Farmer’s Toolbox for Integrated Pest Management

Final report

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November 2022

EUROPEAN COMMISSION

Directorate-General for Agriculture and Rural Development

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European Commission
B-1049 Brussels

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Directorate-General for Agriculture and Rural Development
2023

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Luxembourg: Publications Office of the European Union, 2023

PDF ISBN: 978-92-76-53692-5 DOI: 10.2762/457165 KF-08-22-240-EN-N

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a.s.	Active substance
AT	Austria
BE	Belgium
BG	Bulgaria
BTSF	Better Training for Safer Food
CAP	Common agricultural policy
CAPER	Concerted Action on Pesticides Environmental Risk indicators
CfS	Candidate for Substitution
CY	Cyprus
CZ	Czech Republic
DE	Germany
DG AGRI	Directorate General Agriculture and Rural development
DK	Denmark
DSS	Decision Support System
E.E.I.G.	European Economic Interest Grouping
EASS	European Agricultural Statistics System
EC	European Commission
ECA	European Court of Auditors
EE	Estonia
EFSA	European Food Safety Agency
EL	Greece
EP	European Parliament
ES	Spain
ETR	Exposure to toxicity
EU	European Union
F&V	Fruits and vegetables
F2F	Farm to Fork Strategy
FADN	Farm Accountancy Data Network
FI	Finland
FR	France
FSDN	Farm Sustainability Data Network

GD	European Green Deal
H2020	Horizon research framework 2020
Ha	Hectare
HR	Croatia
HRI	Harmonised Risk Indicators
HU	Hungary
IBCA	Invertebrate BioControl Agents
IE	Ireland
IPM	Integrated Pest Management
IT	Italy
Kg	Kilogram
LT	Lithuania
LU	Luxemburg
LV	Latvia
MO	Micro organism
MRL	Maximum Residues level
MT	Malta
NAP	National Action Plan
NCA	National Competent Authority
NL	Netherlands
NODU	The annual "average" number of treatments with pesticides applied to all crops
PL	Poland
PLI	Pesticide Load Index
POCER	Pesticide Occupational and Environmental Risk indicator
PPP	Plant Protection Products
PRI Nation	Pesticide Risk Indicators at National level
PRIBEL	Pesticide Risk Indicator for BELgium
PRI-Farm	Pesticide Risk Indicators at Farm level
PT	Portugal
R&D	Research and Development
RASFF	Rapid Alert System in Food and Feed

RDP	Rural Development Plan
RO	Romania
SAIO	Statistics on Agricultural Inputs and Outputs
SE	Sweden
SK	Slovakia
SL	Slovenia
SUD	Sustainable Use Directive
SYNOPS	Synoptic evaluation model for plant protection products
TFI	Treatment Frequency Index
WFD	Water Framework Directive
ZEPP	Forecasting models and decision-making support

Abstract

The Pilot Project – Developing a farmers' toolbox for integrated pest management practices from across the Union, was commissioned by the European Commission – Directorate-General for Agriculture and Rural development, following a request from the European Parliament.

The Pilot Project, retitled "Farmer's Toolbox for Integrated Pest Management", was conducted between December 2020 and November 2022, with the main objective to provide background knowledge on the most promising ways that could help farmers, advisors, and policymakers to scale up the reduction of the dependency on pesticide use across the EU, as advocated in the European Commission's Farm to Fork Strategy and in the context of the European Green Deal.

The Pilot Project provides a comprehensive description of the main drivers and barriers regarding the full uptake of IPM practices that lead to a significant reduction of pesticide use. Finally, the Pilot Project has developed a public database of IPM practices and crop- and sector-specific guidelines gathered from the EU Member States, with the ambition to disseminate the database across the EU as a source of inspiration for farmers and farmers' advisors.

Résumé

Le projet pilote - Développer une boîte à outils pour les agriculteurs pour les pratiques de lutte intégrée à travers l'Union européenne, a été mandatée par la Commission européenne - Direction Générale de l'Agriculture et du Développement rural, suite à une demande du Parlement européen.

Ce projet, rebaptisé « Boîte à outils pour la lutte intégrée pour les agriculteurs », a été conduit de décembre 2020 à novembre 2022, avec pour objectif principal de fournir des connaissances de base sur les moyens les plus prometteurs qui pourraient aider les agriculteurs, les conseillers agricoles et les décideurs politiques à intensifier la réduction de la dépendance à l'égard de l'utilisation des pesticides dans toute l'Union européenne, comme le préconise la stratégie « de la ferme à la fourchette » de la Commission européenne et dans le contexte du Pacte Vert européen.

Les conclusions présentent une description complète des principaux moteurs et obstacles à l'adoption complète des pratiques de lutte intégrée conduisant à une réduction significative de l'utilisation des pesticides. Enfin, le projet pilote fournit une base de données publique des pratiques de lutte intégrée contre les parasites et un inventaire des lignes directrices spécifiques aux cultures ou aux filières agricoles développées dans les États membres de l'Union européenne, avec l'ambition de diffuser la base de données le plus largement possible au niveau européen comme source d'inspiration pour les agriculteurs et les conseillers agricoles.

1. Introduction

The *"Pilot Project – Developing a Farmers' Toolbox for Integrated Pest Management Practices from across the Union",* retitled *"Farmer's Toolbox for Integrated Pest Management"* by the European Commission – Directorate General Agriculture and Rural Development (EC-DG AGRI), started in December 2020 following a request from the European Parliament to the European Commission. A consortium of experts led by Arcadia International E.E.I.G. has worked on the project for a period of two years, until November 2022. This document constitutes the final report and present the results of the Pilot Project, as well as provides conclusions and recommendations.

This introductory chapter presents the context of the Pilot Project as well as its objectives, scope and themes. Subsequently, the methodological approach applied is summarised and the structure of the report is presented.

1.1 Context

While pesticides have the function of protecting crops, they may have a negative impact e.g. on human health and the environment. This is why pesticides, and the use of pesticides are strictly regulated at EU and national level. Furthermore, the European Union contributes to the enforcement of a sustainable use of pesticides through **Directive 2009/128/EC** (Sustainable Use Directive - SUD) that i.a. promotes the use and implementation of Integrated Pest[1] Management (IPM) techniques; and through the **Common Agricultural Policy** that includes tools supporting the implementation of the eight IPM principles established in the SUD Directive. It was in this context that the European Parliament requested the European Commission to initiate this Pilot Project aiming to provide background knowledge on promising ways to reduce the dependency on pesticides, targeting a range of stakeholders, and to set up an EU-wide database with promising IPM tools.

1.2 Objectives, scope and themes of the Pilot Project

1.2.1 Objectives

The main objective of the Pilot Project is to provide background knowledge on the most promising ways that could help farmers, advisors, and policymakers to scale up the reduction of the dependency on pesticide use across the EU.

The specific objectives of the Pilot Project are outlined as follows:

1. To provide a comprehensive description of the currently available implementing approaches (e.g., policies, agricultural practices,

[1] In the context of this Pilot Project, « pest » means weeds, diseases and pests.

technologies, private sector initiatives such as certification) to reduce dependency on pesticides use;

2. To assess the potential of the approaches identified in Objective 1 for reducing the dependency on pesticide use, and to prove their effectiveness as well as barriers (real or perceived) that limit their uptake. In particular, the study should list and assess the barriers and explain their roots and possible ways to overcome them;
3. To propose specific strategies on how to scale up good practices throughout the EU; and
4. To set up an EU-wide database containing the relevant information and guidance to enable farmers and advisory services to reduce the dependency on pesticide use and to disseminate it as widely as possible through the EU.

The techniques, technologies and practices which are assessed in this report refer to the ones listed under the eight IPM principles as presented in Annex III of the Sustainable Use Directive 2009/128/EC (the SUD). Each of these has been assessed individually without taking into consideration their possible combination as promoted in agro ecology. Such combination of techniques and practices is very specific to a cropping system and an area of production and, therefore, it is difficult to assess their added value and effectiveness at the European level.

In this context, the conclusions of the present report aim to provide useful information for future actions at EU and Member States' level, including the implementation of the common agricultural policy (CAP) post-2020.

1.2.2 Scope

The examination period considered by the Pilot Project spans from 2010 onwards. However, it should be mentioned that due to the timing of the Pilot Project and the related data collection phase, a full analysis of the new CAP and national action plans was not possible. The geographical coverage of the Pilot Project is the 27 EU Member States. For analytical purposes, the Pilot Project also considers relevant experiences from third countries (e.g. Switzerland, the UK, and the USA).

The Pilot Project covers, without being exclusively limited to, the following agricultural sectors:

- Arable crops;
- Viticulture; and
- Fruit and vegetables (F&V).

These three sectors certainly include the crops on which the number of applications per growing season - estimated by using the Treatment Frequency

Index (TFI) - is the highest, ranging from 4 to 6 for cereal crops to 14 for potatoes and 15-18 for viticulture. For F&V there is a large variability of TFIs, depending on crop species and, also, on production techniques. For certain fruits, the TFI is higher than 10, whereas it may be lower for greenhouse crops where pesticides are being used.

1.2.3 Study themes

The Pilot Project is structured around four different study themes as follows:

Theme 1: Identification and assessment of effective practices and technologies to reduce dependency on the use of pesticides in the European Union; with the aim to establish an overview and analyse agricultural practices, techniques and technologies with the potential and capability to reduce dependency on pesticide use. In addition, this theme investigates pesticide trends, as well as targets and indicators set in Member States, and the level of implementation of agricultural practices and techniques, and their effectiveness, including also IPM implementation. Actions carried out by Member State authorities in this regard are accounted for and particular emphasis is put on the analysis of crop- and sector-specific guidelines in place in the Member States pursuant to the SUD.

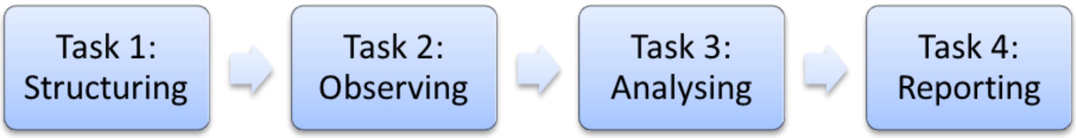
Theme 2: Estimation of the potential to reduce dependency on pesticide use and its key drivers and barriers. This theme aims to assess the potential for reducing pesticide use, and investigates the requirements to make it feasible, identifying key factors to achieve a high level of implementation. In this context, principal drivers and barriers, as well as factors impacting farmers' decisions are identified and analysed.

Theme 3: Assessment of how public policies, private certification schemes, and other strategies are contributing to the reduction of the dependency on pesticide use. Through this theme, existing policies at EU and Member State level are analysed to understand their contribution to the reduction of the dependency on pesticide use and whether farmers' needs are sufficiently accounted for in these policies.

Theme 4: Strategies on how to scale up good practices throughout the EU; has the aim of investigating ways to encourage and promote change in the approaches towards pesticide use, and how to scale up good practices.

1.3 Methodological approach

The methodology of the Pilot Project was structured around four tasks as follows:



The Structuring Phase set out to ensure a clear understanding of the needs and priorities of the Pilot Project, as well as to identify existing evidence and data sources through a preliminary desk research and literature review at EU and national level. This phase also developed and finalised the methodological approached for data collection and analysis.

The Observing Phase had the twofold objective of gathering evidence – both quantitative and qualitative data through the use of methodological tools – to inform the study process; and also to implement the process of responding to the various questions linked to the four themes.

The Analysing Phase implied the analytical work on the four study themes, and also the establishment of the draft EU-wide database. At this stage, data gathered in the previous phases were analysed and findings and results were combined to answer to the study questions and structure the database. A conference was organised in the context of the Pilot Project to present the findings, disseminate results and gather further input from pertinent stakeholders, policymakers and other actors with an interest in IPM, in view of the reporting phase.

The final **Reporting Phase** consisted in the compilation of the final deliverable including the results from previous tasks, combining all outputs and deliverables. Finally, the conclusions and recommendations were developed.

A mix of methodological tools to collect evidence regarding the four study themes and conduct analysis was applied throughout the Pilot Project, as outlined below.

1. **Desk research and literature review** were conducted at both national and EU level. For this purpose, a team of national experts was used to identify and access any relevant documents in the national languages of the Member States. While activities on this task were most intense at the beginning of the Pilot Project, desk research was carried out all along the project and pertinent document were stored and tagged according to topics and themes.
2. **Relevant stakeholders** were identified and mapped in the inception phase of the Pilot Project at EU and national level resulting in a

comprehensive stakeholder mapping. Also for this task, the project relied on the team of national experts to ensure a full coverage of relevant actors in all Member States.

