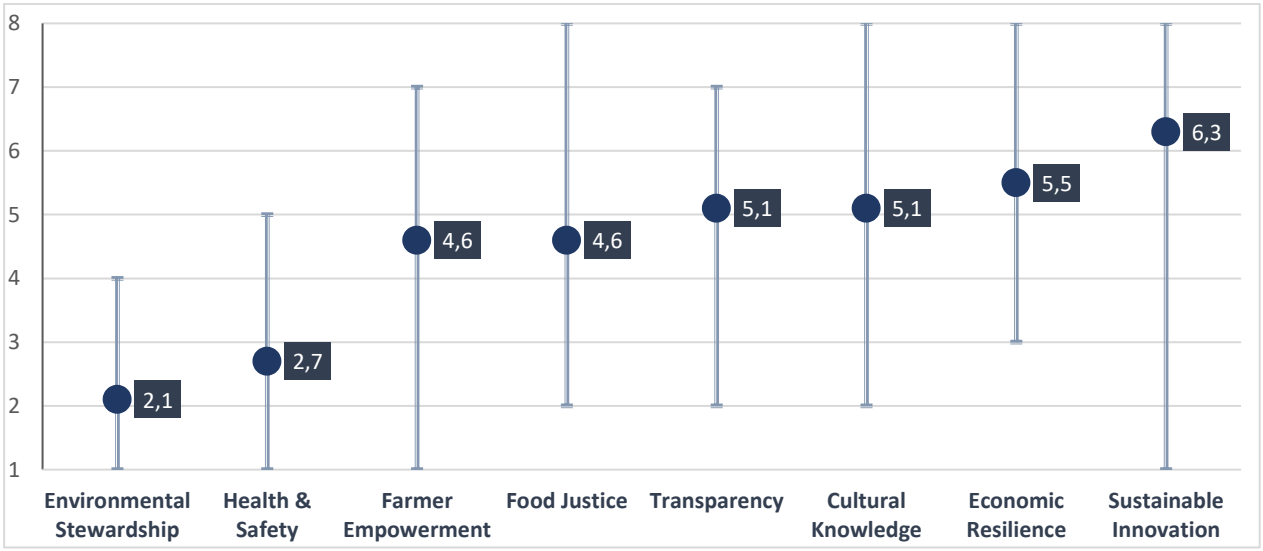

Figure 4: Average ranking of values across workshops

Note: Ranking went from 1 (most relevant) to 8 (least relevant). The bullet points in the figure indicate the average ranking (mean score) of each value across all ten workshops. The bars indicate variation in stakeholder rankings. N=150 replies.

The overall results show a strong, shared emphasis on Environmental Stewardship and Health & Safety, which consistently ranked in the top three in all workshops. These values were seen as foundational drivers of the transition, reflecting broad awareness of the ecological and public health risks associated with PPP use. This widespread prioritisation helped provide normative legitimacy to visions that placed strong emphasis on biodiversity, ecological resilience, and health-conscious farming systems.

More variation can be observed for the other values across the workshops. Food Justice, Farmer Empowerment, and Transparency, clustered in the mid-rank range, but showed greater national variation. For instance, Farmer Empowerment ranked highest in some case studies but mid-tier in others, suggesting diverging perceptions of how central farmer autonomy is to systemic change. Cultural Knowledge exhibited similarly high variation, receiving strong support in Mediterranean case studies (e.g. Spain, Portugal, Croatia) but lower rankings in the French workshop, where it was discussed critically as potentially "retrograde" in the context of viticulture: "It gives the impression of a winegrowing that does not

wish to evolve and adapt to today's challenges." (French workshop) These variations highlight the role of contextual agricultural histories and cultural attitudes in shaping what is valued in a sustainable future.

At the lower end of the overall ranking were Economic Resilience and Sustainable Innovation, though both showed notable national outliers. Economic Resilience was prioritised more highly in the workshops in the Netherlands and Czech Republic, where agriculture has greater economic weight. Sustainable Innovation, despite its low average, was ranked first in the case studies in Czech Republic and second in Spain, indicating that in certain regions, technological modernisation and adaptability are seen as key levers for transformation. In other cases where it ranked low, it might point to the fact that the changes in the agronomic practices are perceived to be rather less decisive for the radical systemic change or are already embedded in current developments.

Despite the diversity in scores, one consistent insight across workshops was that these values were not seen as isolated or competing. Many participants described them as mutually reinforcing: "If there is only one link missing, the change is unfeasible." (Czech workshop), making strict rankings challenging for participants. The clustering of mid-ranked values underscores the perceived interdependency of ethical, social, and technical dimensions of the transition.

B.3.3. Visions

The draft visions for each case study, structured along five shared transformation dimensions, were assessed by stakeholders during the third round of workshops. Each dimension was summarised in a single sentence, and participants were asked to rate their level of agreement on a scale from 1 (strong disagreement) to 4 (strong agreement). In addition to scoring, stakeholders were invited to provide qualitative feedback on each vision dimension. This input was used to refine and finalise the visions, ensuring that they reflected not only shared aspirations but also case-specific realities, priorities, and critiques. The final visions per case study country can be found in Annex 2: SPRINT Case Studies and farming systems.

To illustrate the structure and thematic scope of these visions, an example is presented below (see Box 1) for the Croatian olive farming sector.

Box 1: Vision for 2050 pesticide-free olive growing in Croatia

By 2050, Croatia's olive sector is rooted in biodiversity, regional cooperation, and sustainable land use—showing how pesticide-free farming supports healthy communities, resilient landscapes, and a sustainable agri-food system.

Pesticide-free olive farming is embraced as part of Croatia's cultural heritage, with farmers recognised as stewards of the land, biodiversity, and public health within a locally anchored food system. Olive groves are managed as diverse agroecosystems that integrate agroforestry, habitat mosaics, biodiverse undergrowth, and coordinated pest control strategies, eliminating the need for synthetic inputs. Stable farmer incomes are supported through cooperatives, public procurement, circular practices, and payments for ecosystem services, making pesticide-free farming regionally viable. Collaboration among farmers, advisors, and researchers takes place through Living Labs and training networks, where ecological methods adapted to local conditions are developed, tested, and passed on across generations. Local councils and farmer groups coordinate land use, CAP support, and climate policy to guide olive farming as part of a broader agri-food approach.

As s shown in Figure 5, average scores for all vision dimensions exceeded the midpoint, indicating broad support across the ten case study sites. A closer look, however, reveals systematic variation in the level of agreement (see Table 5). These differences can be understood both as cross-national and as farming

system related. For example, Slovenia's consistently high ratings reflect not only its national policy and institutional context but also its representation of a mixed farming system, which tended to perform strongly across dimensions. By contrast, Denmark's more reserved scores align with both its national setting and its association with cereal-based systems, which showed more cautious assessments overall. This suggests that variation in the visions is shaped by an interplay between national contexts (e.g. governance cultures, policy traditions) and the structural characteristics of the farming systems represented in each case.

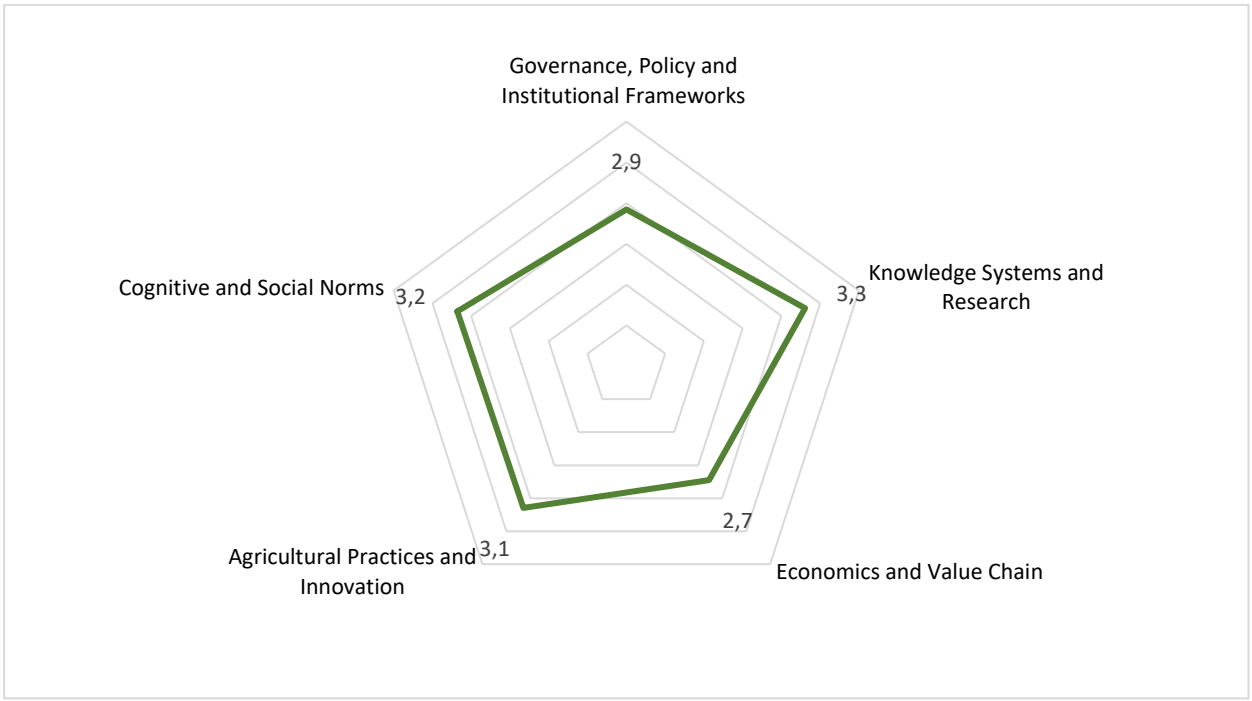

Figure 5: Average scoring of vision's dimensions

Note: N= 150 Participants scored their agreement with a statement for each vision dimension, summing up the vision for the national case study, on a scale from 1 (strongly disagree) to 4 (strongly agree).

Table 5: Average scoring of vision dimensions

VISION DIMENSION	ES	PT	FR	CH	IT	HR	SI	CZ	NL	DK	All
Cognitive and social norms	3	3	2,6	3	3,8	4,1	3,5	3,5	2,3	3,0	3,2
Agricultural practices and innovation	3,3	2,5	3,2	3,1	2,5	3,9	3,6	3,6	3	2,8	3,1
Economics and value chain	3,4	2,5	1,8	3,4	2	3,3	3,8	2	2,7	2,3	2,7
Knowledge systems and research	3,5	3	3,2	2,9	3,3	3,7	3,4	4	3,4	2,7	3,3
Governance, policy and institutional frameworks	2,8	2,5	3,1	2,6	3	3,4	3,7	2,8	2,9	2,4	2,9
VISION	3,2	2,7	2,8	3,0	2,9	3,7	3,6	3,2	2,9	2,6	3,1

The values exercise conducted during the same workshops, just before this exercise, provided an additional layer of interpretation to these ratings. For example, the high consensus around Environmental Stewardship and Health & Safety as top values likely reinforced the broad support for visions that emphasised ecological and public health goals. Meanwhile, diverging opinions on values such as Economic Resilience or Cultural Knowledge may help explain the more mixed ratings on dimensions like value chains or social norms in some countries. These insights suggest a close interplay between ethical priorities and perceived feasibility, which can be further explored in the discussion.

Across several workshops, participants expressed reservations about the vision scoring exercise itself. While the rating format enabled structured feedback, many stakeholders felt that the vision statements were too condensed to fully reflect the complexity of the issues at stake. Several noted that the sentences were overly brief and lacked sufficient detail, making it difficult to assess their feasibility or relevance. Others pointed out that the visions did not include concrete examples, actionable steps, or mechanisms for implementation[2], and therefore remained too abstract. There were also concerns that the statements omitted important challenges or trade-offs that are inherent to real-world transitions. These critiques were acknowledged and discussed during the sessions. However, they were largely addressed through the subsequent exercise of co-developing transition pathways, which offered participants space to specify and refine actions, timelines, and institutional responsibilities in greater detail. It was also clarified that the concise form of the vision statements was a deliberate methodological choice, intended to offer high-level summaries of long-term transformation goals, rather than exhaustive descriptions or prescriptive roadmaps.

In addition to overall support for the vision dimensions, participants across several CSS proposed content-specific refinements to strengthen contextual fit. Some of these insights directly informed the revision of the vision texts, while others were taken forward in the co-design of the transition pathways (see chapter B.3.4.). In Czechia, stakeholders objected to the strong emphasis placed on energy crops in the draft vision. While this had initially been included as a plausible development pathway, based on the current development, participants argued rightfully that such a focus risked perpetuating monocultures and PPP dependence rather than supporting diversification. They recommended shifting the vision toward alternative strategies that reduce reliance on oilseed and better reflect ongoing policy moves to limit energy crop expansion. In France, stakeholders pointed out that cooperatives are already a long-standing feature of the wine sector and therefore should not be presented as a transformative element in the vision. Instead, they emphasised the need to address structural imbalances in the sector, particularly the concentration of power among large buyers and distributors compared to smaller producers. They also stressed the importance of neutral, publicly facilitated knowledge platforms and agroecological labelling schemes to support the transition. Italian participants proposed shifting emphasis away from generic technological innovation toward regionally embedded agronomic strategies and advocated envisioning a farming system that operates independently of subsidies. In Croatia, feedback highlighted the importance of free, lifelong farmer education and the role of cooperatives in enhancing resilience. Participants also recommended addressing the role of digital platforms, inclusive market channels, and enabling public policies, while emphasising the contributions of youth, women, and digitalisation to knowledge exchange and innovation. In Slovenia, participants called for a stronger focus on blending traditional and modern knowledge systems, along with initiatives to raise agricultural literacy across the general population. Finally, Dutch stakeholders felt the vision underplayed systemic constraints and urged greater attention to lobbying influences and improved transparency for both industry and advocacy actors.

[2] "Transition challenges are not mentioned – it would be helpful to realistically present the obstacles and how they could be overcome" (HR)

B.3.4. Pathways

Transition pathways are structured across five key dimensions: Cognitive and Social Norms, Agricultural Practices and Innovation, Economics and Value Chains, Knowledge Systems and Research, and Governance, Policy and Institutional Frameworks. Actions are sequenced both by timeframe—short-term (0–5 years), mid-term (6–11 years), and long-term (12–20 years)—and by transition logic, moving from initial adoption of alternatives, to scaling and mainstreaming, and finally to institutionalisation and system integration.

The pathways synthesise actions were co-developed with stakeholders in each CSS and draw on diverse farming systems and regional contexts. Table 6 summarises the indicative timelines for actions across the five transition dimensions. It illustrates how initial measures—such as awareness campaigns, demonstration farms, and financial incentives—are expected to expand in the medium term through scaling-up, collective initiatives, and stronger policy support, before becoming embedded as long-term systemic changes.

Table 6: Pathways: Indicative timeline of transition activities across vision dimensions

Vision Aspect	Initial Adoption: Short-term (next 5 years)	Scaling and Mainstreaming: Mid-term (6-11 years)	Institutionalisation and system integration: Long-term (11-20 years)
Cognitive & Social Norms	*Raise awareness of pesticide risks and the benefits of agroecological practices through campaigns and outreach.*	*Promote collective thinking, peer learning, and consumer education to shift social expectations.*	*Embed sustainable mindsets as cultural norms across farming, policy, and consumer spheres.*
Agricultural Practices and Innovation	*Support early adoption of diversified cropping systems via demonstration farms and extension services.*	*Expand uptake of ecological practices and technologies across regions and farming systems.*	*Mainstream redesigned farming systems based on agroecological and regenerative principles.*
Economics & value chain	*Introduce financial incentives, grants, and compensation schemes for early adopters*	*Scale up support through risk-sharing mechanisms, cooperative models, and public–private partnerships.*	*Transition to economically resilient systems with premium markets and regionalised, transparent value chains.*
Knowledge Systems and Research	*Launch exchange platforms for alternative pest management, Living Labs for Innovation and improve access to existing training programmes*	*Build capacity through independent advisory services and farmer-led knowledge networks.*	*Institutionalise agroecology within research agendas, education systems, and continuous learning structures.*
Governance, Policy, and Institutional Frameworks reform	*Establish basic regulatory frameworks to support low-risk alternatives and incentivise transitions.*	*Strengthen harmonised PPP regulations and expand policy support for agroecological practices.*	*Integrate pesticide-free agriculture into mainstream policy frameworks, standards, and subsidy regimes.*

The following sections highlight the most supported or frequently proposed measures across all five transition dimensions. The emphasis is on practical interventions, ranging from awareness campaigns and pilot schemes to market transformations and policy reforms, rather than final end-state scenarios. Each action is labelled with the respective case study for reference and transparency, with detailed tables available in Annex 4. In addition, good practice examples were collected to illustrate particular dimensions of the pathways. A short textbox is added when relevant, with a link made to the more complete fiches published on the SPRINT website.

Cognitive & Social Norms

Timeframe	Key actions
Short-term (0–5 yrs) – Initial adoption	• Awareness campaigns (health, environment) • Ecological food culture (schools, festivals, storytelling) • Counter misinformation • Media/social media farmer stories • Recognition awards • Peer storytelling & farmer policy engagement • Labelling & QR codes (trust, transparency)
Mid-term (6–11 yrs) – Scaling & mainstreaming	• School curricula & training integration • Public procurement & retail campaigns • Food councils (local governance) • Peer-led training & mentorship • Farmers as ecosystem stewards • Retailer/caterer product lines & staff training • Wine tourism & regional marketing • Remove aesthetic criteria from food standards
Long-term (12–20 yrs) – System integration	• Sustainability in national curricula & teacher training • Museums, media & local authorities as norm carriers • Ecological farming as national/regional identity • Cultural events & storytelling campaigns • Farming as meaningful profession • Succession planning & youth mentorship

In the **short term**, the pathways emphasise raising public awareness and shifting consumer expectations around pesticide-free farming. Measures include national campaigns on health and environmental risks, and promotion of ecological food culture through schools, festivals, storytelling, and workshops (ES, PT, FR, CZ, CH). Addressing misinformation is also noted as a priority (ES), alongside media and social media outreach showcasing early adopters in sectors such as wine and olive oil (FR, PT, HR). Public recognition is proposed as another lever, for instance through a "Pesticide-Free Champion" award model (DK), which can celebrate pioneers and make ecological farming more visible. Local programmes further illustrate how consumption habits can be influenced in practice. The Dutch "Baby Vegetable Bag" initiative, for example, provided families with infants aged 4–12 months a free weekly bag of organically produced vegetables, together with recipes and preparation tips. By combining convenience, education, and early exposure, the programme demonstrated how small-scale interventions can generate multiple health and sustainability benefits (see de Baby Groente Tas). On the producer side, peer storytelling, public recognition, and participation in policy forums (SI, ES) is presented as ways to validate farmers and reduce isolation. Additional proposals include relaxing appearance-based food standards (IT, ES) and clear labelling/origin traceability to straighten trust (NL, CH).

By the **mid-term,** the emphasis shifts toward embedding ecological values in institutions, education, and consumer environments. This includes integrating pesticide-free and food system literacy into curricula, training, and media (ES, CZ, NL, SI), and expanding public procurement, retail campaigns, and civic food councils (CH, FR, IT). Farmer engagement is framed around peer-led training and mentorship, with an emphasis on reframing farmers as ecosystem stewards (CH, SI, NL). At consumer level, retailers and caterers promote ecological options through staff training, new product lines, and in-store education. Regulatory and market measures also begin to take hold in this period, such as clear labelling and origin traceability schemes (NL, CH), as well as the removal of appearance-based food standards (IT, ES), both of which support transparency and trust. In some cases, wine tourism and regional branding are suggested as additional pathways to reinforce recognition and value (FR, PT). The Danish Whole Grain Partnership (Box 2) shows how coordinated branding, consistent communication, and stakeholder collaboration can make dietary and ecological practices mainstream at national scale**.**

Box 2: The Danish Whole Grain Partnership

The Danish Whole Grain Partnership: shifting a country's consumption habits

Launched in 2008, as a collaborative effort involving governmental agencies, health organisations, the food industry, and NGOs, aiming to significantly increase whole grain consumption among the Danish population. Recognising that dietary changes require shifts in both individual behaviour and social norms, the partnership introduced a clear and easily recognisable logo to identify whole grain-rich products. It combined public awareness campaigns, educational materials, and targeted marketing to encourage consumers to integrate more whole grains into their daily diet.

The results were substantial: by 2019, average daily intake rose from 36 g to 82 g per person, **the highest in Europe.** This increase is linked directly to heightened consumer awareness, improved dietary guidelines, and sustained industry engagement. Recognised by the EU and the OECD as a model for improving public health, the partnership shows how collaborative governance and consistent communication can reshape dietary norms at scale.

Key lessons: involve diverse stakeholders early, maintain clear and consistent messaging, and use intuitive visual tools to build public trust and uptake.

Source: The Whole Grain Partnership - Choose Whole Grains First, Lifestyle, Energy, Diet

In **the long term**, efforts strengthen ecological values and align them with health and nutrition. Actions include embedding sustainability in national curricula, teacher training, and public education systems to normalise practices across generations (ES, SI, NL). Cultural institutions such as museums, media, and local authorities maintain visibility and reinforce collective narratives (CZ, FR, CH). In some contexts, ecological farming was suggested to become part of national or regional identity, supported by cultural events, storytelling, and community platforms (DK, HR, CZ). At the same time, farming is increasingly recognised as a socially meaningful and environmentally responsible profession, supported by succession planning, youth mentorship, and civic recognition programmes (IT, SI).

Agricultural Practices & Innovation

Timeframe	**Key actions**
Short-term (0–5y)	Demo farms • Crop diversification (legumes, oats, brassicas) • Training & peer networks • Machinery-sharing cooperatives • Pest/climate-resilient varieties • Public breeding • AI/sensor monitoring • Ecological practices: habitat-based pest suppression, plant extracts, netting, light mechanisation • Livestock reintegration & nutrient cycling
Mid-term (6–10y)	Systems-level agroecology (intercropping, agroforestry, grazing) • Tech support: site-specific input tools, soil health, microclimate monitoring • Regional infrastructure: biocontrol centres, early-warning, coordinated releases • Co-designed crop-livestock systems, participatory breeding • Subsidies for mixed-use, resilient crops • Digital pest forecasting pilots building on monitoring systems
Long-term (11–20y)	Closed-loop biodiversity systems • Perennial crops, hedgerows, flower strips, tree rows • Landscape-level planning & agroecological hubs • Diversification mainstreamed • Real-time, integrated ecological forecasting within closed-loop systems • Ecological infrastructure • Eco-certification schemes • Full system redesign with ecological functioning central

In the **short term**, the pathway focuses on making pesticide-free practices more accessible through demonstration farms that trial diversification (legumes, brassicas, oats) and agroecological methods adapted to local conditions (DK, NL, CZ, ES). Training programmes and peer learning networks provide hands-on support for early adopters (IT, CH, SI). To reduce barriers, several CSSs propose precision machinery-sharing cooperatives for weeding, sowing, and pest scouting (DK, NL, CZ, FR, HR). Parallel efforts include testing pest- and climate-resilient varieties (IT, ES, PT, FR), public breeding initiatives (IT), and the first generation of AI- or sensor-based monitoring tools (DK, NL, PT, CH), which begin building the datasets needed for future forecasting. Ecological practices such as habitat-based pest suppression, plant extracts, protective netting, and light mechanisation are introduced (PT, FR, CH, HR), while mixed systems emphasise livestock reintegration and nutrient cycling (SI, DK). Together, these actions combine local knowledge with precision tools to initiate transition. Shared access to machinery has proven crucial in lowering adoption barriers; the CUMA cooperatives in France (see Box 3) illustrate how such models not only reduce individual costs but also build the collaborative structures that support long-term agroecological transition.

Box 3: CUMA Cooperatives in France

CUMA Cooperatives in France: Scaling machinery with shared access

France's Coopératives d'Utilisation de Matériel Agricole (CUMAs) offer a longstanding and successful model of shared agricultural equipment. Established post-World War II, to reduce financial barriers for farmers, CUMAs have since evolved into key enablers of agroecological transition.

Today, over 10,000 CUMAs operate across France, encompassing approximately 182,000 farmers, nearly half of France's agricultural workforce. Each cooperative typically comprises about 23 members, pooling resources to access equipment that might be financially out of reach individually. The model ensures access to equipment such as mechanical weeders, seeders, and precision tools essential for pesticide-free farming.

Beyond machinery sharing, CUMAs have evolved into hubs of agricultural innovation. They are offering collective training, field demonstrations, and peer exchange, enabling farmers to stay abreast of advancements in agroecological methods and precision agriculture. This collaborative approach not only reduces individual costs but also fosters a culture of collaboration, experimentation, and continuous learning.

Key lessons: long-term success depends on strong local organisation, peer-led knowledge exchange, and aligning shared infrastructure with ecological goals. CUMAs show how cooperative models can scale both technical capacity and cultural support for low-input farming.

Source: Fédération Nationale des Cuma | FNCuma

In the **midterm**, emphasis shifts to scaling systems-level agroecological models (intercropping, agroforestry, rotational grazing, modular cropping) to enhance soil fertility, pest control, and climate resilience (ES, SI, PT, CZ). Farmers increasingly adopt site-specific management tools for variable input delivery, soil monitoring, and microclimate-based decisions (NL, DK, IT, CH). Regional infrastructures are perceived to be playing a growing role, such as biocontrol rearing centres, pest early-warning systems, and coordinated releases (ES, CH, PT). Stronger research–practice links support co-designed crop-livestock systems (SI), site-specific blueprints (IT), and participatory breeding (FR, PT, CZ). Subsidies and breeding programmes promote mixed-use, resilient crops (SI, CZ). Digital dashboards expand, enabling farmers to integrate pest, plant, and weather data into daily decision-making (DK, CZ, NL, ES). In parallel, pilot forecasting models start emerging, combining these datasets into predictive tools that guide farm management decisions.

In the **long term**, the transition consolidates into closed-loop, biodiversity-based systems that are self-regulating and regionally adapted. These include perennial crops, hedgerows, flower strips, and tree rows (CZ, CH, FR, PT, ES), alongside landscape-level planning and agroecological hubs coordinating nutrient cycling, pest control, and farmer networks (DK, SI, IT). Diversification becomes the norm rather than the exception (e.g. agroforestry and vineyards in FR, mixed systems in SI). Building on the monitoring and dashboards introduced earlier, forecasting tools evolve into fully integrated systems that draw on region-wide datasets to provide real-time ecological decision support. Croatia's PESCAR pilot, for example, already combines weather and pest data to cut PPP use without yield loss, showing the potential for more advanced forecasting models as infrastructures mature (see the SPRINT factsheet for more info sprint-h2020.eu). Ecological infrastructure is increasingly codified in production standards (PT, HR, CZ), while national eco-certification schemes recognise fully closed-loop, pesticide-free systems (IT, ES). Ultimately, the long-term vision moves beyond input substitution toward system redesign, where ecological functioning becomes the central principle of farm management.

Economics & Value Chains

Timeframe	Key Actions
Short-term (0–5y)	• Risk-sharing: CAP transition payments, pest-loss insurance, pooled funds • Subsidies/tax incentives for transition investments • On-farm & local processing units • Storage for pesticide-free goods • Regional cooperatives managing short supply chains • Direct-sale platforms, Community Supported Agriculture, short-chain hubs • Labelling & certification: zero-residue, transition labels, QR traceability • Participatory Guarantee Systems for smallholders • Fiscal/land incentives peri-urban veg • Ecosystem service pilots
Mid-term (6–10y)	• Public procurement for ecological products • Territorial brands & regional marketing hubs • Cooperative infrastructure: storage, logistics, processing • Risk-sharing: price floors, contracts, PPP investment • Circular economy hubs (olive residues, orchard waste) • Digitalisation: CSA platforms, online markets, short-chain systems • Regional identity labelling
Long-term (11–20y)	• Institutionalised fair pricing & transparency frameworks • Polluter-pays & full-cost accounting • Circular by-product reuse: compost, feed, biogas • Regional/urban–rural supply corridors • Ethical food networks & rural development • Export-oriented eco-brands & tourism promotion • Eco-certification systems • Trade & subsidy reforms for seasonal agroecological sourcing • Mandatory PPP/biodiversity/working condition reporting in supply chains

In the **short term**, the pathways focus on de-risking transitions and enabling adoption of pesticide-free practices. CAP transition payments, pest-loss insurance schemes, and pooled risk-sharing mechanisms provide a financial buffer against yield loss and pest damage (ES, CZ, HR). Cooperative-based insurance models, public risk funds, and investment bonuses extend this safety net and create shared responsibility among farmers. Targeted subsidies, grants, and tax incentives (SI, FR, PT) support investments such as composting facilities or on-farm processing units.

Parallel efforts strengthen on-farm and cooperative processing capacity through mobile or shared facilities for cereals, dairy, vegetables, and wine (DK, CH, IT, NL), complemented by dedicated storage infrastructure to ensure traceability and avoid contamination (HR, CZ). Regional cooperatives are tasked with managing these facilities and developing short supply chains (HR, CZ). Market access is supported

by digital direct-sale platforms, Community Supported Agriculture schemes, and short-chain marketing hubs (NL, CH, ES).

Labelling and certification are highlighted as priorities, including "zero-residue" and transition labels (IT), independently verified systems with QR-code traceability (PT, ES, CZ), and Participatory Guarantee Systems to reduce costs and strengthen accountability for smallholders. The Swiss IP-Suisse label provides a pioneering example driving national markets toward reduced PPP use (see the SPRINT factsheet for more info sprint-h2020.eu).

Additional incentives include fiscal and land-use measures in peri-urban zones, such as tax exemptions and streamlined leases for vegetable producers (IT). Innovative models like Land van Ons, a citizen cooperative in the Netherlands that collectively purchases farmland for biodiversity restoration, illustrate new financing approaches (see the SPRINT factsheet for more info sprint-h2020.eu). Finally, pilot ecosystem service payments are introduced to compensate farmers for delivering public goods such as biodiversity, carbon storage, and water management (SI).

In the **mid-term,** the economic dimension shifts toward restructuring agri-food markets through demand-side reforms, investment in infrastructure, and expanded risk-sharing. Public procurement emerges as a cornerstone: multiple case studies (PT, CH, HR, ES) propose institutional sourcing for schools, hospitals, and canteens to stabilise demand for ecological products. Regional governance bodies and procurement labelling schemes (CH, HR) reinforce credibility and strengthen local identity. Public procurement is highlighted as a cornerstone of the mid-term economic transition. Copenhagen's Food Strategy (see Box 4) illustrates how municipal sourcing, when scaled across schools and hospitals, can reshape supply chains and set new market standards.

Box 4: Copenhagen's food strategy

Copenhagen's food strategy: broad public procurement sets the norm.

Since 2001, Copenhagen has pioneered a comprehensive approach to sustainable food procurement. The city's Food Strategy, formalised in 2019, set ambitious goals: achieving 90% organic food in public meals and reducing the carbon footprint of public food services by 25% before 2025. This strategy encompasses over 1,000 municipal kitchens, serving approximately 70,000 meals daily across schools, care homes, and other institutions. The approach integrates organic sourcing, seasonal menus, reduced meat consumption, and substantial waste minimisation, achieving these objectives within existing budget constraints through enhanced kitchen efficiency.

A cornerstone of this transformation is the Organic Cuisine Label, a national certification indicating the percentage of organic ingredients used in kitchens. Copenhagen's public kitchens have embraced this label, with many achieving the gold standard (90–100% organic). The city has invested in extensive training programmes for kitchen staff, developed in collaboration with culinary advisors, to facilitate this shift. These programmes focus on menu planning, sustainable cooking practices, and food literacy, ensuring that staff are equipped to deliver high-quality, climate-friendly meals.

The impact of Copenhagen's approach extends beyond municipal institutions. The city's procurement practices indirectly stimulate market demand for organic products, benefiting local farmers, producers, and distributors. Private businesses, including hotels and restaurants, have gradually adopted similar procurement standards, partially influenced by the public sector's example and the availability of certified organic ingredients. The resulting market shift underscores how municipal procurement policies can facilitate broader transformations in the regional food economy.

Key lessons: meaningful policy instruments brought together into a carefully designed holistic policy strategy offer long-term positive effects both on the population targeted and the surrounding economic environment, all while also setting general standards.

Source: The City of Copenhagen Food Strategy 2019.pdf , The Organic Cuisine Label - Danish Veterinary and Food Administration

Territorial brands and regional marketing hubs (FR, CH) are promoted to aggregate products, coordinate labelling, and run joint campaigns, enabling small producers to access institutional and export markets. A strong illustration comes from Bretagne (FR), where three cooperatives launched the "Cultivées Sans Pesticides" label (Garletti, 2024), converting nearly all regional tomato production to pesticide-free farming in just five years. Alongside branding, mid-term strategies expand cooperative infrastructure for shared processing, storage, and logistics (CZ, DK, NL), reducing post-harvest losses and improving efficiency. Stakeholders also stress stronger risk-sharing mechanisms across the supply chain—through price floors, fairer contracts, and public–private partnerships (PT, DK, IT)—to buffer farmers from market volatility. New circular economy models are proposed, with hubs that process farm by-products (olive residues, orchard waste) into compost, dried fruit, or herbal extracts (HR, CH). In parallel, digitalisation gains traction through CSA platforms, online marketplaces, and short-chain sales systems (ES, SI, IT), linking producers directly with consumers and reinforcing traceability and transparent pricing.