3. **Over 300 in-depth interviews were conducted.** The majority of these interviews were carried out in the EU Member States, while a limited number of interviews were conducted with EU associations, as well as with relevant research projects (e.g. H2020). While interviews at national level were conducted by the national experts, EU-level interviews were carried out by the study team.
4. **12 case studies** were conducted following an open call to select relevant and concrete examples of IPM implementation, highlighting drivers and barriers. The case studies covered 10 Member States and also included two case studies in non-EU countries (Switzerland and Canada). Furthermore, a coverage of different crops and agricultural practices was ensured.
5. **A workshop was organised to feed into Theme 4 in particular.** This was an online event gathering a group of about 10 pertinent experts enabling exchange and discussions on the topic of how to scale up good practices across the EU.

The output of Theme 1 addressing the identification and assessment of effective practices and technologies to reduce dependency on the use of pesticides in the European Union has been used to develop the EU-wide database on how to improve practices to reduce the dependency on pesticide use in an efficient and effective manner. It has the objective to propose inspirational examples as regards IPM implementation across countries and crops. Theme 1 lists and describes agricultural practices, products, and technologies that represent alternatives to the use of chemical pesticides and that contribute the diffusion of IPM principles, practices and sustainable agricultural production.

1.4 Structure of the report

The final report is structured with the aim to provide the reader with a good understanding of the relevant context as regards Integrated Pest Management in the EU and its implementation at the national level, existing practices and techniques, as well as success factors and barriers related to the implementation of IPM in particular, and to reduced dependency on pesticide use in general.

For this purpose, the following chapters are included in the report:

- **Chapter 2: Background and EU policy context.** This chapter provides an overview of Integrated Pest Management, including the eight IPM principles, and presents the EU legislative and policy context.

- **Chapter 3: Analytical chapter.** This chapter of the report represents the core of the work conducted in the context of the Pilot Project and presents the analysis of the four themes outlined in the previous sections.
- **Chapter 4: Case studies.** This chapter give an overview and provide the abstracts of the 12 case studies conducted in the context of the Pilot Project with the aim to gather concrete and tangible examples of IPM implementation and actions to reduce dependency on pesticides use.
- **Chapter 5: General conclusions.** This final chapter provides the conclusions resulting from the work conducted throughout the Pilot Project, as well as some forward-looking recommendations in the field of knowledge dissemination.

2. Background and EU policy context

This chapter first introduces the concept of IPM and then presents the policy and legislative framework at EU level as of June 2022.

2.1 Integrated pest management (IPM)

Pests (insect pests, diseases, weeds, and others) can reduce crop yields and crop quality; crop protection measures are thus necessary to prevent economic losses and ensure food security. Currently, crop protection in the EU relies heavily on the use of pesticides. About 400,000 tonnes of active substances contained in pesticides, of which the major part is chemical pesticides, are being used in the EU every year. Since 2011, this volume has remained stable despite political efforts to reduce pesticide use. The high pesticide use has led to increasing concerns about the related impact on the environment and human health. Pesticide use has also become a topic of the societal debate across the EU and is one of the main causes of controversy between farmers and the civil society, who perceives pesticides as a severe risk to public health[2].

IPM is considered one of the cornerstones of the Directive 2009/128/EC[3], the SUD. The SUD obliges Member States to set up the necessary conditions and incentives to enable all professional users of pesticides to adopt and implement the eight general principles of IPM laid down in Annex III of the Directive and Article 55 of Regulation (EC) No 1107/2009 by January 1, 2014.

IPM is defined under Article 3 (6) of the SUD as "*careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. 'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms*".

IPM hence combines the use of cropping, biological, and chemical practices to control pests[4] in agricultural production. It seeks to use natural mechanisms, predators, or parasites to control pests, using selective pesticides as a last resort option, when pests cannot be controlled by natural or non-chemical means. IPM should not be confused with organic farming. It does not exclude spraying of synthetic pesticides; it promotes spraying with selective pesticides based on

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[2] Eurobarometer 2019, EFSA.

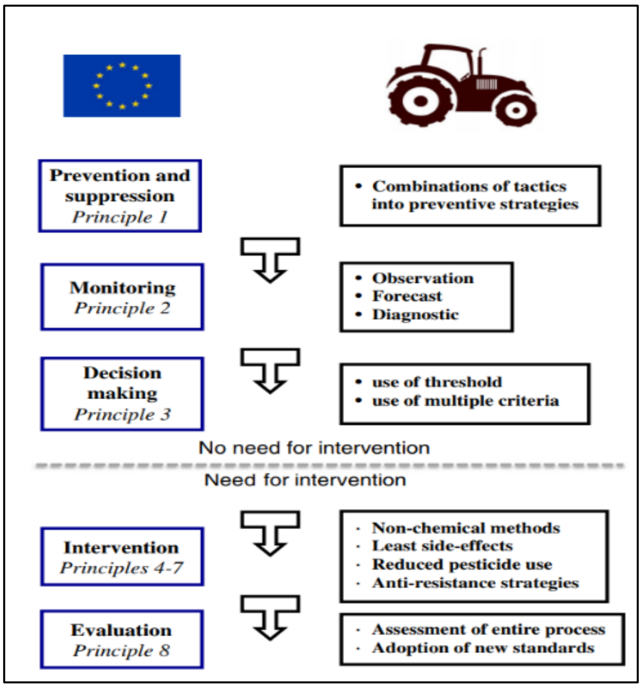
[3] Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

[4] Pests include weeds, diseases, insects or any species harmful to plants or plant products, as defined by the International Plant Protection Convention (2010) International Standards for Phytosanitary Measures No. 5, Food and Agriculture Organization of the United Nations, Italy.

monitoring and threshold values, but only when needed, which aims altogether at using reduced pesticide volumes.

IPM is not a new concept and has a long history dating back the early 1980s. However the SUD made the concept clear and visible. IPM relies on eight principles as defined under Annex III of the SUD. These eight principles and their numbering originate from a logical sequence of events[5] (see Figure 1). Each of these eight principles is briefly described below.

Figure 1: The eight principles of IPM



Source: Barzman et al. Eight principles of integrated pest management. See complete citation below.

Principle 1: Prevention and suppression. The overall goal of reducing reliance on pesticides emphasises the importance of growing healthy crops. The principle of prevention is paving the ground for resilient cropping systems and is the backbone of IPM. Increasing spatial and temporal diversity in terms of e.g. number of crops in the rotation, together with the introduction of spring crops, legumes or under sowing in arable crop rotations dominated by winter crops, can reduce weed pressure; intercropping or cultivar mixtures are also very effective measures to reduce pest pressure. Combining these preventive

[5] Barzman, Marco & Bàrberi, Paolo & Birch, A. & Boonekamp, Piet & Dachbrodt-Saaydeh, Silke & Graf, Benno & Hommel, Bernd & Jensen, Jens Erik & Kiss, Jozsef & Kudsk, Per & Lamichhane, Jay Ram & Messean, Antoine & Moonen, A.C. & Ratnadass, Alain & Ricci, Pierre & Sarah, Jean-Louis & Sattin, Maurizio. (2015). Eight principles of integrated pest management. Agronomy for Sustainable Development. 35. 10.1007/s13593-015-0327-9.

measures with other non-chemical crop protection tactics can significantly reduce the need for pesticides. However, the trends observed in recent years in many Member States – increasing farm specialisation and mixed farming becoming less common – are in contrast with the implementation of Principle 1.

Principle 2: Monitoring. Monitoring is the basis of the actual decision-making process. Monitoring for pests either by scouting individual fields or through regional or national warning/forecasting systems is a prerequisite for making informed decisions. Monitoring is costly and time-consuming and automated monitoring systems are very much needed.

Principle 3: Decision-making based on monitoring and thresholds. For many pests, thresholds are not available or not very reliable because they were developed many years ago in a different cropping context. Prognosis and decision support systems (DSS), which are information systems that supports business or organisational decision-making activities, are the most elaborated tools to support the decision-making process of growers, but they are only available for major weeds, pests, and diseases, and only for a number of regions. In addition, thresholds are very context-specific and should be revised and updated regularly to be of value to farmers

Principle 4: Non-chemical methods. If a treatment is necessary, based on thresholds and/or the results of Decision Support Systems (DSS), growers should prefer non-chemical methods (e.g. bio-pesticides, macro-organisms, mechanical, physical, or bio-technical methods) if they provide sufficient control. In recent years, there has been an increased interest in developing and implementing non-chemical methods partly triggered by the loss of chemical pesticides and lack of alternatives. However, many of the non-chemical methods are so far less effective in short term and/or more expensive than pesticides and the adoption has been slow, except e.g. greenhouse cultivation.

Principle 5, 6 & 7: Pesticide selection, reducing pesticide use, and preventing pesticide resistance. Target-dependent selection and dosage of pesticides is crucial for a successful control and the least side effects to the environment. The right choice of pesticides and of their mode of action, appropriate dose rates and proper timing of their application also mitigate the risk of resistance development or of the adaptation of harmful organisms. The combination of all means should provide sufficient control of pests and ensure the quality of products. If effective non-chemical methods are not available, farmers can use pesticides to protect their crops against pests but should choose the most environmentally and toxicologically benign pesticides and not use higher doses than required to achieve satisfactory control. At the same time, farmers should adopt anti-resistance strategies to prevent the development of pesticide resistance. In some situations, however, reduced pesticide uses and preventing pesticide resistance are conflicting goals.

Principle 8: Evaluation. The soundness of the crop protection strategy adopted by the farmer should be assessed, e.g. at the end of the growing season, and adjusted for the next growing season if required. The challenge here is how to assess the strategy: in terms of e.g., yield, economic benefit, or pesticide use? annually or over several cropping seasons? Experience shows that the evaluation of adequate pest control should use more criteria than the sole yield. The post-assessment of the pest control measures is equally important, as it evaluates the tactical (were pests sufficiently controlled without yield reduction) as well as the strategic component (e.g. does crop rotation result into lower pest pressure?) of crop protection in one cropping season, or the rotation over several cropping seasons. Additionally, post-assessment encourages farmers to critically evaluate the annual measures and thus contributes to knowledge development and evaluation of crop management not only from an economic perspective.

From a European perspective, i.e. under the varying geographic, climatic and market conditions applying across the EU, the implementation of IPM entails considerable complexity. Moreover, crop-specific methods need to be also context-specific, to consider regional and even farm-level differences. The complexity of the integration of several tools and methods simultaneously and over time contributes to the difficulties in evaluating whether the cropping system is following the IPM approach. In an ideal case, the cropping system is optimised for all parameters reducing crop competition with weeds, disease pressure and the occurrence of harmful insects. Even though several Member States have advisory services dedicated to providing specific advice on IPM methods, and have made institutional efforts to promote IPM, the level of IPM adoption and implementation by farmers across the EU remains mostly unknown. To date, most Member States have not developed a system that allows them to monitor and evaluate the changes in farming practices and to determine the level of IPM uptake. At the same time, a widely recognised set of defined criteria is missing to decide whether the general principles of IPM were adopted or not.

2.2 Policy and legislative EU framework

Since pesticides may have harmful effects on the environment and human health, they are strictly regulated at EU level. The placing of pesticides on the EU market has been regulated for 40 years, and currently takes place under Regulation (EC) 1107/2009.[6] The issue of pesticide use has received

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[6] Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC.

considerable attention in the EU over the last 15 years, first within the framework of the Thematic Strategy (2006) setting the ground for sustainable use of pesticides, and then under the subsequent Directive 2009/128/EC[7] on Sustainable Use of Pesticides (the SUD), as mentioned above[8]. The SUD is largely based on actions to be taken at Member State level, given the diversity of the agricultural sector across the EU, and to address subsidiarity considerations.

The EC has started several initiatives to support Member States in the implementation of IPM. A series of Better Training for Safer Food (BTSF) trainings on the implementation of IPM were funded to generate an understanding of the holistic approach of IPM, promote increase on-farm implementation of IPM as well stimulate the development of criteria for IPM implementation.

The Farm to Fork Strategy (F2F)[9], published in May 2020, is at the heart of the European Green Deal (GD) which has brought renewed attention to the sustainability of the agri-food supply chain. European food is known for its high safety, and its nutritional and quality standards. Now it should also become a standard of sustainability. It highlights that "*there is an urgent need to reduce the dependency on pesticides […]*". The GD targets are to reduce the use and risk of chemical pesticides by 50%, and the use of more hazardous pesticides by 50% by 2030. The Commission has published a Staff Working Document on the links between the Common Agricultural Policy (CAP) reform and the GD.[10] The document indicates that "*the new specific objective on societal concerns requires Member States to target the risk and use of chemical pesticides, […], ensuring these major concerns will be tackled in the future CAP Strategic Plans*". It adds that "*novel approaches for IPM should be encouraged. […] Advisors have a crucial role to play in making this happened*" and "*Up-to-date knowledge linked to competent advisors are also key*" to promote the dissemination of IPM measures to farmers and farmer communities.

In the meantime the legal texts reforming the CAP have been adopted and include several tools aiming to support the F2F and Biodiversity strategies objectives mentioned above.

[7] Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

[8] As part of the pesticide package which also includes Regulation (EC) No 1107/2009 (placing on the market of plant protection products), Regulation (EC) No 1185/2009 (statistics on pesticides) and Directive 2009/127/EC (amending the rules concerning machinery for pesticide application).

[9] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Farm to Fork Strategy for a fair, healthy, and environmentally friendly food system. Available at https://ec.europa.eu/info/sites/info/files/communication-annex-farm-fork-green-deal_en.pdf.

[10] Analysis of links between CAP Reform and Green deal - SWD (2020) 93 final.

3. Analytical chapter

The data gathered in the extensive data collection phase of the Pilot Project was analysed by the study team feeding into the four study themes. This chapter presents the results of this analysis per study theme.

3.1 Theme 1: Identification and assessment of effective practices and technologies to reduce the dependency on the use of pesticides in the European Union

3.1.1 The inventories leading to the EU-wide database

With the aim of gathering IPM practices, techniques and technologies currently used or developed in the EU Member States, and assessing the effectiveness of such practices, data were collected and organised in two types of inventories. One inventory gathering tools and techniques with the objective of providing inspirational examples across the eight IPM principles, and another inventory collecting the official crop- and sector-specific guidelines as established in Article 14(5) of the SUD. Upon finalisation, these two inventories were fed into the EU-wide database developed in the context of the Pilot Project. The sections below, however, present the work conducted in the context of these inventories and provide an overview of the content collected.

3.1.2 Inventory and assessment of IPM practices, techniques and technologies

In the data collection exercise of the Pilot Project, the team of national experts collected data on IPM practices, techniques and technologies at Member State level that have the potential and capability to reduce dependency on pesticide use in the EU. This task was carried out through desk research as well as consultations with technical experts, researchers and advisors with the aim to inventory and assess the identified practices. The overall objective of this task was not to build an exhaustive inventory of practices, techniques and technologies from each Member State as this would lead to a huge number of examples, but rather to develop an inventory that would inspire the users. The outcome of this task is thus an inventory of useful inspirational practices and promising technologies for the future, building on the eight principles of IPM as listed under Annex III of the SUD. As a final step, the content of this inventory was fed into the EU-wide database (see Chapter 4).

The inventory was composed of two parts. First, starting from the eight IPM principles, a generic list of practices, techniques and technologies was developed, presented and assessed against a list of criteria:

- Name of the measure;
- Overall description of the measure;
- Crops on which the measure can be applied;

- Target (weed, pest, disease, others);
- Current level of implementation (research/testing or used);
- Potential economic impacts for implementing the measure (cost of implementation);
- Potential impacts on crop production;
- Potential impacts on the environment (based on expert judgement);
- Potential impact on human health (based on expert judgement);
- Potential reduction of pesticide use (based on expert judgement);
- Potential main drivers of the successful implementation of the measure (legal, technical instruments, guidelines); and
- Long-term sustainability (economic, environmental, and social) of the measure.

Then, the second part of the inventory was composed of practical examples of implementation of these measures at national/regional level.

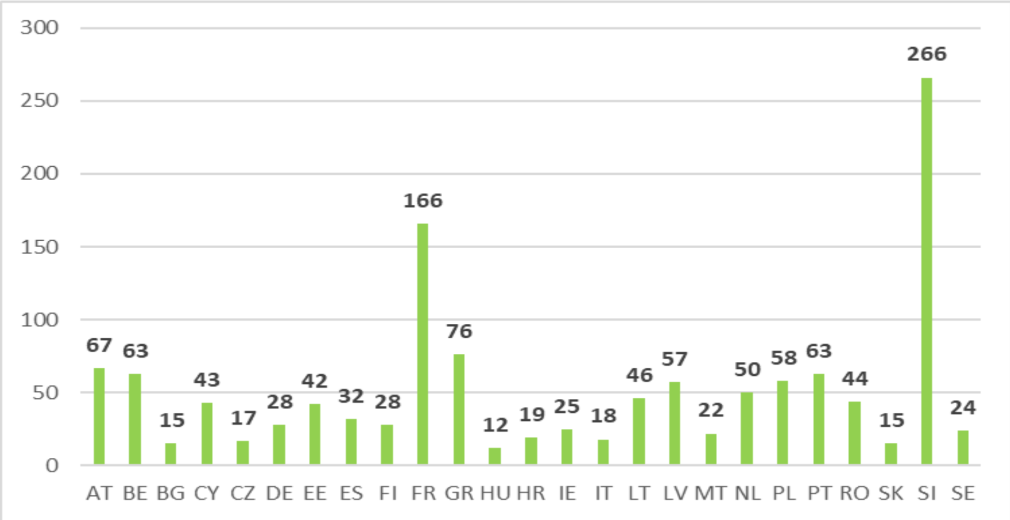
A total of 35 generic practices, techniques and technologies illustrated by about 1300 national examples were gathered in the inventory. The below sections present an overview of the national examples gathered in the inventory.

The graph below shows the identified practices per Member State, indicating that information about over 250 practices was collected in Slovenia, and over 150 practices in France, while a limited amount of information was collected in some countries (HU, IT, HR), with a total of 15-20 practices identified per country. However, it should be noted that this does not necessarily correspond to the level of activities in the field of IPM nor the efforts to reduce pesticide dependency in a specific country.

One crucial factor to consider here is how information about IPM practices and techniques is made available in the Member States and whether the information is easily accessible. Indeed, in both France and Slovenia where most practices were identified, there are national databases in place. In France, this relates to the Ecophytopic[11] database in particular, which gathers numerous practices and techniques as well as detailed fiches about each one of them. In Slovenia, the website IVR[12] includes details and centralised information sorted per crop, including descriptions of examples drafted by experts or advisors. This set-up implies an added value as it provides accessible and trustworthy information to any interested actor and constitutes a good practice that could potentially be implemented in other Member States.

[11] Ecophytopic database, https://ecophytopic.fr/.
[12] IVR website, https://www.ivr.si/.

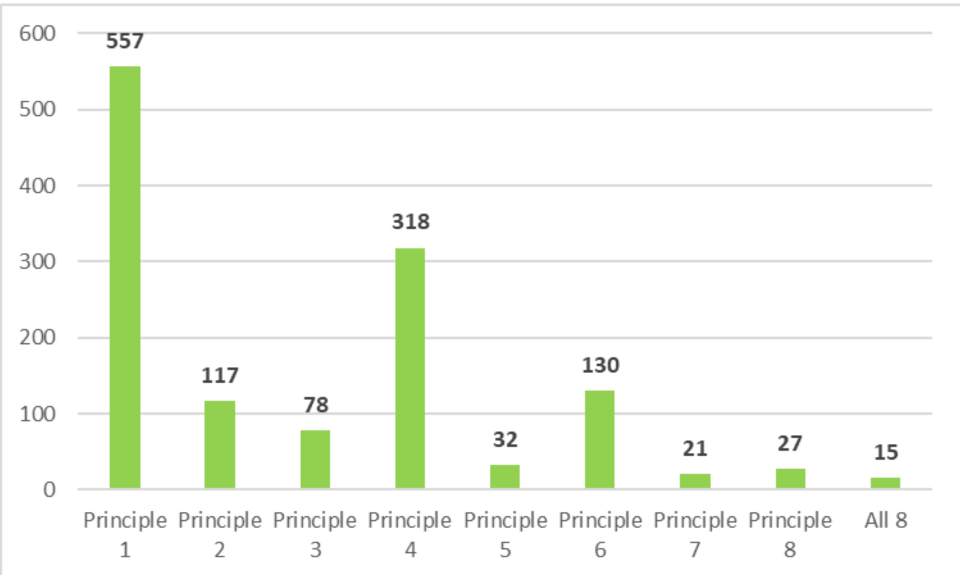
Figure 2: Practices, techniques and technologies identified in the EU Member States



Source: Data collection by the Consortium

As mentioned, practices, techniques and technologies under all eight principles of IPM were collected. The graph below provides an overview of practices per principle, indicating that most practices identified (over 550) were sorted under Principle 1 - Prevention and suppression. Over 300 practices were identified under Principle 4 - Biological, physical and other non-chemical methods, and more than 100 under Principle 6 - Reduced pesticide use. Principles 5 (Pesticide selection), 7 (Anti-resistance strategies), and 8 (Evaluation) had the fewest practices identified. In addition, a few practices were said to cover all eight principles.

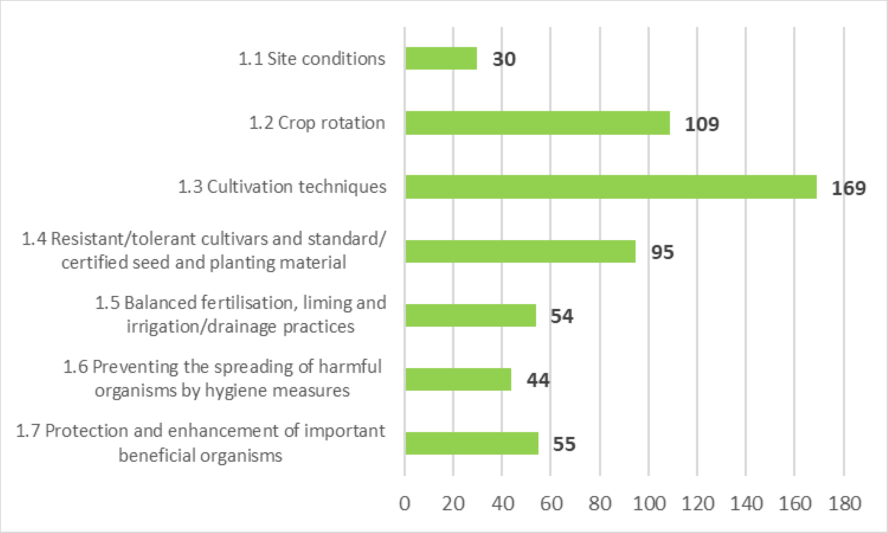
Figure 3: Practices, techniques and technologies identified per IPM principle



Source: Data collection by the Consortium

Figure 3 further outlines the number of practices identified under the sub-principles of Principle 1, with most practices found in 1.3 - Cultivation techniques and 1.2 - Crop rotation.

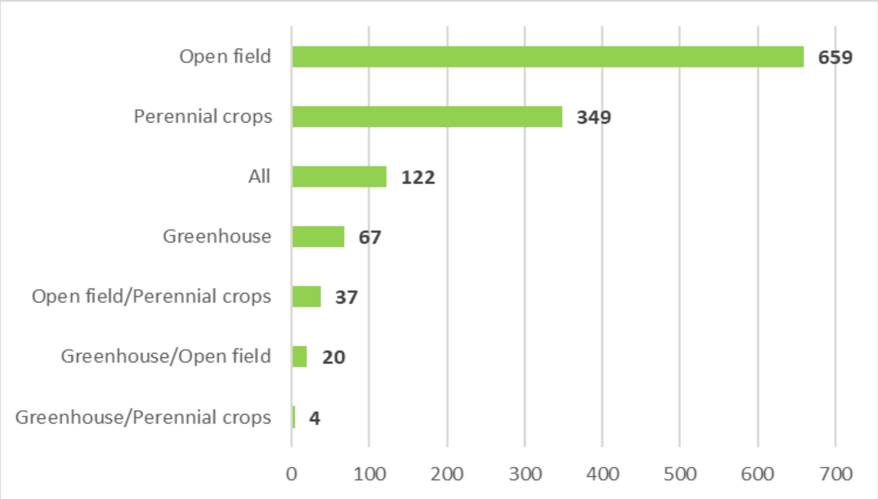
Figure 4: Sub-principles under Principle 1 – Prevention and suppression



Source: Data collection by the Consortium

Information was also collected as regards relevant production types for the practices or technologies identified. Three alternatives were provided to the national experts for this assessment: open field (annual crops); permanent crops and greenhouse productions. However, in some cases national experts indicated that all these production types, or a combination of them, were relevant. In some cases, no information was provided. As can be seen in the graph below, most practices were identified for open field cultivations (659), while less practices were identified for permanent crops (349) and greenhouse production (67).