In the **long-term**, the pathways point to the consolidation of resilient and transparent market structures that embed ecological farming into mainstream economic systems. The importance of fair pricing mechanisms and transparent contracts (CH, IT, SI) got highlighted, complemented by proposals for ecosystem-based pricing and polluter-pays principles (DK, NL, CH) to internalise environmental externalities. A recurring focus is the circular reuse of by-products, with olive pomace, wine residues, or oilseed cake envisioned as inputs for compost, animal feed, or biogas (CZ, DK, NL, SI). Such measures diversify farm income while improving resource efficiency. The strengthening of regional and territorial markets also features prominently. Proposals include the development of urban–rural supply corridors for vegetables (ES), cooperative-led rural development strategies (SI), and ethical food networks that generate local employment (IT). In parallel, eco-certification schemes and traceability tools are considered essential to consolidate trust in ecological products and facilitate scaling (FR, PT). Some proposals see high-value ecological products (e.g. wines and cereals) linked to export promotion and tourism strategies (FR, PT, DK), reinforcing both economic resilience and regional identity. Finally, long-term transformation is also tied to structural policy reforms, such as trade and subsidy frameworks privileging agroecological production (ES), and mandatory reporting requirements on PPP use, biodiversity impacts, and working conditions across supply chains, with relevance in vegetables.

Knowledge Systems & Research

Timeframe	Key Actions
Short term (0–5 yrs)	• Farmer platforms for peer exchange • Retrain advisors in low-input & agroecology • Living Labs & innovation hubs for trials & pilots • Field labs, demo farms, farmer research clusters • Open-access tools for pests, soils, ecology • Digital skills for marketing/exports • Agroecology in vocational training
Midterm (6–11 yrs)	• Participatory research, demo networks, peer clusters • Online training, modular courses, digital tools • Independent ecological extension • Open-data platforms & dashboards • Capacity-building for advisors/trainers

Long term (12–20 yrs)	• Decentralised, participatory knowledge systems • Lifelong learning via AKIS & funding frameworks. • Agroecology in all education levels • Regional hubs & agroecological data commons • Institutionalised farmer–researcher partnerships & on-farm trials. • Knowledge reframed as public infrastructure for resilience.

Short-term efforts focus on strengthening advisory systems and farmer-centred knowledge exchange. Initiatives include retraining advisors in low-input and agroecological practices, supported by peer mentoring, networks, and field-based training (DK, NL, ES, FR, CH). Living Labs and farmer-led innovation hubs provide spaces for experimentation and piloting both agronomic and economic aspects of transition (HR, IT, CH, FR). Platforms like *Landfiles* enable farmers to collaborate in regionally specific groups, exchange solutions, and co-develop practices (FR, ES, PT) (see Box 5). Additional measures include the establishment of regional field labs, demo farms, and research clusters to test biological inputs, rotations, and pest management (NL, CZ, PT). Open-access digital tools are proposed for real-time monitoring of pests, soils, and ecological indicators (CZ, FR, NL), complemented by training in digital skills for farm marketing and exports (HR). Agroecology is also recommended for integration into vocational training programmes (DK, NL).

Box 5: Landfiles Platform

Landfiles: A digital networking site for farmers.

Landfiles, a French-based digital platform founded in 2017, is dedicated to facilitating participatory research, data sharing, and collaborative experimentation within the agricultural sector. Its primary aim is to accelerate the adoption and development of agroecological techniques by connecting farmers, agronomists, agricultural advisers, and researchers. By early 2025, the platform had grown significantly, engaging approximately 10,000 users across over 400 active workgroups.

One notable example hosted on Landfiles is the Iberian Community of Agroforestry and Mixed Farming Systems (Comunidad de Sistemas Agroforestales y Cultivos Mixtos), established in 2023. This specific thematic network connects farmers, advisers, and researchers from Spain and Portugal to regionally exchange relevant experiences, practical solutions, and knowledge focused explicitly on agroforestry and diversified farming methods. Community activities include quarterly webinars featuring farmer experiences and detailed discussions addressing regional challenges, solutions, and innovations in agroforestry and mixed cultivation systems.

Through such targeted communities, Landfiles demonstrates how digital, decentralised platforms enable practical knowledge transfer and shared innovation within agriculture. Members directly contribute observations, trial results, and experiential insights, thereby creating a dynamic repository of localised expertise.

Key lessons: peer-to-peer learning allows for the rapid dissemination and scaling of context-specific agricultural practices from farmers for farmers, rather than relying solely on external expert knowledge. This digital approach strengthens systems thinking and participatory advisory frameworks, effectively bridging gaps between farmers, researchers, and technical consultants.

Sources: Inicio - Landfiles , Comunidad de sistemas agroforestales y cultivos mixtos - Landfiles

Mid-term actions emphasise applied knowledge production and institutionalisation of inclusive, practice-oriented systems. Suggested measures include participatory action research, regional demo networks, and peer-learning clusters (DK, SI, HR, PT). Digitalisation plays a stronger role, with online training formats, modular courses, and advisory tools expanding access (SI, CZ, IT). Extension services are proposed to provide independent, region-specific ecological advice (IT, PT). Knowledge infrastructures

are strengthened through open-data platforms and dashboards linking pest, crop, and soil data to tailored guidance (CH, ES). Capacity-building for advisors and farmer trainers is also highlighted to enhance both technical and facilitation skills (FR, SI, PT).

In the **long term**, the actions describe decentralised and participatory knowledge ecosystems embedded within lifelong learning frameworks. Proposals include dedicated training pathways for farmers and advisors, supported by public–private partnerships and Agricultural Knowledge and Innovation System (AKIS) structures (DK, CH, HR, SI). Agroecology and systems thinking are integrated into all levels of agricultural education, from vocational schools to professional certification (ES, IT, CZ). Territorial hubs and agroecological data commons are developed as multi-actor platforms for shared research and governance (NL, CZ, HR). Farmer–researcher partnerships, innovation consortia, and on-farm experimentation are institutionalised as core mechanisms of knowledge co-creation. Across contexts, agroecological knowledge is reframed as a public good, underpinning long-term transition and resilience.

Governance, Policy & Institutional Frameworks

Timeframe	Key Actions
Short term (0–5 yrs)	• National/regional PPP phase-out roadmaps • Fast-track approval of biocontrol/biostimulants • Public procurement reforms in schools/hospitals • Simplified certification & access to advisory/finance • Transition offices / one-stop hubs • Neutral, accessible advisory services • Tax reforms: VAT cuts, PPP levies; recognition programmes.
Midterm (6–11 yrs)	• Multi-level governance & territorial coordination • Food policy councils & transition platforms • CAP top-ups, procurement standards, ecological subsidies • Spatial planning & land governance incl. climate/biodiversity • National agroecology strategies & accords • Clear national goals & timelines.
Long term (12–20 yrs)	• Agroecology/pesticide-free as legal baseline • Harmonised international standards & labelling • Land tenure security & anti-fragmentation measures • Territorial governance bodies for ecosystem services • Rights-based/constitutional approaches to food, biodiversity, participation.

Short-term measures emphasise building institutional capacity and regulatory readiness for transition. Suggested actions include the development of national and regional phase-out roadmaps for PPPs (DK, ES, CZ, NL) and the fast-track approval of ecological alternatives such as biocontrol and biostimulants. Public procurement is identified as a key entry point. Reforms include requirements for pesticide-free and locally sourced food in schools and hospitals, implemented through new tendering criteria (PT, IT, CH) and procurement quotas (HR). Several proposals highlight simplifying certification procedures and improving access to advisory services and financial incentives (FR, PT, IT). New institutional structures, such as agricultural transition offices or "one-stop hubs," are suggested to coordinate information, funding, and support (CZ, ES). Advisory services are also expected to become more neutral and accessible, particularly for small and transitioning farms (IT, HR). Additional recommendations include tax reforms, such as VAT reductions on ecological alternatives, ecotoxicity-weighted PPP levies to fund transition, and recognition schemes for sustainable production (CH, FR). Complementing these institutional reforms, some short-term actions also emphasise consumer-facing initiatives, such as national campaigns on health and environmental risks or the promotion of ecological food culture through schools and festivals. While similar measures are listed under *Cognitive & Social Norms*, here they are framed as governance levers, underscoring the role of public authorities in funding, coordinating, and mainstreaming awareness within formal policy frameworks.

In the mid-term, focus shifts to multi-level governance and territorial coordination to manage the complexity of long-term agroecological transition. Proposals included multi-stakeholder food policy councils and regional transition platforms that connect municipalities, farmer organisations, cooperatives, and civil society (SI, CH, ES, DK). CAP implementation is seen as a critical tool, with adaptive top-up measures, ecological procurement standards, and targeted subsidies aligning incentives to ecological production (CZ, PT, NL). Spatial planning and land governance enter the agenda, with decentralised approaches that integrate biodiversity and climate adaptation goals into agricultural development (HR, FR, CZ). National strategies and accords are recommended to link education, extension, and policy coordination under coherent agroecology frameworks (CH, PT), with clear goals and timelines identified as key to maintaining momentum (PT). In the Netherlands, agri-environmental collectives (Box 6) show how farmer cooperatives can take responsibility for designing and implementing ecological measures at landscape level. By coordinating mowing schedules, managing buffer zones, and streamlining compliance, these collectives reduce administrative burdens while achieving results that would be difficult for individual farms alone.

Box 6: Agri-environmental collectives in the Netherlands

Agri-environmental collectives in the Netherlands: Implementing agri-environmental measures at the communal level.

In the Netherlands, agri-environmental policy implementation has undergone a major structural change with the formalisation of farmer-led agri-environmental collectives, known as *Agrarische Natuurverenigingen* (ANVs). Introduced nationally in 2016, this system delegates the design and delivery of agri-environmental measures (AEM) from the government to certified regional collectives. 40 such collectives currently operate across the country, each functioning as a legal entity responsible for coordinating environmental actions on behalf of their member farmers. These cooperatives are geographically defined, enabling a place-based approach to environmental planning, often at the landscape or catchment scale, together managing approximately about 100.000 hectares of farmland.

The collectives negotiate contracts with the Netherlands Enterprise Agency and are responsible for managing applications, monitoring, and compliance checks for participating farmers. They support the administrative process and offer technical guidance, thus reducing bureaucratic burdens on individual farms. Through this structure, collectives facilitate the spatial coordination of agri-environmental measures across multiple holdings, essential for achieving ecological connectivity and the conservation of species such as meadow birds. In practice, this has allowed for coordinated mowing schedules, shared buffer zone management, and consistent habitat maintenance; efforts which are difficult to achieve through isolated farm-level interventions.

The Dutch ANV model illustrates the potential of participatory and decentralised governance in agri-environmental management. With farmers playing a central role in decision-making and implementation, the system encourages higher levels of engagement and local knowledge integration.

Key lessons: collective landscape management, the approach aligns ecological objectives with farming practices, while also delivering on administrative efficiency and legitimacy. As a model, it demonstrates how well-structured, participative, regionally anchored institutions can bridge policy goals and practical realities in the transition towards more sustainable land use.

Source: BoerenNatuur

Long-term governance reforms are expected to consolidate into a participatory and ecologically integrated policy architecture. Proposals include embedding agroecology and pesticide-free farming as legal and regulatory baselines within national agricultural laws and subsidy frameworks (DK, CZ, SI). At

the international level, workshop outcomes pointed to the need for harmonised sustainability standards and labelling systems that ensure transparency and traceability across borders (PT, NL, ES, FR). Land governance becomes a defining theme, with long-term tenure security and anti-fragmentation measures seen as vital for ecological producers (NL, HR, SI). Territorial governance bodies are envisioned as anchors for ecosystem service management, monitoring, and enforcement (CH, HR, ES). In addition, some visions explore rights-based or constitutional approaches to food, biodiversity, and farmer participation, grounded in transparency and civic accountability (IT, FR, ES).

B.4. Discussion

While existing research has acknowledged the need to reduce pesticide use in agriculture, most studies have focused narrowly on efficiency gains or technical substitutions, such as IPM strategies. However, these approaches often fail to challenge the structural and cognitive foundations of pesticide dependency. There remains a critical research gap in how to design and implement regionally grounded, system-level transitions that go beyond incremental reform.

By engaging a broad range of stakeholders, from farmers and advisors to civil society and policymakers, the transition work presented in this report complements existing efforts with grounded, co-creative processes that help envision what system transitions could look like in diverse farming contexts. Taken together, these methodological innovations—stakeholder back-casting, multi-case policy translation, and an explicit focus on transformative system levels (Levels 3–5)—represent a distinctive contribution of SPRINT to the broader debate on agri-food transitions. They demonstrate how abstract transition theory can be operationalised through participatory design, yielding both context-sensitive pathways and policy-relevant guidance for EU and national decision-makers.

The next sections provide an analysis of the stakeholder discussions on the visions and pathways and implications for future transition work. Recommendations for policy reforms are presented in Section B.5.

B.4.1. Legitimacy and uptake: feedback, values, and visioning

Across the ten case studies, the final workshops engaged a broad range of stakeholders—farmers, advisors, policymakers, researchers, and civil society representatives. In total, more than 245 participants took part, with women representing around half. Formats varied (online versus in-person), as did duration and composition. While all case studies sought diversity, some were more successful in including underrepresented groups such as young or female farmers. Mobilising advisors, input providers, and retailers proved consistently difficult across sites.

The workshops met with positive feedback across all case study sites. Compared to earlier workshop rounds (see Deliverable 7.2**), participant engagement and uptake improved markedly**, likely due to the increasing concreteness and practical orientation of the materials. The more actionable and hands-on the building blocks of the transition were, the more positively participants reacted. Stakeholders described the process as inclusive, constructive, and respectful, with consistently high levels of engagement. Workshop reports highlighted the positive atmosphere, with participants noting the balanced mix of structure and openness. For example, the Dutch workshop was described as "engaged, dynamic, and at times humorous," while common feedback from Croatia noted that "all important actions are mentioned," with one participant adding that "the proposal is already rich and thoroughly developed." The methodology itself was also well received. As one Croatian participant put it:

> *"I agree with the proposed measures and their prioritisation across different timeframes. It is clear that the goals cannot be achieved overnight, and structuring them over short-, mid-, and long-term horizons is key to their sustainability and realistic implementation."*

A further innovation was the values-ranking exercise, which added a normative dimension to co-design. Across contexts, **Environmental Stewardship and Health & Safety consistently emerged as top priorities**, reflecting widespread concern over ecological degradation and public health risks linked to pesticides—a concern well-documented in agroecological transition research (e.g., Gliessman, 2015; Wezel et al., 2020). This provides a strong moral foundation for transition thinking. Other values, such as Cultural Knowledge, Economic Resilience, or Food Justice, varied more strongly by case, reflecting diverse agrarian traditions, market structures, and political cultures. Yet many participants stressed their interdependence rather than conflict, pointing toward an **emerging ethics of transition** that is multi-dimensional and reform oriented. These findings echo calls in transition theory for more normatively explicit approaches to sustainability that clarify not only technical goals but also the values underpinning them (e.g. Coe and Coe, 2023; Hazard et al., 2022).

Despite their salience, these values were not consistently translated into operational criteria during vision or pathway development. For example, *Farmer Empowerment* often ranked highly but was rarely visible in the resulting actions. This gap reflects not stakeholder disinterest, but rather **a methodological shortcoming of the process design**: differences in workshop duration, facilitation styles, and thematic focus (see Section A.2) made it unfeasible to apply values as comparative metrics or decision rules. As a result, values functioned more as reflective anchors than structuring tools. Such limitations are not unusual in participatory foresight, where normative depth often competes with practical constraints. They nonetheless highlight an area for methodological refinement. Future co-creation could strengthen this link by adopting frameworks that better embed ethical reasoning into collective planning (Jakobsen et al., 2019; Galvin, 2025).

The visioning exercise marked a critical step in consolidating stakeholder input into shared transformation goals. By structuring each vision along five shared dimensions, the process sought to balance comparability with contextual sensitivity. **The feedback gathered from stakeholders during the third round of workshops suggests that this aim was largely achieved**: all vision dimensions received average support scores above the midpoint, and no major factual inaccuracies or omissions were identified. At the same time, some participants found the one-sentence components too abstract, underscoring the trade-off between comparability and specificity. Dutch, Italian, and French participants proposed refinements ranging from attention to lobbying influences on regionally grounded innovation and cooperative power balances. These suggestions not only improved the visions but also directly shaped the transition pathways, illustrating the iterative nature of the process.

To summarise, the workshops **confirmed both the feasibility and the value of deliberative foresight in sustainability transitions**. The visioning process enabled participants to articulate long-term aspirations, while the values exercise foregrounded normative priorities and ethical tensions. Together, these elements enhanced the legitimacy of the transition pathways and provided methodological insights for future participatory policy design. From a methodological perspective, the visioning exercise reaffirms that imagining desirable futures can help shift attention from incremental optimisation to system-level redesign (Hebinck et al., 2018). However, the quality and credibility of such visions depend on how they are constructed, by whom, and under what conditions. As recent work in co-production and transition governance has shown, inclusive and reflexive approaches to visioning can open political space for more ambitious change, especially when linked to institutional mechanisms that embed long-term thinking into present-day decision-making (Sørensen and Torfing, 2022). To fully harness the transformative potential of co-creation, more robust methods are needed to translate stakeholder-articulated values into institutional design choices and implementation logic.

Importantly, the gaps observed (such as the limited translation of values into actions or the sometimes abstract wording of visions) should not be seen as shortcomings, but as expected tensions in participatory foresight. They reflect the challenge of balancing normative reflection with the practical constraints of workshop design, and they highlight where methodological refinements can further

strengthen future processes. In this sense, the visioning phase provided not only legitimacy and direction but also valuable insights into the kinds of obstacles that arise when moving from aspirations to strategy. The next section (B.4.2) explores these strategic challenges in greater depth, focusing on how visions were translated into pathways and what this reveal about the conditions for credible transition design.

B.4.2. From visioning to action: strategic challenges

Translating shared visions into structured transition pathways was a key step in connecting long-term aspirations with context-sensitive strategies. The pathways reflected regional realities and stakeholder inputs, and in principle enabled sequencing of actions across five transformation dimensions. Yet, as is common in participatory transition processes, several challenges emerged that illuminate both the promise and the limits of such exercises.

A recurring feature was the **uneven level of specificity across case studies**. Some groups formulated detailed institutional reforms and policy timelines, while others advanced broader objectives without clear implementation routes. This variation does not signal methodological weakness but rather highlights how outputs are shaped by contextual starting points: the maturity of local policy agendas, stakeholders' prior experience with agroecology, workshop preparation, and facilitation style. Where enabling conditions were stronger, pathways could be elaborated in more concrete terms; where they were weaker, the process functioned more as an exploratory space to open future possibilities.

A second, equally instructive feature was **stakeholder scepticism about feasibility**. While endorsing the overall direction of pesticide-free futures, many participants questioned whether mid-term or systemic reforms could realistically be achieved. Rather than undermining the exercise, these concerns expose the political and institutional lock-ins that transitions must contend with (see D7.2 for further analysis on this). They also underscore the need for future co-creation to link visionary proposals with explicit enabling conditions, resource needs, and implementation scaffolds: an insight that is valuable for both researchers and policymakers.

A third limitation was the **limited exploration of trade-offs and synergies** across domains. Although systems thinking was encouraged, tensions such as reconciling biodiversity goals with economic viability were often addressed only superficially. This was partly due to workshop design: trade-off sessions often came late in the agenda and under time pressure. The outcome, however, reveals the importance of building in earlier and more systematic deliberation on interdependencies—something that future processes can address.

Despite these challenges, the workshops showed that it is possible to move from normative visions to structured pathways in a participatory setting. Participants valued the balance of structure and openness, and many outputs went beyond incremental improvements to engage with redesign, governance, and power relations. Importantly, the unevenness and scepticism observed here should not be read as shortcomings, but as evidence of where policy momentum exists, where additional capacity-building is needed, and where institutional lock-ins remain strongest. In this way, the process itself served as an exploratory tool, surfacing both opportunities and obstacles for system change.

Looking ahead, three methodological refinements appear particularly valuable:

- Introduce trade-off deliberation earlier in the agenda, to allow participants to identify synergies and conflicts before finalising proposals.
- Ensure greater methodological consistency through facilitator training and harmonised guidance, while preserving space for local contextualisation.
- Embed stronger feedback loops between values, visions, and pathways, so that normative priorities remain visible and ethically grounded throughout the process.

Taken together, these lessons point to a broader conclusion: co-created pathways should be understood less as definitive blueprints and more as provisional scaffolds that capture both ambition and constraint. Their value lies not only in the concrete actions identified, but also in the insights they generate about the enabling conditions, capacities, and governance innovations required to make pesticide-free futures credible and actionable. Precisely because the outputs were uneven and context-specific, a further step was required: translating these diverse proposals into a format that makes their systemic ambition and policy relevance visible. The next section (B.4.3) outlines how this was achieved by applying the transformation framework and clustering actions into coherent domains of intervention.

B.4.3. From pathways to policies: linking co-created actions to systemic change

The transition pathways developed in the case studies produced a wide range of actions, spanning from technical fixes at the farm level to broader institutional reforms. This diversity reflects the richness of stakeholder input and the multiple entry points available for reducing pesticide dependency. Yet such diversity also presents a challenge: when considered side by side, these actions risk appearing as fragmented lists, with uneven depth, varying levels of specificity, and limited comparability across contexts. Some proposals are highly concrete and directly actionable, while others remain aspirational or exploratory, making it difficult to assess their collective policy relevance. For policymakers, however, actionable guidance depends not only on knowing *what* stakeholders propose, but also on understanding the degree of systemic change implied and the kinds of instruments needed to support it. To make the pathways meaningful for policy design, they must therefore be interpreted in terms of their systemic ambition and then translated into coherent domains of intervention.

The transformation framework (adapted from Gliessman, 2015; Jones et al., 2022) serves precisely this purpose. It is not simply a different way of presenting the pathways but functions as a translation device. By categorising actions according to whether they primarily improve efficiency, substitute inputs, redesign systems, reconnect markets, or reform governance, the framework enables us to assess the depth and ambition of stakeholder proposals. This analytical perspective highlights the distinction between incremental measures that can be addressed with existing tools and more transformative proposals that require new forms of policy innovation. In doing so, it allows us to see not only what kinds of change stakeholders envisioned, but also which types of policy instruments are needed to enable them.

To move from these analytical insights to policy recommendations, a second step was required: the policy-relevant elements of the pathways were clustered thematically into six overarching domains (see Chapter B.5). This clustering translates heterogeneous and context-specific actions into structured policy areas that align with institutional responsibilities, ensuring the recommendations are not only grounded in stakeholder proposals but also actionable within EU and national policy frameworks.

Applied to the ten case studies, the framework shows that most pathways include Level 1–2 actions, such as improved advisory services, substitution with biocontrol, or investment in mechanical weeding. These measures align well with current EU and national policy agendas and can be supported through existing tools like CAP subsidies, extension services, and R&D funding. However, stakeholders also articulated Level 3 redesign elements, such as diversified rotations, agroforestry pilots, or regional biocontrol infrastructures. These require more ambitious policies—support for landscape-level planning, targeted subsidies for diversification, and independent advisory systems—that move beyond efficiency toward structural transformation of farming practices.

Elements of Levels 4 and 5, while less frequent and more uneven across contexts, nonetheless surfaced in several workshops. Proposals for cooperative storage and processing, civic food councils, and public procurement reforms point to socio-economic reconnection between producers and consumers (Level 4). In some countries, participants also raised governance renewal (Level 5), including farmer-led agri-

environmental collectives in the Netherlands, or calls for constitutional recognition of food rights in Italy and Spain. Although less detailed than technical measures, these proposals reveal stakeholders' willingness to engage with deeper institutional and power structures, even when constrained by workshop time and facilitation.

Table 7 summarises this translation process. It shows how stakeholder proposals map onto different levels of systemic ambition, and how these, in turn, point toward specific policy domains developed further in Chapter B.5.

Table 7 Mapping transformation levels to policy levers for pesticide-free agriculture

Type of change (Framework level)	What stakeholders proposed (examples from pathways B.3.4)	Examples of policy levers (see Ch. B.5)
Level 1 *– Improving input efficiency (incremental within existing systems)*	Mechanical weeding, precision spraying, better training for advisors,	**On-farm innovation**: CAP eco-schemes, advisory reform, training modules, investment grants
Level 2 – *Substituting with less harmful inputs (technical fixes)*	Fast-track approval of biocontrol, biostimulants, plant extracts; transition labels	**On-farm innovation & financial incentives**: R&D funding, regulatory streamlining, targeted subsidies
Level 3 – *Redesigning agricultural systems (structural transformation of practices)*	Agroforestry pilots, diversified rotations, crop–livestock reintegration, regional biocontrol hubs	**On-farm innovation & knowledge systems**: landscape planning, participatory breeding, Living Labs, targeted subsidy schemes
Level 4 – *Reconnecting producers and consumers (socio-economic restructuring)*	Cooperative storage/processing, civic food councils, public procurement of ecological products, regional brands	**Fair value chains & public engagement**: procurement reforms, cooperative investment support, labelling, territorial branding
Level 5 – *Rebuilding governance and equity (deep institutional reform)*	Farmer-led collectives, constitutional food rights, international standards, transparency mandates	**Governance reform & knowledge systems**: participatory governance platforms, legal reforms, international harmonisation, transparency requirements

This dual process of using the transformation framework to assess the systemic ambition of actions, and clustering them into policy domains, helps clarify where current policies are already equipped to act (Levels 1–2), where incremental adaptation is insufficient and more structural support is required (Level 3), and where entirely new forms of governance and civic engagement are needed (Levels 4–5). Without such a lens, the risk is that policymakers focus only on the "low-hanging fruit" of efficiency and substitution, neglecting the more ambitious but necessary system-level transformations. The analysis presented here thus provides the scaffolding for Chapter B.5, where each of the six policy domains is elaborated as a coherent set of recommendations.

It is important to emphasise that the pathways should be understood as partial and situated outputs, shaped by the realities of the co-creation process. Their content reflects what could be collectively articulated and agreed upon within the constraints of limited time, varying facilitation styles, pre-existing background materials, and the available literature. As such, they do not capture a complete picture of stakeholder priorities, but rather the outcomes of what was feasible to negotiate in the workshop setting. In several cases, the more ambitious or transformative ideas only surfaced through iterative exchanges between stakeholders and researchers, underscoring the importance of facilitation in enabling deeper structural insights. Moreover, participants often focused on measures that felt actionable under current institutional conditions, even while recognising the need for more far-reaching change.

B.5. Policy recommendations to enable transition pathways

Building on the analysis in Section B.4.3, this chapter translates the co-created transition pathways into concrete policy recommendations. The pathways generated a wide variety of actions, ranging from technical measures to institutional reforms. To move from this diversity to structured recommendations, two steps were taken. First, the transformation framework was applied as a diagnostic lens to assess the systemic ambition of stakeholder proposals, distinguishing between incremental measures (Levels 1–2) and more transformative actions that involve redesign, socio-economic restructuring, or governance renewal (Levels 3–5). Second, the policy-relevant elements of the pathways were clustered into six overarching domains of intervention: (1) boosting on-farm innovation and biodiversity, (2) aligning financial incentives, (3) supporting fair markets, (4) reforming governance, (5) ensuring transparency and engagement, and (6) strengthening knowledge systems.

This dual approach ensures that the recommendations are both grounded in stakeholder input and strategically aligned with institutional responsibilities at EU and national levels. The six domains reflect recurring proposals and commonly identified barriers across the case studies, while also corresponding to key levers in existing and emerging EU policy frameworks, including the CAP, the Sustainable Use Directive, the Farm to Fork Strategy, the Nature Restoration Law, and Horizon Europe. The following sections present targeted measures in each domain, with an emphasis on coherence, feasibility, and the potential to support systemic change across multiple governance levels.

Each subchapter follows a common structure. It begins with the context and barriers identified by stakeholders, outlining why action in this domain is critical for transition. It then situates the domain within the EU policy landscape, highlighting opportunities, gaps, and contradictions in current frameworks. Finally, it presents a set of concrete recommendations, framed in terms of actionable steps that EU and national policymakers can take to support systemic change.

B.5.1. Boost on-farm innovation and biodiversity

Context and barriers

On-farm practices are the front line of reducing pesticide dependence. Across the SPRINT case studies, stakeholders highlighted a broad range of agroecological strategies considered essential: diverse crop rotations to break pest cycles, mechanical and precision weeding, cover crops to improve soil health, agroforestry systems that provide habitat diversity, and the restoration of ecological infrastructure such as hedgerows, flower strips, and field margins. These measures are not marginal adjustments but core components of resilient, pesticide-free farming systems, where biodiversity functions as a productive input for natural pest control and ecosystem stability.

Despite their potential, the uptake of such practices remains limited. Farmers pointed to several barriers: lack of access to adapted machinery, insufficient locally relevant agronomic knowledge, and few opportunities to test innovations in real conditions. In many cases, biodiversity-enhancing measures are treated as optional add-ons rather than integral elements of productive systems, reducing incentives for adoption.

At the same time, farmers emphasised that innovation at the farm level does not occur in isolation. Many argued that substantial changes require a level playing field, where rules and standards apply equally across the sector so that those adopting ecological practices are not disadvantaged against competitors. Others highlighted the role of finance: investments in new practices often depend on convincing banks or credit providers that yields and revenues will remain stable. These dynamics underline a fundamental difficulty. While farms are the arena where transitions materialise, they cannot drive systemic change on their own. On-farm innovation therefore depends on both practical enablers (equipment, knowledge, biodiversity infrastructure) and institutional support (rules, incentives, risk-sharing) to ensure that costs and risks are not borne by farmers alone.

EU policy landscape

Several EU frameworks already provide entry points for supporting this transition, but their implementation remains fragmented. The **Common Agricultural Policy (CAP)** includes eco-schemes and agri-environmental measures that can incentivise diversification, non-chemical pest management, and biodiversity restoration, but stakeholders noted that these are often underutilised or poorly adapted to regional realities. Stronger prioritisation of agroecological redesign is needed (see Section D.4 for CAP-specific recommendations).

Research and innovation support is available through Horizon Europe and the EU Mission "A Soil Deal for Europe," yet projects often remain pilot-based and disconnected from everyday farming practice. Stakeholders repeatedly stressed the need for farmer-led and practice-oriented research, coupled with independent advisory systems to ensure knowledge reaches the ground.

The **EU Biodiversity Strategy for 2030** and the **Nature Restoration Law** provide further frameworks by recognising the role of hedgerows, field margins, and habitats in ecosystem restoration. Importantly, **LIFE programme** funding can help scale biodiversity-based pest control through habitat restoration, landscape diversification, and ecological demonstration projects. **National Restoration Plans (NRPs**) under the Nature Restoration Law should explicitly link ecosystem restoration to pesticide reduction, reinforcing CAP measures with ecological pest control functions.

Recommendations

Level 4 – Reconnecting producers and ecosystems

- **Restore biodiversity infrastructure:** Incentivise the integration of hedgerows, field margins, flower strips, and habitat corridors as essential elements of farming systems, recognising their role in natural pest control.
- **Embed nature restoration in agriculture**: Ensure that National Restoration Plans explicitly link ecosystem restoration (e.g. riparian buffers, wildflower habitats) to pesticide reduction and farm resilience.
- **Scale up LIFE programme funding:** Prioritise biodiversity-based pest control through habitat restoration, farm landscape diversification, and demonstration project.

Level 3 – Redesigning farming systems

- **Fund Living Labs and pilot farms:** Support co-creation platforms where farmers, researchers, and advisors jointly develop, test, and scale agroecological alternatives.
- **Promote agroecological practices:** Prioritise crop rotation, mechanical weeding, cover cropping, agroforestry, and other systemic approaches as central to CAP eco-schemes and national transition plans.
- **Support participatory breeding:** Expand funding for pest-resistant and locally adapted crop varieties, ensuring farmers play a central role in breeding priorities.

Level 2 – Substitution and incremental innovation

- **Implement coordinated IPM systems:** Invest in real-time pest surveillance, forecasting networks, and digital tools to improve decision-making and reduce chemical reliance.
- **Improve equipment access:** Provide subsidies, leasing schemes, or cooperative access models for IPM and mechanical weeding machinery, with special support for smallholders and farms in marginal regions.

B.5.2. Support fair value chains and markets

Context and barriers

Agroecological innovation cannot succeed in isolation from the broader economic structures that shape food systems. Without reforms in how food is processed, priced, and distributed, even the most promising on-farm changes remain economically precarious. Across the transition pathways, stakeholders consistently described current markets as biased in favour of chemically intensive production, where ecological producers carry higher risks and costs but receive little reward. Market concentration further amplifies these challenges. Conventional buyers and retailers dominate storage, processing, and distribution channels, leaving small-scale or transitioning farmers with limited bargaining power. Stakeholders noted that the largest share of profits is captured downstream (in packaging, processing, logistics, and supermarkets) while only a small fraction of revenues reach the producer. As a result, ecological farmers often find themselves locked in disadvantageous positions, unable to compete on price despite delivering public goods such as biodiversity, reduced exposure risks, and healthier landscapes. Some pointed out that alternative channels, such as local shops, cooperatives of organic retailers, or direct sales to small circles of consumers willing to pay a premium for ecological produce, can offer better returns. Yet these remain niche markets, limited in scale and reach. The contrast illustrates both the structural disadvantages of mainstream food chains and the untapped potential of alternative models, provided they receive greater institutional support.

Another critical barrier concerns price stability. Farmers seeking to reduce PPP use face uncertainty about whether the market will absorb their products at fair prices, particularly when yields fluctuate or cosmetic standards penalise minor defects. Early adopters often shoulder higher costs and greater risks, with little recognition for the public goods they deliver (such as biodiversity, reduced exposure risks, and healthier landscapes). In terms of the transformation framework, these dynamics illustrate the difficulty of moving beyond Levels 1–2 (efficiency and substitution): markets continue to reward yield and cosmetic appearance rather than ecosystem services. When read through this lens, it becomes clear that addressing such imbalances requires Level 3–4 changes: structural redesign of value chains and stronger reconnection between producers and consumers, if dependency is to be overcome.