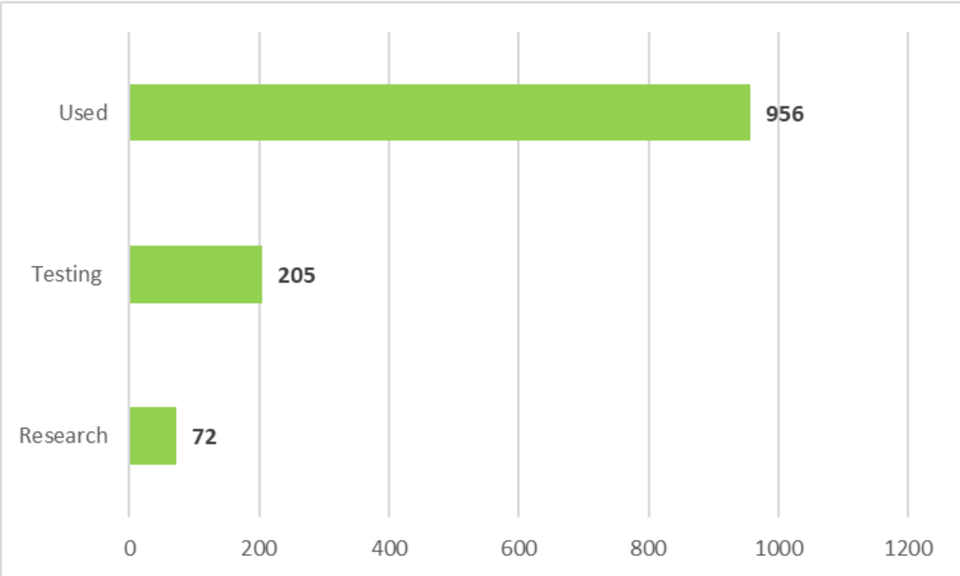
Figure 5: Practices identified per production type



Source: Data collection by the Consortium

Furthermore, national experts were asked to understand the level of development for the practices and technologies identified. Also here, three alternatives were given for the assessment, including research, testing and used/in use. For some practices no information was provided. As clearly demonstrated by the graph below, the majority of practices can be classified as used/in use (956), while about 205 were sorted under testing, and 72 under research.

Figure 6: Level of development of identified practices, techniques and technologies



Source: Data collection by the Consortium

As mentioned, the preliminary inventory presented above fed the EU-wide database developed in the context of the Pilot Project. It was agreed with the Steering Group during the inception phase of the Pilot Project, that the database should be inspirational rather than exhaustive in term of number of practices, techniques and technologies.

3.1.3 Inventory of crop-specific guidelines

In addition to the inventory of practices, an inventory gathering information on crop- and sector-specific guidelines was developed. This inventory had the objective of identifying and gathering the guidelines in place in the Member States as referred to in Article 14(5) of the SUD Directive. These guidelines are further discussed and analysed in Section 3.1.5 in relation to Member State activities to ensure uptake of IPM at farmer level. The paragraphs below provide an overview of existing guidelines and what they entail, as well as an assessment of these guidelines, resulting from the inventory.

Since there is no specific definition established for the sector- and crop-specific guidelines mentioned in Article 14(5), the nature of the documents developed in the Member States differs considerably and this resulted in some difficulties concerning the identification of relevant documents. Some National Competent Authorities (NCAs) consulted about the guidelines could not provide clear information and others were not sure about what documents were referred to. Answering to what crop-specific guidelines regarding IPM exist at Member State level, and what they entail, proved to be a rather complex question with a variety of different answers.

The inventory of guidelines includes and describes the documents identified per Member State, as well as related information such as coverage of crops, coverage of IPM principles, target audience of the guidelines, whether they include any obligations for farmers, and whether they are used by authorities for control. The inventory of guidelines was fed into the EU-wide database which enables the consultation of the information related to these guidelines as well as links to the relevant documents when available online.

Overview of guidelines

In several Member States, the guidelines identified cover various crops, generally of main importance to the agricultural sector of the country. However, the total amount of crops/guidelines differs. For example, in Sweden, the guidelines cover 10 different crops, while Latvia’s guidelines cover 26 different crops. Croatia and Belgium have elaborated guidelines covering rather production sectors than specific crops, including arable farming, fruit growing, vegetable production, etc. In most Member States, the guidelines have the aim to provide guidance to farmers, however, in some countries, they are used also for control of IPM implementation by authorities. This is the case in Belgium for example, where different regional guidelines have been developed for Wallonia and Flanders, providing both guidance for the farmers, as well as one part used for verification and control. The Wallonian context and guidelines are further analysed in one of the case studies (see Chapter 4). In Slovakia, IPM guidelines exist only as a part of the Rural Development Plan (RDP) 2014-2020 covering the fruit and vegetable sector and viticulture. These guidelines focusing on the fruit sector are a condition for subsidies as a part of the agri-environmental climate measures linked to integrated production. In addition to these guidelines, one crop-specific guideline for maize has been developed and others are under development. In Germany, existing guidelines are divided into two parts, where the first one covers overarching areas (preventive measures, natural control mechanisms, decision-making aids, etc.), and a second part provides guidance in relation to specific pests.

In the Netherlands, Romania and Luxemburg, no officially approved guidelines were identified. However, this does not mean that cropping IPM guidance is not available in these countries, as in several (if not all) EU Member States a variety of public and private guidelines and guidance, often referred to as cropping guidelines co-exist with the officially approved/official crop-specific guidelines in the context of Article 14(5) of the SUD Directive.

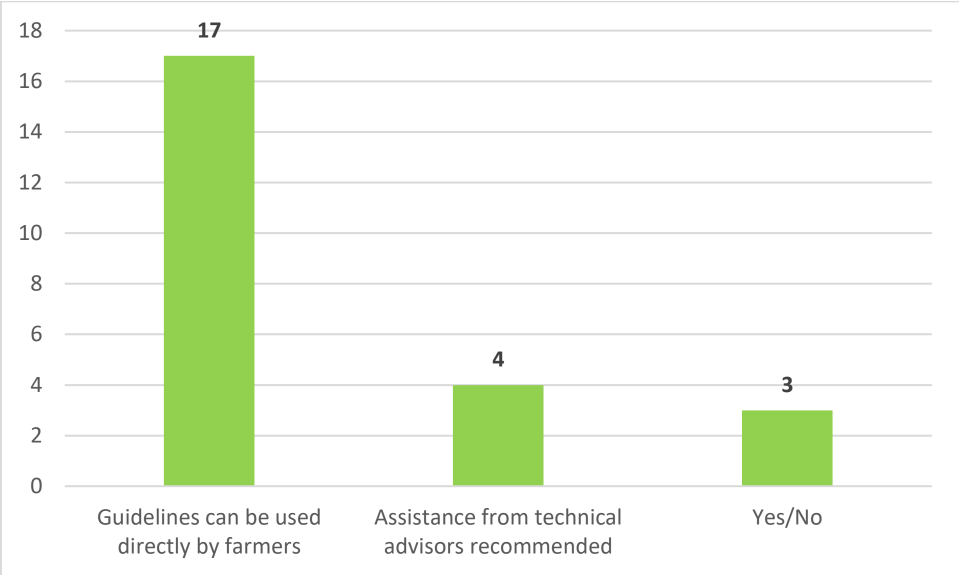
In France, four national crop specific guidelines per group of crops have been developed (fruits, vegetables, tropical crops, polyculture farming) and loaded on the ECOPHYTO website. The main specificity of these guidelines is to provide generic information and to indicate the readers that more information must be consulted to be able to understand what to do at farm level. Therefore, these guidelines are linked to national, regional, and local cropping guidelines developed by public and private organisations (e.g. technical institutes, chambers of agriculture). The initial idea was to develop additional crop specific guidelines to cover the remaining sectors, but this work has not been completed as the guidelines have not shown any significant added value and were not largely used by farmers. The technical information included in these national documents was perceived as too generic and not adapted to any specific local use. In addition, these guidelines are not including any regulatory obligation.

Assessment of guidelines

A total of 24 EU Member States are considered in the below sections (i.e. all EU MS except NL, RO, and LU).

One important point that has been assessed is the **target audience of the crop-specific guidelines, and whether the guidelines can be used by farmers directly**, i.e. without the support of technical advisors. Indeed, as the graph below shows, for the majority of the guidelines this was the case, even though it was often suggested that the support from advisors may provide added value. In some Member States, assistance from technical advisors was recommended. As regards the "Yes/No" in the below graph, this refers to three specific countries including Poland, Belgium and Italy. In Poland, there are guidelines in place targeting farmers, as well as other guidelines targeting advisors. Furthermore, in Belgium, there are parts of the guidelines directed to the farmers and other parts used for inspections. Similarly, in Italy, the national general guidelines are not specific enough to be applied by farmers, while the regional guidelines are.

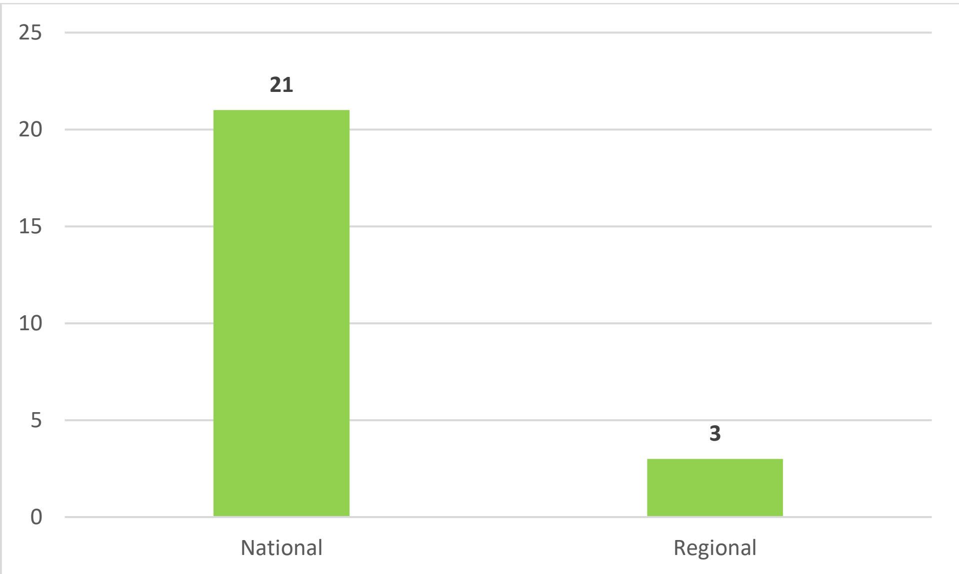
Figure 7: Direct use by farmers



Source: Data collection by the Consortium

The graph below provides an overview of whether the crop-specific guidelines have been developed at national or regional level. While only Belgium, Italy and Greece have elaborated the guidelines at regional level, the majority of Member States have developed guidelines at national level. In the case of Italy, a first general guideline has been developed at national level, and then more specific versions at the regional level.

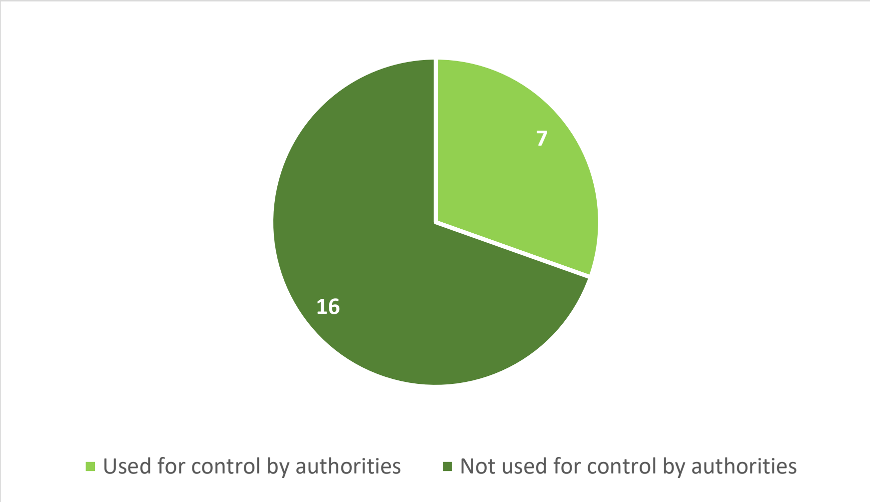
Figure 8: Development of guidelines



Source: Data collection by the Consortium

Another point of interest is **whether guidelines are used for control by national authorities.** As shown by the below graph, some Member States use the guidelines for official control of IPM implementation, while 16 Member States do not. However, in several of these countries, the guidelines can be used by inspectors as a support tool even though they have other check lists or guidance documents for control. Please note that Bulgaria has not been considered in the below graph as inconsistent information was provided by interviewees.

Figure 9: Guidelines used for control by authorities



Source: Data collection by the Consortium

Please consult Section 3.1.5 of this report for further information on the guidelines, as well as the EU-wide database.

3.1.4 Data trends on the use of pesticides (low-risk pesticides excluded)

The following section presents information on trends on pesticide sales and pesticide use over the course of the last 10 years. It is mostly based on official statistics from Eurostat (on pesticide sales) and national statistics (on pesticide use). As the analysis below illustrates, data on the annual use of pesticides is patchy. Although there is an EU Regulation[13] requiring Member States to report on pesticide use, national authorities are free to choose the sample of products they focus on for the data collection. Consequently, data on pesticide use is not comparable across EU Member States. However, data on pesticide sales are arguably a good proxy for the actual amount of pesticides used. As an economic operator, it is in the best interest of farmers to be as efficient as possible in their purchases of pesticides. This implies that the amount of pesticides sold is closely correlated to the actual use of pesticides over a 2-3-year period.

[13] Regulation (EC) No 1185/2009 of the European Parliament and of the Council of 25 November 2009 concerning statistics on pesticides (Text with EEA relevance).

This section starts to present trends in the number of active substances available over the course of the last ten years. Following this, trends on pesticide sales and pesticide use by Member State are presented.

3.1.4.1 Trends on the number of approved active substances

Plant protection products (PPP) are commercial products that contain one or more active substances protecting vegetation from harmful organisms and weeds. Active substances, building the basis of PPP, are the active component that affects the harmful organisms and weeds. New PPPs are authorised at Member State level, while active substances are approved at EU level.

In the EU, the placing on the market of PPP is regulated by Regulation (EC) No 1107/2009. Directive 2009/128/EC regulates the sustainable use of pesticides. In parallel to the legislative process that led to the introduction of Regulation (EC) No 1107/2009, The European Food Safety Authority was mandated to re-assess the active substances available on the market at that time. In the wake of this re-assessment, a large proportion of available substances was deemed unsafe for use. Since the implementation of the legislation from 2011 onwards, the number of available active substances has not significantly changed.[14]

Table 1: Total number of approved active substances cumulated

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Active substances	427	432	443	467	483	490	494	484	487*		454
of which were low-risk substances	---	---	---	---	3	7	11	14	18	24	33

*Source: European Commission[15] *September 2019[16]*

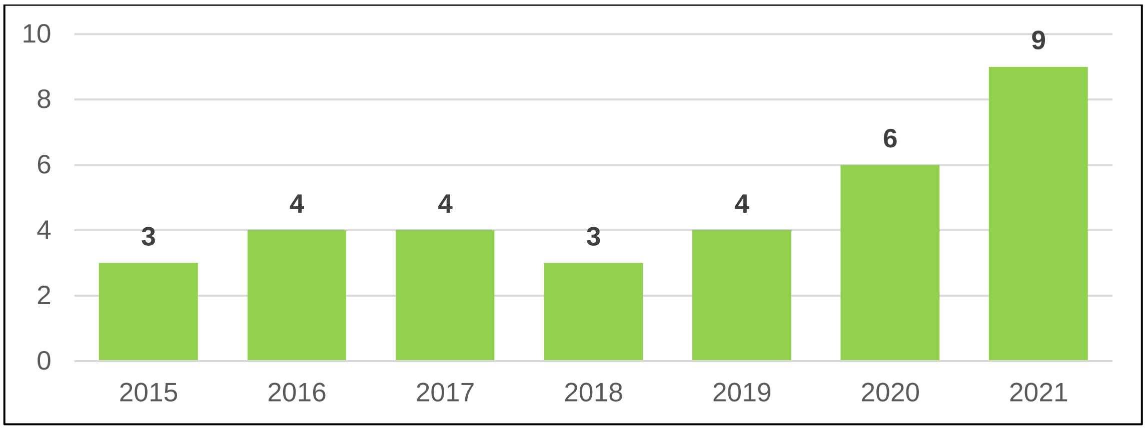
3.1.4.2 Trends on the number of approved low-risk substances

The concept of low-risk active substances was introduced in the Regulation in 2009[17]. Approval periods for low-risk active substances are longer as they are deemed to present a low environmental and health risk. While the concept was introduced in 2009, work on the definition of low-risk substances continued in the following years. Therefore, only from 2015 onwards, substances have been approved as low risk. Since then, an average of four new low-risk substances have been approved per year (see figure below). By April 2021, 26 were the

[14] European Commission, Study supporting the REFIT Evaluation of the EU legislation on plant protection products and pesticides residues (Regulation (EC) No 1107/2009 and Regulation (EC) No 396/2005) (2018)
[15] Commission Staff Working Document SWD(2020) 87 final.
[16] Special Report: Sustainable use of plant protection products: limited progress in measuring and reducing risks. European Court of Auditors 2020.
[17] Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC.

low-risk substances approved, accounting for 6.8% of the total and showing a modest progress of 3% compared to September 2019 (16)[18].

Figure 10: Number of new approved low-risk substances per year (2015-2021)



Source: European Commission

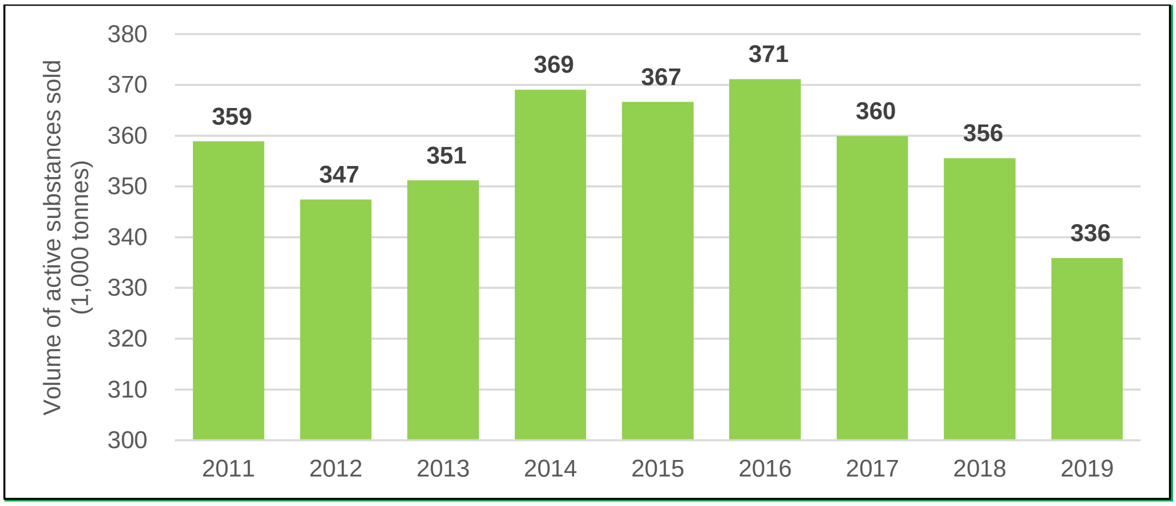
3.1.4.3 Volume of pesticides sales in the EU

Regulation (EC) No 1185/2009 stipulates the collection of data on pesticides placed on the market in the EU. Therefore, data on the volume of active substances sold per year is collected by the EU (Eurostat) for the EU-27MS. For reasons of accessibility, the following text speaks of pesticides sales, even though sales of active substances would be more appropriate.

Pesticide sales in the EU have been increasing throughout the first half of the last decade. In 2011, a total of 359 thousand tonnes were sold in the EU-27. After a drop of sales in 2012,[19] sales increased to some 371 thousand tonnes by 2016. Since then, total sales have decreased by about 10% to almost 336 thousand tonnes in 2019.

[18] Special Report: Sustainable use of plant protection products: limited progress in measuring and reducing risks. European Court of Auditors 2020.
[19] Note that data is missing for Bulgaria (2011) and Croatia (2011 and 2012).

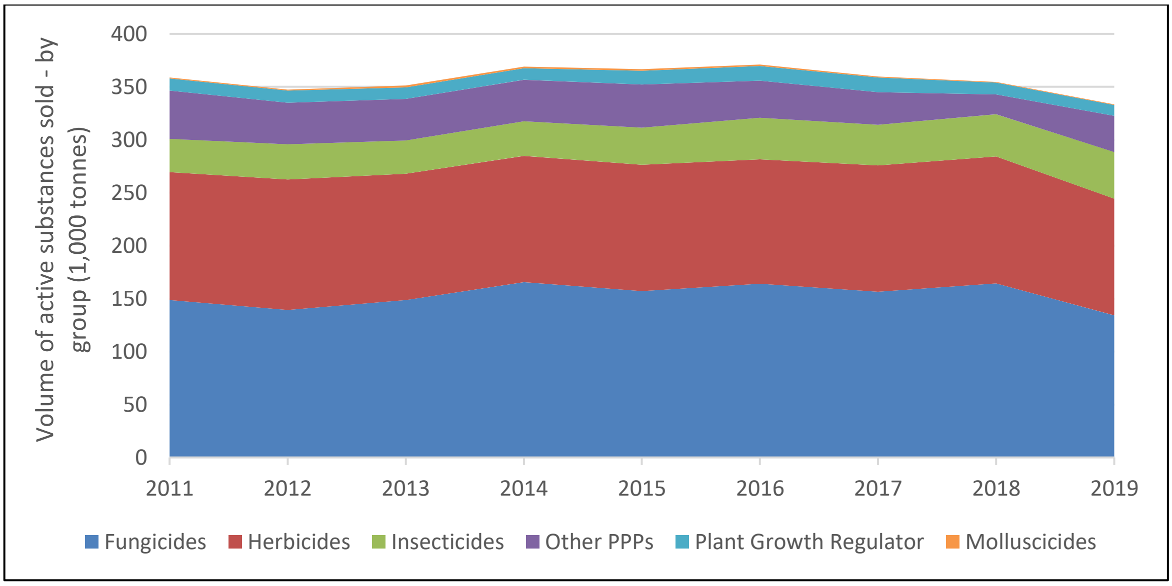
Figure 11: Evolution of pesticide sales over the last 10 years in the EU



Source: European Commission

Between 2011 and 2019, the distribution of sales of active substances across different groups stayed very stable. Fungicides account for the largest share, approx. 43%, of annual sales of pesticides. Herbicides account for another 33% of annual sales, meaning that the two groups of pesticides account for about three quarter of total sales (expressed in volume of active substance sold). Insecticides (10% of annual sales) and other products (excluding plant growth regulators and molluscicides) account for the remaining share of annual pesticides sales.