EU policy landscape

Several EU frameworks provide levers to address these barriers, but they currently operate at different transformation levels. The forthcoming **Sustainable Food Systems (SFS) Framework** is particularly important, as it could establish enforceable provisions for transparency, sustainability, and fairness across supply chains — a step toward Level 4 reconnection between producers, consumers, and institutions. It could oblige Member States to develop national action plans with concrete mechanisms for fair pricing and market access for agroecological producers. The **Farm to Fork Strategy**, although politically weakened, remains a key basis for procurement reform, requiring public institutions to embed sustainability in their food purchasing. Public procurement of ecological products in schools, hospitals, and canteens was repeatedly identified by stakeholders as a high-impact entry point, able to create stable demand and shift food norms — another clear Level 4 intervention. The **EU Organic Action Plans** already support local value chains, eco-labelling, and consumer recognition of sustainable practices; these tools mostly reinforce Level 2 substitution but could be extended to reward broader agroecological practices. Finally, the **EU Green Public Procurement (GPP) criteria** and **Cohesion Funds** offer instruments to align public purchasing with sustainability goals yet remain underused because criteria are voluntary and "best value" often defaults to lowest price. Making these mechanisms binding would allow them to function as enablers of Level 3–4 systemic redesign, but to reach Level 5 governance renewal, stronger accountability for retailers and buyers will also be necessary.

Recommendations

Level 5 – Governance renewal

- **Strengthen retailer accountability by requiring mandatory transparency and due diligence from retailers and large buyers,** ensuring equitable trading relations and reducing incentives to import pesticide-intensive products.
- **Reinforce enforcement mechanisms to address unfair trading practices and market concentration,** ensuring that smaller or transitioning farms are not disadvantaged

Level 4 – Reconnecting producers and consumers

- **Mandate sustainability requirements in public food contracts** (climate, biodiversity, social fairness).
- **Include specific agroecological criteria in food procurement,** ensuring contracts reward farming systems beyond organic certification.
- **Establish fair-pricing mechanisms:** Combine binding measures such as guaranteed minimum prices and long-term contracts with innovative models (e.g. eco-label-linked or regional brands) to stabilise revenues and reward agroecological practices.

Level 3 – Redesigning markets and value chains

- **Enable and scale up cooperatives and producer networks:** Provide legal templates, administrative support, and targeted investment to strengthen collective market access and logistics.
- **Fund shared infrastructure:** Invest in group logistics, mobile processing units, and regional storage centres to reduce transaction costs and create resilient, decentralised supply chains.

Level 2 – Substitution and transparency tools

- **Expand the coverage and recognition of eco-labels and digital traceability systems to enhance transparency,** build consumer trust, and prevent greenwashing in food supply chains.

B.5.3. Reform governance for systemic change

Context and barriers

The effectiveness of pesticide reduction strategies depends heavily on the governance framework in which they are embedded. Evidence from the case studies and the wider literature shows that current governance arrangements are often fragmented, slow, and inconsistent. Complex regulatory requirements, overlapping schemes, and administrative burdens discourage innovation and create uncertainty for farmers and other actors. In many regions, limited approval pathways for biocontrol products and stringent cosmetic standards in certain sectors further reinforce pesticide dependence. These dynamics illustrate that without addressing governance structures, transitions risk remaining confined to incremental improvements (Levels 1–2). More systemic action is required to enable coherence, accountability, and long-term institutional reform (Levels 3–5).

EU policy landscape

Several EU instruments provide relevant entry points for governance reform. The **Sustainable Use of Pesticides Directive (2009/128/EC)** has been widely recognised as insufficiently enforceable and ambitious. Its planned replacement, the **Regulation on the Sustainable Use of Plant Protection Products**, was withdrawn in 2024 after political opposition, leaving a regulatory gap that must be addressed. A revised EU legal framework with binding pesticide reduction targets, clear responsibilities for Member States, and robust monitoring would represent a decisive move toward systemic change. Regulatory approval processes under **Regulation (EC) No 1107/2009** remain a key bottleneck, with lengthy procedures delaying the uptake of ecological alternatives (see Part C). Ongoing discussions on a **2025 simplification package** could help by introducing clearer definitions and faster pathways for low-

risk biocontrol. Beyond regulation, the **CAP's LEADER approach** offers a foundation for inclusive, territorially embedded governance, while the proposed **European Land Observatory** could help address structural issues such as land access, concentration, and speculation — all of which were identified as crucial enablers for Level 5 transitions

Recommendations

Level 5 – Governance renewal

- **Ensure legally binding EU-wide pesticide reduction targets with clear enforcement mechanisms and regionally adapted national action plans,** providing a robust regulatory framework for systemic change.
- **Make ecological and low-pesticide practices the baseline standard for farming systems,** allowing exceptions only under strict agronomic or environmental justification.
- **Guarantee secure and equitable land access by supporting land tenure rights and preventing land concentration,** with EU-level monitoring through initiatives such as the European Land Observatory.
- **Redefine food security in policy frameworks as resilience and public good provision,** placing equal weight on biodiversity, ecosystem health, and farmer livelihoods alongside productivity.

Level 4 – Participatory governance and territorial coordination

- **Establish and scale up participatory governance structures such as food policy councils, territorial transition platforms, and strengthened LEADER-type initiatives**, ensuring that diverse actors co-design and oversee pesticide transition strategies.
- **Strengthen coordination across EU, national, and regional governance levels** to align pesticide phase-out roadmaps, regulatory measures, and support instruments.

Level 3 – Redesigning governance support structures

- **Create agricultural transition hubs and one-stop offices** to provide farmers with integrated access to information, funding, and administrative support, reducing bureaucratic complexity.
- **Ensure that advisory services are independent, adequately funded, and accessible to all farm types,** so that ecological practices can be widely adopted and sustained

Level 2 – Enabling alternatives

- **Accelerate the approval and uptake of biocontrol and other low-risk alternatives** by clarifying definitions, introducing fast-track authorisations, and expanding EFSA's evaluation capacity.
- **Introduce fiscal instruments such as VAT reductions on ecological inputs and ecotoxicity-weighted levies on PPPs**, using the revenues to fund transition measures and reward sustainable practices.

B.5.4. Transparency and public engagement

Context and barriers

Transparency and public engagement are essential for steering a credible and socially robust transition away from pesticide dependency. Access to reliable, accessible, and regionally disaggregated data on pesticide use, residues, and environmental impacts is still limited, constraining both evidence-based policymaking and informed consumer choice. As discussed in Section B.3.2, transparency emerged as a shared value across the case studies, seen as fundamental for trust, legitimacy, and accountability in food system governance. However, as highlighted in Section B.3.4, existing monitoring tools often fail to capture real-world exposure dynamics, leaving knowledge gaps that hinder effective decision-making. Engagement was understood as more than one-way communication: it involves participatory mechanisms that allow farmers, citizens, and institutions to jointly define priorities, address trade-offs, and oversee implementation. Visible, tangible examples of change — such as pesticide-free farms supplying public kitchens or restored landscapes that deliver biodiversity benefits — were considered

more effective in shifting social norms than information campaigns alone. At the same time, persistent concerns about the influence of lobbying and unequal power relations show that transparency must also include mechanisms for democratic oversight of decision-making.

EU policy landscape

Several EU instruments can help address these transparency and engagement gaps. The proposed revision of the SUD is a critical entry point. It could mandate public disclosure of pesticide use at regional and local levels, and support the development of real-time, spatially explicit monitoring systems — key for achieving Level 2 substitution and efficiency improvements while also creating the foundation for higher-level change.

The Farm Sustainability Data Network (FSDN) offers the potential to institutionalise systematic data collection. Expanding it to include farm-level pesticide use, agroecological practices, and socio-economic indicators would strengthen the evidence base for policy evaluation and enable Level 3 redesign, where data are used to assess trade-offs and support systemic planning.

The Unfair Trading Practices (UTP) Directive (EU) 2019/633 is another key lever. Expanding and strictly enforcing the Directive could help rebalance relations between retailers, processors, and ecological producers, and prevent contractual terms that penalise early adopters of pesticide-free practices. The Farm to Fork Strategy (F2F), despite losing political momentum, remains significant for its holistic framing of sustainability. Its initial ambition to reframe food system goals around health, biodiversity, and resilience aligns with Levels 4–5 of the transformation framework. Future iterations should better integrate pesticide reduction with climate policy instruments, food environment reforms, and pricing measures to strengthen systemic legitimacy.

Finally, the EU's support for participatory governance (e.g. through the LEADER approach and upcoming Sustainable Food Systems Framework) provides an avenue to institutionalise Level 4 participation. These instruments could formalise local food councils, transition platforms, and citizen initiatives. The European Citizens' Initiative (ECI) offers an additional, underutilised mechanism for direct citizen involvement at EU level. The success of the "Save Bees and Farmers" ECI demonstrates public demand for ambitious pesticide reduction, but its limited policy impact has raised concerns about responsiveness. Future reforms could strengthen the ECI by requiring systematic follow-up, such as formal parliamentary hearings, impact assessments, and clear legislative proposals when initiatives meet participation thresholds.

Recommendations

Level 5 – Governance renewal

- **Mandate corporate responsibility and fair-trading practices by strengthening the Unfair Trading Practices Directive** with enforceable rules and penalties against unfair contracts, late payments, and buyer power abuses.
- **Embed pesticide reduction as a cross-cutting objective** in the Sustainable Food Systems Law, the Biodiversity Strategy, and relevant climate policy instruments to ensure coherence and long-term legitimacy.
- **Revive and strengthen EU food system ambitions** by re-establishing the transformative goals of the Farm to Fork Strategy, linking them explicitly to pesticide reduction, biodiversity recovery, and resilience

Level 4 – Participatory governance and societal reconnection

- **Create and support sustainable food councils and regional transition platforms** that enable farmers, citizens, processors, retailers, and policymakers to co-design and oversee pesticide-free transition pathways.

- **Institutionalise deliberative mechanisms in policy processes** to reduce polarisation, build mutual trust, and ensure that diverse perspectives are integrated into decision-making.
- **Introduce binding sustainability criteria in public procurement policies** for schools, hospitals, and other public institutions, making pesticide-free and ecological sourcing the norm.
- **Support collective bargaining and fair contracts by** Providing legal frameworks and enforcement mechanisms that strengthen producer organisations, enabling them to negotiate equitable terms and resist exploitative practices in supply chains.

Level 2–3 – Redesigning information and accountability infrastructures

- **Mandate timely public disclosure of PPP use, residue levels, and exposure data** at farm, regional, and EU scales, ensuring accessibility through open data platforms and maps
- **Expand and institutionalise the Farm Sustainability Data Network (FSDN)** to systematically include pesticide use, agroecological practices, and socio-economic indicators for robust, long-term monitoring.
- **Strengthen eco-labelling and digital traceability systems to improve consumer trust,** support ecological producers, and prevent misleading or greenwashed sustainability claims.

B.5.5. Strengthen knowledge and advisory systems

The transition away from pesticide dependency is less about isolated technological breakthroughs than about building learning infrastructures that enable experimentation, co-creation, and trust. Evidence from SPRINT case studies, research, and literature Kurtsal et al. (2024) shows that existing advisory services are often narrow in focus, centred on yield maximisation, and closely tied to commercial input suppliers. This limits their ability to support long-term ecological resilience or systemic redesign, while smaller and more marginal farms are left with inadequate guidance.

Opportunities for peer-to-peer learning and farmer-led innovation exist in the form of Living Labs, demonstration farms, and participatory R&D projects, but these remain fragile and underfunded, often ending with project cycles instead of being embedded as permanent structures. Without stable infrastructures, transitions risk remaining confined to isolated pilots rather than scaling across farming systems.

Education and training gaps compound these challenges. Vocational and higher education curricula continue to emphasise technical efficiency rather than agroecology, integrated pest management (IPM), or systems thinking. Soft skills such as communication, collaboration, and entrepreneurship are often underrepresented, slowing both systemic change and generational renewal. Digitalisation presents further opportunities for ecological pest management, for example through decision-support tools and real-time pest forecasting, but risks reinforcing dependency on proprietary technologies if not developed and governed inclusively.

EU policy landscape

Several EU-level instruments can support stronger knowledge and advisory systems. **Horizon Europe** and the **Agroecology Partnership** can fund regionally adapted research, demonstration farms, and participatory innovation structures, while also recognising educators and advisors as key actors in transition. **Erasmus+** provides a vehicle for updating vocational and higher education curricula, including IPM, agroecological practices, and food system literacy at multiple educational stages. The **SCAR-AKIS agenda** offers a framework for integrating research, advisory services, and education into coherent Agricultural Knowledge and Innovation Systems, but its implementation remains uneven across Member States.

The **CAP's cooperation measures** could play a decisive role in re-establishing **independent advisory services** with explicit mandates to support ecological transition, while Structural and Investment Funds provide opportunities to strengthen lifelong learning and farmer-to-farmer networks in regions where capacity is weak. The **European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-Agri)** has demonstrated the value of operational groups for collaborative innovation, but participation is uneven, and funding cycles are short. Embedding agroecology and pesticide-free farming as explicit EIP priorities, combined with longer-term support, could help move from pilot projects to durable system redesign.

Recommendations

Level 5 – Governance renewal

- **Rebuild independent, publicly funded advisory systems through CAP cooperation instruments and national programmes**, ensuring they have a clear mandate to support agroecological transition and are not tied to commercial input sales.
- **Institutionalise agroecological knowledge as a public good by integrating advisory services, research, and education into coherent Agricultural Knowledge and Innovation Systems**, strengthening their role in systemic transformation.

Level 4 – Societal reconnection and participatory governance

- **Expand and secure long-term funding for Living Labs, demonstration farms, and farmer-led networks** so that collaborative experimentation and knowledge exchange become permanent features of agricultural innovation.
- **Integrate local and experiential knowledge into research and advisory agendas** to ensure that ecological transition pathways are grounded in practice and adapted to diverse regional realities.
- **Promote food literacy and systems thinking across all levels of education**, embedding understanding of agroecology, health, and sustainability from primary schools to universities.

Level 3 – System redesign

- **Modernise agricultural and veterinary curricula across Member States to align with EU-level "fit-for-practice" frameworks**, prioritising agroecological methods, IPM, and system-level approaches.
- **Equip the next generation of farmers, advisors, and agronomists with both technical expertise and soft skills in communication, collaboration, and entrepreneurship**, ensuring they are prepared to lead systemic transitions.

Level 2 – Substitution and enabling tools

- **Improve access to inclusive, farmer-driven digital decision-support systems for pest monitoring, ecological forecasting, and resource management,** ensuring that digitalisation enhances farmer autonomy rather than reinforcing technological dependency.

B.5.6. Align financial and economic incentives with agroecology

Context and barriers

The financial and economic environment is a central driver of pesticide dependence. Evidence from case studies and the wider literature (see Section B.3.1; Deliverable 7.1) shows that existing systems largely reward input-intensive, yield-maximising strategies while providing limited incentives for long-term ecological resilience. In high-value fruit, grape, and vegetable sectors, strict cosmetic standards and buyer requirements make pesticide use appear indispensable to secure market access. In lower-margin crops such as cereals and oilseeds, even modest yield risks translate into significant income losses, reinforcing risk-averse practices.

At the same time, SPRINT findings confirm that farmers' decisions are not solely profit-driven: pest management strategies are shaped by habits, risk perceptions, cultural values, and access to information. This indicates that financial incentives need to be flexible and tailored to diverse contexts, reflecting both economic and non-economic motivations. The transition pathways (see Section B.3.4) highlighted the importance of financial and market reforms to ensure that early adopters are not left to shoulder disproportionate risks and costs. Suggested measures ranged from short-term tools such as transition payments, crop insurance, and tax incentives, to mid- and long-term instruments that enable structural change, including cooperative marketing models, revenue-sharing schemes, polluter-pays mechanisms, and long-term land policies. Regional variation is notable: while liquidity and income security are pressing concerns in Southern and Eastern regions, Northern and Western contexts emphasise price stability, market differentiation, and consumer demand.

The recommendations in this section reflect systemic needs identified by stakeholders, such as transition payments, risk-sharing tools, and ecosystem service remuneration. They are presented as directional priorities, outlining what must be incentivised to enable agroecological transitions. The specific instruments of the CAP (GAECs, eco-schemes, agri-environmental measures, AKIS, and others) are analysed in Part D, which examines how these priorities can (or cannot) be delivered in practice, and what reforms are required at programming or legislative level.

EU policy landscape

The CAP is the most immediate instrument for re-aligning financial incentives with agroecological goals (see Section D.4.1). CAP Strategic Plans now provide flexibility through eco-schemes and agri-environmental measures, yet the absence of binding ring-fencing for environmental spending in the 2028–2034 proposal (see EC press release from 17 July, 2025) raises concerns about insufficient support for pesticide reduction and diversification. Stronger earmarking for transition payments, biodiversity-enhancing practices, and ecosystem service remuneration would be essential to create stable incentives for change. CAP also enables the use of cooperation instruments to fund collective approaches, including mutual funds, group-based insurance schemes, and shared infrastructure investments. These tools could directly address farmer concerns about risk and liquidity, especially for those facing higher costs during the early phases of transition.

Complementary frameworks play a supportive role. The Farm to Fork Strategy and the Sustainable Food Systems Framework can reinforce CAP reforms by embedding fair pricing, pesticide reduction, and ecosystem services into wider sustainability and food system objectives. The Nature Restoration Law offers an additional lever to link financial support with landscape-level ecological restoration, ensuring that economic incentives contribute to long-term resilience. The Unfair Trading Practices (UTP) Directive is relevant to this domain as well: by addressing retailer dominance and contract imbalances, it can strengthen the fairness of markets in which CAP-supported ecological producers must operate, thereby underpinning Level 4–5 systemic change.

Recommendations

Level 5 – Governance renewal

- **Mandate ecological budget ring-fencing within the CAP by requiring Member States** to dedicate a significant share of funds to pesticide reduction, agroecological diversification, and ecosystem service remuneration, ensuring that support for transition is stable and non-optional.
- **Channel investments into rural cohesion** so that transition costs and benefits are distributed fairly across farmers and communities, ensuring the viability of rural economies.

Level 4 – Societal reconnection

- **Link public procurement policies to agroecological objectives**, creating reliable demand and stable markets for ecological producers.
- **Support territorial cooperation and collective market organisation** through regional initiatives, cooperatives, and short supply chains *(see Part D.4.2–D.4.3 for CAP-based delivery options).*

Level 3 – System redesign

- **Develop flexible financial tools,** such as transition payments, revenue-sharing contracts, and pest-loss insurance, to accommodate diverse farmer needs and reduce the risks of adopting low-input practices.
- **Expand results-based payment schemes that reward ecosystem services** (e.g. biodiversity, soil health, reduced pesticide use), ensuring that ecological benefits are properly valued and incentivised. *Part D.4.2 provides concrete CAP mechanisms for operationalisation*.

Level 2 – Efficiency and substitution

- **Ensure affordable access to low-risk alternatives** (biocontrol, mechanical weeding, precision technologies), particularly for smallholders and farms in less-favoured regions.
- **Strengthen monitoring and reporting systems for financial schemes,** integrating pesticide-use and agroecological indicators into existing data frameworks. The CAP's Farm Sustainability Data Network is a central delivery tool for this.

C. Pre and post market policy recommendations

C.1. Context

In addition to co-developing transition pathways and policy recommendations to support reduced reliance on PPPs, the SPRINT project generated scientific results to inform the policies for pesticide risk assessment at the EU level.

Although designed to be comprehensive, the EU system for PPP approval and post-market surveillance has many shortcomings that reduce its effectiveness in protecting human health and the environment. **Pre-market authorisation** is a two-stage process governed by a unified regulatory framework (Reg. (EU) 1107/2009) and uniform evaluation criteria (Reg. (EU) 546/2011) (**Error! Reference source not found.**). Individual active substances are assessed and approved/disapproved at the EU level, with a review by the European Food Safety Agency (EFSA). PPPs, typically a mixture consisting of one or more active substance(s), safeners, synergists, and co-formulants, are evaluated and authorised in individual Members States with mutual recognition in three geographic zones. Specific data requirements for active substances approval (Reg. (EU) 283/2013) and PPPs authorisation (Reg. (EU) 284/2013) outline testing and evaluation criteria for **human health and environmental risk assessment**. However, the limitation of current data requirements, testing methodology, and modelling approaches often **fail to identify risks associated with realistic use** of the products. A particular challenge is accounting for **cumulative and long-term exposure** to pesticide, given that residue mixtures are already widespread in the environment.

While pre-market approval is designed to assess potential risks for humans and the environment, an effective **post-market surveillance policy** is necessary to detect and react to exposures and risks that arise from real-world pesticide use and fate in the environment. EU post-market policy for monitoring pesticides is particularly fragmented, with no one unified framework for monitoring pesticides in the environment. Strict legal limits are set for pesticide residues in/on food (Regulation (EC) No 396/200), as well as for water under the Drinking Water Directive (Directive (EU) 2020/2184), and the Water Framework Directive (Directive 2000/60/EC)—including its daughter Environmental Quality Standard Directive (Directive 2008/105/EC) and Groundwater Directive (Directive 2006/118/EC). Each of these laws requires regular pesticide monitoring and reporting from Member States. On the other hand, **no legally binding thresholds for most pesticide residues exist for soils, air, or surface waters**. While the Sustainable Use Directive (Directive 2009/128/EC, or SUD) focuses on reducing environmental contamination and occupational pesticide exposure through training and regular inspection of application equipment, there is **no EU regulation or program implementing systematic human biomonitoring for pesticides**, which would capture the real exposure of vulnerable populations like farm workers.

EU policymakers and regulators need strong mechanisms and tools to translate monitored exposures, pollution, and adverse outcomes to meaningful actions that reduce risk. The Sustainable Use Directive requires National Action Plans setting "quantitative objectives, targets, measures and timetables to reduce risks and impacts of pesticide use on human health and the environment". The **harmonised risks indicators (HRI and HRII)** established under SUD have often been criticised for being too crude or failing to incorporate pesticide usage (European Court of Auditors, 2020). HRI is based on the PPP sales weighted by hazard class, but does not account for geographically explicit usage, human exposure, pesticide residue mixtures already in the environment or environmental vulnerability. HR2 is based only on emergency pesticide authorisations. Revised EU indicators and tools for targeted risk reduction could better account for spatially explicit pesticide usage, to identify high risk patterns of pesticide application.

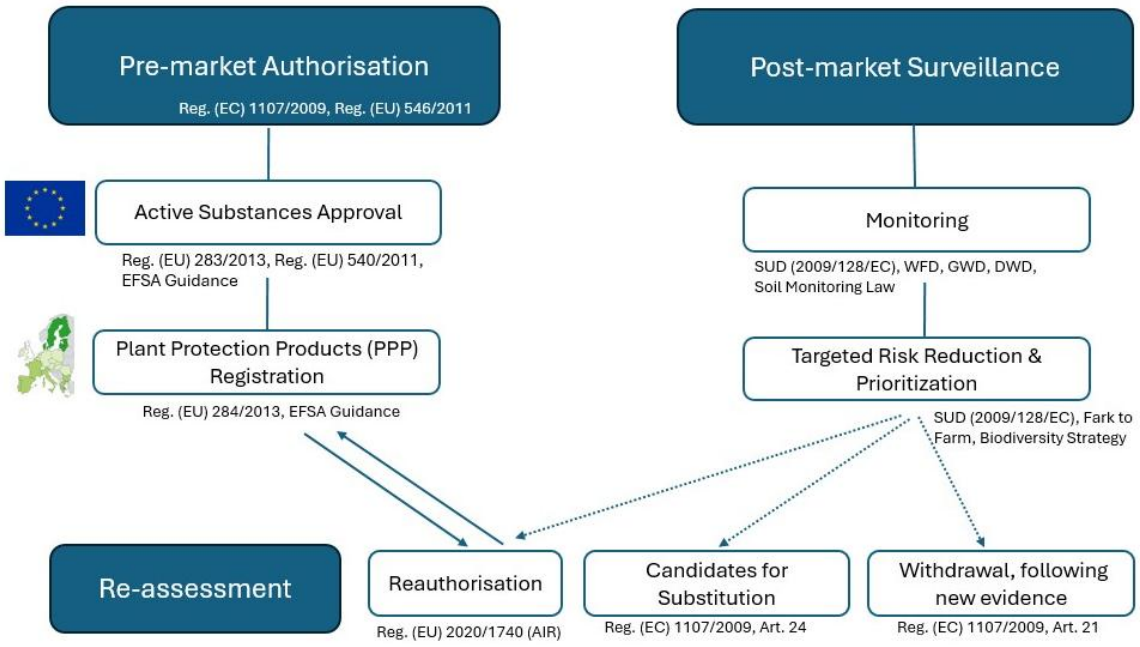

Figure 6: Key policies regulating and supporting pre-market authorisation and post-market surveillance of active substances and plant protection products (PPPs).

The European Parliament's report on SUD implementation (Guteland, 2019), and a report of the European Court of Auditors (European Court of Auditors, 2020), point to weaknesses in the implementation, application and enforcement and a failure to sufficiently achieve its overall objective. One of barriers cited is that **lack of data currently hampers efforts to evaluate progress** in reducing the use of and risk associated with pesticides and limit the evidence available to inform policymaking. EU CAP promote sustainable pesticide use in number of instruments. PPP related data of sufficient quality, validity and resolution will be needed for the implementation and efficiency monitoring of these instruments and strategy. The tools related to post-registration phase of pesticides are missing to direct sustainable agricultural production and to support more evidence-based and tailored agri-environmental policy. Many of dataset are already collected with great potential to serve in this area, however these lack harmonisation, quality and quantity.

Finally, the current plant protection approval framework (Reg. (EC) 1107/2009) provides several mechanisms to formally re-evaluate active substance approvals. Under the AIR Regulation (Reg. (EU) 2020/1740), active substances undergo a reassessment after 10 years and must account for updated research on the pesticide. Currently approved active substance can also be added to a "candidate for substitution" list if they come to meet certain hazard criteria (Reg. (EC) No 1107/2009, Annex II), leading to shorter approval periods and other strict scrutiny. Under Article 21 of Reg. (EC) 1107/2009, new data on the risks of an active substance may allow for the new assessment at any time, potentially leading to withdrawal on a short time scale. However, **mechanisms for linking post-market monitoring results to regulatory risk assessment are weak**, even when monitoring is required. For example, no EU Member States have an established process for linking chemical surface water monitoring data with regulatory risk assessment (Spycher et al., 2024). Insights from post-market surveillance could be better linked with these regulatory safety mechanisms.

C.2. Methodology

Recommendations were based on the results of the SPRINT research work packages and developed through a systematic process of mapping, drafting, and internal/external review during the final year of the project (Sep. 2024 - Aug. 2025), in close collaboration with SPRINT scientists (WP2 – WP6) and external experts, and employing mix of methods including policy mapping and review, expert interviews and workshops. This ensured the scientific validity and consortium consensus of these policy recommendations.

First, based on the key research objects and scope of SPRINT, we conducted an **EU policy mapping** for the topics defined above. This was conducted through document review and drawing on insights from interviews with policymakers (D7.1), SPRINT objectives and researcher input (Sep. – Nov. 2024). In parallel to the policy mapping exercise, each SPRINT work package lead was asked to submit 3-5 **key messages for policymakers** arising from their SPRINT research. A first draft of messages was generated during a SPRINT plenary meeting (Sep. 2024), then refined further for a Horizon review meeting (November 2024), during which reviewers and a DG AGRI policy officer provided feedback.

Combing the results of the submitted *SPRINT Researcher Policy Messages* and *Policy Mapping*, we developed a framework to guide interviews with SPRINT researchers and develop a basis for analysis of policy gaps (Dec. 2024). Separate **policy-focused interviews** were then conducted with each relevant SPRINT research team: Ecotoxicology, Human Toxicology, Exposure Assessment, Pesticide Environmental Fate, SPRINT Toolbox (Risk and Exposure Mapping), and Life-cycle Analysis (Jan. – Mar. 2025). The interviews were guided by a collaborative notetaking template, containing sections for the target policy areas: pre-market authorisation, monitoring, risk mitigation, and prioritisation/withdrawal. The goal was to capture any recommendations or policy insights from each of the topics areas, while ensuring grounding in the SPRINT project. Researchers were given the opportunity to revise and synthesise the notes.

A **first draft of the policy recommendations** was developed, incorporating policy mapping, SPRINT researcher interviews, published SPRINT publications and deliverable, EFSA feedback (see next section), and other policy analyses on related topics (Mar. – May 2025). SPRINT researchers validated the policy recommendations before public dissemination (May – June 2025).

Together with EFSA Staff, we organised a meeting to share SPRINT findings with implications for human health and environmental risk assessment (March 2025). **Ninety-six EFSA staff** members from relevant divisions and **18 SPRINT researchers** were in attendance. We incorporated feedback from regulators in the drafting of recommendations

During the **final event for the SPRINT project**, research findings and policy recommendations were presenting to a broad group of 400+ stakeholders, including 54 identified government representatives from Europe. During Q&A and targeting panel discussions, attendants were invited to discuss the recommendations and provide further feedback, which was incorporated into a final draft of the recommendations. The finalised recommendations were reviewed one final step by **scientific coordination**.

In addition to the preparation of policy recommendations, each work package was given time to propose **top research priorities** related to their work in SPRINT. These were later organised into a four-pillar research agenda, which researchers review for accuracy (see Annex 6: Research Agenda: Reducing the Risk of and Reliance on Pesticides). These priorities have been distributed in survey to EFSA regulators, researcher, and other stakeholders for validation and prioritisation. As of July 2025, there are 50+ responses, which will be incorporated into a peer-reviewed manuscript involving all SPRINT researchers.

C.3. SPRINT Overall Approach and Key Findings

The SPRINT H2020 Project (2020 – 2025) is an interdisciplinary project that addresses several key research objectives in support of enhancing PPP pre-market and post-market risk assessment. Employing a novel harmonised sampling campaign for 209 pesticide residues in 10 European countries, the project captured a real-world snapshot of pesticide residue mixtures present in humans and in the environment (air, water and soil) during the 2021 sampling season.

SPRINT policy-aligned research objectives on pesticide risk assessment:

- Measure residue mixtures & distributions in the environment (soil, water, air, plants), animals and humans and in different farming systems, generating a post-market snapshot into pesticide contamination.
- Test toxicological effects of mixture on humans and non-target species, demonstrating the hazards and risks posed by realistic whole mixtures found in the environment.
- Develop novel "SPRINT indicators" for ecotoxicology and human toxicology testing, which can add realism and sensitivity to testing approaches in the current pre-market regulations.
- Develop and test approaches for improving estimates of integrated human exposure, supporting a more realistic pre-market exposure assessment and post-market human biomonitoring.
- Create a Toolbox for scaling up existing pesticide data to better capture the exposure and risk to the environment and human health across selected countries in Europe, supporting targeted risk reduction at the European, national, and regional level
- Assess integrated risks, costs and benefits of PPP use in different farming systems at micro- and macroeconomic level, including internal and external costs of PPP use, guiding strategic policy decision for pesticide economic and sustainability.

Sprint Key Findings:

- Pesticide mixtures were detected across a broad spectrum of environmental samples — including soil, surface water, sediments, air, and indoor dust — many of which contain hazardous compounds that may pose significant risks to non-target organisms, including animals and humans.
- Realistic pesticide mixtures often showed toxicity to non-target species in the environment and in animal toxicity testing, even when the levels of individual active substances were present at levels considered safe.
- New SPRINT indicators for human toxicology and ecotoxicology proved to be sensitive to pesticide residues, often complementing the results of standards tests used by EFSA
- Non-dietary sources can contribute to overall exposure, while dietary exposure is prioritised in risk assessment and post-market monitoring.
- Methodology to create a Global Health Risk Toolbox has been developed, but depends on better access to harmonised, complete and open data on pesticide usage in Europe.

C.4. Pre-Market Risk Assessment

C.4.1. Background

At the core of the pre-market authorisation process (Reg. (EC) No 1107/2009) are **environmental and human health risk assessments**, which are designed to be underpinned by the precautionary principle. **Risk** in pesticide regulation is defined as the likelihood that a pesticide will cause harm to human health or the environment, based on both its **hazard** (how toxic it is) and the level of **exposure** (how much people or the environment come into contact with it) (EFSA et al., 2017). The principles for evaluation (Regulation (EU) 546/2011) and detailed data requirement for authorisation and risk

assessment are laid out in regulations for individual active substances (Regulation (EU) 283/2013) and plant protection products (Regulation (EU) 284/2013). In addition, detailed methodology for testing and modelling in the risk assessment process is communicated in the technical guidance documents for the EFSA. Requirements include toxicity testing, studying the environmental behaviour of pesticides (e.g., in air, water, and soil), and estimating potential exposure levels for humans, animals, and ecosystems. The goal is to ensure that approved pesticides are used safely under realistic conditions established in EU regulations (see

Table 8).

Table 8: Regulations for Uniform Principles of Evaluation (Reg. (EU) No 546/2011) and Data Requirement for Pesticide Pre-Market Approval. Reg. (EU) 283/2013 covers the approval or basics substances. Reg. (EU) 284/2013 covers PPP registrations.