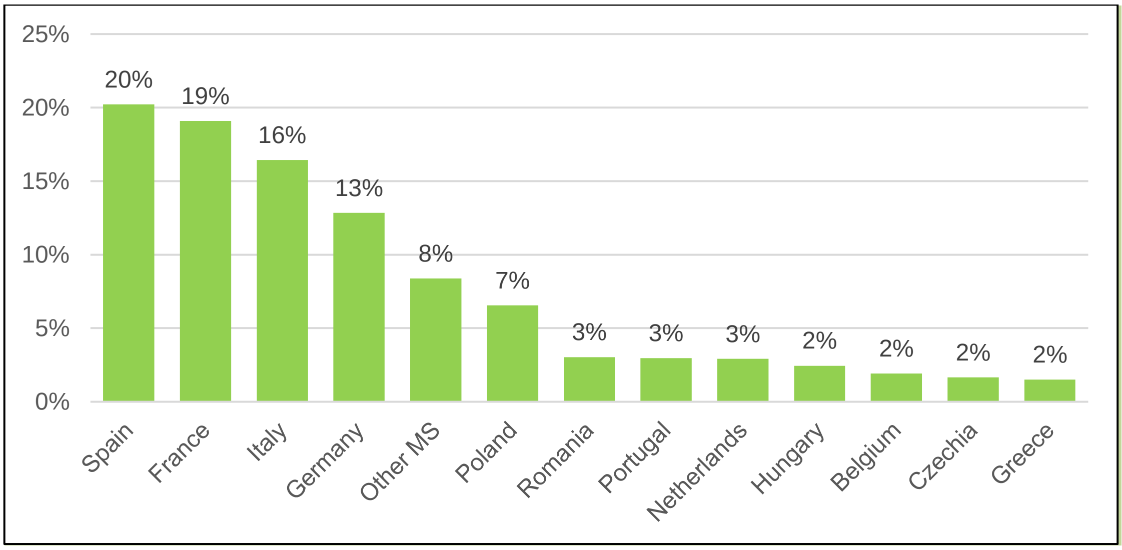
Figure 12: Evolution of pesticides sales by group over the last 10 years in the EU



Source: European Commission

Across the years explored, Spain (annual average 20%), France (19%), Italy (16%) and Germany (13%) account for the largest shares of pesticides sales in the EU-27, followed by Poland (7%). Across time, ten Member States show an increase in pesticide sales throughout the period. In 15 Member States, pesticide sales have decreased throughout the decade. The largest decrease can be observed in Denmark (42%), followed by Italy (31%) and Portugal (30%).

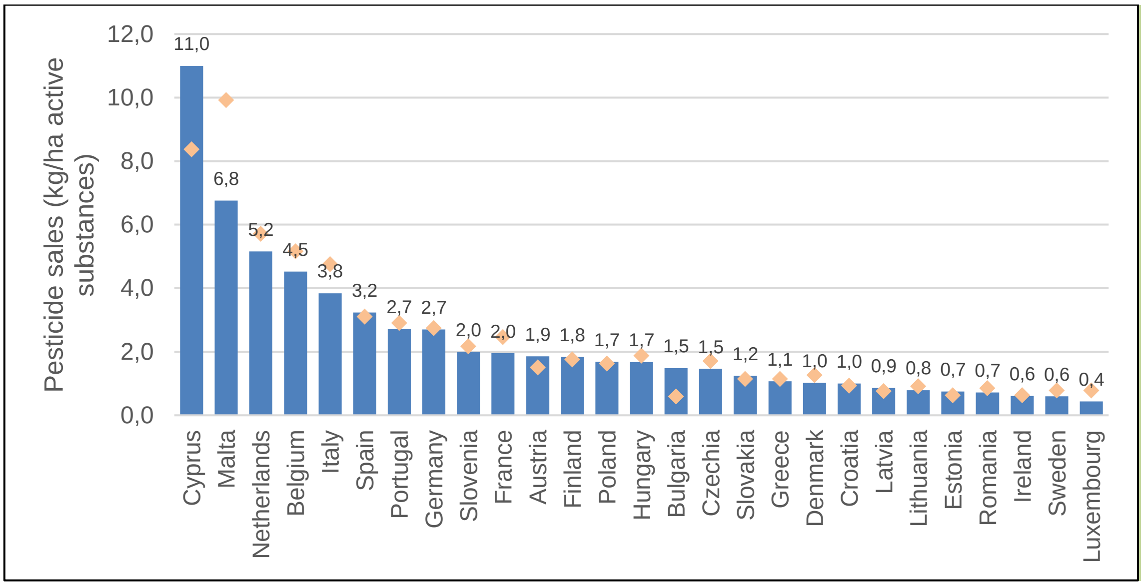
Figure 13: Pesticides sales per Member State as share of overall sales in EU-27 (average 2011 to 2019)



Source: Eurostat

Annual pesticides sales in the EU amount to about 2.3kg/ha of active substance. This value has remained very stable over the course of the years, only ranging between 2.4kg/ha of active substance in 2016 and 2.1kg/ha in 2019. The on average highest sales per hectares UAA can be found in Malta (average of 9.9kg/ha between 2011 and 2019), followed by Cyprus (8.4kg/ha) and the Netherlands (5.7kg/ha). The lowest sales per UAA can be observed in Bulgaria, Estonia, and Ireland (all 0.6kg/ha). The figure below reports on the sales of pesticides per UAA in 2019 (blue columns) in comparison to the average sale per UAA over the period from 2011 to 2019 (yellow diamonds).

Figure 14: Pesticides sales (kg/ha active substances)



Source: European Commission

Table 2: Total pesticide use in tons

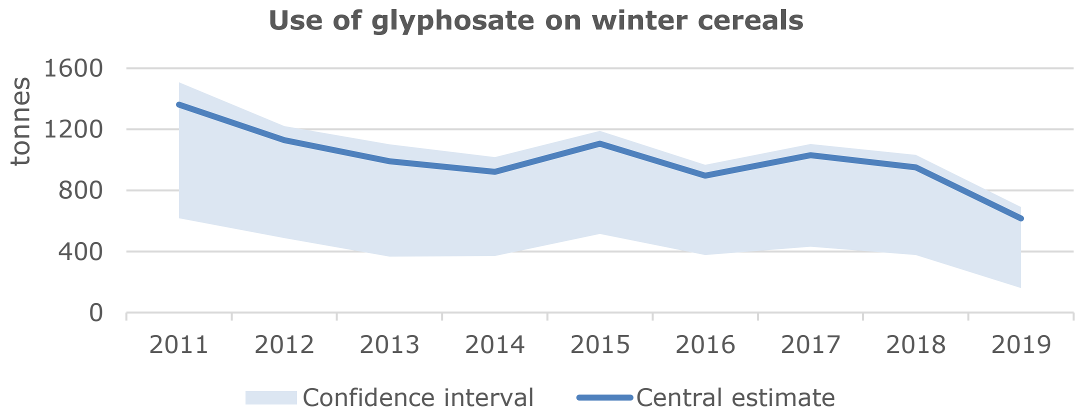
MS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BE	-	-	-	-	-	-	-	419	-	-
CZ	-	-	-	-	-	-	-	-	-	262
EE	-	-	-	-	2	4	-	-	-	-
IE	-	24	1,137	597	9	-	-	405	-	-
EL	-	-	-	-	27	-	-	-	-	1,242
FR	-	166	-	-	-	-	-	54	-	-
HR	-	-	-	-	-	-	-	-	-	812
IT	19,078	600	-	-	-	24,633	16,031	-	-	-
LV	-	-	-	-	30	-	-	-	-	-
LT	-	-	-	-	55	-	-	-	155	-
LU	-	-	-	-	-	-	-	-	-	-
HU	-	-	-	-	1,172	-	-	-	-	1,023
MT	-	-	-	-	34	-	-	-	-	-
NL	-	-	1,540	-	-	-	1,421	-	-	-
PT	-	-	858	5,928	-	-	-	3,688	-	-
RO	-	-	-	9,286	-	-	-	-	1,028	-
SI	-	-	-	-	134	-	-	26	-	-
SK	-	-	-	-	94	-	-	-	15	-

Source: Eurostat

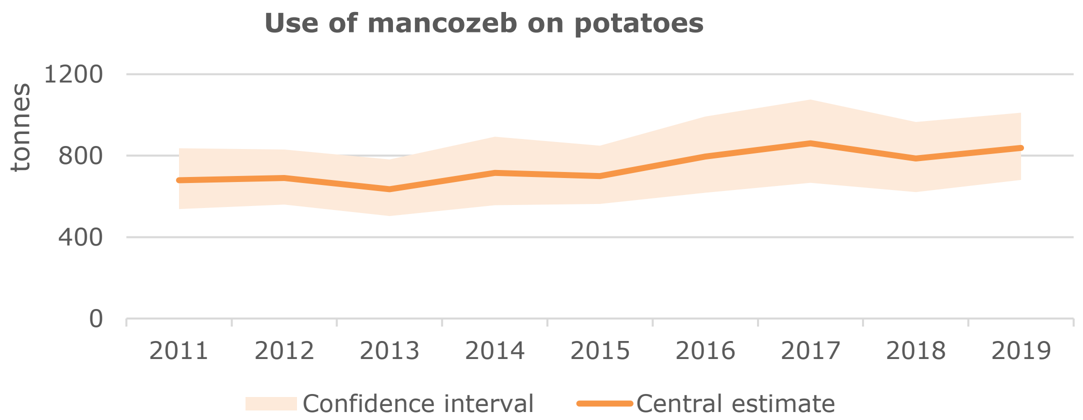
National statistics usually provide more detail. For example, while Eurostat provides estimates of pesticide use for certain crops for Germany only for those years in which Germany reports to the EU under the Regulation, national statistics contain time series for all years since 2011.

Box 1: Country Example - Germany

In Germany, the Julius-Kuehn Institute (JKI) has monitored the actual use of pesticide in agriculture since 2000. With the changes in the EU legislation, the research institute created the PAPA project ("Panel Pflanzenschutzmittel-Anwendungen") and collects data in line with the EU wide requirements since 2011.[20] For several crops, namely winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, and vine, the institute collects data from a sample of farmers. In the selection of farms, the institute factors in considerations of representativeness, e.g., with regards to regional distribution. For each crop, the institute collects information from at least 100 different farms (80 for hops).[21] Farmers that agree to cooperate collect the data themselves and transmit the information to JKI. Based on this information, the research institute extrapolate data on the use for each crop to the country level. Estimates are reported annually, by crop and by active substance. The institute does not report overall estimates by type of use, pesticide use overall, or by area.



Source: Compiled by Ecorys



Source: Compiled by Ecorys

As the JKI acknowledges itself, the extrapolations to country level based on data from reporting farms might under- or overestimate the actual amount of pesticides used. Therefore, JKI also provide upper and lower bounds (confidence intervals with a

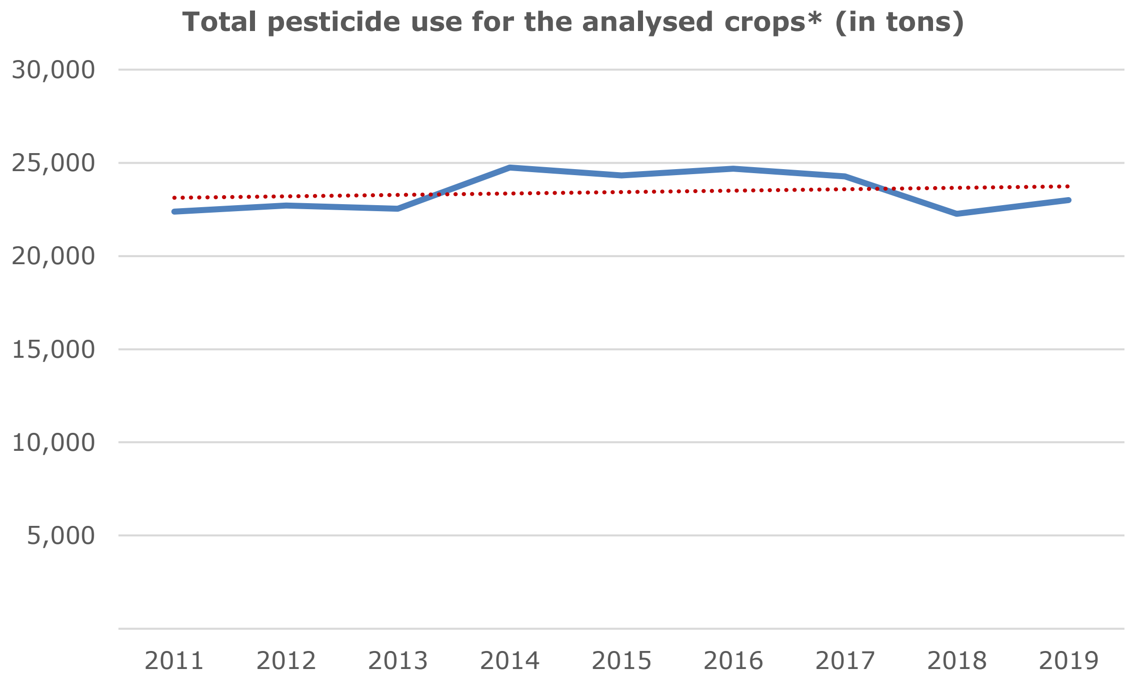
[20] Julius Kuehn Institute, Panel Pflanzenschutzmittel-Anwendungen. https://papa.julius-kuehn.de/.
[21] Julius Kuehn Institute, Panel Pflanzenschutzmittel-Anwendungen https://papa.julius-kuehn.de/index.php?menuid=38.

probability of 97.5% to contain the actual amount of active substance used). These upper and lower boundaries can be large, as the two examples provided above show.

The analysis of available data on pesticide use in Germany focusses on nine specific crops (winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, and vine) which represent around 39% of Germany's utilised agricultural area (UAA)[22]. It covers six main categories of pesticides, namely fungicides, herbicides, insecticides/acaricides, growth regulators, pheromones and molluscicides.

Between 2011 and 2019, pesticide use for the analysed crops slightly increased in Germany from 22,400 tons in 2011 to 23,000 tons in 2019 (+2.7%). However, the progression of pesticide use was not linear during this period. Use increased between 2013 and 2014 by about 10%. After a short period between 2014 and 2016, during which pesticide use remained at similar levels, pesticide use declined to a similar level to 2011, before increasing again from 2018 onwards.

The overall upward trend (see red dotted line below) of pesticide use between 2011 and 2019 aggregates disparities among the types of crops analysed. For hops (+39%), vine (+24%) winter barley (+23%), corn (+21%) and potatoes (+19%), the use of pesticides increased the most over the period covered. Contrary to this, winter rape (-33%), winter wheat (-9%) and sugar beet (-2%) crops saw a decrease in the use of pesticides during the period.



**The analysed crops are: winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, and vine.*

Source: Compiled by Ecorys based on data from PAPA[23]

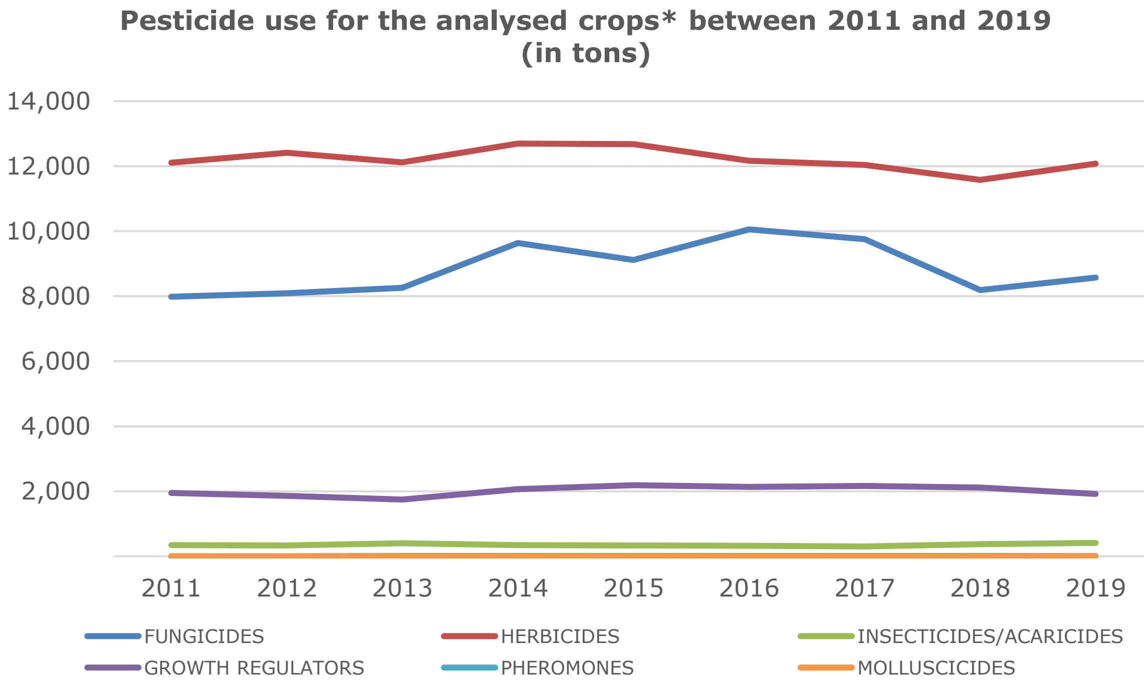
Pesticide use for the nine analysed crops is broken down into several categories. Fungicides and herbicides are the two most used categories of pesticides with levels

[22] Based on data from Eurostat and DESTATIS.
[23] Panel Pflanzenschutzmittel-Anwendungen, https://papa.julius-kuehn.de/index.php?menuid=33.

around 12,000 tonnes per year for herbicides and between 8,000 and 10,000 tonnes per year for fungicides. Among the most used active substances, schwefel represents 15 to 19% of the total amount of fungicides used each year and glyphosate 19% to 27% of herbicides. Between 2013 and 2016, the use of glyphosate drives the variations in herbicide use.

Growth regulator use remains over the period 2011-2019 around 2 000 tonnes per year, with chlomequat representing 72% to 83% of the active substances applied. Insecticides/acaricides use is around 350 tonnes per year while molluscicides and pheromones use levels remain below 100 tonnes per year[24].

The increase by 10% of pesticide use observed between 2013 and 2014 can mainly be attributed to the increased use of two categories of pesticides: fungicides and herbicides. During this period, fungicide used for the analysed crops increased by 16.5%, and herbicides by 5%. Similarly, the decrease in pesticide use coincides with the decrease of fungicide use between 2016 and 2018.



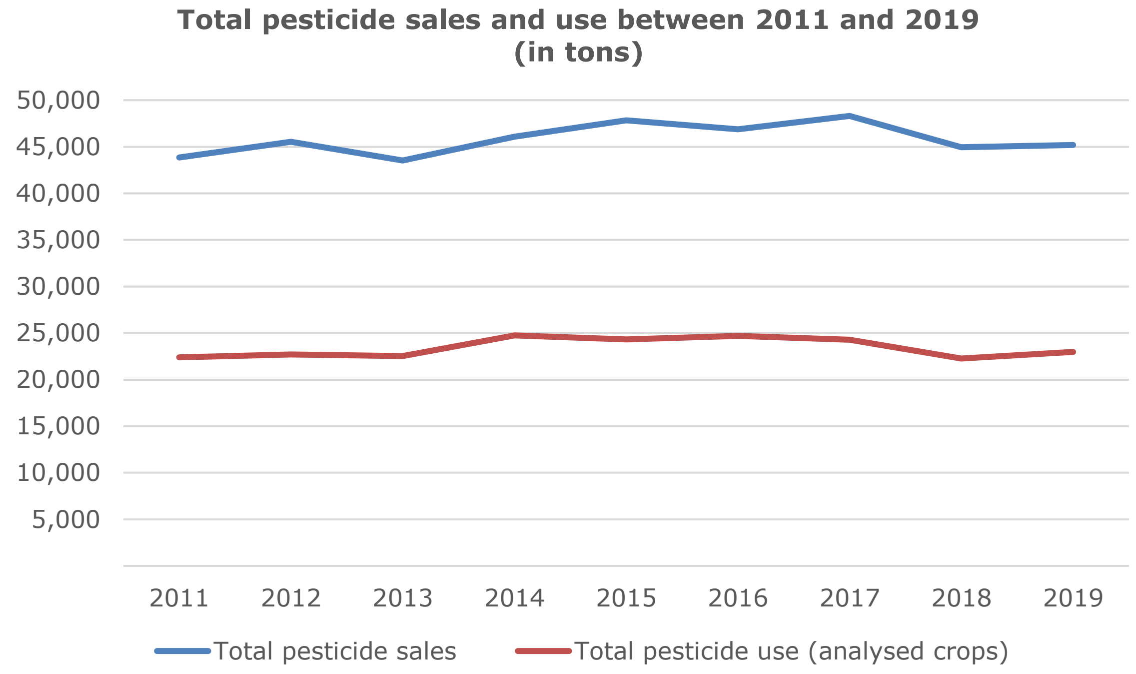
**The analysed crops are: winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, and vine.*

Source: Compiled by Ecorys based on data from PAPA[25]

On average, the annual pesticide use amounts analysed for the nine crops in Germany represents 51% of the annual pesticides sales data for Germany. However, this number encompasses heterogeneities amounf the different categories of pesticides: amounts of fungicides, herbicides and growth regulators used represent more than 70% of their respective sales, while amounts of insecticides/acaricides used only represent 3% of the sales.

[24] This is partly explained by the lack of available data on molluscicide use between 2011 and 2018.
[25] Panel Pflanzenschutzmittel-Anwendungen, https://papa.julius-kuehn.de/index.php?menuid=33.

The comparison between the data on pesticide use for the nine specific crops and the total amount of pesticide sales for agricultural use in Germany reveals overall a positive correlation between pesticide sales and use with a correlation coefficient of 0.8. Although this correlation is not perfect, similar trends between pesticides sales and use can be observed with an increase for both dataset starting from 2013 and a decrease between 2016 and 2018. This analysis suggests that pesticide sales can be used as a proxy to estimate pesticide use. However, this should be corroborated by future research with larger datasets. As highlighted in the European Commission's report on the implementation of Regulation (EC) No 1185/2009, other elements also need to be considered as pesticides sales do not necessarily reflect pesticide use in a systematic manner. The location of pesticides sales may not be utlimately the location where it is applied as pesticides can be sold directly by retail sellers in neighbouring countries.[26]



Note: Data on pesticide sales reflect the total amount of pesticides sold in Germany for agricultural use. Data on pesticide use only reflect the amount of pesticides used for the nine crops analysed for this analysis, namely winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, and vine.

Source: Compiled by Ecorys

While reporting requirements are the same across countries in terms of unit of measurement and reporting format (by type of active substances, i.e. fungicides, herbicides, etc.), the methodologies employed and the indicators to measure pesticide use are not. The methodologies that the EU Member States have developed differ on a variety of aspects, which render a comparison of

[26] European Commission (2017), Report on the implementation of Regulation (EC) No 1185/2009 of the European Parliament and of the Council of 25 November 2009 concerning statistics on pesticides.

results (almost) impossible. For example, the methodologies differ with regards to:

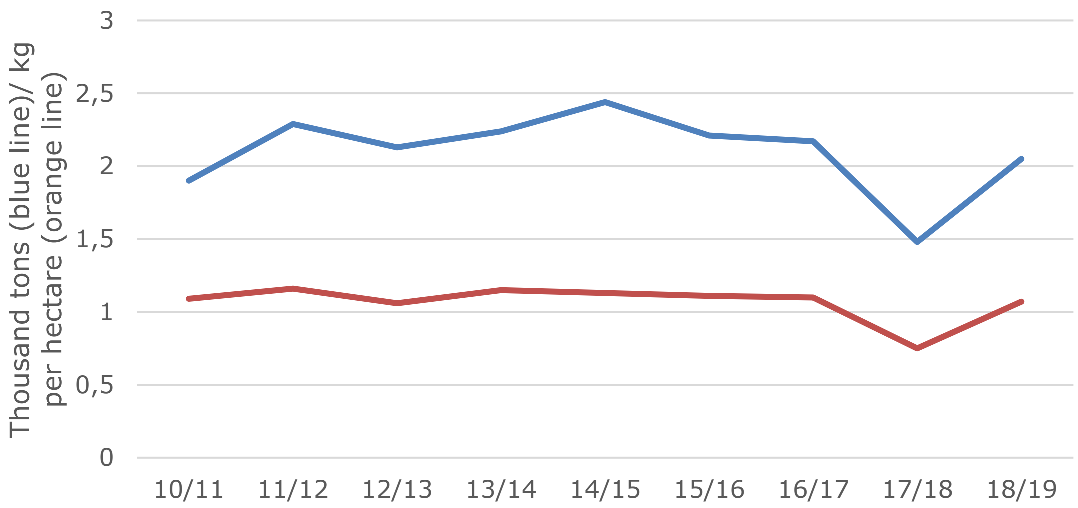
- Overall approach employed. In some Member States, representative sample farms are selected to collect data, while in other surveys are sent out and data collection is based on those farmers who share their information. In at least one country (Denmark, see below), farmers are legally obliged to provide data on pesticide use to the Ministry of the Environment.
- Indicator to measure pesticide use. E.g., NODU and TFI in France vs Pesticide Load Indicator and TFI in DK.
- Time coverage. In some countries, data is collected each year, resulting in time-series for all years from 2011 to 2019/20. In some other Member States, data collection occurs only in select years.
- **Reporting time period**. In several Member States, pesticide use is calculated for a growing season (e.g. from August to July of next year), while other countries seem to report data per calendar year.
- **Level of aggregation**. Some Member State statistics provide detailed information of pesticide use by active substance, while other Member States report on the type of use (herbicide, insecticide, etc.). At the same time, some of the Member States, which provide a very detailed breakdown of pesticides used do not provide estimates for the amount of active substances used overall.
- **Crop coverage**. Finally, each Member State selects the crops for which data are collected. Usually, Member States select the main crops grown in their countries. However, these differ of course due to many (climatic and economic) factors. At least in one country (Latvia), there are two different groups of crops for which data on pesticide use are collected alternatingly.