	HAZARD (TOXICOLOGY)	**EXPOSURE**
ENVIRONMENTAL RISK ASSESSMENT (546/2011 – SECTION 1.5, 2.5)	283/2013 – Section 8: Ecotoxicological Studies 284/2013 –Section 10: Ecotoxicological studies	283/2013 – Section 7: Fate and Behaviour in the Environment 284/2013 –Section 9: Fate and behaviour in the environment
HUMAN HEALTH RISK ASSESSMENT (546/2011 – SECTION 1.4, 2.4)	283/2013 – Section 5: Toxicological & Metabolic Studies 284/2013 – Section 7: Toxicological Studies	<u>Dietary:</u> 283/2013 – Section 6: Residue in or on treated products, food and feed 284/2013 – Section 8: Residues in or on treated products, food and feed <u>Non-Dietary:</u> 284/2013 – Section 7: Toxicological Studies

A key focus of SPRINT was **accounting for the risks posed by pesticides mixtures,** one of the main challenges in the risk assessment process. Although pesticide safety is largely evaluated on a substance-by-substance basis, pesticides occur in widely variable mixtures in the environment and homes (Alaoui et al., 2024; Navarro et al., 2023, 2024; Silva et al., 2019, 2023; Tang et al., 2021). When PPPs are registered on the market, the toxicity of the whole formulated product is considered (Regulation (EU) 284/2023, Section 7), including the safety of all "safeners, synergists and co-formulants". However, tank mixes, in which a PPP is mixed with another during spraying, are only sometimes evaluated. Even where a new product label includes requirements for mixture with other products, "the need to perform supplementary studies shall be discussed with the national competent authorities on a case-by-case basis" (Section 7.1.8). Toxicity of mixtures encountered for real-world environmental and dietary human exposures remain difficult to capture in pre-market evaluation and are not included anyway in the pre-market regulatory framework. Furthermore, realistic environmental mixtures (incl. legacy pesticides) in the water, soil, and even homes vary widely, leading to potential human and ecological exposure to incidental (unplanned) mixtures. The **widely variable nature of incidental pesticide mixtures** makes them difficult to account for in pre-market authorisation of new pesticides.

EFSA addresses chemical mixtures through cumulative risk assessment frameworks that group substances by shared toxic effects, apply dose addition models, and follow a tiered approach—from conservative screening to more refined, data-driven assessments—guided by evolving scientific evidence and regulatory needs. EFSA Guidance (EFSA, 2019) lays out mixture testing approaches for pre-market testing. By default, EFSA relies on a **component-based approach,** involves assessing the toxicity of each chemical in a mixture individually and then combining their effects to estimate the overall risk. It

assumes that the chemicals act **additively**, meaning their combined toxicity is the sum of the individual toxicities, unless evidence suggests otherwise. This method is also used when there is evidence or concern that chemicals in the mixture may interact, leading to **synergistic or antagonistic effects** that cannot be predicted by additive models. In SPRNT, planned mixtures of pesticides were tested for the toxicity and compared additive toxicity predictions from the component-based model, allowing for a side-by-side comparison and to detect potential synergistic or antagonistic effects.

Box 7: SPRINT Goals for Risk Assessment

SPRINT Goals for Risk Assessment
A central goal of SPRINT was to develop hazard, exposure and risk assessment methodology that account for real-world conditions and that better account for uncertainty, particularly a potential background of pesticide residue mixtures in the environment (soil, water, air), crops, livestock and humans. Work packages focused on:

- **Hazard (and partly risk):** Ecotoxicology and Human/Animal toxicology (WP4)
- **Exposure:** Environmental Fate (WP2/WP3) and Human Exposure Assessment (WP3)

In the ecotoxicology and human toxicological work packages of SPRINT, the tiered-testing and component-based approach was applied alongside experiments testing mixtures, allowing for a side-by-side comparison and to detect potential synergistic or antagonistic effects. Several new indicators and toxicity tests were developed and applied.

In human exposure assessment, the contribution of dietary and non-dietary (environmental) sources of pesticide exposure were estimated and compared by modelling, leading to insights on the relative contribution of non-dietary to dietary exposure in pre-market testing. In studies of environmental fate, modelling approach were applied and developed to assess what happens to the PPPs after their release into the environment. This includes, for example, how the PPPs breaks down, accumulates in soil and sediments and/or are transformed into other substances.

In the sections below, we outline lessons for SPRINT for the pre-market risk assessment, relevant to the regulated data requirements for active substance and PPP approval see (

Table 8).

C.4.2. Environmental Risk Assessment

The main goal of **environmental risk assessment (ERA)** is to ensure that approved pesticides, when used according to their intended purpose, do not pose unacceptable risks to non-target species in the environment, on biodiversity, in food webs, or on ecosystem functioning.

A key challenge in environmental risk assessment is enhancing the **ecological relevance and realism** of testing approaches and approval criteria. Environmental conditions—such as landscape structure, climate, soil type, and native species composition—vary significantly across the EU, and even within individual PPP approval zones. Furthermore, the presence of **pesticide residue mixture in the environment contributes** to background contamination levels that are often not captured by current environmental exposure models, potentially underestimating cumulative risk.

C.4.2.1. Ecotoxicology

Background

The goal of "**ecotoxicological studies"** (Reg. (EU) 283/2013, Section 8; 284/2013, Section 10) in the pesticide risk assessment procedure is to assess the effects of active substance and PPPs on non-target species in the environment, potential impacts to biodiversity, food webs, and ecosystem functioning. The goal is to evaluate whether pesticide use causes adverse effects in both the short and long term, and to establish safe exposure levels that effectively prevent significant environmental harm. Several aspects and of the pre-market testing regulations were addressed in SPRINT:

- Lower-tier ecotoxicity tests rely on standard OECD laboratory species, which may not capture all effects on non-target species. Data requirements for both active substances and PPPs begin with lower-tier testing approaches involving single-species laboratory studies using standard non-target indicator organisms. These include vertebrates (birds, mammals, fish, amphibians), aquatic and sediment-dwelling invertebrates, aquatic macrophytes, bees and other non-target arthropods, earthworms, soil invertebrates, and terrestrial plants. The aim of these studies is to determine effect concentrations (e.g., ECx values), identify no-effect thresholds (e.g., NOEC), and provide the fundamental hazard data for the risk assessment process. Hazard data (Section 8) are combined with predicted environmental exposure (Section 6) to calculate risk quotients (RQ) or toxicity exposure ratios (TER), which are then compared against regulatory thresholds to evaluate risk acceptability. However, current data requirements **do not include native species in standardised lower-tier ecotoxicological assessments.** Although native species may be considered in higher-tier studies, their integration into the testing process remains limited and problematic (see below).

- Higher-tier studies can incorporate more realistic exposure scenarios and multi-level ecosystem effects, thus enhancing ecological relevance, but are not always applied. Higher-tier studies are generally only required when single-species laboratory tests indicate an unacceptable risk (e.g. TER < trigger or RQ > 1 (EFSA, 2013; EFSA et al., 2017). These studies typically address population-, community-, and ecosystem-level effects under semi-field, mesocosm, or field conditions, and can include native species. They are especially relevant for assessing non-target arthropods, bees, aquatic organisms, and soil organisms when lower-tier data alone are insufficient. By incorporating more **realistic exposure scenarios** and accounting for indirect effects, recovery potential, and species interactions, they add important ecological relevance that cannot be captured in standardised single-species tests (EFSA, 2013)

- Higher-tier studies are not conducted under harmonised guidelines and can lead to bias in favour of approvals. Higher tier studies are intended to capture ecosystem, population and community effect of pesticides. However, they do not follow standardised methodology, but rather scenario-specific designs guided by EFSA Scientific Opinions and Guidance Documents. This flexibility allows tailoring to realistic conditions but also introduces greater variability, uncertainty, and potential bias in the interpretation of results (EFSA et al., 2009). In fact, **the results of higher-tier studies are often used as a factor weighting towards approval of pesticides** that have failed tests for single-species toxicity. This come from the general concept that no authorisation shall be granted to substances/PPPs if they exceed given thresholds in Reg. 546/2011, "unless clearly established through an appropriate risk assessment that under field conditions no unacceptable impact occurs after PPP use in accordance with the proposed conditions of use" (Reg. 546/2011).

- Pesticides are generally tested on a substance-by-substance basis, not in realistic environmental mixtures: During the approval of active substances (Reg. (EU) 283/2013), only the ecotoxicology testing of individual substances is required, along with some select associated surfactants and co-formulants. At PPP registration (Reg. 284/2013), an analysis of mixtures is required only if the PPP is more toxic than the individual active substance. The threshold for

increased toxicity, triggering further testing and modelling approaches, is a source of debate (CTGB, 2025). Furthermore, while the PPP regulation suggests the testing of tank formulation and other frequent combinations, this is not always carried out in practice. Finally, **mixtures that occur incidentally in the environment**, due to typical use such as serial spraying of alternating pesticides, are not accounted for in these regulations (Kienzler et al., 2014).

SPRINT Approach and Findings

A major contribution of the SPRINT ecotoxicology work was to compliment the standards single-species ecotoxicology tests required by EFSA with new indicators, including native species, new endpoints and higher-tier testing system.

The SPRINT project adopted a mixture testing strategy, conducting ecotoxicological assessments of pesticide mixtures on various soil and aquatic species through a tiered framework aligned with EFSA's 2019 guidance on combined chemical exposure. This stepwise approach progressed from lower-tier, simplified single-species tests to the development of novel "SPRINT indicators" involving alternative native species and culminated in higher-tier evaluations using complex multi-species microcosms.

Ecotoxicological tests were performed on 11 realistic pesticide mixtures, each representing a crop-specific scenario and comprising up to five prioritised pesticides. These mixtures were selected based on SPRINT environmental measurements, using two main criteria: the frequency of occurrence in water samples and the Risk Quotient (RQ), calculated as the ratio between the Predicted Environmental Concentration (PEC) and the Regulatory Acceptable Concentration (RAC). Both values were normalised and multiplied to rank the pesticides, with the top five in each scenario included in the final mixture. The concentrations tested for the 11 mixtures were the measured concentrations found in the water, for each crop (MEC) and a predicted environmental concentration (PEC) from EFSA reports, step 1, when data were available, or calculating using the FOCUS simulation model (steps 1-2) (Abrantes et al., 2024).

<u>The following key SPRINT results were identified:</u>

- Mixtures of pesticides in the environment can adversely affect soil, aquatic, and other species, **even when the levels of individual substances are considered safe through EFSA assessment** (Abrantes et al., 2024a; Tourinho et al., 2024)**.**
- Native species (e.g., bees and earthworms) and new toxicological endpoints (e.g., soil functional genes, zebrafish swimming behaviour) often showed different sensitivity to pesticide toxicity than the laboratory indicator species used in typical EFSA/OECD singe-species tests, **demonstrating that standard regulatory testing may miss some locally relevant lethal and sub-lethal ecotoxicological impacts** (Abrantes et al., 2024a; Tourinho et al., 2024)**.**
- Adverse Effects of pesticides on soil microbes often appeared only after 56 days, while standard OECD test required by EFSA only run 28 days, **suggesting that many long-term soil effects are missed in current testing methods** (Mäder et al., 2025).
- In the terrestrial mesocosm experiments, showed the potential for bioaccumulation of several tested pesticides in earthworms, an important food source for birds and mammals**, demonstrating a risk of pesticide biomagnification in the whole terrestrial food web** (Abrantes et al. 2024b).
- Although the aquatic systems tested did not show a risk of pesticide biomagnification, pesticide toxicity had a disproportionate impact on primary producers—the foundation of the food web—**potentially disrupting the structure and functioning of the entire ecosystem** (Abrantes et al. 2024b).

Overall, the results of SPRINT demonstrate the promise of new SPRINT lower-tier laboratory indicators for improving the pre-market testing of pesticides, as well as mesocosm approaches for capturing trophic effects. Furthermore, the risk posed by real environmental mixtures is not captured by single-substance safety thresholds set by EFSA. Detailed Recommendations can be found in Annex 5: Detailed Recommendations for Improvement to Ecotoxicology Section

Recommendations

#1: Mixtures required for pre-market testing and evaluation should better reflect the realistic use of the PPP under consideration, including stronger requirements to assess required/recommended tank mixtures, typical application sequences with other pesticides, and pesticide mixtures already present in the soil.

#2: Expand the portfolio of required single-species test to capture more environmentally realistic effects and sensitive species, including native species tests, more endpoints for soil microorganisms and functional diversity, early-warning signs of damage.

#3: Expand the use of, and implement standardised guidelines for, higher-tier testing of ecosystem effects to ensure consistency and prevent subjective bias in pesticide approvals.

#4: Account for mixtures in the environment by increasing the margins of safety thresholds used for the approval of pesticides, e.g. Toxicity to Exposure Ratio (TER).

In particular, the results of the SPRINT ecotoxicology can directly inform the planned revisions of key documents in 2025:

- A forthcoming update on the guidance on terrestrial ecotoxicology, which will include a review of the risk assessment of for non-target arthropods, in-soil organisms, and for non-target terrestrial plants outside the treatment area.
- A "guidance to assess potential indirect effects on biodiversity via trophic interactions under agro-environmental condition" (Environmental risk assessment of pesticides | EFSA)

C.4.2.2. Fate and Behaviour in the Environment

Background

Pesticides are assessed for their "fate and behaviour in the environment", both for individual active substances (Reg. (EU) 283/2013, Section 7) and in their formulated PPP (Reg. (EU) 284/2013, Section 9). The focus of both regulations is to assess the degradation and transport of pesticides in the environment, to determine the **predicted environmental concentrations (PEC)** in soil, surface water, aquatic sediment, groundwater and air. Established PEC serve as exposure estimates for non-target organisms in pre-market ecological risk assessments – how much and where will the pesticide be present in the environment. During the approval of active substances, exposure (PEC) is compared to an ecotoxicological threshold (e.g. LC50, NOEC and EC50) to calculate either risk quotients (RQ) or toxic exposure ratio (TER), providing a determination of whether pesticides in the environment will pose an unacceptable risk to non-target organisms. Thus, the important **PEC value** of an approved active substance serves as a **theoretical maximum found in the environment** and **a safe threshold for non-target species.** The calculation of predicted environmental concentrations of pesticides relies heavily on models of pesticide transport in the environment such as GAPFATE for pesticide volatilisation and atmospheric dispersion, FOCUS Groundwater Scenarios, MACRO Model for Pesticide Fate in Structured Soils, FOCUS SWASH to simulate spray drift, runoff, drainage, and deposition to surface waters. Each of model has uncertainties and drawbacks, which may affect the accuracy of predicted environmental concentrations used to authorise pesticide active substances and products.

SPRINT Approach and Findings

Key objectives of SPRINT were to conduct wide scale sampling campaign to measure residue mixtures & distributions in the environment (soil, water, air, plants) generating a post-market snapshot into pesticide contamination. Furthermore, SPRINT developed an innovative modelling approach, by integrating PPP use with observed concentrations and exposure levels and linking fate and transport of PPPs to direct and indirect health impacts, resulting in a paradigm shift in this field of research. Monitoring in SPRINT allowed for direct comparison of modelling results to field measurements.

Specifically, the objectives in the environmental fate section were to:

- Evaluate the fate and transport of select pesticides used in the three case study sites (Portugal, the Netherlands and Denmark) in soil, surface water, sediment, air and crops.
- Use of the calculated Predicted Environmental Concentrations (PECs) to assess the exposure of aquatic organisms (invertebrates and fish) and soil organisms (earthworms) to the pesticides selected.
- Compare PECs with monitoring results to assess of the appropriateness of model calculations.
- Develop and validate the performance of the wind erosion module SWIPPE, developed within SPRINT, by comparing the simulated data with the monitoring data from the two modelling reference case study sites, Portugal and The Netherlands.

The following key SPRINT results were identified:

- Pesticide residues with hazard classifications relevant to non-target species including humans are widespread in the environment and farmer residences, including indoor dust (Alaoui et al., 2024; Navarro et al., 2023; Silva et al., 2023)
- Aquatic sediments can act as a sink and a potential secondary emission source for surface water, highlighted by the occurrence of banned-use substances in surface water (Khurshid et al., 2024).
- Modelling results demonstrate that exposure of water depends greatly on local hydrological conditions (Suciu et al., 2023).
- The new SPRINT SWIPPE Model appears to work well to predict pesticide dispersion (Suciu et al., 2023).
- Predicted (PEC_{soil}) from farmers' application patterns and measured environmental concentrations (MEC_{soil}) are not well-correlated (Knuth et al., 2024), suggesting that current EFSA methodology for assessing soil concentration of pesticide may require further refinement.

Overall, the results of SPRINT demonstrate that the regulatory predictions for environmental distribution of pesticide fall short of predicting the real fate and persistence of pesticide residues in the environment. SPRINT modelling approaches, future research, and new regulatory testing requirements can help address these shortcomings.

Recommendations

#1: Regulations calculating for the allowable pesticides in the environment (PEC) should account for a background of pesticide mixtures, including persistent banned substances.

#2: Connectivity between farm pesticide application sites (farms) and other environmental compartments needs to be better resolved in pre-market testing. This includes:

- Local (more representative) hydrological situations should be considered in future assessments, as current scenarios are unrealistic.
- Fate of particle-bound pesticides should be addressed. It is currently not included in the FOCUS models.

#3: The fate of and degradation of pesticide active substances in the indoor environment need stronger evaluation and pre-market testing, which primarily focuses on degradation in outdoor conditions.

C.4.3. Human Health Risk Assessment

Assessing the potential health risks of pesticide active substances and PPPs is an essential step in the pre-market authorisation processes. Pesticides used in plant protection are designed to be toxic to target species such as insects, plants, and pathogens, but should not pose a health risk to humans. According to the PPP approval regulation (Reg. (EC) No 1107/2009), PPPs can only be placed on the market if their residues do not demonstrate "any harmful effects on human health, including that of vulnerable groups, or animal health, taking into account known cumulative and synergistic effects" (Art. 4, 3(a)). However, concerns about the human health impacts of previously and currently approved pesticides remain.

In epidemiological studies – analyses of large real-world populations – exposure to pesticides has been associated with several adverse health outcomes (Kim et al., 2017), including childhood cancer (Vinson et al., 2011), mental health issues during childhood (James & OShaughnessy, 2023) and adolescence (Rohlman et al., 2019), reduced fertility and pregnancy outcomes (Albadrani et al., 2024; Chiu et al., 2018), Parkinson's disease (Freire & Koifman, 2012), and Autism Spectrum Disorders (Román et al., 2024). Children and foetuses may be especially vulnerable to the toxic effects of pesticides and environmental chemicals (The Consortium for Children's Environmental Health, 2025). Humans face potential exposures to pesticides from a variety of sources, including food and the environment. Farm workers and their families may be especially vulnerable to environmental exposure to pesticides while spraying on agricultural fields.

The data regulations for active substance (Regulation (EU) 283/2013) and PPP approval (Regulation (EU) 284/2013) drive the methodology for evaluating human health risk from pesticides. EU pesticide risk assessment regulations assess both the **toxicology** of pesticides (hazards) and the potential for human **dietary and non-dietary exposure**. In general, pesticide toxicity is evaluated on a substances-by-substance basis or in the formulation of market product (PPP). However, farmers and others encounter mixtures of pesticides not covered in pre-market testing, such as in food residues, in PPPs combined during spraying, encountered through sequential applications, or through persistent environmental occurrence of pesticides, such as in indoor dust.

C.4.3.1. Toxicology

Background

During pre-market authorisation, pesticide active substances undergo toxicological evaluation to identify potential adverse effects on humans (Reg. (EU) 283/2023, Section 5). Required studies cover acute, sub-chronic, and chronic toxicity, including carcinogenicity, reproductive and developmental effects, neurotoxicity, endocrine activity, and genotoxicity, generally based on OECD test guidelines. A central outcome is the *No Observed Adverse Effect Level (NOAEL)*—the highest dose at which no harmful effects are observed in test animals—which is used to set health-based reference values for safe human exposure. Substances cannot be approved if classified as carcinogenic, reproductive toxic, or endocrine disrupting, unless exposure is shown to be negligible (Reg. (EC) 1107/2009, Annex II).

These studies rely on *in vitro* assays and *in vivo* animal models, but translating results to humans remains a key challenge due to interspecies differences. Despite limitations, animal studies remain the best available whole-body system. New areas, such as pesticide impacts on the gut microbiome, are not yet covered in regulations, although SPRINT experiments examined microbiome effects of glyphosate and other pesticides, linking disruptions to inflammation, neurodevelopmental changes, and disease risks (Gois et al., 2023; Ueyama et al., 2022). Developmental and reproductive studies are particularly important for capturing potential effects during early-life stages, when sensitivity is higher and adverse impacts may be long-lasting or irreversible.

Combined toxicity of multiple pesticide active substances in a concern in human health risk assessment. To address this, EFSA developed Cumulative Assessment Groups (CAGs), which cluster pesticides with a shared toxicological effect or mode of action to enable cumulative risk assessment of human exposure (EFSA, 2013). Further guidance on tiered testing approaches was provided in *Guidance on harmonised methodologies for human health, animal health and ecological risk assessment of combined exposure to multiple chemicals* (EFSA, 2019). This provides a framework for considering additive toxicity, though its practical application in pre-market regulatory decisions remains limited. Testing this tiered approach was a focus of the SPRINT work in toxicology.

SPRINT Approach and Findings

The toxicology work in SPRINT had several key objectives, focuses on improving the realism and sensitivity of toxicology testing approaches, as well as addressing the effects of mixtures. The SPRINT approach followed the EFSA *Guidance on harmonised methodologies for human health, animal health and ecological risk assessment of combined exposure to multiple chemicals* (EFSA, 2019).

SPRINT human toxicology objectives included:

- **Employ the EFSA tiered component-based testing strategy** (EFSA, 2019): starting with in silico pre-screening of 200 pesticides (Tier 1), advancing to *in vitro* testing of the top 10 (Tier 2), and culminating with in vivo assessment of the top 3 mixtures (Tier 3). This allowed for direct, side-by-side comparison between mixture toxicity testing and EFSA's default component-based approach and provided a practical test of the EFSA tiered testing methodology.
- **Develop new SPRINT indicators (*in vitro* and *in vivo***) to complement current standard (OECD) tests used in pre-market testing, including effects on:
    - Gut microbiome in mice
    - Social behaviour in mice
    - Human organoids and cells lines
- **Assess the effect of pesticides on early life and developing embryos,** compared to adult animals.
- **Assess the gut microbiome composition of humans exposed to pesticides**

<u>The following key SPRINT results were identified:</u>

- The EFSA tiered testing approach was useful for the prioritisation of pesticides for toxicity testing, showing at least one positive signal in each tier (Mandrioli et al., 2025). **The tiered testing and prioritisation approach is appropriate and useful to test pesticides and mixture of highest concern, during the PPP approval, which conserving resources.**
- Exposure to mixtures of pesticides were consistently more detrimental than individual pesticides. When comparing full mixture testing to the EFSA component-based mixture approach, no synergistic toxic effects were found (Mandrioli et al., 2024; Mandrioli et al., 2025). **The EFSA component-based approach is appropriate for testing known mixtures and can be useful to analyse mixtures in the regulatory process.**
- The standard (existing EFSA/OECD tests) and the new SPRINT toxicological indicators, both in vitro and in vivo, proved to be sensitive and relevant for a range of relevant toxicological endpoints (Mandrioli et al., 2024; Mandrioli et al., 2025). **New SPRINT laboratory test are promising tools to increase the sensitivity and realism of the pre-market testing process**.
- Prenatal and early exposures, even at low doses, proved to be consistently more detrimental in rodents, chicken and zebrafish embryo models, in line with "developmental origin of health and disease" (DOHAD) model (Mandrioli et al., 2025).
- Exposure to several different pesticides, including glyphosate, was associated with changes in the human gut microbiome composition, based on human samples collected in SPRINT (Alaoui et al., 2022)**.**
- Mice exposed to glyphosate showed behavioural changes, including social impairment and anxiety-like behaviour (Mandrioli et al., 2025).

Overall, SPRINT results demonstrate that mixtures of pesticides are a concern for human and animal toxicology, especially at vulnerable developmental life stages, with effects presenting event where individual pesticide concentrations are at levels considered safe. Pre-market testing process can be improved supplementing EFSA testing approaches with new SPRINT indicators and tests, which include test for new sensitive toxicological endpoints.

Recommendations

#1: Strengthen neurotoxicity screening, including animal social behavioural tests, and microbiome changes in pesticide pre-market testing requirements.

#2: Include more tests to account for effects on early life stages of and vulnerable populations.

#3: Include mixture tests of pesticides commonly combined in specific crops and spray tank mixes, which humans may be exposed to.

C.4.3.2. Human Exposure

Background

Human exposure refers to the routes of uptake (ingestion, inhalation, or skin contact) and sources that lead to contact (e.g. via food and beverages, outdoor/indoor environment). It is crucial in pesticide risk assessment because understanding exposure levels helps determine whether a pesticide poses a health risk and informs safety regulations and protective measures. In general, the assessment of human exposure is not as integrated into the pre-market authorisation as the hazard assessment.

An assessment of potential human exposure is as essential part of the active substance and PPP approval frameworks. Human exposure is divided into **dietary** and **non-dietary** pathways, with the regulations built on the presumption that consumers experience primarily dietary exposure. Non-dietary (environmental) exposure is considered more relevant in the occupational setting.

Internal Exposure. At the stage of active substance approval, Regulation EU 283/2013 focuses mainly on toxicological hazard of individual substances, with studies that are relevant for internal exposure. Under the "Toxicology Studies" (Section 5), systemic exposure – related to the biotransformation of the active substance in the body – is evaluated through the submission of toxicokinetic data (5.1), that includes absorption, distribution, metabolism and excretion following exposure by ingestion, with dermal and inhalation exposure something additionally assessed.

Dietary Exposure. The exposure of humans to pesticides in food is higher regulated at the pre-market approval stage. Several studies are required to demonstrate how pesticide residues remain on or in crops, animal products and processed foods for active substances (Regulation (EU) 283/2013, Section 6) and PPPs (Regulation (EU) 284/2013, Section 8).

The establishment of **acceptable daily intake (ADI)** is an important step in the approval of active substances (Regulation (EU) 283/2013, Section 5), as ADI is the main universal exposure threshold for humans. The ADI is generally based on the toxicity threshold known as the No Observed Adverse Effect Level (NOAEL) from laboratory animal studies. The NOAEL is divided by a safety factor of 100 to determine the ADI. This safety factor typically accounts for two key uncertainties in extrapolation from animals to humans: one for the uncertainty in extrapolating animal data to humans (interspecies, a factor of 10), and another for variability between individuals (intraspecies, a factor of 10). These assumptions are reflected in Regulation (EU) 1107/2009 – Annex II – 3.6. In some cases, the risk assessment agency may apply additional safety factors to address other sources of uncertainty, such as differences in susceptibility among vulnerable groups or concerns about long-term exposure (Robinson et al., 2020).

Non-Dietary/Environmental Exposure of Humans. At the PPP registration phase, the potential for realistic human exposure is more broadly evaluated (Regulation (EU) 284/2013). Section 7.2 covers data that must be collected for exposure assessment. Non-dietary exposure pathways are defined in the occupational context: operators, workers, residents (defined as living near farms) and bystanders, but does not extend to "consumers" who do not live near farms. The focus of testing and modelling is to estimate the potential of exposure from different scenarios for use, ensuring that, given realistic use, the health of farm employees and nearby residents is protected. Inhalation and dermal absorption are the main non-dietary routes considered. The acceptable operator exposure level (AEOL) is the maximum systemically available quantity of an active substance that an operator can be exposed to via oral, dermal, or inhalation routes without suffering any adverse health effects, over a lifetime (European Commission, 2017).

Challenges in Measuring Human Exposure. Exposure assessment is crucial to the outcome of risk assessment but is under-rated compared to the assessment of hazard. Our findings stress the importance to include aggregated exposure assessment (all routes) in the cumulative (PPP mixtures) risk assessment calculations, which is not currently implemented in the regulatory framework. A central challenge is that there are many knowledge gaps regarding human exposure routes that limit the possibility of accurate exposure assessment at the pre-market stage.

SPRINT Approach and Findings

The SPRINT project included several studies with relevance for human exposure to pesticides, including studies of pesticide occurrence in the home and environment, calculations of exposure from human biomonitoring, and model predictions of contributions from non-dietary exposure.

- **SPRINT sampling of pesticide occurrence near humans** - Pesticides residues were sampled in the environment to which humans are exposed, including indoor air and dust, outdoor air, and soil.
- **Wristband study as a proxy for environmental exposure** – Study participants wore wristbands to collect pesticides as a personal sampler, serving as a proxy for possible direct contact with pesticides (to the extent that they are absorbed in the silicon material) and reflects non-dietary exposure. It does not provide information on uptake by inhalation or dermal uptake.
- **Sampling of Real Dietary Exposure – Duplicate Portion Analysis -** Participants set aside a second portion of each meal for pesticide analysis to compare consumption of processed food portions to acceptable daily intake (ADI).
- **Dietary vs. Non-Dietary Exposure Contribution** – Drawing on studies on of dietary and non-dietary exposure in SPRINT, an estimate of the relative contribution of route by model prediction was made by modelling.
- **Human Biomonitoring and exposure calculations** – Human samples (blood, urine, and faeces) were collected from participating farmer and families in 10 countries and analysed for pesticide residues. These concentrations of a subset of pesticides were back calculated and compared to reference values considered safe: ADI (standard for dietary exposure) or biological guidance values (limits for levels considered safe in human samples). This was intended as a snapshot aggregate exposure determination from dietary and non-dietary sources.

The following key SPRINT results were identified:

- **Pesticides occur frequently in the environment where humans are present, including the home.** While levels of each individual residue detected in the study were low, they are a potential source of non-dietary exposure to pesticide. **Future research on pesticide uptake of these pesticide sources would be needed to confirm their contribution to non-dietary exposure.**

- Indoor dust contained the highest number of pesticide residues. Consumer homes, not accounted for in EFSA non-dietary exposure assessment, also contained pesticides, including biocides.
    - Although levels are overall lows, this presents a possible exposure route to humans, especially young children (Silva et al., 2023).
- In on-farm outdoor air (NL and PT) 97% of samples contained at least one pesticide, 95% of samples contained mixtures, and 91% of the detected pesticides are classified as hazardous for human health.
    - While overall pesticide concentrations were low and well-below ADI, the health impacts of pesticide inhalation are not well understood. Furthermore, the safe intake level ADI (dietary) does not account for the inhalation route (Debler et al., 2024).
- Pesticide mixtures were detected on most wristbands worn by participants, with farmers and neighbours generally higher than levels for consumers (Figueiredo et al., 2025b).
    - These are a potential source of non-dietary exposure for humans, although uptake of pesticides found on wristbands was not studied.

- **In the human biomonitoring studies, most sampled participants did have pesticide residues and mixtures in their blood, but individual levels did not exceed safe values for exposure.** However, these results should be interpreted with caution, as there are many data gaps regarding the processing of pesticides in the human body. (Scheepers et al., 2025).
- **Non-Dietary exposure can be a contributor to overall pesticide exposure** – Diet is generally the most common route of exposure, but non-dietary exposure may provide a more important contribution in occupational settings and when dietary exposure is very low (Figueiredo et al., 2025a).

Overall, SPRINT results demonstrate that humans have the potential for exposure from both dietary and non-dietary sources, but many data gaps in the metabolic and kinetic processing of pesticides impede the full picture. It is important to understand the effect of internal exposure of pesticide on organs and tissues to evaluate the effect of an external exposure on the human body.

Recommendations

#1: Non-dietary exposure needs better integration in the EFSA exposure assessment. Both aggregate exposure (dietary and environmental) and cumulative exposure (multiple pesticides) should be considered for all exposed groups, where non-dietary exposure is currently mainly considered in the occupational context (workers and operators).

- **Scenarios for assessing residential and bystander exposure can be improved** by accounting for the exposure from multiple farms in the proximity.

#2: Increase safety factors to lower exposure thresholds (e.g., ADI), where safety values are missing critical testing and data, especially for vulnerable groups.

#3: Require the pre-market establishment of human Biological Guidance Values (safety thresholds in human matrices) to allow for the post-market monitoring of aggregate human exposure.

#4: Require the pre-market establishment of guidance values for residue levels in air and dust, environmental matrices that humans may be exposed to.

C.5. Post-Market Monitoring and Targeted Risk Reduction

While pre-market PPP risk assessment is designed to predict potential risks and set safe conditions for pesticide use, post-market assessment measures capture real-world factors that cannot be fully accounted for in pre-market tests and models. Once PPPs are in widespread use, real-world factors such as environmental conditions, cumulative exposure, mixtures and interactions with other chemicals can reveal previously unknown health or ecological effects. Measures such as **pesticide monitoring** ensure that adverse impacts on human health, wildlife, or ecosystems are detected early, allowing for as timely mitigation responses, such as usage restrictions, and authorisation withdrawals (Reg. (EC) 1107/2009,

Art. 21). The following present SPRINT results and recommendations on the post market monitoring of a) environment and food, and b) humans.

C.5.1. Pesticide Monitoring in Environment and Food

Background

Pesticides applied to crops can enter multiple environmental matrices through leaching and runoff, wind erosion, volatilisation into air, and even household contamination from nearby fields (EFSA, 2014). Pre-market regulation requires predicting their environmental fate, with approval contingent on breakdown rates that prevent accumulation in key compartments. Monitoring programmes are essential to verify that residues remain within safe limits, validate modelling predictions, and trigger mitigation when needed. These monitoring frameworks are embedded in several EU and national policy initiatives. A central challenge is to define benchmarks that both safeguard health and the environment and remain feasible for routine monitoring.

The **EU Zero Pollution Action Plan** (COM/2021/400) sets the goal of reducing pesticide pollution in air, water, and soil to levels no longer harmful to human health and the environment. Despite progress in reducing pesticide use, pesticides remain widely detected in all environmental compartments, undermining the plan's "healthy environmental status" objective (European Environment Agency & European Commission. Joint Research Centre., 2025).

At EU level, **binding limits for pesticide residues** apply only to groundwater, drinking water, and food (Reg. (EC) No 396/2005). Under the **Water Framework Directive (WFD)**, only a few pesticide "priority substances"—mainly already-banned actives—are regulated. For groundwater and drinking water, precautionary mixture standards apply: 0.1 µg/L for any single pesticide and 0.5 µg/L total. These remain the only binding EU thresholds for mixtures. On food, residue levels for individual substances are strictly monitored under EU and national control programmes, yet no thresholds exist for total residues, leaving open the risk of higher dietary exposure from mixtures. The **Air Quality Directive** (2008/50/EC) does not cover pesticides, and no EU air quality standards address pesticide inhalation despite rising concern.

Under the **Sustainable Use Directive (SUD)**, Member State National Action Plans (NAPs) define monitoring programmes, mainly addressing occupational protection, groundwater and drinking water contamination (in line with the WFD), and food residues. Some Member States extend monitoring further, while programmes such as **Natura 2000** (Directives 92/43/EEC & 2009/147/EC) enforce monitoring in protected areas.

For soils, there are still **no binding EU environmental quality standards (EQS)**. The pan-European LUCAS survey found pesticide residues widespread, with mixtures posing risks to soil organisms at 14% of 3,473 sites (Franco et al., 2024). Risk-based soil indicators are used nationally in some cases but remain non-binding at EU level (Kotschik et al., 2024).

The proposed **Soil Monitoring Law (SML)** provides an opportunity to strengthen this gap. A provisional agreement on the Commission text was reached on 10 April 2025 (Legislative resolution P9_TA (2024)0204). The directive could introduce pesticide-related benchmarks and a soil health definition that explicitly includes pesticides. Key elements include:

- A new EU definition of soil health, though pesticide residues are not yet explicitly included.
- An indicative watchlist of substances posing significant risks to human health and the environment.

- Non-binding targets for healthy soils, but binding obligations for Member States to establish support measures.

SPRINT Approach and Findings

In the SPRINT project, a novel harmonised sampling campaign for residues from 209 active substances in 10 European countries was conducted, capturing a snapshot of pesticide residue mixtures in humans and in the environment (air, water and soil) during the 2021 growing season. Using measured and realistic concentrations of pesticides from the sampling campaign, and ecological risk assessment was conducted for soil and aquatic systems.

Several key results support the need for expanded monitoring and provide insight into implementation:

- Pesticide residue mixtures were detected in **nearly all samples or air, water, soil, aquatic sediments and indoor dust**, with most samples containing residues hazardous to humans and animals (Alaoui et al., 2024; Khurshid et al., 2024b; Navarro et al., 2024; Silva et al., 2023). While in organic farming fewer pesticide residues were observed than conventional farms, pesticides were still widely detected in organic fields.
- Measured environmental concentrations of pesticides in soil (MEC_{soil}) were not well correlated with predicted environmental concentrations (PEC_{soil}) determined by EFSA methodology (Knuth et al., 2024).
- In laboratory tests, native aquatic and soils species showed sensitivity to measured and realistic pesticide mixtures in the environment (Abrantes et al., 2024a; Tourinho et al., 2024), demonstrating that monitoring results could reveal real ecological risk.
- Based on risk-based soil indicators, measured concentrations of pesticides showed unacceptable risk to earthworms, important species for soil health. (Suciu et al., in prep)
- A SPRINT prioritisation index was developed to residues of concerns from monitoring data, integrating occurrence, distribution, and hazard of the pesticides detected. High scoring residues can be prioritised for use and risk reduction actions (Silva et al., 2023).

SPRINT findings demonstrate that pesticides are widely distributed in the environment, may pose an ongoing risk to non-target species at environmental concentrations, and that monitoring data can be used to inform prioritisation and risk reduction. We recommend the expansion of EU monitoring policies, including in future revision of SUD and the upcoming Soil Monitoring Law, compelling the creation of national monitoring programmes to capture the real extent of pesticide contamination in the environment.

Recommendations

#1: Introduce legally binding risk-based benchmarks for pesticide residues for soil, aquatic sediments, air, and indoor dust in EU monitoring policies (Water Framework Directive, Air Quality Directive, Soil Monitoring Directive), with clear thresholds for corrective exaction with exceedance.

- Pesticide residue thresholds can be derived from ecotoxicology testing already conducted due active substance assessment.

#2: Pesticide environmental quality standards (EQS) and maximum residue levels (MRLs) should include a threshold for total pesticide residues, accounting for the effect of mixtures on humans and the environment.

#3: Under the new Soil Monitoring Law:

- Include pesticide residues in the new definition of soil health.

- Adopt the SPRINT hazard-based prioritisation index to identify pesticides of highest concern from monitoring data.
- Integrate pesticides of concern from SPRINT into the chemicals watch list.
- Strengthen requirements for soil remediation and regional management changes in response to high levels of pesticide contamination.

C.5.2. Human Biomonitoring

Background

Humans face potential pesticide exposure from a variety of sources, including food, drinking water, and the environment. Farmers, farming families and other residents near farms may face a higher potential exposure to pesticides in their environment than consumers, people who live far from farm where pesticides are applied (Shekhar et al., 2024). Consumers may also encounter pesticides in the environment, including in indoor dust. Some published studies suggest a contribution from pesticides authorised for biocide applications (e.g. insecticides or veterinary medicines). Exposure to high levels of pesticides over a long period of time such as in professional use is associated with a range of chronic disease, some of which are recognised occupational diseases (e.g. Parkinson's Disease in France and Germany).

While the pre-market registration of PPPs (Reg. (EU) 284/2013) requires an evaluation of potential human exposure, post-market monitoring is essentially to detecting and preventing exposure breakthroughs under real use of PPPs.

Current regulations for monitoring and controlling pesticide exposures are focused primarily on the dietary sources of pesticides – food and water – and on ensuring compliance with farmer occupational protection standards. Dietary pesticide residues face strict legal limits and harmonised EU / Member State monitoring programmes for food (Reg. (EC) No 396/2005) and drinking water (Drinking Water Directive (EU) 2020/2184). There is no EU regulation or monitoring program covering the environmental exposure of consumers to pesticides. Under the Sustainable Use Directive (2009/128/EC), National Actions Plans require measures and monitoring to reduce occupational and public pesticide exposure, such as training, equipment inspection, reduced spraying near sensitive areas. Non-compliance can lead to penalties, with severity and enforcement determined by Member States. However, neither SUD nor another EU policy requires human biomonitoring of farm workers or families for their actual internal exposure to pesticides.

HBM provides a powerful tool for assessing pesticide exposure by directly measuring pesticide residues or their metabolites in human biological samples such as urine, blood, or hair. Unlike environmental and food monitoring, HBM reflects the **internal dose** a person has absorbed from **all exposure routes** (ingestion, inhalation, dermal), and from all sources—food, air, water, occupational, and residential. This makes HBM particularly valuable for understanding **real-world aggregate exposure**, especially in vulnerable groups like children, farmworkers, or residents living near treated fields.

The **HBM4EU** project (2017–2022) was the first EU-wide effort to harmonise biomonitoring methods and generate comparable data across countries, identifying pesticide biomarkers and exposure levels in the general population, and setting **biological guidance values (BGVs) –** health-based thresholds for internal exposure. Building on this, the ongoing PARC (Partnership for the Assessment of Risks from Chemicals) program continues to use HBM data to inform **chemical mixture risk assessments**, identify population subgroups at risk, and support policy decisions with real-world evidence. Human biomonitoring aligned with HB4EU (5 countries, 2024 – 2021) found that **84% of samples** from the

bodies of children and adults contained residues of two or more pesticides (*How Pesticides Impact Human Health (Signal)*, 2024).

Setting **BGVs** is key to making human biomonitoring (HBM) data useful for assessing pesticide exposure and health risks. European initiatives like HBM4EU and PARC have advanced this work, but many pesticides still lack clear BGVs, and methods for deriving them need better harmonisation and toxicokinetic data. Several members states – such as the Netherlands (Health Council of the Netherlands, 2025) and Germany (Kommission Humanbiomonitoring, 2014) --- have already endorsed biological limit values (BLVs) – using BGVs as legally binding thresholds in policy. **BGVs and BLVs are not currently uniformly adopted as standards by EU agencies.** Currently acceptable daily intake (ADI) which only covered dietary exposure, is the only reference value for human exposure in the general population that is universally recognised across EU agencies and policies.

Pesticide **human biomonitoring programmes**, at the EU and national level, would allow for the detection of real aggregate exposure from all routes and sources of uptake and identify exposure hotspots, allowing for targeted corrective action. This provides a check for real incidents of human exposure before health problems arise and are detected.

SPRINT Approach and Findings

The SPRINT project included several studies with relevance for human exposure to pesticides, including studies of pesticide occurrence in the home and environment, calculations of exposure from human biomonitoring using HB4EU and PARC methodology, experiments assessing internal pesticide exposure, and estimates of contributions from non-dietary exposure.

- **Internal Exposure and Toxicokinetic Studies –** Several toxicokinetic studies of pesticide effects were conducted, providing important insights to support the derivation of BGVs.
- **SPRINT sampling of pesticide occurrence near humans** - Pesticides residues were sampled in the environment to which humans are exposed, including indoor dust, outdoor air, and soil.
- **Wristbands as a proxy for direct contact** – Study participants wore wristbands to collect pesticides as a personal sampler, serving as a proxy for possible direct contact with pesticides (to the extent that they are absorbed in the silicon material) and reflects non-dietary exposure. It does not provide information on uptake by inhalation or dermal uptake.
- **Sampling of Real Dietary Exposure – Duplicate Portion Analysis -** Participants set aside a second portion of each meal for pesticide analysis to compare to acceptable daily intake (ADI). This approach accounts for portion size and any food preparation and processing losses.
- **Dietary vs. Non-Dietary Exposure Contribution** – Drawing on studies on of dietary and non-dietary exposure in SPRINT, an estimate of the relative contribution of route.
- **Human Biomonitoring and exposure calculations** – Human samples (blood, urine, and faeces) were collected from participating farmer and families in 10 countries and analysed for pesticide residues. These concentrations of a subset of pesticides were back calculated and compared to reference values considered safe: ADI (standard for dietary exposure) or biological guidance values (limits for levels considered safe in human samples). This was intended to detect a snapshot aggregate exposure from dietary and non-dietary sources.
- **MCRA (Monte Carlo Risk Assessment) will be applied to human biomonitoring results** probabilistically linking internal residue exposure levels with dietary and non-dietary sources to assess cumulative and aggregate risks across populations.

<u>The following key results were identified:</u>

1. **Pesticides occur frequently in the environment where humans are present, including the home.** While levels of each individual residue detected in the study were low, they are a potential source of non-dietary exposure to pesticide. HBM is an important tool to evaluate that aggregate exposure from these sources for vulnerable populations.
    - Indoor dust contained the highest number of pesticide residues not accounted for by EFSA. Indoor dust contained many pesticide residues explained in part by residential biocide applications.
        - Although levels are overall low, this represents a possible exposure route to humans, especially young children (Silva et al., 2023).
    - In on-farm outdoor air (NL and PT) 97% of samples contained at least one pesticide, 95% of samples contained mixtures, and 91% are classified as hazardous for human health.
        - While overall pesticide concentrations were extremely low, the health impacts of pesticide inhalation are not well understood. Furthermore, the safe intake level ADI (dietary) does not account for the inhalation route (Debler et al., 2024).
    - Pesticide mixtures were detected on most wristbands worn by participants, with farmers and neighbours generally higher than levels for consumers (Figueiredo et al., 2025b).
        - Banned pesticides were detected at high frequencies confirming the persistent occurrence of these pesticides near humans.
        - There was little difference in the occurrence of pesticides on wristbands of organic farmers, conventional farmers.
        - These are a potential source of non-dietary exposure for humans, although uptake of pesticides found on wristbands was not studied.
2. **In the human biomonitoring studies, most sampled participants did have pesticide residues and mixtures in their blood, but individual levels did not exceed safe values for aggregate exposure.** However, exposure values varied widely between participants, and we don't know how often exposure is exceeded by farmers across Europe. **HBM is an important tool to monitor exposure in European population.**
3. **Analysis of prepared food portions combined with biomonitoring** help to verify the current practice of assessing pesticide residue levels in food commodities.
4. **Non-Dietary exposure can be a contributor to overall exposure** – Diet is generally the most common route of exposure, but non-dietary exposure may provide a more important contribution in occupational settings especially when dietary exposure is very low.

Recommendations

#1: Introduce harmonised EU and national Human Biomonitoring Programmes to study exposure from all routes and sources of uptake and identify exposure hotspots.

#2: Adopt harmonised biological guidance values (BGVs) and legally binding limit values (BLVs) in pesticide active substance pre-market registration and across EU bodies (DG-SANTE, EFSA, ECHA), to support better monitoring and control of aggregate exposure.

C.5.3. Scaling up the Impact – Targeted Risk Reduction and Prioritisation

Background

Scaling up efforts to reduce the health and environmental impacts of pesticides requires robust approaches to identify the agricultural practices, crops, and pesticide uses that pose the highest risks. This entails accounting for the spatio-temporal accumulation of risks from pesticide mixtures across landscapes and over time and highlighting geographic hotspots where interventions would be most effective. By pinpointing which crops, farming methods, and pesticide applications carry the greatest risks, policymakers and regulators can better **target interventions and prioritise action** at national and EU levels.

EU strategies such as the Farm to Fork Strategy, EU Biodiversity Strategy for 2030, and the Zero Pollution Action Plan explicitly recognise the need to reduce risks from pesticides, including the objective to cut by 50% the use of the most hazardous pesticides by 2030. Under the Sustainable Use Directive (Directive 2009/128/EC), Member States must develop National Action Plans setting "quantitative objectives, targets, measures and timetables to reduce risks and impacts of pesticide use on human health and the environment." However, the level of ambition and the scope of implementation vary significantly between countries.

Current progress tracking relies heavily on the **Harmonised Risk Indicator I (HRI, Directive (EU) 2019/782)**, which is based on pesticide sales weighted by hazard class. While useful, HRI does not capture geographically explicit usage, pesticide residue mixtures already present in the environment, or differences in environmental vulnerability. As the **European Court of Auditors** emphasised, the risks posed by pesticides depend on "where, when and how users apply them in practice." More spatially explicit, real-use–based indicators are therefore needed to complement existing indices and better reflect actual risks and exposure patterns.

Monitoring approaches—such as environmental monitoring and human biomonitoring—are valuable but resource-intensive. Large-scale **modelling approaches** can complement monitoring by demonstrating pesticide exposure and risk patterns across time and space, provided that high-quality, harmonised data are available. Yet, data gaps remain a central barrier:

- **Authorisation data**: Although EU legislation (Reg. (EC) 1107/2009, Art. 57) requires national registers of authorised pesticide products, there is no harmonised, centralised EU-wide registry. Public access is fragmented, and comprehensive solutions are often available only via costly private databases.
- **Usage data**: Member States are not yet required to maintain systematic registries of actual pesticide applications at farm level, which are essential to assess real-world exposure. Some countries (e.g. Denmark, Czech Republic, the Netherlands) maintain high-quality usage registries, but methodologies differ, hampering EU-wide comparability. The **EU Regulation on Statistics on Agricultural Input and Output (SAIO, Reg. (EU) 2022/2379)** will mandate improved and harmonised reporting from 2028 onwards, but detailed pesticide use registries remain to be established.

Finally, enabling the sustainable use of pesticides requires considering their **full life cycle**—from synthesis and manufacturing, through field application, to end-of-life treatment. Life-cycle assessments show that emissions and resource use occur at every stage, with impacts ranging from climate change to human and ecological toxicity. Only by considering all stages can trade-offs be identified and burden-shifting avoided.

SPRINT Approach and Findings

SPRINT generated key tools and approaches that can support policy making at the scale of individual countries or whole EU level:

SPRINT Toolbox

The SPRINT Toolbox (SPRINT toolbox) applies large-scale datasets on PPPs to model pesticide exposure distributions across ecosystems and human populations in Europe and to quantify risks to health and the environment.

Key features and insights from ongoing toolbox development include:

- **Spatio-temporal risk mapping:** The Toolbox integrates PPP usage and spatial data to produce maps that capture the cumulative distribution of hazardous exposures and unacceptable risks over space and time. These maps support prioritisation of active substances for targeted reduction, substitution, or withdrawal.
- **Policy applicability:** Outputs are designed for EU and Member State policymakers. Results are presented as annual exposure–risk heat maps with clear interpretation notes, enabling non-specialists to understand the outputs while preserving scientific transparency.
- **Data limitations:** Development of the Toolbox revealed significant shortcomings in current PPP datasets. National registers, usage statistics, and EUROSTAT PPP data lack sufficient resolution, harmonisation, and accessibility to reliably parameterise exposure–risk models across Europe.
- **Potential with improved data:** With harmonised EU-wide data on PPP authorisations and usage (national registries), the Toolbox methodology could systematically identify high-risk application patterns and cropping systems, providing a robust decision-support tool for guiding interventions that maximise protection of health and ecosystems.

Life-cycle Analysis: Pesticide Damage Costs

SPRINT used life-cycle analysis (LCA) to estimate **quantified damage costs (USD) of pesticides** by linking farm-level use with emissions, supply chain impacts, environmental fate, exposure, and toxicity modelling. This approach shows that **pesticide** impacts vary widely across crops, farms, and application methods, but **are often dominated by a small number of active substances** (e.g. captan for high application rates, emamectin benzoate for high toxicity potential) (Fantke et al., 2023a; Fantke et al., 2023b).

While damage-cost estimates are uncertain, assigning an economic value to pesticide impacts offers policymakers a decision-support tool to prioritise which pesticides and practices to target for reduction.

Recommendations

#1: Require the harmonisation of national PPP usage registries and national PPP authorisation registries in all member states, including information on pesticide application mixture, timing, quantity, crop, and application method. This will allow for a quality assessment of pesticide exposure across Europe.

#2: Adopt tools and maps in the **SPRINT Toolbox to identify and target pesticides and cropping combinations with highest risk for human and environmental health**, using exposure models based on actual pesticide usage data.

#3: Complement HRI 1 with annual indicators that account for real pesticide usage, such as the annual maps from the SPRINT Toolbox and LCA damage costs estimates.

D. CAP appraisal and specific recommendations

D.1. Context

The Common Agricultural Policy (CAP) remains the EU's primary instrument for translating strategic objectives into concrete actions at farm level. Introduced in 1962, the CAP channels a significant portion of the EU budget to ensure food security, stabilise markets, and provide a fair standard of living for farmers. Over time, its scope has broadened to include rural development as well as environmental and climate-related objectives. Today, the CAP commands an average annual budget of approximately EUR 55 billion, accounting for 31% of the total European Commission budget for the 2021–2027 programming period (Giuliani and Baron, 2025), making it a pivotal instrument for promoting sustainable agricultural practices, including the transition towards reduced dependency on synthetic pesticides. This expanded scope gives the CAP not only the potential but also the responsibility to serve as a catalyst for sustainability transitions. In particular, its influence at the farm level positions it as a central mechanism for enabling the long-term shift away from synthetic pesticide dependency towards ecologically integrated farming systems.

The current CAP 2023-2027 is structured around a new delivery model that grants MS increased flexibility to define national-level implementation through CAP Strategic Plans (CSPs), while operating within a common EU-wide framework. These plans are required to contribute to a set of overarching goals, including nine specific objectives (SOs) and one cross-cutting objective. Among these, three objectives are particularly pertinent to environmental sustainability: climate change mitigation and adaptation (SO4), sustainable management of natural resources (SO5), and the protection of biodiversity and ecosystems (SO6). Moreover, in accordance with transparency and monitoring requirements, Member States (MSs) are required to link interventions to a comprehensive set of result indicators (RIs), which are intended to demonstrate the relationship between specific measures and their intended outcomes. Of the 44 RIs identified under the current CAP, two are especially relevant to pesticide reduction: sustainable and reduced use of pesticide (R24), and development of organic agriculture (R29). While these objectives and indicators frame environmental ambition, their true transformative potential lies in how they are operationalised across instruments. A transition-oriented CAP requires CSPs to foster coherent, cross-dimensional change, supporting farmers not just to reduce pesticide use, but to progressively redesign systems in ways that prevent pest pressures and reduce synthetic reliance structurally.

Within this framework, the CAP's environmental and climate ambitions are operationalised through its so-called *Green Architecture,* a suite of policy instruments that support (the transition toward) more sustainable farming practices. The Green Architecture comprises different layers and instruments. The foundation lies in conditionality, which includes Statutory Management Requirements (SMRs) and Good Agricultural and Environmental Conditions (GAECs). SMRs are legal obligations that apply to all farmers, regardless of their receipt of CAP funding, while GAECs establish specific environmental standards that must be met to qualify for direct payments under the CAP. Building on this baseline, additional voluntary instruments such as eco-schemes, agri-environment-climate (ENVCLIM), and investment (INVEST) interventions provide targeted support for the adoption of more sustainable practices.

Although not formally part of the Green Architecture, complementing these instruments are cross-cutting measures designed to facilitate knowledge exchange, capacity building, and innovation. Interventions linked to AKIS play a key role in facilitating systemic change by improving the generation, dissemination, and application of knowledge across the agricultural sector. In addition, sectoral interventions represent another important layer of CAP implementation. These are primarily implemented through sector-specific operational programmes managed by producer organisations, which receive co-financing from the CAP. Environmental and climate objectives are increasingly integrated into these programmes, with producer organisations – such as those in the fruit and vegetable sector – required to allocate a minimum share of

their budgets to environmental actions. These sectoral interventions also intersect with AKIS, creating further opportunities for innovation, knowledge transfer, and collective action at the organisational level.

Table 10 provides an overview of these core CAP instruments relevant to supporting more sustainable pesticide management.

Table 9: Overview of CAP instruments particularly relevant for supporting more sustainable pesticide management.

CAP Instrument	Main Purpose	Duration / Coverage	Funding
Conditionality (GAEC requirements)	Ensure compliance with minimum environmental and climate standards as a prerequisite for receiving CAP payments	Always applicable; mandatory for all recipients of direct payments	European Agricultural Guarantee Fund (EAGF); fully EU-funded
Eco-schemes	Incentivise voluntary adoption of sustainable farming practices beyond the baseline	Annual payments; mandatory for MS to offer, voluntary for farmers to participate; under Pillar I	EAGF; fully EU-funded
Agri-Environment-Climate (ENVCLIM) Interventions	Support more long-term environmental practices and commitments	Multi-annual payments (typically 5–7 years); mandatory for MS to offer, voluntary for farmers to participate; under Pillar II	European Agricultural Fund for Rural Development (EAFRD); co-funded by national/regional authorities
Investment (INVEST) Interventions	Support structural and technological improvements on farms	One-time support for long-term projects; voluntary	EAFRD; co-funded by national/regional authorities
Agricultural Knowledge and Innovation System (AKIS)	Foster innovation, capacity building, and collaboration among farmers, advisors, and researchers	Project-based; scope and timeline vary	EAFRD; co-funded by national/regional authorities
Sectoral Interventions	Support competitiveness and sustainability in specific sectors (e.g., fruit and vegetables, wine, apiculture)	Sector-specific programmes, often annual or multi-annual	EAGF; may involve producer organisations' operational funds

Building on the co-created transition pathways as outlined in Part B, this chapter explores how the current CAP architecture and its instruments can contribute to reducing pesticide dependency and supporting a broader shift towards sustainable farming systems. While Part B.5.6 articulated the systemic priorities for realigning financial and economic incentives (i.e. what types of measures must be incentivised, such as transition payments, risk-sharing mechanisms, and remuneration for ecosystem services), the present analysis addresses how these priorities can be operationalised within the CAP framework. Specifically, it assesses whether and how the CAP's structural components enable changes in pest management practices, and how Member States have made use of these options in their CSPs. The results suggest that the CAP holds significant potential to support more sustainable pesticide management, and to some extent, this potential is already being utilised. However, there remains considerable room for improvement, both in terms of increasing the scope and ambition of existing measures and in reallocating resources towards more effective and systemic transformative practices.

D.2. Methodology

An analysis of the CAP architecture and the Member States' CSPs was conducted between March and May 2025 to assess the extent to which the CAP 2023–2027 supports interventions promoting more sustainable pesticide use. The analysis drew on data from the Agri-Food Data Portal and was complemented, where relevant, by the integration of insights and arguments from existing policy discussions and related scholarly work.

The policy recommendations presented in Chapter B.6 are informed by an analysis of the extent to which the current CAP supports interventions aimed at promoting more sustainable pesticide use. This analysis focused on how the various intervention types within the CAP architecture and the national CSPs contribute to the adoption of farming practices that foster more sustainable pesticide management.

The primary data source for the analysis was the European Commission's CAP Agri-Food Data Portal, which provides comprehensive, structured information on planned interventions as outlined in the CSPs. Where possible, interventions' relevance to sustainable pesticide management was identified by linking them to relevant farm practices.

These linkages build on a recent mapping of farming practices included in the CSPs (EC, 2024), employing a typology of agricultural practices developed by Angileri et al. (2024). In that framework, interventions are associated with one or more labels, indicating the specific farming practices they are designed to support. For the following analysis, a subset of farming practices was selected based on their relevance and potential to support more sustainable pesticide use, either through prevention, substitution, or reduction strategies (see **Error! Reference source not found.**).

Table 10: Mapping of Farming Practices

Sector	**Farm Practice**
Plant protection	Non-chemical control (biological and chemical)
	Limitation in use of plant protection products (bans, limitations, restrictions "other than along watercourses")
	Integrated production (adoption of integrated IPM)
Soil management	Soil cover crops (summer and winter)
	Green soil cover on permanent crops
Crop rotation and diversification	Crop rotation
	Land laying fallow
	Crop diversification
	Mixed cropping/intercropping
Landscape	Landscape features: Hedgerows/individual or group of trees/trees in line (creation, maintenance, conservation)
	Landscape features: Field margins, patches and unproductive buffer strips along water courses (creation, maintenance, conservation)
Water	Ban of plant protection products along water courses
Assessment and management plans	Pesticide management plans
Precision agriculture	Variable rate application technologies
Organic farming	Organic farming (maintenance of and conversion to)
Low input systems	Low input systems

Data at farm practice level are available only for eco-schemes, ENVCLIM, and INVEST interventions. In other cases, relevance was inferred based on the associated result indicators R24 (sustainable and reduced use of pesticide) and R29 (development of organic agriculture).

D.3. Results

This chapter presents the results of the analysis of the CAP and the national CSPs in terms of their contribution to more sustainable pesticide management. The analysis is structured in several steps. It begins with the GAECs, which establish the mandatory baseline requirements for all farmers. It then turns to the main voluntary instruments – eco-schemes and the environmental and climate interventions – that are designed to encourage more ambitious practices. This is followed by an examination of the complementary instruments, including knowledge exchange, advisory services, and sectoral support measures. Finally, the chapter assesses the extent to which these different instruments are aligned with one another and whether they collectively provide a coherent framework for supporting sustainable pesticide use.

D.3.1. Conditionality (GAECs)

The GAECs represent baseline standards that farmers must comply with to be eligible for CAP support and thus, form the foundation upon which other CAP interventions are built. While none of the GAECs is explicitly designed to regulate pesticide use, several of them play a crucial role – either directly or indirectly – in shaping conditions the conditions for more sustainable pesticide management across European agriculture.

GAEC 4, which mandates buffer strips along watercourses, is directly relevant to pesticide management because these strips act as protective zones where pesticide application is prohibited. This measure reduces the risk of pesticide runoff into rivers and lakes, thereby safeguarding aquatic ecosystems, drinking water quality, and downstream biodiversity. GAEC 7, requiring crop rotation, represents one of the strongest agronomic levers for reducing pesticide dependence. Rotating crops disrupts pest and pathogen lifecycles, decreases weed pressure, and enhances soil microbial diversity, thereby lowering the need for chemical inputs to manage infestations. GAECs 5 and 6, which focus on erosion control and maintaining soil cover, also contribute to reduced pesticide reliance by supporting soil health and preventing weed proliferation. Permanent or temporary cover crops provide habitat for beneficial organisms such as predatory insects and improve soil fertility, which enhances crop resilience against pests and diseases. GAEC 8, by preserving landscape features such as hedgerows, trees, and fallow land, creates ecological refuges that are crucial for pollinators and natural pest enemies. These habitats support biological control functions that can significantly reduce the need for synthetic pesticides. Finally, the exemption of organic farms from compliance checks under GAECs 3, 5, 6, and 7 may indirectly incentivise conversion to organic farming, which is inherently pesticide-free, thus reinforcing broader sustainability goals.

While these GAEC standards provide an important baseline framework and offer potential to support more sustainable pesticide use, their overall effectiveness is significantly compromised by regulatory exemptions and increased MS discretion (European Parliament, 2024). Particularly, greater national flexibility in defining GAEC 2 to 6 has enabled context-sensitive implementation but risks fragmenting environmental standards and diluting uniform environmental protection. Moreover, the dilution of crop rotation obligations under GAEC 7 compromises one of the most effective agronomic tools for breaking pest cycles, thereby encouraging monocultures and reliance on synthetic pesticides. Similarly, the removal of the requirement for non-productive areas under GAEC 8 eliminates essential habitats for natural pest predators, reducing landscape diversity and potentially exacerbating pest outbreaks. Although Member States were required to offer an eco-scheme as an alternative, these voluntary measures are unlikely to provide equivalent coverage, as their uptake depends on sufficiently high compensatory payments.

Overall, the GAECs hold considerable potential to serve as a structural backbone for more sustainable pesticide management in the EU, but in their current form this potential remains underexploited. While these standards do not function as proactive tools to drive reductions in pesticide use, they are best understood as safeguards that mitigate the worst environmental impacts of pesticide use. Their effectiveness is greatest where the standards are ambitious and rigorously enforced, but substantially weaker where exemptions, flexibility, or diluted requirements enable intensive farming systems to persist with minimal change. Strengthening the mandatory provisions of GAECs is therefore essential to ensure they provide more consistent and robust support for reducing pesticide dependence and advancing the transition towards sustainable agricultural practices.

D.3.2. Eco-schemes and ENVCLIM interventions

The main tools that incentivise farmers to adopt more sustainable practices that go beyond conditionality are eco-schemes and ENVCLIM interventions. Both instruments have important potential in the context of promoting more sustainable pesticide management. While eco-schemes typically provide flexible, annually renewable incentives that can promote the uptake of sustainable practices across a broad base of farmers, ENVCLIM measures offer multi-year support geared towards achieving more sustained environmental improvements, typically reaching only a smaller subset of committed farmers.

Looking at MS CSPs, an analysis of financial allocations to interventions contributing to the pesticide-related result indicators (RIs) indicates that 42.5% of eco-schemes and 63.6% of ENVCLIM budget is linked to area-based payments that contribute to a sustainable use of pesticides (R24). Allocation is significantly less for measures dedicated to support organic farming (R29) with approximately 23.8% of eco-schemes budget and 35.5% of ENVCLIM budget for this objective. Looking at support for specific farming practices – as outlined in Table *10*, p. 78– among eco-scheme interventions, the most widely supported practices across CSPs are the limitation in the use of PPPs and the establishment of unproductive areas and strips, each supported via at least one eco-scheme by more than 20 MS. For ENVCLIM interventions, nearly all MS have implemented at least one intervention linked to the limitation in the use of PPPs and the maintenance of and conversion to organic farming.

Error! Reference source not found. and Figure 8 illustrate the share of interventions and corresponding budget allocations dedicated to farm practices relevant to sustainable pesticide management (as outlined in Table *10*) under eco-schemes and ENVCLIM interventions, respectively. The intervention share refers to the proportion of interventions labelled with relevant farm practices out of the total number of eco-scheme and ENVCLIM interventions, respectively. The budget share indicates the proportion of total funding allocated to these relevant interventions within the overall eco-scheme or ENVCLIM budget.

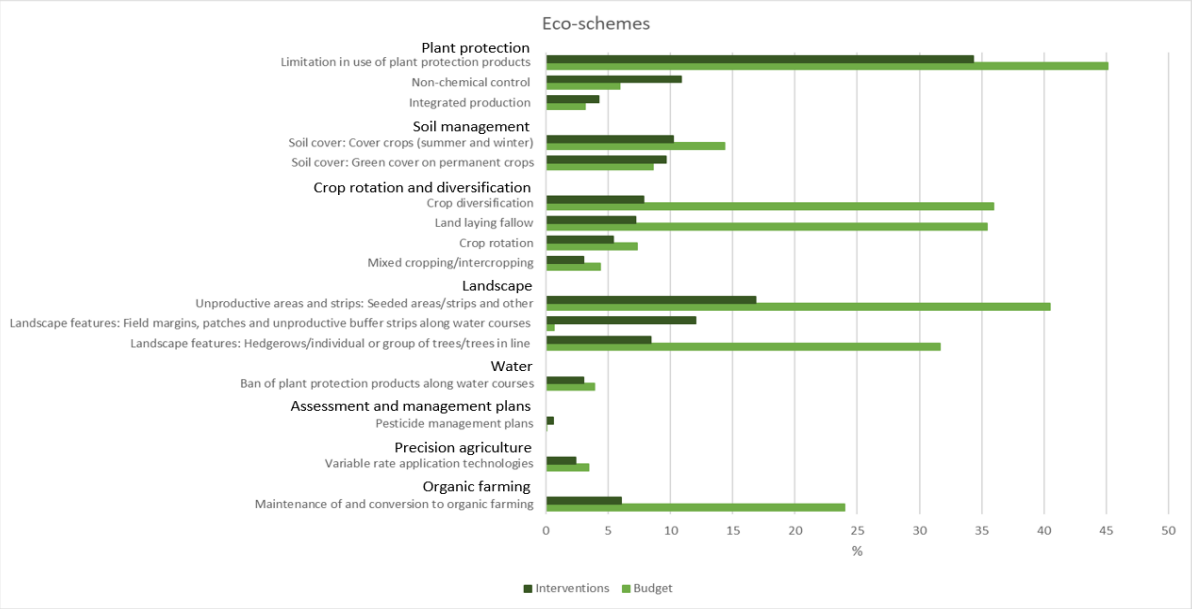

Figure 7: Share of eco-scheme interventions and corresponding share of budget allocations dedicated to farm practices relevant to sustainable pesticide management

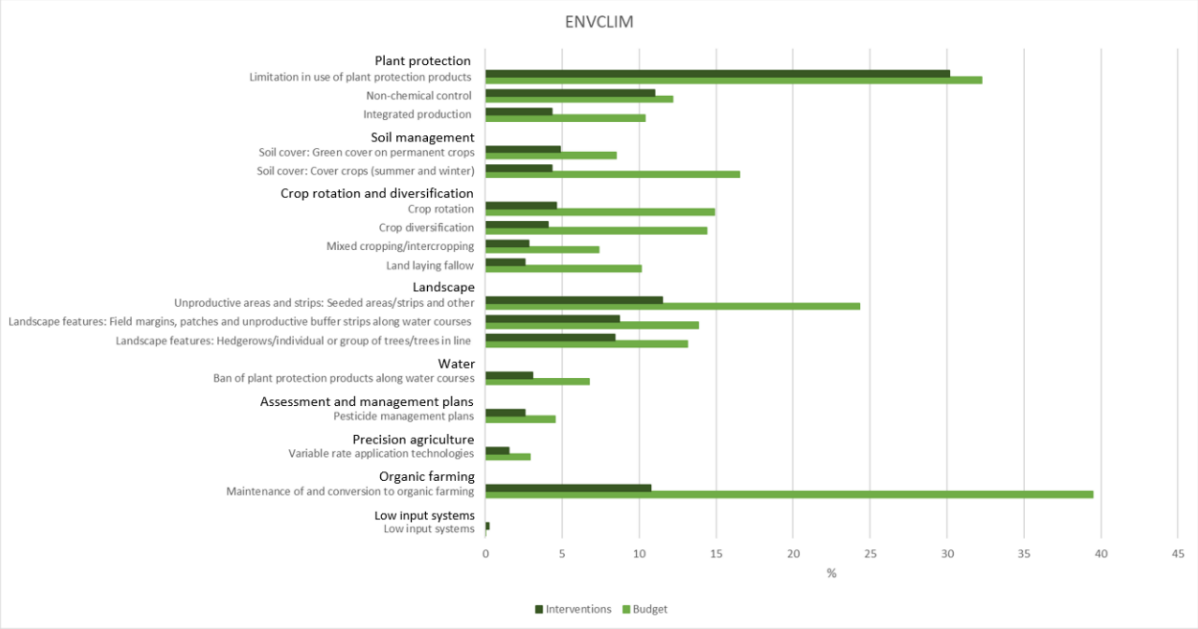

Figure 8: Share of ENVCLIM interventions and corresponding share of budget allocations dedicated to farm practices relevant to sustainable pesticide management

Across both instruments, establishing limits in the use of PPPs stands out as a frequently programmed measure, characterised by a high share of interventions and an even greater share of budget allocation. For eco-schemes, 34% of interventions are linked to this farm practice, accounting for around 45% of the total eco-scheme budget. For ENVCLIM interventions, approximately one-third of both interventions and corresponding budget are linked to this practice. The maintenance of and conversion to organic farming commands a significantly smaller share of interventions, but disproportionally high substantial financial support. For eco-schemes, only 6% of interventions relate to this farm practice, yet they receive

23% of the total budget. For ENVCLIM, this practice is supported by around 11% of interventions and captures 39% of the budget.

Significant shares of 30 to 40% of eco-scheme budget are also allocated to interventions including practices such as crop diversification, land lying fallow, and landscape features including unproductive areas and strips, hedgerows, and trees. In ENVCLIM, interventions promoting unproductive areas and strips similarly attract considerable funding. Management-based and technological farming practices receive very limited support under both eco-schemes and ENVCLIM interventions, both in terms of the number of interventions and the associated budgets. Notably, low-input systems are supported in only one CSP, corresponding to a single ENVCLIM intervention in BE-FL.

Most of the eco-schemes and ENVCLIM interventions are currently designed as action-based rather than result-based approaches. Under an action-based model, farmers receive remuneration for adopting or maintaining a set of predefined agricultural or environmental practices, such as planting cover crops, establishing buffer strips, or reducing fertiliser use. In contrast, result-based interventions link payments directly to the achievement of tangible, measurable outcomes, such as improvements in biodiversity indicators, reductions in greenhouse gas emissions, or increases in soil organic matter. In an assessment of CAP interventions, the European Commission (2024) finds that only 14 interventions across nine CSPs are result-based. An example with relevance to pesticide use is the French ENVCLIM intervention 70.27 "Flat-rate AECM – Transition of practices". This hybrid model, which links payments to both action- and result-based parts, directly rewards farmers for reducing pesticide use without prescribing specific cultivation methods. Particularly, it includes a "Plant health strategy" under which beneficiaries must achieve a reduction of at least 30% of the Treatment Frequency Indicator for herbicides and non-herbicides (EC, 2024).

Overall, eco-schemes and ENVCLIM interventions represent important complementary tools to conditionality in advancing more sustainable pesticide management. Within current CSPs, they channel significant resources to promote practices that limit pesticide use and support organic farming. Nevertheless, their transformative potential remains only partially realised. In particular, the potential of more management-based and technological practices remains largely untapped, owing to the limited allocation of resources to these practices. Moreover, a closer examination of the design of individual interventions reveals structural shortcomings that constrain interventions' effectiveness. Taking organic farming as an example, as outlined in IFOAM Organics Europe (2022), current CAP support often fails to provide adequate incentives and meaningful competitive advantage for organic farming practices. In many cases, payments for organic farming are equivalent to those for less transformative practices that offer significantly lower environmental benefits. Some MS provide financial support only for conversion to organic farming, but not for its long-term maintenance, which discourages continued participation. Regulatory constraints designed to prevent double funding can force farmers to choose between overlapping schemes, creating a structural disadvantage and reducing the overall incentive to opt for or remain in organic production. Furthermore, the predominance of action-based over result-based approaches limits intervention effectiveness, as farmers are rewarded for following prescribed practices rather than achieving measurable reductions in pesticide use or environmental impact, which can lead to suboptimal outcomes where practices are implemented without generating the intended environmental benefits.

D.3.3. Complementary instruments

Beyond these schemes, other CAP instruments hold potential to support more sustainable pesticide management. The cross-cutting SO10 aims to enhance the generation, dissemination, and adoption of knowledge, innovation, and digital technologies, thereby fostering the modernisation and sustainable transformation of agriculture and rural areas. Central to this objective is the Agricultural Knowledge and Innovation System (AKIS), which facilitates the generation, exchange, and application of relevant agricultural knowledge. Farm Advisory Services (FAS) constitute a vital element of AKIS by providing

tailored, farm-specific advisory support. Complementing this, the European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP AGRI) fosters cooperation between farmers, researchers, and advisory bodies through operational groups (OGs) and the support of innovation projects to co-create practical solutions for agriculture, forestry, and rural communities.

Moreover, under sectoral support programmes, MS can develop operational programmes for specific sectors such as fruit and vegetables, apiculture, wine, hops, and olives. These programmes provide support to producers who organise themselves into producer organisations to implement joint actions aimed at environmental improvements or strengthening their position in the food supply chain. Sectoral support can facilitate investments as well as a range of activities, including diverse forms of knowledge exchange and capacity-building initiatives.

Across MS, 232 CAP interventions – representing 9% of the total – are linked to key RIs related to AKIS. These correspond to enhancing the performance through knowledge and innovation (R1), linking advice and knowledge systems (R2), and environmental or climate-related performance through knowledge and innovation (R28). MS are required to set target values for the number of beneficiaries per RI, revealing significant variation across countries.

For all three indicators, target values range widely, from only a few individuals to several thousand or even exceeding one million, and median and average values differ substantially. Moreover, some MS did not indicate any targets, indicating highly uneven ambition levels and/or divergent strategic priorities or implementation capacities. For example, for R1, which targets the number of persons benefitting from advisory, training, knowledge exchange, or participation in EIP operational groups, values range from 4 to 1,329,127. The average target across MS is approximately 230,940, with a median of 110,290 (excluding Luxembourg, which reported no target).

Figure 9 displays the 232 interventions linked to R1, R2, and/or R28, disaggregated by type of intervention. Among these, the most frequently used intervention type is knowledge exchange (KNOW), which accounts for 73 interventions. This is followed by cooperation (COOP) with 46 interventions. 39 interventions are advisory services (ADVI1), and 38 are training and coaching (TRAINCO) measures. Investment in research and innovation (INVRE) is less common but still notable with 22 interventions. Other intervention types occur only once or twice with 14 interventions in total. The figure illustrates varying strategic priorities among MS in their use of intervention types. For instance, in BE-F, 13 out of 24 interventions are INVRE, indicating a strong focus on innovation-related investments. In contrast, Portugal places greater emphasis on KNOW, which account for 11 of its 18 interventions.

Within the CAP framework, while KNOW and COOP interventions are supported under rural development, the other intervention types are supported under the sectoral programmes.

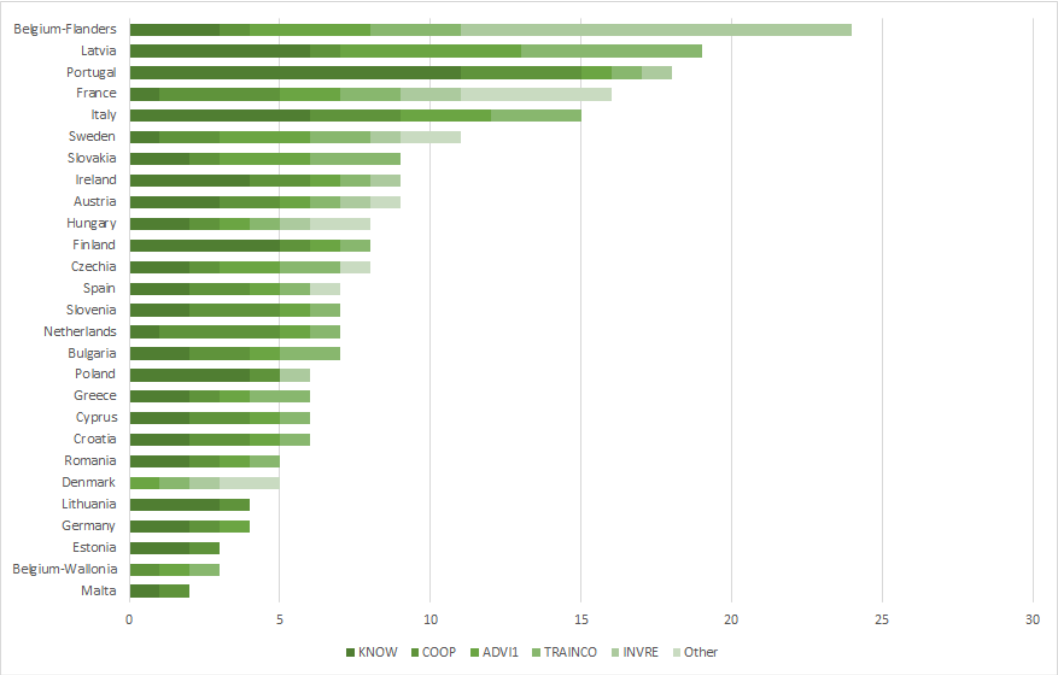

Figure 9: Number of interventions linked to result indicators (R1, R2, and/or R28), disaggregated by type of intervention.

Budget estimates are available for KNOW and COOP interventions, as MS are required to indicate financial commitments for these types in their CSPs. The 73 KNOW interventions account for 99% of both the total number of KNOW interventions and the KNOW budget in the CAP catalogue. The 46 COOP interventions represent 29% of all COOP interventions and 18% of the COOP budget. For the other intervention types, budget allocations are specified only at the level of OPs, i.e., financial data for these interventions are not included in the intervention catalogue, and relevant figures only become available once OPs are approved and reported in MS annual implementation reports to the Commission.

Assessing the extent to which these CAP interventions support sustainable pesticide use is difficult to determine. Of the 232 interventions, only four are formally linked to the relevant result indicators (R24 and/or R29). An additional nine explicitly reference sustainable pesticide use or organic production in their titles. However, these figures likely underestimate the true number of relevant interventions. This is partly due to the flexibility MS have in assigning result indicators, which may lead to the decoupling of thematically relevant interventions from the most directly associated RIs. Moreover, the intervention types ADVI1 and TRAINCO are, by definition, intended to address sustainable pest and disease control among other topics.

From a sectoral support perspective, 811 interventions – corresponding to approximately 33% of interventions in the CAP catalogue – fall under sector-specific schemes. Among the 811 interventions, 197 – representing ca. 24% – are linked to the result indicators R24 and/or R29. 23 of these are not classified as eco-schemes or ENVCLIM interventions and primarily include interventions for organic or integrated production (ORGAN, 16 interventions) and innovation-related investments (INVRE, 3 interventions). Notably, 14 of these 23 interventions are associated with the F&V sector, indicating a partial but targeted alignment of sectoral support with sustainable pesticide management objectives.

Overall, the evidence base on complementary instruments such as AKIS, FAS, and sectoral programmes provides only limited grounds for assessing their actual relevance and effectiveness in promoting more sustainable pesticide management. The flexibility granted to MS in assigning RIs, combined with the very low number of interventions explicitly linked to pesticide-related RIs, makes it difficult to systematically

identify and track interventions of direct relevance. Moreover, uneven ambition levels across countries, significant variation in target setting, and the lack of systematic budget data further constrain the ability to draw robust conclusions. While some interventions can be identified as potentially relevant, current CAP programming ultimately offers only a partial and highly fragmented picture of their concrete impact on sustainable pesticide use.

D.3.4. Alignment of instruments and interventions

At the overarching level of CAP architecture, the complementary and mutually reinforcing potential across instruments and interventions remains largely untapped. Rather than being designed as part of a coherent, strategically integrated framework within the national CSPs, instruments are often developed in parallel. This results in limited coordination, fragmented implementation, and missed opportunities to generate synergies that could drive systemic change.

This is illustrated by the example of organic farming. Eco-schemes and ENVCLIM interventions are well-suited to support the different phases of organic transition: eco-schemes could provide timely incentives to encourage broad uptake of organic conversion, lowering the entry threshold for a wide range of farmers, while ENVCLIM could offer more stable, long-term support for the maintenance phase, helping to sustain organic practices over time and ensuring continuity in environmental outcomes. However, this strategic complementarity is rarely realised in practice. In many CSPs, both instruments are formally used to support organic farming, but their design and implementation are poorly coordinated. Rather than building on one another, they tend to operate in parallel, with separate administrative requirements and limited integration in planning. The distinction between conversion and maintenance support, while clear in principle, is often not entirely clear-cut in practice. Farmers may struggle to navigate the transition between the two, particularly as they are required to actively reapply, meet new eligibility criteria, or comply with distinct procedural frameworks. This lack of continuity can lead to gaps in support, creating disincentives to remain in organic production once initial aid expires, and undermining both the long-term development of the organic sector and the durability of its environmental benefits. In many MS, however, support is offered through only one of the two instruments, precluding any possibility of strategic alignment.

The problem of fragmentation is equally evident in the field of knowledge and advisory support. Training, advisory services, and knowledge exchange are often implemented in isolation or on an ad hoc basis, without being systematically embedded in the broader incentive architecture of other instruments. Consequently, their contribution to sustainable transformation – for example in contributing to the growth and consolidation of the organic sector – remains limited. Advisory services, for example, are rarely connected to the practical challenges farmers face when moving from conversion to maintenance, leaving gaps in support at precisely the moment when continuity is most needed. Similarly, training on organic methods is typically offered as a standalone measure, without direct linkage to financial incentives such as eco-schemes or agri-environment-climate measures. This weakens the capacity of knowledge-based interventions to lower entry barriers, provide continuity, or sustain environmental outcomes. The absence of integration is also apparent in sectoral programmes: although they could play a decisive role in expanding organic production in high-input sectors such as fruit and vegetable farming, they often operate separately from the main instruments, reinforcing the fragmented nature of CAP support for organic farming.

D.4. Discussion and recommendations

Building on the preceding analysis, it can be argued that the CAP offers substantial opportunities to foster and incentivise more sustainable pesticide management, and the current CAP already incorporates a range of useful approaches and instruments in this regard. However, these measures remain insufficient to drive a fundamental shift in pesticide management, leaving considerable potential

untapped. The following section outlines concrete policy recommendations to address these gaps and unlock the CAP's transformative capacity.

D.4.1. Strengthen the GAECs to establish a strong environmental baseline

To effectively support broader environmental goals in general and sustainable pesticide management in specific, the GAEC framework must be reinforced and clearly positioned as a coherent, enforceable environmental baseline. Ambitious and well-defined GAEC standards are essential for fostering resilient, integrated farming systems, delivering tangible environmental outcomes, and maintaining the overall credibility of the CAP. Such strong regulatory foundation is essential for instruments such as eco-schemes and agri-environmental measures to function effectively. Particularly, the voluntary instruments are intended to build upon – not substitute – the mandatory requirements, as only the latter can reliably ensure consistent and widespread implementation across MS. Thus, a more robust GAEC framework should establish harmonised, ambitious standards that offer clarity and consistency across the EU. These standards must provide a reliable sustainability floor for all farms, act as a regulatory signal to drive systemic change, and support long-term transitions toward more sustainable practices. Without this foundation, efforts to reform pesticide use in agriculture risk being fragmented and ineffective.

Recommendations

#1: Reinforce the **GAEC framework as a coherent, enforceable environmental baseline** to support sustainable pesticide management and broader environmental goals.

#2: **Strengthen agroecological foundations within GAEC standards** to enhance natural pest control and build resilient farming systems. This includes in particular:

- **GAEC 8**: Reinstate and strengthen mandatory requirements for landscape features and ecological focus areas to promote biodiversity and natural pest regulation.
- **GAEC 4**: Harmonise definitions and enforcement of buffer strips across Member States to protect all ecologically significant watercourses from pesticide runoff.
- **GAEC 7**: Preserve robust crop rotation obligations to meaningfully disrupt pest cycles and improve agronomic resilience.

#3: Strictly **limit exemptions and derogations that compromise environmental integrity** within the GAEC framework to ensure consistency, credibility, and effectiveness of standards.

D.4.2. Enhance eco-schemes and ENVCLIM interventions as levers of practice change

To improve the effectiveness of eco-schemes and ENVCLIM interventions in supporting more sustainable pesticide management, future programming should place greater emphasis on designing well-targeted incentives. The portfolio of supported measures should be widened to include more resources for management-based and technological practices, which currently remain underfunded despite their potential to drive systemic reductions in pesticide dependency. More robust and differentiated support is required to strengthen the competitiveness of more sustainable practices. Payment levels and eligibility criteria must be carefully calibrated to ensure that sustainable approaches constitute a clear and attractive alternative to conventional ones – particularly given the significantly greater delivery of public goods – including the avoidance of unintended disincentives (e.g. due to overlapping schemes) or inadequate payment levels. Moreover, support needs to encompass both transitional phases and long-term maintenance to promote continuity and cumulative improvement over time. Furthermore, a shift is needed from the prevailing reliance on action-based schemes towards result-based payment frameworks. Rather than merely compensating farmers for adopting or maintaining a set of predefined practices, schemes should be designed to reward demonstrable environmental outcomes. As highlighted in the

European Commission's (2024) assessment, a few examples in current CSPs illustrate the feasibility of this approach and may serve as valuable models for future policy design.

Recommendations

#1: Expand the range of supported measures, including **increased resources for management-based and technological practices** to facilitate the uptake of innovative solutions.

#2: Ensure support schemes for more sustainable practice **offer a clear and attractive alternative to conventional practices** to create real incentives for practice adoption and maintenance.

#3: Shift from a model of action-based schemes to result-based schemes to **actively incentivise environmental performance.** Examples from current CSPs include farmers receiving payments:

- if a **certain number of valuable plant species** are detected on their land (as currently done in e.g., Germany);
- if they achieve a **minimum reduction of 30% of (non-)herbicide treatment frequency** (as currently done in e.g., France);
- if **high floral diversity is maintained or improved** for five consecutive years (as currently done in e.g., Spain),

D.4.3. Integrate knowledge exchange and sectoral support into broader incentive architectures

To maximise their complementary potential, knowledge, advisory, and sectorial support instruments must be more strategically mobilised and better aligned with pesticide-related objectives. For these instruments to function as effective levers, their design and implementation must be more explicitly geared towards pesticide-related outcomes. This requires tighter integration of sustainable pest management into AKIS activities, clear prioritisation of pesticide reduction within sectoral support schemes, and enhanced monitoring and reporting frameworks to ensure visibility, comparability, and accountability across MS. Only by strengthening the coherence, targeting, and measurability of these complementary interventions can the CAP harness their full potential in supporting innovation-driven and knowledge-based transitions away from pesticide dependency.

Recommendations

#1: Strengthen the **integration of sustainable pesticide management into knowledge exchange and sectoral support programmes** to provide farmers with coherent access to knowledge, innovation, and targeted support.

#2 **Improve the consistency and ambition of MS targets** to ensure progress and comparability across countries.

#3: Establish **mandatory reporting and tracking mechanisms** to increase transparency and allow systematic tracking of outcomes.

D.4.4. Strategically align instruments and interventions to drive systemic change

Currently, the portfolio of instruments and interventions within CSPs tends to appear fragmented and insufficiently guided by a coherent strategic framework, which ultimately limits its capacity to achieve systemic and enduring reductions in pesticide use. To address this, a more strategic approach and integrated funding architecture are needed. Taking the example of organic farming, support should be designed to encompass the full trajectory, i.e., from initial conversion to long-term maintenance and

development. This requires effective coordination between eco-schemes and ENVCLIM interventions, leveraging the respective strengths of each instrument. A clearly structured and integrated support pathway for knowledge systems, innovation networks, and sectoral support mechanisms can complement efforts, including e.g., targeted advisory services, dedicated training programmes, and cooperative platforms that ensure continuity and coherence across the entire farming transition process. Additionally, INVEST-type interventions could be integrated into the framework to support complementary investments, e.g., by helping farmers acquire innovative technologies and equipment that enable more resource-efficient, resilient, and environmentally friendly crop management. More generally, instruments should be differentiated, ambitious, and strategically aligned within a comprehensive framework that ensures mutual reinforcement and creates genuine incentives for systemic transformation.

Recommendations

#1: Ensure **complementarity and coherence between eco-schemes and ENVCLIM interventions** to maximise synergies and deliver greater impact.

#2: **Embed knowledge systems, advisory services, and sectoral support mechanisms within the broader incentive architecture** to equip farmers with the necessary skills, networks, and market and value-chain support.

#3: **Adopt a more strategic approach in the design of CAP instruments (its 'Green Architecture') for sustainable use of pesticides** by ensuring coherence and continuity of support enabling the large scale transition towards Integrated Pest Management and organic farming.

E. Summary of Policy Recommendations

Building on the evidence and transition pathways outlined in this report, achieving the EU's 2030 pesticide reduction target will require both immediate policy action and a sustained research effort. As emphasised in the executive summary and introduction, incremental change will not suffice: systemic transformations across farming practices, markets, governance, institutions and legislation are indispensable. Several lines of future research have been identified during the SPRINT project, summarised in a **research agenda of 40 priorities developed by the whole consortium** (Annex 5). These priorities support informed policy and regulatory decision-making across domains ranging from risk assessment to economics. In particular, there is a need for more comprehensive hazard assessment methodologies that capture the impacts of pesticides on human and ecosystem health under realistic exposure conditions, while also addressing population diversity and long-term effects. Advances in monitoring and modelling can shed light on the pathways of pesticide transfer across landscapes, and harmonisation of usage data is essential for upscaling risk and impact assessment to the European level. Beyond scientific analysis, research must also engage with the social and economic dimensions of change, including farm-level costs and benefits, consumer choices, and the effectiveness of incentive structures. By bridging science and governance, the research agenda and the **consolidated table of policy recommendations** (Table 11) provide a coherent framework to strengthen pre- and post-market regulation, unlock the CAP's potential for driving systemic change, and chart credible transition pathways—together equipping policymakers to deliver a safer, more resilient, and fairer European food system.

Table 11 Summary of SPRINT policy recommendations

Dimension	Recommendations
Vision and Transition Pathways	
Boost on-farm innovation and biodiversity	Level 4 – Reconnecting producers and ecosystems • **Restore biodiversity infrastructure:** Incentivise the integration of hedgerows, field margins, flower strips, and habitat corridors as essential elements of farming systems, recognising their role in natural pest control. • **Embed nature restoration in agriculture**: Ensure that National Restoration Plans explicitly link ecosystem restoration (e.g. riparian buffers, wildflower habitats) to pesticide reduction and farm resilience. • **Scale up LIFE programme funding:** Prioritise biodiversity-based pest control through habitat restoration, farm landscape diversification, and demonstration projects. Level 3 – Redesigning farming systems • **Fund Living Labs and pilot farms:** Support co-creation platforms where farmers, researchers, and advisors jointly develop, test, and scale agroecological alternatives. • **Promote agroecological practices:** Prioritise crop rotation, mechanical weeding, cover cropping, agroforestry, and other systemic approaches as central to CAP eco-schemes and national transition plans. • **Support participatory breeding:** Expand funding for pest-resistant and locally adapted crop varieties, ensuring farmers play a central role in breeding priorities. Level 2 – Substitution and incremental innovation • **Implement coordinated IPM systems:** Invest in real-time pest surveillance, forecasting networks, and digital tools to improve decision-making and reduce chemical reliance.

Dimension	Recommendations
	• **Improve equipment access:** Provide subsidies, leasing schemes, or cooperative access models for IPM and mechanical weeding machinery, with special support for smallholders and farms in marginal regions.
Support fair value chains and markets	Level 5 – Governance renewal • **Strengthen retailer accountability by requiring mandatory transparency and due diligence from retailers and large buyers,** ensuring equitable trading relations and reducing incentives to import pesticide-intensive products. • **Reinforce enforcement mechanisms to address unfair trading practices and market concentration,** ensuring that smaller or transitioning farms are not disadvantaged Level 4 – Reconnecting producers and consumers • **Mandate sustainability requirements in public food contracts** (climate, biodiversity, social fairness). • **Include specific agroecological criteria in food procurement,** ensuring contracts reward farming systems beyond organic certification. • **Establish fair-pricing mechanisms:** Combine binding measures such as guaranteed minimum prices and long-term contracts with innovative models (e.g. eco-label-linked or regional brands) to stabilise revenues and reward agroecological practices. Level 3 – Redesigning markets and value chains • **Enable and scale up cooperatives and producer networks:** Provide legal templates, administrative support, and targeted investment to strengthen collective market access and logistics. • **Fund shared infrastructure:** Invest in group logistics, mobile processing units, and regional storage centres to reduce transaction costs and create resilient, decentralised supply chains. Level 2 – Substitution and transparency tools • **Expand the coverage and recognition of eco-labels and digital traceability systems to enhance transparency,** build consumer trust, and prevent greenwashing in food supply chains.
Reform governance for systemic change	Level 5 – Governance renewal • **Ensure legally binding EU-wide pesticide reduction targets with clear enforcement mechanisms and regionally adapted national action plans,** providing a robust regulatory framework for systemic change. • **Make ecological and low-pesticide practices the baseline standard for farming systems,** allowing exceptions only under strict agronomic or environmental justification. • **Guarantee secure and equitable land access by supporting land tenure rights and preventing land concentration,** with EU-level monitoring through initiatives such as the European Land Observatory. • **Redefine food security in policy frameworks as resilience and public good provision,** placing equal weight on biodiversity, ecosystem health, and farmer livelihoods alongside productivity. Level 4 – Participatory governance and territorial coordination • **Establish and scale up participatory governance structures such as food policy councils, territorial transition platforms, and strengthened LEADER-type initiatives**, ensuring that diverse actors co-design and oversee pesticide transition strategies. • **Strengthen coordination across EU, national, and regional governance levels** to align pesticide phase-out roadmaps, regulatory measures, and support instruments. Level 3 – Redesigning governance support structures

Dimension	Recommendations
	• **Create agricultural transition hubs and one-stop offices** to provide farmers with integrated access to information, funding, and administrative support, reducing bureaucratic complexity. • **Ensure that advisory services are independent, adequately funded, and accessible to all farm types,** so that ecological practices can be widely adopted and sustained <u>Level 2 – Enabling alternatives</u> • **Accelerate the approval and uptake of biocontrol and other low-risk alternatives** by clarifying definitions, introducing fast-track authorisations, and expanding EFSA's evaluation capacity. • **Introduce fiscal instruments such as VAT reductions on ecological inputs and ecotoxicity-weighted levies on PPPs**, using the revenues to fund transition measures and reward sustainable practices.
Transparency and public engagement	<u>Level 5 – Governance renewal</u> • **Mandate corporate responsibility and fair trading practices by strengthening the Unfair Trading Practices Directive** with enforceable rules and penalties against unfair contracts, late payments, and buyer power abuses. • **Embed pesticide reduction as a cross-cutting objective** in the Sustainable Food Systems Law, the Biodiversity Strategy, and relevant climate policy instruments to ensure coherence and long-term legitimacy. • **Revive and strengthen EU food system ambitions** by re-establishing the transformative goals of the Farm to Fork Strategy, linking them explicitly to pesticide reduction, biodiversity recovery, and resilience <u>Level 4 – Participatory governance and societal reconnection</u> • **Create and support sustainable food councils and regional transition platforms** that enable farmers, citizens, processors, retailers, and policymakers to co-design and oversee pesticide-free transition pathways. • **Institutionalise deliberative mechanisms in policy processes** to reduce polarisation, build mutual trust, and ensure that diverse perspectives are integrated into decision-making. • **Introduce binding sustainability criteria in public procurement policies** for schools, hospitals, and other public institutions, making pesticide-free and ecological sourcing the norm. • **Support collective bargaining and fair contracts by** Providing legal frameworks and enforcement mechanisms that strengthen producer organisations, enabling them to negotiate equitable terms and resist exploitative practices in supply chains. <u>Level 2–3 – Redesigning information and accountability infrastructures</u> • **Mandate timely public disclosure of PPP use, residue levels, and exposure data** at farm, regional, and EU scales, ensuring accessibility through open data platforms and maps • **Expand and institutionalise the Farm Sustainability Data Network (FSDN)** to systematically include pesticide use, agroecological practices, and socio-economic indicators for robust, long-term monitoring. • **Strengthen eco-labelling and digital traceability systems to improve consumer trust,** support ecological producers, and prevent misleading or greenwashed sustainability claims.
Strengthen knowledge and advisory systems	<u>Level 5 – Governance renewal</u> • **Rebuild independent, publicly funded advisory systems through CAP cooperation instruments and national programmes**,

Dimension	Recommendations
	ensuring they have a clear mandate to support agroecological transition and are not tied to commercial input sales. • **Institutionalise agroecological knowledge as a public good by integrating advisory services, research, and education into coherent Agricultural Knowledge and Innovation Systems**, strengthening their role in systemic transformation. <u>Level 4 – Societal reconnection and participatory governance</u> • **Expand and secure long-term funding for Living Labs, demonstration farms, and farmer-led networks** so that collaborative experimentation and knowledge exchange become permanent features of agricultural innovation. • **Integrate local and experiential knowledge into research and advisory agendas** to ensure that ecological transition pathways are grounded in practice and adapted to diverse regional realities. • **Promote food literacy and systems thinking across all levels of education**, embedding understanding of agroecology, health, and sustainability from primary schools to universities. <u>Level 3 – System redesign</u> • **Modernise agricultural and veterinary curricula across Member States to align with EU-level "fit-for-practice" frameworks**, prioritising agroecological methods, IPM, and system-level approaches.
Align financial and economic incentives with agroecology	<u>Level 5 – Governance renewal</u> • **Mandate ecological budget ring-fencing within the CAP by requiring Member States** to dedicate a significant share of funds to pesticide reduction, agroecological diversification, and ecosystem service remuneration, ensuring that support for transition is stable and non-optional. • **Channel investments into rural cohesion** so that transition costs and benefits are distributed fairly across farmers and communities, ensuring the viability of rural economies. <u>Level 4 – Societal reconnection</u> • **Link public procurement policies to agroecological objectives**, creating reliable demand and stable markets for ecological producers. • **Support territorial cooperation and collective market organisation** through regional initiatives, cooperatives, and short supply chains *(see Part D.4.2–D.4.3 for CAP-based delivery options).* <u>Level 3 – System redesign</u> • **Develop flexible financial tools,** such as transition payments, revenue-sharing contracts, and pest-loss insurance, to accommodate diverse farmer needs and reduce the risks of adopting low-input practices. • **Expand results-based payment schemes that reward ecosystem services** (e.g. biodiversity, soil health, reduced pesticide use), ensuring that ecological benefits are properly valued and incentivised. *Part D.4.2 provides concrete CAP mechanisms for operationalisation*. <u>Level 2 – Efficiency and substitution</u> • **Ensure affordable access to low-risk alternatives** (biocontrol, mechanical weeding, precision technologies), particularly for smallholders and farms in less-favoured regions. • **Strengthen monitoring and reporting systems** for financial schemes, integrating pesticide-use and agroecological indicators into existing data frameworks. The CAP's Farm Sustainability Data Network is a central delivery tool for this (see Part D.4.3–D.4.4).

Dimension	Recommendations
Pre and Post Market Policy	
Pre-Market Risk Assessment: Ecotoxicology	**#1: Mixtures required for pre-market testing and evaluation should better reflect the realistic use of the PPP under consideration,** including stronger requirements to assess required/recommended tank mixtures, typical application sequences with other pesticides, and pesticide mixtures already present in the soil. **#2: Expand the portfolio of required single-species test to capture more environmentally realistic effects and sensitive species,** including native species tests, more endpoints for soil microorganisms and functional diversity, early-warning signs of damage. **#3: Expand the use of, and implement standardised guidelines for, higher-tier testing of ecosystem effects** to ensure consistency and prevent subjective bias in pesticide approvals. **#4: Account for mixtures in the environment by increasing the margins of safety thresholds used for the approval of pesticides**, e.g. Toxicity to Exposure Ratio (TER).
Pre-Market Risk Assessment: Fate and Behaviour in the Environment	**#1:** Regulations calculating for the allowable pesticides in the environment (PEC) should account for a background of pesticide mixtures, including persistent banned substances. **#2:** Connectivity between farm pesticide application sites (farms) and other environmental compartments needs to be better resolved in pre-market testing. This includes: • Local (more representative) hydrological situations should be considered in future assessments, as current scenarios are unrealistic. • Fate of particle-bound pesticides should be addressed. It is currently not included in the FOCUS models. **#3:** The fate of and degradation of pesticide active substances in the indoor environment need stronger evaluation and pre-market testing, which primarily focuses on degradation in outdoor conditions.
Human Health Risk Assessment: Toxicology	**#1:** Strengthen neurotoxicity screening, including animal social behavioural tests, and microbiome changes in pesticide pre-market testing requirements. **#2:** Include more tests to account for effects on early life stages of and vulnerable populations. **#3:** Include mixture tests of pesticides commonly combined in specific crops and spray tank mixes, which humans may be exposed to.
Human Health Risk Assessment: Human Exposure	**#1: Non-dietary exposure needs better integration in the EFSA exposure assessment.** Both aggregate exposure (dietary and environmental) and cumulative exposure (multiple pesticides) should be considered for all exposed groups, where non-dietary exposure is currently mainly considered in the occupational context (workers and operators). • **Scenarios for assessing residential and bystander exposure can be improved** by accounting for the exposure from multiple farms in the proximity. **#2: Increase safety factors to lower exposure thresholds (e.g., ADI), where safety values are missing critical testing and data, especially for vulnerable groups.**

Dimension	Recommendations
	#3: Require the pre-market establishment of human Biological Guidance Values (safety thresholds in human matrices) to allow for the post-market monitoring of aggregate human exposure. **#4: Require the pre-market establishment of guidance values for residue levels in air and dust**, environmental matrices that humans may be exposed to.
Post-Market Monitoring and Targeted Risk Reduction: Pesticide Monitoring in Environment and Food	**#1: Introduce legally binding risk-based benchmarks for pesticide residues for soil, aquatic sediments, air, and indoor dust in EU monitoring policies** (Water Framework Directive, Air Quality Directive, Soil Monitoring Directive), with clear thresholds for corrective exaction with exceedance. • Pesticide residue thresholds can be derived from ecotoxicology testing already conducted due active substance assessment. **#2: Pesticide environmental quality standards (EQS) and maximum residue levels (MRLs) should include a threshold for total pesticide residues**, accounting for the effect of mixtures on humans and the environment. **#3: <u>Under the new Soil Monitoring Law</u>:** • Include pesticide residues in the new definition of soil health. • Adopt the SPRINT hazard-based prioritisation index to identify pesticides of highest concern from monitoring data. • Integrate pesticides of concern from SPRINT into the chemicals watch list. • Strengthen requirements for soil remediation and regional management changes in response to high levels of pesticide contamination.
Post-Market Monitoring and Targeted Risk Reduction: Human Biomonitoring	**#1: Introduce harmonised EU and national Human Biomonitoring Programmes** to study exposure from all routes and sources of uptake and identify exposure hotspots. **#2: Adopt harmonised biological guidance values (BGVs) and legally binding limit values (BLVs)** in pesticide active substance pre-market registration and across EU bodies (DG-SANTE, EFSA, ECHA), to support better monitoring and control of aggregate exposure.
Post-Market Monitoring and Targeted Risk Reduction: Targeted Risk Reduction and Prioritisation	**#1: Require the harmonisation of national PPP usage registries and national PPP authorisation registries in all member states**, including information on pesticide application mixture, timing, quantity, crop, and application method. This will allow for a quality assessment of pesticide exposure across Europe. **#2:** Adopt tools and maps in the **SPRINT Toolbox to identify and target pesticides and cropping combinations with highest risk for human and environmental health**, using exposure models based on actual pesticide usage data. **#3: Complement HRI 1 with annual indicators that account for real pesticide usage**, such as the annual maps from the SPRINT Toolbox and LCA damage costs estimates.
CAP Appraisal	

Dimension	Recommendations
Strengthen the GAECs to establish a strong environmental baseline	#1: Reinforce the **GAEC framework as a coherent, enforceable environmental baseline** to support sustainable pesticide management and broader environmental goals. #2: **Strengthen agroecological foundations within GAEC standards** to enhance natural pest control and build resilient farming systems. This includes in particular: • **GAEC 8**: Reinstate and strengthen mandatory requirements for landscape features and ecological focus areas to promote biodiversity and natural pest regulation. • **GAEC 4**: Harmonise definitions and enforcement of buffer strips across Member States to protect all ecologically significant watercourses from pesticide runoff. • **GAEC 7**: Preserve robust crop rotation obligations to meaningfully disrupt pest cycles and improve agronomic resilience. #3: Strictly **limit exemptions and derogations that compromise environmental integrity** within the GAEC framework to ensure consistency, credibility, and effectiveness of standards.
Enhance eco-schemes and ENVCLIM interventions as levers of practice change	#1: Expand the range of supported measures, including **increased resources for management-based and technological practices** to facilitate the uptake of innovative solutions. #2: Ensure support schemes for more sustainable practice **offer a clear and attractive alternative to conventional practices** to create real incentives for practice adoption and maintenance. #3: Shift from a model of action-based schemes to result-based schemes to **actively incentivise environmental performance.** Examples from current CSPs include farmers receiving payments: • if a **certain number of valuable plant species** are detected on their land (as currently done in e.g., Germany) • if they achieve a **minimum reduction of 30% of (non-)herbicide treatment frequency** (as currently done in e.g., France) • if **high floral diversity is maintained or improved** for five consecutive years (as currently done in e.g., Spain).
Integrate knowledge exchange and sectoral support into broader incentive architectures	#1: Strengthen the **integration of sustainable pesticide management into knowledge exchange and sectoral support programmes** to provide farmers with coherent access to knowledge, innovation, and targeted support. #2 **Improve the consistency and ambition of MS targets** to ensure progress and comparability across countries. #3: Establish **mandatory reporting and tracking mechanisms** to increase transparency and allow systematic tracking of outcomes.
Strategically align instruments and interventions to drive systemic change	#1: Ensure **complementarity and coherence between eco-schemes and ENVCLIM interventions** to maximise synergies and deliver greater impact. #2: **Embed knowledge systems, advisory services, and sectoral support mechanisms within the broader incentive architecture** to equip farmers with the necessary skills, networks, and market and value-chain support. #3: **Adopt a more strategic approach in the design of CAP instruments (its 'Green Architecture') for sustainable use of pesticides** by ensuring coherence and continuity of support enabling the large scale transition towards Integrated Pest Management and organic farming.

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G. Annex

Annex 1: Workshop agenda and exercise instructions

Agenda

1. Overview of transition journey (15 min): method, activities and results on vision
2. Stakeholders' understanding of priorities – Exercise 1 (10 min)
3. Stakeholders' feedback on vision (15 min): refine priorities and align perspectives – Exercise 2
4. Stakeholders' validation on pathways (20 min): Collaboratively confirm and adjust future directions – Exercise 3

Exercise 1: Understanding Priorities in Values

Facilitation prompt: *"Your task is to rank these statements in order of importance, starting with the one that is most significant to you personally when planning for the agri-food future. This isn't about reaching a consensus—it's simply a way to capture the diversity of perspectives and priorities in the room. Please follow the QR code by opening your smartphone camera to take part in the ranking."*

The most important in the transformation towards synthetic pesticide-free agriculture is…

- … empowering farmers in the market and strengthening trust and understanding between producers and consumers.
- …fostering economic resilience in agriculture markets in a changing world.
- ...caring for nature and the environment as a whole.
- …enhancing and protecting the health and safety of individuals and communities.
- …ensuring that everyone has equitable access to safe, nutritious, and sufficient food.
- …encouraging curiosity, research, and innovative solutions that align with ethical and sustainable practices.
- …valuing and supporting traditional agricultural knowledge and practices that align with regional history and the environment.
- …ensuring transparency in supply chains, ethical trade, and accountability in labelling and pricing.

Exercise 2: Feedback on the vision

Facilitation prompt: *"Building on input from stakeholders and several iterations with the project team, we developed a vision that illustrates a comprehensive future scenario in the farming system. This detailed text incorporates all key elements discussed in previous workshops and serves as a foundation for refinement. In the next step, we will review the highlighted summary and ask for your feedback and agreement sentence by sentence. You will see 5 vision sentences presented individually. For each sentence, you'll be asked to rate how accurately it reflects what a vision of a pesticide-free future would entail for the country and farming system discussed. The scale goes from 1 (strongly disagree) to 4 (strongly agree). In the following slide you can give your direct feedback to this. "*

-The description of the case study site visions is detailed in Annex 3-

Exercise 3:

Facilitation prompt: *"You are provided with a table with the key activities identified as most relevant in the pathway towards the pesticide-free vision. They are categorised along the 5 thematic dimensions and along 3 timescales (short-, medium- and long-term actions). "*

1. Please rate: Which dimension do you consider the most critical for achieving the vision's goals? Why?
   (Consider Cognitive & Social Transformation, Agricultural Practices and Innovation, Economics & Value Chain, Knowledge Systems and Research, or Governance, Policy, and Institutional)
2. Do you agree with the proposed actions in the table and their prioritisation across the short-, mid-, and long-term timelines?
   - Which actions do you find especially relevant in your local or regional context?
   - Are there other actions you believe should be added?
   - Are there any actions that seem less relevant or should be adjusted or removed?
3. How do you suggest managing trade-offs in the pathways?
   For example, how do we balance global market development with strengthening local markets?

Annex 2: SPRINT Case Studies and farming systems

Case Study	Region	Dominant Farming System
1 Spain	Campo de Cartagena	Vegetable and Row Crops
2 Portugal	Bairrada	Permanent Crops (Vineyards)
3 France	Nouvelle Aquitaine	Permanent Crops (Vineyards)
4 Switzerland	Canton Bern	Permanent Crops (Apple orchards)
5 Italy	Po Valley	Vegetable and Row Crops
6 Croatia	Istria	Permanent Crops (Olives)
7 Slovenia	Central Slovenia	Mixed Farming (Livestock + Cereals)
8 Czech Republic		Cereals and Oilseeds (Rapeseed)
9 The Netherlands	Friesland and Groningen	Vegetable and Row Crops (Potato)
10 Denmark	North and Central Jutland	Cereals and Oilseeds (Cereals)

Annex 3: Visions for 2050 by Case Study

1. Spain

By 2050, Spain's vegetable sector is resilient and low input. Pest control is based on biodiversity, greenhouses follow ecological principles, and public investment, fair markets, and strong cooperatives support pesticide-free farming.

1) By 2050, pesticide-free vegetable farming is widespread in Spain. Farmers are seen as land stewards, and consumers, retailers, and institutions share responsibility for sustainability across the food system.

2) Vegetables are grown in open fields and greenhouses using biodiversity, biological control, and farmer-led solutions instead of synthetic pesticides, within ecologically designed systems.
3) Public investment, fair procurement, and cooperative marketing make ecological farming viable. Small and medium producers succeed in local food networks with stable demand and clear contracts.
4) Farmers, advisors, and researchers share knowledge through field learning, digital tools, and inclusive networks, making ecological pest control locally adapted, practical, and accessible.
5) By 2050, pesticide-free farming in Spain is supported by subsidies for ecological practices, fast biocontrol approvals, regional agencies, and labour laws, ensuring joined-up support across government.

2. Portugal

By 2050, wine in Portugal is grown without synthetic inputs, in ways that protect biodiversity, soil health, and public well-being. This is made possible by investment in research, training, and support that empowers farmers to grow resilient, high-quality grapes in diverse, living landscapes using native and climate-adapted varieties.

1) By 2050, pesticide-free wine is standard in Portugal. Consumers value it, and sustainable viticulture is part of public identity, education, and national culture.
2) Wine is grown in low-input, diverse systems using native and adaptive grapes, soil-friendly practices, modern monitoring and forecasting and tailored biocontrol instead of synthetic pesticides.
3) The wine value chain supports ecology through certification, fair pricing, cooperative infrastructure, and strong demand for pesticide-free wines at home and abroad.
4) Farmers co-develop solutions through training, field trials, and regional hubs, ensuring practical, research-based methods spread across Portugal's vineyards.
5) Portugal's policies phase out synthetic pesticides through aligned incentives, monitoring, and inclusive governance that responds to farmers' needs at all levels.

3. France

By 2050, Bordeaux's viticulture leads as a global model of sustainability, combining reduced volumes of pesticide-free wine of exceptional quality, supported by ecologically integrated farming landscapes, innovative technologies, robust knowledge-sharing networks, and policies that ensure environmental stewardship, economic resilience, and cultural preservation.

1) Pesticide-free wine is celebrated for its quality and sustainability, with winemakers seen as custodians of biodiversity, inspiring eco-conscious consumption and preserving cultural heritage through agroecological practices and wine tourism.
2) Viticulture embraces ecologically integrated systems with pest-resistant varieties, biocontrol methods, and biodiverse landscapes, supported by precision agriculture and Living Labs that drive resilient, low-input, high-quality production tailored to evolving climates and terroirs.
3) Bordeaux's viticulture thrives through reformed cooperatives and regional marketing hubs that strengthen the position of small and medium producers, rebalance power across the value chain, and enable equitable negotiations in a pesticide-free, globally competitive market.
4) A robust and publicly funded knowledge-sharing network, including digital platforms, regional hubs, and conservatories, empowers winemakers with the tools, education, and collaboration needed to adopt sustainable practices, preserve genetic diversity, and strengthen the industry's resilience.
5) A cohesive policy framework provides robust financial support, innovative insurance schemes, and market-driven incentives, ensuring viticulture's economic resilience, environmental responsibility, and inclusivity for producers of all scales.

4. Switzerland

By 2050, Switzerland's transition to pesticide-free apple farming is sustained by a culturally rooted and socially supported food system, ecologically resilient orchards, fair and cooperative market structures, farmer-led knowledge networks, and coherent, democratic governance that ensures equity, accountability, and long-term ecological alignment.

1) Pesticide-free apple farming is widely accepted as a cultural and environmental norm in Switzerland, supported by informed consumers and socially respected farmers.
2) Apple orchards are ecologically complex, climate-resilient systems that rely on pest-resistant varieties, agroforestry, and precision tools.
3) Cooperative sales hubs, public procurement, and fair pricing policies ensure that pesticide-free apple farming is economically viable. Farmers have access to stable markets, risk-sharing tools, and multiple income streams.
4) Farmers co-lead innovation through Living Labs, breeding consortia, and regional research hubs. Knowledge is open access, embedded in education, and continuously updated through peer networks and digital platforms.
5) Coherent and democratic governance drives the transition, with public-private collaboration, regionally anchored decision-making, and transparent monitoring systems. These structures ensure equity, accountability, and long-term alignment with ecological goals.

5. Italy

By 2050, Italy's horticulture is climate-resilient and pesticide-free. Farmers are respected land stewards, ecological practices are the norm, markets and policies reward sustainability, and knowledge is co-created through inclusive, local innovation.

1) Pesticide-free horticulture is part of Italy's food culture and identity. Farmers are valued as ecological stewards who support public health, local landscapes, and community wellbeing.
2) Farms use pest control based on ecology, soil care, and climate-smart tools. Systems are adapted to Italy's diverse regions and driven by farmer innovation and resilient cropping strategies.
3) Fair prices, local processing, and eco-labels support strong markets and cooperatives. Public incentives and procurement help make sustainable horticulture profitable across Italy.
4) Farmers, researchers, and advisors share solutions through regional hubs, field schools, and participatory breeding, making agroecology central in practice and education.
5) Aligned Italian and EU policies, simpler certification, and inclusive governance promote pesticide-free farming as a key part of a just, ecological food system.

6. Croatia

By 2050, Croatia's olive sector is rooted in biodiversity, regional cooperation, and sustainable land use—showing how pesticide-free farming supports healthy communities, resilient landscapes, and a Mediterranean One Health food system.

1) Pesticide-free olive farming is embraced as cultural heritage in Croatia. Farmers are seen as stewards of land, biodiversity, and public health in a locally rooted food system. Farmers area more diverse group of young and females
2) Olive groves are diverse agroecosystems combining agroforestry, habitat mosaics, biodiverse undergrowth and group pest control strategies that eliminate synthetic inputs.
3) Cooperatives, public procurement, and circular practices support stable farmer incomes. Payments for ecosystem services help make pesticide-free farming regionally viable.
4) Farmers, advisors, and researchers collaborate in Living Labs and training networks to test and share ecological methods adapted to local conditions and passed across generations.

5) Local councils and farmer groups coordinate land use, CAP support, and climate action to guide olive farming toward pesticide-free production as part of a One Health approach.

7. Slovenia

By 2050, Slovenia's mixed crop-livestock farms form the heart of biodiverse, low-input agroecosystems rooted in mountain landscapes. Farmers and consumers shape resilient, local food systems through ecological practices, cooperation, and shared stewardship.

1) Mixed farms are embraced as cultural and ecological foundations. Aware consumers drive demand for local, seasonal, diverse foods, while a new generation of farmers blends inherited farming knowledge with agroecological science, digital tools, and hands-on learning in thriving rural communities.
2) Farms manage crops, livestock, and landscapes as one system. They use rotational grazing, habitat-rich mosaics, and farmer-led design to control pests, restore soils, and adapt to Slovenia's varied terrain.
3) Regional cooperatives ensure fair pricing, local processing, and logistics. Public procurement, mobile infrastructure, and mutual aid networks keep mixed farms viable and resilient.
4) Innovation is anchored in regional model farms and Living Labs, where education and peer learning are central. Here, traditional practices are reintegrated through participatory research, digital technologies, and cross-generational knowledge exchange that sustain adaptive, agroecological systems.
5) Place-based governance, secure land access, and food policies support livestock-crop reintegration. Co-created adaptive policies enhance biodiversity, climate resilience, and rural wellbeing.

8. Czech Republic

By 2050, Czech oilseed farms grow pesticide-free crops in diverse rotations with legumes and cover crops. They use biocontrol, advanced pest monitoring, and autonomous machines. This is supported by low-input certification, public procurement, cooperative processing, and policies that phase out pesticides, reward ecosystem services, and stabilise markets through resilient local food systems, with biofuels playing a limited, complementary role.

1) Czech consumers prefer pesticide-free food for health and biodiversity. Farmers are valued as cultural stewards and adopt integrated farming as part of a national move toward sustainability, local food, and generational renewal.
2) Oilseed is grown in diverse, climate-smart rotations with intercropping, biocontrol, flowering margins, and modern pest monitoring techniques. Further, pesticide dependency is reduced by smart machinery use and microbiome-based solutions.
3) Czech oilseed farmers work in stable, cooperative value chains. These are supported by low-input certification, premium contracts, and circular systems that connect farming with regional processing. SMEs primarily turn crops into healthy food, while limited volumes are channelled into sustainable by-products such as biogas or niche biofuels.
4) Farmers co-create local solutions with scientists and advisors through living labs, digital tools, and lifelong learning. Real-time data, monitoring tools, and advisory networks help them adapt continuously.
5) Czech farming follows a legal pesticide phase-out, fast biocontrol approvals, and large-scale land planning. Policies give targeted subsidies, while farmer cooperatives and public procurement ensure fair market access and support.

9. The Netherlands

By 2050, Dutch potato farming has transformed into a digitally driven, pesticide-free system rooted in soil health, ecological resilience, and circular value chains. Farmers are seen as public stewards and innovators in a health-focused food economy.

1) Dutch citizens see pesticide-free potatoes as part of public health and ecology. Trusted labels, media, and education guide choices, while farmers are recognised as stewards and innovators.
2) Farming uses diverse rotations, strong cultivars, and soil microbiomes. Biocontrol and regionally adapted AI guide real-time, plant-specific care without synthetic pesticides.
3) Potato growers thrive in certified markets with fair contracts and local processing. Retailers and processors co-invest with farmers in circular supply chains that are transparent and traceable, serving both domestic and export markets
4) Regional labs, digital tools, and farmer trials drive innovation. Open advisory networks and lifelong learning are embedded in education and supported by public funding.
5) A pesticide phase-out, fast biocontrol approvals, and green procurement drive the transition. Policies are coordinated through regional agroecology hubs and EU-aligned frameworks.

10. Denmark

By 2050, Denmark has become a global frontrunner in pesticide-free, plant-based agriculture, where biodiverse landscapes, cooperative economics, farmer-led innovation, and integrated governance create a resilient food system that delivers public health, climate action, and rural prosperity.

1) Danish society has fully embraced plant-based diets and pesticide-free agriculture as cultural cornerstones, phasing out feed-driven cereal production and fostering a food culture rooted in health, climate action, and social solidarity, where farmers are recognised as key contributors to public and environmental well-being.
2) Denmark's cereal farming now operates within highly diversified, biodiverse landscapes, combining microbiome engineering, region-specific biocontrol, diverse crop rotation and modern decision support tools to eliminate pesticides while building resilient, self-regulating agroecosystems.
3) A cooperative-driven value chain fairly distributes risks and rewards, securing farmers stable, premium incomes through long-term contracts, shared infrastructure, and new markets for pesticide-free, plant-based cereals that have repositioned Denmark as a leader in sustainable agri-food exports, diversifying markets for high-value products.
4) Farmer-led innovation hubs, living labs, and cutting-edge agroecological research form the backbone of a collaborative knowledge system where continuous learning and open data-sharing accelerate the mainstreaming of regenerative, pesticide-free farming.
5) Denmark has pioneered an integrated governance model, harmonising local and national agroecological policies in a phase-out plan, embedding pesticide-free standards in public procurement, supporting through regional transition offices and positioning itself globally as a policy leader in climate-resilient and socially inclusive cereal production.

Annex 4: Pathway Tables by Case Studies

Note: Text with * was actively identified as priority in the 3rd stakeholder workshops or strongly emphasised.

1. Spain

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **national awareness campaigns** about the long-term sustainability aspects of the transition.	**Train farmer peer-leaders** to facilitate regional agroecology circles and on-farm workshops.	Institutionalise **municipal food councils** with consumer, farmer, and retailer participation. Integrate **ecological food literacy** into national education standards. *

	Fund storytelling programmes and awards to **showcase early adopters** and **ecological farm success cases**. Develop **public education materials** on pesticide-free food for schools and municipalities. Correct misinformation.	Launch **supermarket campaigns and certification** that promote biodiversity-friendly, fair-labour produce. Include **ecological farming narratives in school curricula** and vocational programmes. * Promote dietary biodiversity and changes in consumer habits.	Enforce **retailer responsibility** to promote low-input products in mainstream marketing. Eliminate aesthetic-based quality standards for food. Ensure generational renewal in farming and address labour shortages. Educate consumers to prefer quality and short value chains.
Agricultural Practices & Innovation	Launch **regional pilot farms** testing habitat-based pest suppression, biological control, and agroecological greenhouse designs. Provide **subsidies for pest-resistant cultivars** and local landraces. **Fund advisory support** to redesign crop plans and rotations for pest resilience. Targeted **farmer training** on the risks and alternatives to pesticide use. Enhance biodiversity conservation.	**Scale intercropping, habitat corridors, and flower strips** across protected and open-field farms via cooperative planning and funding. Integrate **pest-forecasting and soil health monitoring** into **digital farm dashboards.** Fund cooperative and farm-based programmes for **local insect rearing** and coordinated biological pest control releases.	Retrofit all large-scale greenhouses for **circular water systems, vertical biodiversity, and passive pest exclusion**. Establish **regional biodiversity blueprints for farm landscapes**. Fund **widespread composting and closed-loop fertility solutions** across vegetable zones. Enhance biodiversity in urban spaces and establish agroecological zones. Cultivate with eco-friendly inputs and a wide range of traditional seeds.
Economics & Value Chain	Introduce **targeted transition payments, pest-loss insurance, and pooled risk funds** to protect especially small and medium farms during their shift away from synthetic inputs. Fund **local processing units** and **mobile packaging hubs** for short chain produce. **Reform seed laws** to fast-track approval of resilient, locally adapted varieties and support farmer-led breeding and exchange systems. Limit the influence of large-scale retailers.	Provide **fiscal incentives** to cooperatives that market pesticide-free, locally adapted produce. * Implement **public procurement targets** for ecological vegetables in schools, hospitals, and canteens. Launch **region-based CSA platforms** and **online marketplaces** for direct marketing. Support profitable biodiversity-friendly crops.	Restructure **trade and subsidy** frameworks to prioritise seasonal, agroecological imports/exports. Introduce **mandatory impact labelling or reporting frameworks** for vegetable supply chains, covering pesticide use, biodiversity impact, and working conditions. Institutionalise **urban–rural supply corridors** supporting regional vegetable resilience. Link public (e.g. CAP) subsidies to pesticide-free production.
Knowledge Systems & Research	Co-develop **Living Labs** with universities, cooperatives, and farmers to generate region-specific innovation. Scale **peer-learning and mentoring networks** focused on ecological pest control. * Train **independent advisors** in ecological practices and embedded greenhouse support. Better communication and visibility of primary studies. Increase monitoring systems. Hire more technical staff. Increase funding for research.	Create regional farmer-led "**transition hubs**" with demo farms, pest monitoring, and local trials. Maintain **open-access data** on ecosystem performance, linked to advisory dashboards.	Establish a **national knowledge platform** connecting pest data, farm trials, and extension tools. Fund **public breeding programmes** for pest-tolerant varieties and microbial inoculants. Embed **agroecology and systems thinking into vocational curricula and technician certifications**.

Governance, Policy, & Institutional Frameworks	**Fast-track approval of biocontrol agents and ecological inputs** under simplified, EU-aligned procedures. * Create a **national registry** of approved pesticide alternatives and their field effectiveness. Introduce **workplace protections and exposure limits** for greenhouse workers. Ban nitrate overuse.	Establish **regional transition taskforces** to coordinate subsidies, training, and pest data flows. Mandate **ecological procurement standards** in public food institutions. **Reward regional governments** for meeting pesticide-reduction milestones. Optimise EU border controls for pest and disease management. Eliminate lobbying influence. Redistribute land from large estate holders. Regulate intensive farming practices.	Embed **pesticide-free production benchmarks in CAP** subsidy design and compliance systems. Support the **harmonisation of international trade rules** to reflect ecological and labour protections. * Mandate **cross-sector governance platforms** with binding roles for farmer, civil society, and scientific actors. Protect and ensure water availability.

2. Portugal

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **public national campaigns** on pesticide risks, ecological farming, and wine quality. **Increase local consumer interest** in pesticide-free wine, especially in regions with higher eco-consciousness.	Enhance local **wine tourism** and **direct marketing**, building trust in transparent production. Support and showcase **early adopter winemakers** committed to pesticide-free practices. Promote ecological wine as part of **Portugal's culinary and cultural identity**.	Cultivate a **national food culture** that values sustainable wine as part of civic and regional identity. Integrate **food sustainability in school curricula, media, and public events**.
Agricultural Practices & Innovation *	Develop **decision support tools**, based on weather, soil health, and pest dynamics. * Promote the use of **native and climate-adapted grape varieties** through participatory breeding. * Research and apply **biocontrol methods and natural antagonists**. * Implement **custom cover crop mixes** for pest control and erosion mitigation, especially on steep slopes. *	Investigate **ecosystem interconnections** (soil, plants, insects, microbes) to develop nature-based pest solutions. Experiment with **farming system diversification** (e.g., agroforestry, polycultures, habitat corridors). Expand **early-warning systems and local pest surveillance networks**.	Mandate **ecological infrastructure in all vineyards**, integrating 1/3 of land for biodiversity support. Fully **phase out high-risk synthetic pesticides** in viticulture. Scale **integrated vineyard landscapes** using polyculture models and natural pest-regulating niches.
Economics & Value Chain	**Enhance financial support systems** for yield losses, insurance, and infrastructure. Support **product certification and digital traceability** to differentiate ecological wine. Encourage **wine tourism** as a sustainability-linked economic driver.	Facilitate **short supply chains**, connecting producers with consumers via direct channels. Promote **cooperative models** for marketing, bottling, and certification, especially for small-scale producers. Introduce **minimum pricing** in public procurement to stabilise demand.	Establish **regional branding hubs** to link ecological producers to global markets. Implement **advanced traceability systems** (e.g., blockchain) to reinforce consumer trust. Embed pesticide-free wine in **national tourism and export strategies**.
Knowledge Systems & Research	**Adopt** known biological and IPM solutions immediately via training, demos, and digital advice. **Disseminate** scientific results and practical guidance through farmer networks.	Raise awareness and improve farmer **readiness for new techniques**. Build **regional innovation networks**, peer learning, and digital advisory tools.	Institutionalise **farmer–researcher partnerships** and on-farm experimentation. Launch **socio-economic knowledge** platforms on farm viability, labour, and climate resilience.

	Set up **regional demo vineyards** and **open-access knowledge hubs**.	Implement **training programmes** on vineyard management, pest ecology, water, and soil health.	Create **continuous training incentives** and education pathways for ecological viticulture.
Governance, Policy, & Institutional Frameworks	**Phase out the most toxic pesticides** through regulatory bans and reform. Establish **public-private transition partnerships** targeting small/medium producers. **Simplify certification** and support access to regional incentives.	Develop a **national strategy** with clear goals, timeline, and monitoring. Implement **regional policies** tailored to agroecological conditions, including adaptive pest response support. Align CAP instruments with ecological viticulture priorities	**Harmonise national and international certification standards**. Establish **legal frameworks** for traceability and sustainability reporting. Secure **institutional platforms for participatory governance** involving farmers, researchers, and consumers.

3. France

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms *	Develop **public campaigns by retailers** to build consumer awareness and demand for new premium sustainable wines. Start **social media campaigns with** stories of vineyards transitioning to pesticide-free.	Support the creation of **partnerships** (schools, doctors) to increase knowledge on potential risks of pesticides and health benefits of pesticide-free production. Multiply **wine-tourism offers** increase societal recognition, while also providing a secondary source of income.	Host **Multi-Stakeholder Forums** for dialogue between winemakers, policymakers, researchers, and consumers to align on goals and strategies. Introduce **social contract for the region**, connecting winegrowers and citizens to preserve local biodiversity and natural resources.
Agricultural Practices & Innovation	Invest in **research for resistant** varieties. Examine the feasibility and benefits of reduced-volume, high-value production through **pilot programs**. Research more strongly alternative options to pesticides to combat mildew.	Create **diversified vineyard systems (e.g., agroforestry, crop rotation).** Scale up **accessible digital tools** for pest monitoring and ecosystem management.	Make **widespread adoption of resistant varieties and biocontrol methods** the norm. Implement **landscape-scale biodiversity initiatives** and fund transition to **agroforestry**.
Economics & Value Chain	Provide **financial incentives,** grants, and compensation for early adopters of pesticide-free systems. Introduce **insurance** systems for crop loss due to pests.	**Partner distributors and retailers with local producers** for market visibility and to create demand. Establish **regional marketing hubs** to bridge the gap between smaller vineyards and global markets. Take political action to **support retail** in offering more sustainable products.	Strengthen **export markets** for pesticide-free wines. Define **certification schemes for eco-labelling and fair-trade pricing.**
Knowledge Systems & Research	Produce **simple tutorials or low-effort training** for replicating existing solutions. * **Disseminate transition practices** through existing networks (e.g., DEPHY, VitiREV). Establish **regional knowledge hubs** that facilitate dialogue.	Expand **training programmes** for agroecological practices and pest management. **Living Labs and field schools** to refine and scale agroecological practices and create viable business models.	Design and implement **farmer-to-farmer training programmes** for new varieties. Train and introduce more **independent advisors.**
Governance, Policy, & Institutional Frameworks	**Revise existing specifications** for designations of origin to include environmental factors. **Reward sustainable practices** through financial incentives and recognition. Secure **public funding mechanisms** to provide ongoing investments in innovative practices.	**Introduce stricter environmental regulations** to make high-volume, unsustainable practices less viable. **Create a new governance entity** that brings together associative groups, state services, private actors. **Standardise policies** across Europe. **Regulate lobbying** more strongly.	Integrate vineyards into **broader regional sustainability goals**. Ensure **long-term investments** in innovative practices.

4. Switzerland

Vision Dimensions	Short term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **campaigns on pesticide impacts** and consumer responsibility. Develop **trust-building tools** like QR code traceability and in-store storytelling.	Reframe **farmers as stewards** of ecosystems and health (media, school programmes, and food policy councils). Promote sustainable farming as a respected career for youth.	Establish **long-term public engagement platforms** (e.g. food councils, annual public reporting on food system health). Incorporate **food system literacy** into national sustainability indicators and cultural reporting frameworks.
Agricultural Practices & Innovation	Launch **pilot orchards** for low-input designs with hedgerows, cover crops, and resistant cultivars. Support regional trials of alternative and net systems. Support **widespread adoption of protective structures** (e.g. nets, low tunnels) for climate and pest resilience.	Scale up **diversified orchards** (intercropping, agroforestry). Establish **public infrastructure for biocontrol rearing** and distribution across fruit-growing regions. Deploy **orchard phenology and microclimate monitoring systems** to guide adaptive management.	Implement **fully diversified, self-regulating apple orchards** across regions. **Adapt orchard designs** to evolving climate stressors.
Economics & Value Chain	Launch **cooperative sales hubs** with shared storage, marketing, and processing. Provide **transition support schemes** (e.g. yield-loss insurance, investment bonuses). Launch **targeted subsidies** to help farmers invest in equipment (e.g., on-farm processing units, composting systems). Start **public procurement** for pesticide-free apples in schools and hospitals.	Establish **territorial brands and legal frameworks** for fair pricing and long-term retailer contracts. Scale **circular economy hubs** that use orchard by-products (e.g. compost, dried fruit) Develop **public procurement labels** tied to regional identity and zero-residue certification	**Legislate retailer accountability frameworks** that mandate fair pricing, contract transparency, and ecological procurement standards. **Expand ecosystem service payments** to include climate mitigation, pollinator services, and soil carbon
Knowledge Systems & Research	Create **Living Labs** to trial agroecological orchard practices in diverse Swiss landscapes. Deploy **transition coaches and advisory team**s to support early adopters. Launch **collaborative breeding consortia** for resistant apple varieties.	Create a **repository of successful practices**. Develop **open-access digital platforms** on pest forecasting, soil health, and local biodiversity trends. Facilitate **continuous, easy access to new knowledge for farmers**, possibly through existing networks. Secure **permanent funding** for farmer-led breeding programmes and agroecological research hubs	Integrate **sustainable farming knowledge into apprenticeship curricula.** Institutionalise **lifelong agroecological learning.** Create a **national fund for knowledge infrastructure** (platforms, advisors, seed banks) through long-term public–private investment. Foster **open innovation consortia** linking farmers, researchers, and SMEs to accelerate ecological tech.
Governance, Policy, & Institutional Frameworks	Create a **favourable policy environment** and support for research into alternative pest management techniques. Incorporate **ecotoxicology into pesticide regulation** by introducing a toxicity-weighted tax on harmful products and streamlining the approval of ecological alternatives **Pilot consumer-facing incentives** such as tax credits for ecological food purchases or lower VAT on pesticide-free products	Establish a **National Agroecology Accord** aligning cantonal and federal strategies, subsidy criteria, and transition metrics. **Decentralise support** via regional councils managing transition grants and land access.	Embed **multifunctional farms** (e.g. agro-tourism, on-farm processing) into regional rural development strategies. Establish **regional land governance bodies** with mandates to manage ecosystem service payments, monitor biodiversity, and enforce pesticide limits. Establish **participatory governance structures** that allow public input into pesticide regulation and subsidy design.

5. Italy

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **campaigns on food origin**, ecosystem health, and intergenerational wellbeing. * Promote **acceptance of imperfect produce** to cut food waste and shift norms. *	Scale **education and communication** on health and environmental benefits of pesticide-free farming, as well as on nutrition and health more broadly. * Boost **demand for traceable, ecological products**. *	Elevate **farmers as sustainability leaders** via public recognition and participation. Embed **ecological values** in education, media, and consumption culture.
Agricultural Practices & Innovation	Support rollout of **electric, light machinery** for diverse farms to reduce the use of mechanisation and passes on the soil. Use sensors and data tools for **early-stage precision practices**. Trial **diverse, climate-resilient crops** through farmer-led innovation. * Pilot **climate-adaptive CEA** in key regions (e.g. Sicily, Veneto). Launch **public breeding programmes** for pest-resilient vegetable varieties.	**Align research with farm needs,** e.g. seed resilience, local adaptation, low-input systems. Expand **regenerative practices** through pilots and peer learning. Develop and test vegetable-crop-specific **agroecological design templates** (e.g. intercropping models, habitat plantings) through farmer-researcher collaborations. * Improve and emphasise the urgency of maintaining ecosystem services.	**Mainstream interdisciplinary agronomic knowledge** across farming and training. Establish **climate-resilient, biodiverse landscapes with closed-loop systems**. **Transition large-scale greenhouse horticulture** to fully closed-loop, pesticide-free systems, recognised through national eco-certification. Rescale greenhouse production to reduce dependency altogether.
Economics & Value Chain	Fund **ecological farm investments** (e.g. hedgerows, trees, corridors). * Launch "zero-residue" and transition **labels**. Offer **multi-year transition support.** * Fund **cooperative storage and mobile processing units** (drying, fermenting, packaging). Introduce **fiscal and zoning incentives** for vegetable production in peri-urban areas (e.g. land tax exemptions, fast-track leases).	Pilot **transparent value and pricing communication** for ecological products. Raise farm incomes via **fairer contracts and stable prices**. Offer **incentives for renewables and zero-residue practices** in CEA, e.g. by charging polluters more. Integrate **mobile processing hubs** into public procurement and CSA networks. **Digital marketplaces** for short-chain vegetables	Enable producers to **co-manage supply chains and pricing**. Strengthen **local and regional markets** through ethical, employment-generating food networks. Institutionalise **near-market production corridors** as part of climate and food resilience policies, with dedicated infrastructure and advisory support.
Knowledge Systems & Research	Increase funding for **applied accessible research**. Support **peer learning**, field trials, and farmer-to-farmer exchanges.	Restructure **extension services** to provide free, impartial, sustainability-focused advice, including tailored pest management plans based on region-specific ecological design tools for both open-field and greenhouse vegetable production. Advance **adaptive learning** models where farms act as living labs.	Build a **decentralised knowledge system** blending science, tradition, field practice, and digital tools. Integrate **agroecology and systems thinking** in all agricultural education. Scale up **breeding programmes** through open-access seed banks and participatory variety selection networks
Governance, Policy, & Institutional Frameworks	**Simplify certification** and reduce admin burden. * Expand **neutral advisory services** for navigating support and land rules. * Reform **procurement** to favour local, low-input food in public institutions.	Update **food standards** to reflect sustainability, safety, and nutrition Introduce **food waste laws** supporting redistribution and imperfect produce use. Prioritise **peri-urban agroecological zones** in municipal food and green infrastructure planning.	Provide integrated support in **vulnerable areas**, linking income and ecosystem care. **Reduce lobby influence** and boost transparent, inclusive policymaking. *

6. Croatia

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)

Cognitive & Social Norms *	Launch **campaigns** promoting pesticide-free, local olive oil & healthy diets. Establish **participatory rural networks** to reframe olive farmers as landscape and health stewards.	Promote **farming as a desirable career** for youth. *	Normalise pesticide-free olive farming as the **societal and market norm** through cultural, policy, and educational alignment.
Agricultural Practices & Innovation *	Launch **regional pest monitoring** via farmer-led tools. * Support farmers to **blend traditional & modern low-input practices**. * Research **regional symbiotic relationships of plants** and the use of plant extracts in pest management. Set-up **sharing pools for equipment**. *	**Diversification of olive groves** with agroforestry elements, intercrops, or companion planting. * Integrate **precision agriculture & AI** for pest and input management. *	Implement **diversified, self-regulating olive agroecosystems** with widespread agroforestry, intercropping, and ecological pest management. *
Economics & Value Chain *	Strengthen and expand regional cooperatives to build and manage **short supply chains**. * Launch **targeted subsidies and tax incentives** to help farmers invest in equipment (e.g., on-farm processing units, composting systems). Introduce **transition support schemes** (e.g., yield-loss insurance and risk-sharing funds) to buffer farmers against short-term financial risks.	Develop **territorial brands & local procurement** for public institutions. * Scale up **circular economy hubs** that process olive by-products into value-added products (e.g., compost, herbal extracts, renewable energy). * Secure stable demand through **public procurement** frameworks for pesticide-free olive oil in public institutions, coordinated via regional councils and cooperatives, e.g. through procurement quotas. *	Fully **integrate diversified and circular regional olive value chains**. Operationalise **payments for ecosystem services (PES**) for providing biodiversity conservation, landscape stewardship, and climate regulation services at the territorial level. Ensure multifunctional farms are fully embedded in the **rural economy** (e.g., agritourism, on-farm processing, and ecosystem service). *
Knowledge Systems & Research	Create **Living Labs** to trial agroecological practices. Deploy **advisory teams & peer-learning** to assist early adopters transitioning. Educate farmers about digital marketing and export.	Develop **open-access platforms** on territorial biodiversity & pest dynamics, accessible to farmers, advisors, and policymakers. Scale up **farmer-to-farmer learning networks** (e.g., local learning circles, farm visits, participatory trials). Strengthen **public-private partnerships** to expand applied research on reducing labour intensity	Institutionalise **lifelong learning**. Operationalise **fully integrated AKIS networks** (research, advisory services, farmer organizations) for territorialized, co-created knowledge production and dissemination. Institutionalise **regional agroecological research hubs** within local governance structures.
Governance, Policy, & Institutional Frameworks	Establish **territorial food councils** to lead land-use and transition planning. **Fund climate adaptation** (drought-tolerant olives, agroforestry, and nature-based water) and **soil conservation** measures in priority regions. Integrate traditional olive farming into **Croatia's cultural heritage protection policies**. Provide **systematic monitoring and enforcement** of pesticide use compliance.	**Decentralise land-use planning** increase the share of semi-natural habitats. **Transfer CAP fund management to regional councils** to tailor agroecological subsidies and ecosystem service payments to local olive landscapes. Strengthen **local governance** with **participatory processes**.	Embed **permanent regional governance frameworks** responsible for managing biodiversity targets, land-use strategies, and ecosystem service payments as part of territorial food systems. Establish **land consolidation strategies** that ensure secure land tenure and protect agricultural land from fragmentation.

7. Slovenia

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)

Cognitive & Social Norms	**Catalyse public discourse** on food systems through multi-stakeholder fora, community-led events, and media campaigns, fostering collective awareness of the environmental and health impacts of pesticide use. Empower far**mers to participate in policy and landscape planning** through local councils and civil society platforms.	Conduct **national socio-psychological research** to identify barriers and motivations for ecological farming. Support **intergenerational knowledge exchange** (e.g. storytelling, farm visits, mentoring), connecting food heritage with sustainability. Support **intergenerational mentorship and succession programmes** pairing young and elder farmers.	Embed **full-spectrum food literacy** in schools and vocational programmes, linking diets, ecology, and local farming. Normalise **dietary shifts** that reduce waste and align with landscape-linked mixed farming (e.g. offal use, pasture-based dairy).
Agricultural Practices & Innovation	Pilot **agroecological pest control**, **rotational grazing, and cover crop systems** adapted to terrain. Support **compost inoculants, modular machinery, and species-rich pastures**. Advance **nutrient-sharing platforms** and reintegration of livestock into crop systems.	Scale **collective planning of cropping mosaics**, including biodiversity corridors and habitat integration. Establish **breeding programmes** for mixed-use, pest-resilient, regionally adapted crops.	Support **researchers and advisors to co-design crop-livestock systems with farmers** that deliver on productivity, biodiversity, and soil carbon targets.
Economics & Value Chain	Develop **transition funding** tailored by farm type, size, and region. Pilot **ecosystem service payments** for biodiversity, carbon, and water management in mixed farms. Fund **shared-use mobile units** for small-scale dairy, grains, and meat processing. Support **local procurement policies** favouring pesticide-free, seasonal food.	Redesign cooperatives into **full-service food hubs** coordinating marketing, processing, and logistics. Expand **partnership farming models** that foster closer relationships between farmers and consumers through direct sales channels. Expand **short supply chains**, digital marketplaces, and value-added product labels.	Institutionalise **fair pricing, regional branding, and risk-sharing mechanisms** for mixed-farm producers. Scale **mutual labour networks** and **circular value chains** using farm by-products. Anchor **rural development** through integrated local food systems, regional branding, and cooperative-led job creation.
Knowledge Systems & Research	Strengthen the "**triangle cooperation**" between research institutions, advisory services, and farmers. Provide **incentives for farmers engaging in research**. Launch **pilot networks of experimental and demonstration farms** ("Master Farms"). Institutionalise **EIP-AGRI operational groups and study farms**.	Develop advanced **agroecology training programmes and continuous professional development** for advisors. Develop **online learning platforms** offering modular and accessible training. **Co-develop digital tools** for integrated planning of livestock, pastures, and crops.	Institutionalise **adaptive learning networks** linking farmers, researchers, and policy through shared data and feedback loops Embed **ecological literacy and traditional knowledge** into all agricultural education. Promote **intersectoral collaboration**, linking agriculture, public health, education, and environmental sectors.
Governance, Policy, & Institutional Frameworks	Public projects and incentives to stimulate **dietary adaptations**. Provide **start-up grants** for reintegration of crops or livestock into previously specialized farms. Ensure that **policy frameworks actively promote the transition** of all farm types and sizes.	Establish **multi-stakeholder national agroecology council** to oversee long-term transition. Launch **regional food policy councils** with municipalities, cooperatives, and civil society. Introduce **a fair land tenure system**.	**Safeguard farmland** as ecological and cultural infrastructure. Institutionalise **participatory landscape governance and land stewardship policies**. Mandate **food procurement quotas** from pesticide-free, diversified farms.

8. Czech Republic

Vision Dimensions	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **national awareness campaigns** on pesticide-free farming benefits. *	Support **farm-to-city initiatives** (CSA programmes, school partnerships, field trips).	Embed pesticide-free farming into **national identity** through museums, festivals, and media.

	Promote **farmer success stories** via media to shift public perception. * Foster **urban-rural partnerships** through farm visits, open days, and CSA promotion.	Integrate basic agroecology and food systems content into **school curricula**. Introduce **regional eco-labelling** reflecting health and biodiversity. *	Promote **ecological food values** in advertising and public life. Normalise **consumer acceptance of "imperfect" but healthy local food**.
Agricultural Practices & Innovation	Set up **regional demo farms** trialling diversified rotations, trap crops, and AI-assisted pest scouting. * Provide **financial and technical support** for farmers to trial green manures, cover crops, and oilseed–legume rotations. * Deploy **subsidies** for implementing flower strips, hedgerows, grass strips, and agroforestry corridors in oilseed regions.	Expand **precision machinery cooperatives** for sensor-based pest and weed monitoring. Launch **national catalogue of regionally adapted pest-resistant oilseed cultivars**. Introduce **adaptive sowing calendars** to disrupt pest cycles, based on agroclimatic zones.	Mandate **ecological buffers and minimum crop diversity** on large-scale oilseed farms. Promote **perennial oilseed systems** and **alley-cropping models** with oilseed shrubs and tree rows. Enable **AI-driven dashboards** for farm-level biodiversity and pest alert.
Economics & Value Chain	Support creation of **medium-sized, farmer cooperatives** for sustainable oilseed processing and distribution. Develop **procurement contracts** with major biofuel processors and food retailers for certified products. Launch **transition funds and risk-sharing mechanisms** (e.g., crop insurance, cooperative insurance).	Expand subsidies, risk-sharing mechanisms, and public-private partnerships to reduce costs. Fund **shared processing, storage, and marketing infrastructure**. Incentivise **short value chains** through funding for regional processing hubs and digital direct-sales platforms.	Implement **pricing frameworks** that reflect ecosystem services and sustainable production methods. Institutionalise **market standards and long-term contracts** with processors prioritizing low-input certified oilseeds. Enable **circular systems**: oilseed by-products feed biogas, compost, and local livestock.
Knowledge Systems & Research	**Pilot business models** which increase welfare without losing profitability. Launch a **national open-access digital platform for real-time monitoring** of pest dynamics, soil health, and ecological indicators. Fund **farmer-led research clusters** for testing biological inputs and diversified rotations. *	Strengthen **targeted, farm-specific advisory services**. Scale **farmer-led demo farms** and field schools in regenerative oilseed systems and IPM. Develop **training programmes and online platforms** to share alternative pest management practices.	Embed **agroecology and IPM in education and lifelong learning**. * Require **farmer involvement in applied research**. Establish a **Czech Agroecology Data Commons** (shared by universities, farmers, policymakers). *
Governance, Policy, & Institutional Frameworks	Implement a **pesticide phase-out roadmap** with clear targets. * Create **fast-track registration** for biocontrol products. Set up **regional "Agricultural Transition Hubs"** offering one-stop access to policy, advisory, and funding info.	Link **climate adaptation funds to drought-tolerant crops and ecological infrastructure**. Adjust **public procurement** to favour pesticide-free, local crops (e.g., schools, hospitals). Require **ecological practices** (e.g., rotations, field margins) as **conditions for CAP** top-ups.	Embed **landscape water and biodiversity protection in rural planning**. Institutionalise **agroecology and pesticide-free farming as the baseline** in national agricultural law and rural development policy frameworks.

9. Netherlands

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	Launch **national awareness campaign** on soil–plant–human health and pesticide impacts. **Showcase farmers** as ecosystem stewards through media. Support **peer learning** and **citizen-led food transparency.**	Introduce **pesticide-free certification** on retail shelves with traceability tools (e.g. QR codes). Promote **collective thinking** via networks and dialogues.	Integrate pesticide-free and soil health into **education standards and certification** (e.g. teacher, health curricula). Use public procurement and tax policy to reinforce **consumer demand**.

Agricultural Practices & Innovation	Establish **demo farms** on diversified 6-year rotations, soil care, and biocontrol. **Pilot resistant varieties and natural pest practices** (e.g. biocontrol, microbiome amendments). Launch **machinery-sharing hubs** for precision weeding tools.	Scale **biostimulant and microbiome input** use via subsidy programmes. Regional roll-out of **field-based AI pest monitoring tools.** Train all farmers in using **autonomous, crop-specific care** (e.g., variable irrigation, nutrient delivery).	Implement **region-wide ecological design strategies** (e.g., buffer zones, flower strips). Adopt **large-scale AI-driven decision support** for field-level input optimisation and real-time plant health monitoring.
Economics & Value Chain	Create **transition fund** covering early risks and costs. Support **new processing capacity** for differentiated pesticide-free potato products. Launch **digital direct-sale platforms** for certified farmers with consumers.	Secure **long-term contracts with retailers/processors**. Expand **cooperative storage, processing, and marketing infrastructure**. Explore **fiscal incentives**, including potential VAT adjustments.	**Mixed economic models**: premium ecological exports, not undermining territorial food-system Institutionalise **fair pricing with transparent value chains**. **Close loops with circular reuse** (e.g., reuse of by-products in compost, biogas).
Knowledge Systems & Research	Set up **regional field labs** for pest, crop, and soil trials. **Retrain advisors** for low-input transition and co-innovation. Launch program for **digital literacy and data infrastructure.** Include **pesticide-free modules in agricultural MBO/HBO education programmes**.	Expand **open data** on pests, soils, weather. Scale **farmer-led research and trials** in potato regions. Set up **peer learning networks and demo clusters**.	Maintain a **national agroecological R&D program co-led by farmers**. Institutionalise **lifelong learning** for advisors and growers. Develop **multi-stakeholder ecological data commons** with shared governance, farmer ownership of data, and public access to performance benchmarks.
Governance, Policy, & Institutional Frameworks	Co-develop **pesticide roadmap** with milestones, opt-ins, and incentive mechanisms. **Co-design data infrastructure, digital literacy**. **Fast-track approval and registration** of nature-based inputs (biocontrol, biostimulants). Mandate **pesticide-free procurement** in public food contracts.	Integrate **pesticide-free into CAP** implementation and spatial planning. Strengthen **regional/national institutional capacity** to implement, enforce, and evaluate pesticide-free policy. Provide landscape-level transition support via **regional agroecology coordinators**. **Establish risk insurance and financial buffers** to small and medium farms. Regulate the influence of private lobby and the power imbalance between actors in the value chain.	Make **pesticide-free standards** a baseline in Dutch law. **Link biodiversity, water, and health in food policy**. Lead EU negotiations on pesticide-free **trade standards and cross-border certification**. **Land tenure policies** with ecological goals, prioritising access for farmers committed to long-term soil health.

10. Denmark

Vision Aspect	Short-term (next 5 years)	Mid-term (6-11 years)	Long-term (11-20 years)
Cognitive & Social Norms	**National campaigns** promoting pesticide-free farming and plant-based diets. **School programmes and public workshops** on sustainable food and farming. **Recognition programmes** (e.g., "Pesticide-Free Champion" awards) to spotlight early adopters.	Support **civil society initiatives** promoting plant-based, pesticide-free diets. Integrate **pesticide-free standards in institutional catering** (schools, hospitals). Embed **sustainable food training** in professional sectors (chefs, educators, media).	**National identity campaigns** framing pesticide-free farming as part of Danish culture. **Curriculum and media shifts** promoting plant-based, pesticide-free agriculture.
Agricultural Practices &	Set up **demonstration farms** for pesticide-free cereal production &	Advance **crop rotations** and **biological control systems**.	Implement **landscape-level pest control** via ecological design (e.g., habitat mosaics).

Innovation	accessible farmer training on agroecological practices. Launch **precision machinery-sharing cooperatives**. Initiate **pilots on crop diversification pilots** (e.g., legumes, brassicas, oats), **Biological pest control agents** (e.g., parasitoids, beneficial insects), **AI-driven pest monitoring and decision-support tools**.	Expand **collective machinery ownership** and **labour-sharing models**. Establish **regional nutrient loops** through **mixed farming** (livestock-crop integration). Develop **ecological infrastructure networks** (e.g., habitat corridors, hedgerows).	Form **regional agroecological hubs** coordinating biodiversity, crop rotations, and nutrient cycling. Adopt **hyper-localised, AI-driven agroecological decision-support systems**.
Economics & Value Chain	Launch **transition funds** to cover farmers' upfront costs. **Early-stage risk-sharing model** with cooperatives and retailers & cooperative-based insurance schemes. Support **new processing capacities** for pesticide-free cereals (e.g., flours, malt, plant-based food ingredients). Continue **environmental taxes** on pesticides to fund transition support.	Expand **producer cooperatives and joint marketing groups**. Redirect cereals to **plant-based product markets.** Establish **value-added processing infrastructure** (e.g., mills, alt-protein ingredients). Improve **supply chain transparency** (e.g., pesticide-free labelling). *	**Stabilise farmers' incomes** through diversified, value-added product streams. Solidify **Danish cereals as premium plant-based ingredients** in export markets. Institutionalise **full cost internalisation** via polluter-pays systems. Ensure **circular supply chains** where plant-based food by-products are reused (e.g., compost, biogas).
Knowledge Systems & Research	Retrain **advisory services** to specialise in pesticide-free transition support. Create **farmer-led innovation hubs** with mentorship programmes and living labs. Integrate pesticide-free farming into **vocational and higher education curricula**.	Scale **farmer-led research collectives and participatory action research** and interdisciplinary link with socio-economic studies Develop **open-access digital platforms** sharing real-time data on soil health, pests, and biodiversity. Expand **peer-to-peer farmer networks**.	Institutionalise **lifelong learning on regenerative agriculture** across the sector. Create a **national agroecological data commons** to support open research and on-farm decision-making. Position Denmark as a **global leader** in pesticide-free R&D.
Governance, Policy, & Institutional Frameworks	Launch **pesticide phase-out roadmap** and **align national and EU policies**. Implement **public procurement requirements** for pesticide-free cereals. Enable **regional councils** to tailor biodiversity and agroecology policies locally. Create **agricultural transition offices** to coordinate implementation.	Embed **pesticide-free standards** into DK's CAP implementation. Establish **regional multi-stakeholder governance platforms** (farmers, councils, regulators). Introduce **legally binding climate-smart agriculture goals** (carbon sequestration, drought resilience).	Fully **integrate agricultural, climate, and biodiversity policies at all levels**. Scale **public procurement** of pesticide-free cereals across all public institutions. Enable **regional governance of ecosystem services** (e.g., landscape biodiversity corridors, water management).

Annex 5: Detailed Recommendations for Improvement to Ecotoxicology Section

SPRINT Ecotoxicologists highlighted several areas of technical concern and opportunities for improvement.

Shortcoming of EFSA Risk Assessment and Suggestions for Improvement

The current risk assessment framework for pesticide active substances and plant protection products (PPPs) has several limitations that hinder its ability to fully capture real-world ecological risks and account for uncertainty in the risk assessment process. Below, we outline key shortcomings and propose improvements to enhance regulatory reliability and environmental safety.

1. **Inadequate Consideration of Mixture Effects**
   - Current regulatory frameworks primarily assess individual pesticides, underestimating the cumulative risks posed by multiple chemical residues in the environment.
   - The mixture effect is only considered when two or more active substances occur in the same PPP (Regulation 284/2013), failing to account for complex environmental mixtures.
   - **Improvement:** Risk assessment should integrate cumulative and synergistic effects from exposure to multiple compounds, supported by ecological studies.

2. **Overreliance on Standard Laboratory Species**
   - Many sensitive native species are excluded from first-tier testing, leading to underestimation of ecological impacts.
   - **Improvement:** Include native and ecologically relevant species in first-tier risk assessment, alongside traditional model organisms.

3. **Inconsistencies in Higher-Tier Testing**
   - Higher-tier methods lack standardisation and are often subject to biased interpretation, allowing registrants to secure approvals for substances that fail lower-tier tests.
   - Scientific studies have shown that species in real ecosystems are often more sensitive than laboratory species under controlled conditions.
   - **Improvement:** Implement standardised guidelines for higher-tier testing to ensure consistency and prevent subjective bias in pesticide approvals.

4. **Weak Safety Margins in Toxicity Exposure Ratios (TERs) or Risk Quotients (RQ)**
   - Current Toxicity to Exposure Ratios (TERs) and other safety factors do not adequately account for real-world interactions with other chemicals.
   - **Improvement:** Increase TERs and similar safety factors to better reflect the co-occurrence of multiple stressors in natural ecosystems, namely other pesticides that are rather rule than exception.

5. **Lack of Long-Term and Multi-Species Studies**
   - Current assessments rely heavily on short-term laboratory studies, which fail to capture long-term ecological effects.
   - Multi-species interactions and field-based studies are rarely considered, leading to incomplete risk evaluations.
   - **Improvement:** Conduct long-term studies (over multiple seasons) and include multi-species experiments to assess chronic exposure risks.

6. **Limited Guidance on Assessing Complex Mixtures**
   - Existing guidelines do not provide clear methodologies for analysing tank-mixes, pesticide sequences, and environmental mixtures.
   - **Improvement:** Develop clear regulatory guidance on evaluating combined pesticide exposures in both pre-registration and post-approval phases.

7. **Insufficient Consideration of Soil Microorganisms and Aquatic Systems**
   - Standard tests focus mainly on a limited set of species, neglecting critical soil microbial communities and aquatic organisms.

- **Improvement:** Expand the OECD test portfolio to include:
  - Microcosm tests for soil and aquatic systems.
  - More endpoints for soil microorganisms to assess functional biodiversity.
  - Sub-individual endpoints for aquatic species (e.g., early warning biomarkers of damage).

8. Weak Link Between Application Schemes and Risk Assessment

- Current regulations do not sufficiently link pesticide application schemes (e.g., dosage, frequency) to actual risk assessment models.
- **Improvement:** Develop realistic exposure scenarios based on actual farm practices, including farms in transition to sustainable agriculture.

To strengthen EFSA risk assessment, we propose:

- Integrating mixture toxicity assessments rather than evaluating single chemicals in isolation. SPRINT results suggest the most frequently detected substances in all compartments, which can be incorporated into toxicity assessment.
- Expanding testing protocols to include native species, multi-species studies, and long-term field research.
- Standardising higher-tier testing to ensure scientific validity and transparency.
- Enhancing guidance for complex mixtures, including tank-mixes and sequential applications.
- Improving safety margins in TERs to account for co-exposure risks.

Annex 6: Research Agenda: Reducing the Risk of and Reliance on Pesticides

The goal of the research agenda was to identify new research directions and outstanding "unknowns" that can support a more comprehensive and safer pesticide risk assessment, as well as support the uptake of more sustainable plant protection practices.

Research Pillars

Through interviews with each work package lead, top research priorities were identified related to the project activities and results. Each of the research priorities was grouped into four thematic pillars:

Pillar	**1 -** Comprehensive Assessment of Pesticide Effects on Health and the Environment:	**2 -** Exposure and Robust Monitoring Methodologies	**3 -** Scaling up to risk and larger spatial scales	**4 -** Agroecological innovations, Economics and Stakeholder Adoption
Feeding SPRINT WPs	WP2-Health status assessment; integration WP4-Ecotox and Human toxicology	WP2/WP3-Human /Environmental Monitoring WP3-Human Exposure	WP5-Toolbox & Health Impact Assessment WP6-Cost-Benefit Analysis	WP2-Innovative practices WP6-Cost-Benefit Analysis WP7-policies
Keywords/ main topic areas	Mixtures New indicators Differentiated data collection, analysis, and recommendations	Comprehensive assessments	Data availability & harmonization challenges	Stakeholder adoption Consideration for gender^{+} inclusion

Survey: Stakeholder Ranking of Priorities

We invited individuals with expertise in any aspect of pesticide-related work—whether from policy, regulation, science, industry, NGOs, agriculture, or beyond —to take part in a short 15-minutes survey to prioritise future research topics about pesticides and environmental/human health. Specifically, the survey was circulated within EFSA.

Link to survey: **https://app.onlinesurveys.jisc.ac.uk/s/glos/sprint-research-agenda** (closed July 31, 2025)

Participants were invited to rank their top 3 research priorities under each of the pillar or sub-subsections presented. The survey ranking data and free-form comments will be used to identify the highest priorities research direction, which will be published in a peer-reviewed letter representing the SPRINT consortium.

Research Agenda Priorities and Published Working Draft

Pillar 1: Comprehensive Assessment of Pesticide Effects on Health and Environment

Human Health	Environment
Advance research on pesticide hazards during vulnerable periods (e.g. pregnancy, early life) and introduce safeguards where health risks remain uncertain. Advance research on long-term, low-level effect of pesticides on human health outcomes. Use hazard assessments to gather toxicologically relevant findings that go beyond existing OECD guidelines (the standard tests used in active substance approvals). Link population-based studies to laboratory toxicology work to identify the mechanisms or pesticides of concern. Further develop methods to assess pesticides dose and exposure thresholds, accounting for data limitations and uncertainties. Find ways to translate animal toxicology results to human health. Develop approaches to identify indirect effects of pesticides on human health. Reassess the scientific basis for prioritising higher-tier data over lower-tier data in pesticide approval decisions.	Expand OECD testing methods (the standard tests used in active substance approvals) to more accurately reflect real-world ecological conditions in pesticide risk assessments. Improve the way chemical mixtures are considered in ecotoxicity testing and ecological risk assessment of active substances and pesticides. Build a better understanding of how pesticide accumulation through ecosystem transfer affects biodiversity and ecosystem health on land and in water. Reassess the scientific basis for prioritising higher-tier data over lower-tier data in pesticide approval decisions.

Pillar 2: Exposure to Pesticides and Robust Monitoring Methodologies

Human Health	Environment
Improve understanding of how pesticides behave in the human body to better assess internal exposure and health risks. Expand assessment of external pesticide exposure to include pathways beyond diet and workplace contact. Develop a database on farm animal feed composition to support pesticide risk assessments. Establish practical methods for long-term human biomonitoring to support routine monitoring programmes. Continue developing biological guidance values (BGVs) as reference points for assessing human pesticide exposure. Develop harmonised definitions and standard operating procedures (SOPs) for monitoring across studies and programmes.	Investigate how local practices and characteristics influence pesticide monitoring results. Expand monitoring and tracer studies beyond research fields to better assess diffuse pesticide pollution. Establish reference values for pesticide residues and mixtures in more environmental media to guide action. Develop harmonised definitions and standard operating procedures (SOPs) for consistent monitoring across studies and programmes.

Pillar 3: Upscaling Findings to Larger Spatial Scale

Human Health	Environment
Further develop spatial modelling methods to estimate human exposure to pesticides across regions and countries, supporting health-related risk assessments. Standardise data collection and formats and ensure public access to support spatio-temporal models of human pesticide exposure and health risk. Apply health impact assessments to evaluate how pesticide use, and related policies, influence specific human health outcomes. Refine lifecycle assessment (LCA) methods to estimate the health-related damage costs of pesticide use across the value chain. Assess the full lifecycle impacts of biopesticides on human health, particularly in the context of integrated pest management (IPM) and organic farming. Identify pesticide uses and practices with the highest human exposure potential and health risk and propose safer alternatives. Investigate innovations and agronomic alternatives that reduce health risks associated with pesticide use.	Further develop spatial modelling methods to predict environmental pesticide exposure across regions and countries, accounting for landscape and ecological variation. Harmonise environmental data collection and formats and make datasets publicly available to support spatio-temporal models of environmental exposure and ecological risk. Refine lifecycle assessment (LCA) methods to estimate environmental damage costs of pesticide use across the entire value chain. Investigate the full lifecycle impacts of biopesticides on ecosystems, especially in IPM and organic farming systems. Identify pesticide uses and practices with the highest environmental impact and ecological risk and propose sustainable alternatives. Explore innovations and agronomic alternatives to reduce environmental harm from pesticide use.

Pillar 4: Agroecological innovation, Economics, and Stakeholder Adoption of Low-Pesticide Practices

Economic and Farming Systems Research
Continue research to better understand the real farm-level costs and performance of lower-pesticide farming systems, such as integrated pest management (IPM), regenerative farming, and pesticide-free approaches. Provide crop-level economic analysis to give farmers clearer information on costs, yields, and income in different farming systems. Study what influences conventional farmers' perceptions of risk when considering a swich to organic farming. Investigate how to increase consumer and market demand for disease-resistant crop varieties. Explore economic models and ways to share financial risks between farmers, markets, and other actors.
Social, Cultural and Participatory Research
Include gender and other social dimensions in research approaches to better reflect diverse experiences and needs. Investigate alternative participatory methods for involving stakeholders in decision-making about pesticide use and its alternatives. Study how different groups present alternatives to chemical pesticides as viable or not, and how this influences policy, regulation, and innovation funding. Examine how power imbalances affect who gets to participate and influence decisions in policymaking processes. Research how both formal and informal power dynamics shape public consultation processes—who takes part, who has influence, and which voices are heard or overlooked.

Policy, Governance, and Systemic Change
Assess how EU policies on pesticides and farming are implemented and whether they work well together. Explore how to design systemic transitions that are integrated, practical, and adapted to local contexts. Investigate the cultural and psychological factors that influence decisions about shifting to lower-pesticide or alternative farming systems.

Open Working Draft: **https://sprint-h2020.eu/index.php/2-uncategorised/253-research-agenda-doc**