Box 2: Country Example - Denmark

Since 2011, farmers in Denmark are required to maintain spray logs, recording the actual use of pesticides. The farmers are required to maintain these spray logs for each planning period (running from August until July of the following year) and report data on pesticide use to the national Ministry of the Environment. The ministry compiles and reports on the data in annual reports.[27] These reports provide annual estimates of the overall amount of pesticides used (expressed in millions of kg of active substances applied). The reports further provide data on the usage of active substances per area (kg per hectare) overall, as well as broken down by its purpose (insecticide, herbicide, etc.). Similarly, use data in terms of amount of active substance per hectare is further provided for several important crops, notably cereals (winter and spring seeds), rapeseed, other seed crops, potatoes, beets, legumes,

[27] https://eng.mst.dk/chemicals/pesticides/pesticides-statistics/agriculture-etc/.

corn, and vegetables. The figure reports annual usage of pesticides in absolute and relative terms for the last nine years.



Source: Compiled by Ecorys

The estimates of the use of pesticides reported by the Danish government are not complete, e.g., because of exemptions from the reporting requirement for small farms, and no complete capturing of the use data for all crops and uses. Yet, for the main crops mentioned above, completeness of data has improved over years. Whereas in 2010/11 the estimate captured pesticide use for an average of 78% of the total area on which these crops are grown conventionally, this share increased to 95% in 2018/19. The table below provides the area (in million hectares) of arable land in Denmark in total and the area captured by the reporting requirement for Danish farmers.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Arable land (total)	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2
Arable land (captured by reporting)	1.4	1.9	1.9	1.9	2.2	2	2	2	1.9

Source: Compiled by Ecorys

However, a comparison of sales and use is also not possible for these crops, as the timeframe for which data are collected differs for the sales (January to December) and usage statistics (August to July).[28]

From the analysis of interviews and desk research conducted in the context of the Pilot Project, the differences in the methodologies were mapped for a number of Member States. The results of these are presented below. The feedback received in interviews in other Member States suggest that methodologies in the other EU Member States are similarly varied. This leads to

[28] https://www2.mst.dk/Udgiv/publikationer/2021/03/978-87-7038-279-3.pdf.

the conclusion that estimates for the overall amount of pesticides used per Member States will not be available.

Table 3: Pesticide use data set characteristics

MS	Time period	Annual	Overall estimate	Breakdown by types	Methodology employed
BE(FL)	2004-2017	Yes	Yes	No	Extrapolation based on sampling
BE(W)	2011-2018	Yes	Yes	No	Extrapolation based on sampling
CZ	2009 - 2020	Yes	Yes	Type of use	Extrapolation based on sampling
DK	2011 - 2019	Yes	Yes	No	General reporting requirement
DE	2011 - 2019	Yes	No	Type of use	Extrapolation based on sampling
EE	2010-2015, 2020		Yes	No	Extrapolation based on sampling
IE	2011-2017	Yes	No	Type of use	Extrapolation based on sampling
ES	2013, 2019	No	No	Type of use	Extrapolation based on sampling
FR	2011, 2014, 2017	No	No	Type of product	Extrapolation based on sampling
IT	2016, 2017	No	Yes	Type of use	Extrapolation based on sampling
LV	2012,2014, 2017, 2019	No	No	Type of use	Extrapolation based on survey, 2 groups of crops
LT	2014, 2018		Yes	No	
LU	2014/15 - 2018/19	Yes	Yes	Type of use	Extrapolation based on sampling
HU	2014, 2019	No	No	Type of use	Extrapolation based on sampling
NL	2012, 2016	Yes	Yes	Type of product	Extrapolation based on sampling
AT	2012, 2017	No	tbd	Type of use	Extrapolation based on sampling
PL	2015/16-2018/19		No	No	
RO	2013, 2018	No	Yes	Type of product	Extrapolation based on sampling
SI	2017	No	No	Type of use	Extrapolation based on sampling
FI	2013, 2018	Yes	Yes	Type of product	
SE	2010, 2017	Yes	Yes	No	Extrapolation based on sampling

Source: Compiled by the Consortium

Table 4: Pesticide use data set characteristics (crop coverage)

MS	Crops covered
BE	Strawberries, sugar beet, spring wheat, dry peas, sugar chicory, witloof chicory, green beans, grain maize, potatoes, extensive outdoor vegetables, green peas.
CZ	Winter wheat, spring barley, winter barley, field maize, field peas, potatoes, sugar beet, rap, sunflower seeds, poppy, green maize, apples, hops, grapes, legumes, vegetables, fruits.
DK	wheat (winter and summer seeds), rapeseed, other seed crops, potatoes, beets, legumes, corn, and vegetables.
DE	winter wheat, winter barley, winter oilseed rape, potatoes, corn, sugar beet, hops, apples, vine.
EE	cereals, legumes, potatoes, forage crops, industrial crops, open-field vegetables, greenhouse crops, fruits trees and berry bushes, strawberries.
IE	Arable crops (barley, spring and winter wheat, oats, oilseed rape, peas and beans, potatoes), grassland and fodder, vegetables, fruits.
ES	barley, citrus fruits, sunflower, vegetables, olive trees, wheat, grapes.
FR	soft wheat, durum wheat, barley, triticale ,rape, sunflower, protein peas, fodder maize, grain maize, sugar beet, potato , sugar cane.
IT	Durum wheat, barley, oats, grain maze, potato, tomato, vineyard, olive plantation.
LV	Winter wheat, rye, winter barley, winter triticale, summer triticale, summer wheat, summer barley, oats, buckwheat, mistress, winter rape, summer rape, field beans, apples, pears, plums, cherries, raspberries, strawberries, cabbage, beets , carrots, onions, potatoes, maize for silage and forage.
LT	Winter wheat, winter triticale, winter rye, spring wheat, spring barley, rye, triticale, barley, oats, buckwheat, grain maize, dried pulses, sugar beet (for industry), winter rape.
LU	winter wheat, summer wheat, durum wheat, winter rye, barley, summer barley, oats, triticale, rape, potatoes, corn, temporary meadow, permanent meadow, vine.
HU	winter wheat, maize, sunflower, rape, grapes, apples.
NL	Apples, ware potatoes, lilies (bulb), maize, maize for processing, pears, seed potatoes, sugar beet, winter Wheat, tulips open ground, onions for sowing, starch potatoes, tomatoes, carrots, leek, other crops.
AT	Apples, potatoes, corn, rapeseed, soybeans, winter barley, spring barley, vine, winter wheat, spring wheat, sugar beet, oats, oil pumpkin, sunflowers, winter rye, winter triticale.
PL	Cereal, vegetable, permanent crops, other crops, storage.
RO	Fruit trees, vegetable, potatoes, corn grain, sunflower, wheat, vineyard.
SI	cereals (cereals and maize for grain), silage maize, oilseed rape and hops, and orchards and vineyards.
FI	winter wheat, spring wheat, rye, feed barley, malting barley, oats, turnip rape and rape, food and processed food potatoes, sugar beet, fodder grass (pasture

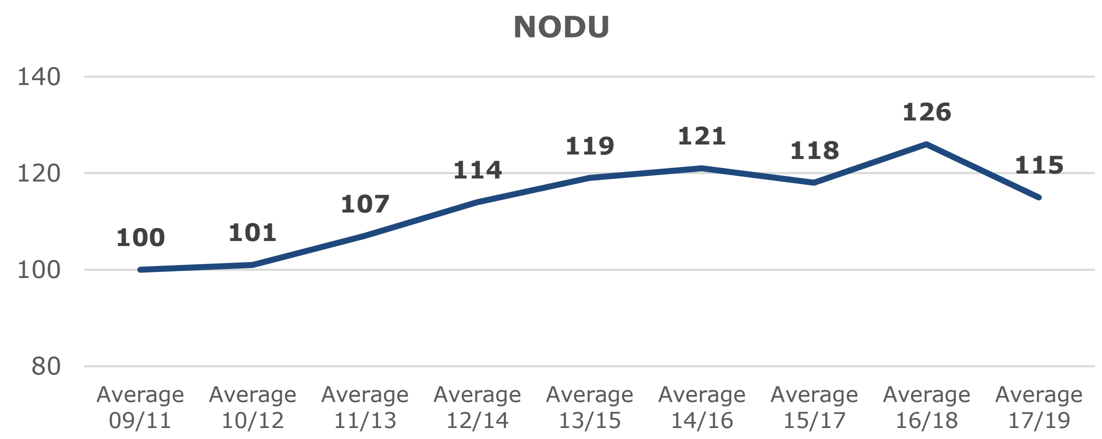
MS	Crops covered
	excluded), broad bean (2018 only), caraway (2018 only), garden pea, white cabbage, carrot, onion, black, red, white and green currants, strawberry, apple.

Source: Compiled by the Consortium

Box 3: Country example - France

In France, the national agency for agricultural statistics[29] distributes surveys to farmers, collecting information on their use of pesticides. Based on the data farmers provide, the agency calculates the treatment frequency index (TFI) for a given crop plot. This indicator counts the number of reference dosages per ha during a given cropping season.[30] Data is collected every three years (2011, 2014, 2017). The TFI is provided for a number of main crops (including e.g. wheat, barley, corn, and potatoes) and by type of use (herbicides vs fungicides vs insecticides vs others).

Data for the calculation of the TFI is also utilised for another indicator, namely the NODU. This indicator expresses the annual "average" number of treatments with pesticides applied to all crops on a national basis. Calculated annually, the NODU is expressed as an index of a three-year average compared to the three-year average of 2009 to 2011. The figure below plots the development of the NODU over the course of the last years, showing an increase of the average number of doses employed. However, this does not necessarily allow a judgement of the amount of pesticides used as it does not include the exact dosages being used.



Overall, while data on sales of pesticides are available at EU level, the information currently available on the actual use remains patchy, incomplete, and difficult to compare across Member States. Efforts are made and increase to provide more exact estimations of pesticide use, and in some countries (e.g. Denmark), data suggests that the estimates are close to the actual amount used. However, the methodologies employed continue to differ among the EU

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29 Ministry of Agriculture, France https://agreste.agriculture.gouv.fr/agreste-web/.
30 Ministry of Agriculture, France https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Chd1903/cd2019-3%20PK%20_%20janvier%202020%20v2.pdf.

Member States, even though the current legislative framework provides already some minimum requirements that Member States need to comply with.

This lack and fragmented data sets on pesticide use is an issue that is addressed in the context of the revision of the statistics on agricultural inputs and outputs (SAIO). In the EU agricultural sector, statistical data are collected in the framework of the European agricultural statistics system (EASS), which includes more than 50 datasets, and consists of ten legal acts and their implementing measures. This system is no longer suited to current needs: it is not very coherent, devoid of harmonisation and does not allow the new data needed to fulfil new requirements to be gathered. Therefore, the EC launched a process in 2018 to modernise the EASS[31]. Under this initiative a new legislative proposal (the SAIO) was released on 2 February 2020. SAIO covers inputs to and outputs of the agricultural sector, with regard to agricultural production (crops and animals) as well as organic farming, plant protection products/pesticides, nutrients and agricultural prices data, with a view improving the quality, comparability and coherence of European agricultural statistics.

In addition, the current EU initiative, in line with the objectives of the CAP, the Green Deal and its Farm to Fork and Biodiversity strategies, aiming at expanding the scope of the current Farm Accountancy Data Network (FADN) network collecting accounting data on EU farms to include data on their environmental and social practices in the so-called Farm Sustainability Data Network (FSDN). Under such new data collection, pesticide use data will be collected at consolidated EU level. Such data set will allow to benchmark farm performance and give farmers tailored advice and guidance on IPM on pesticide use.

3.1.5 Mapping and description of the targets or indicators MS set about a reduced risk of pesticide use and/or IPM implementation

3.1.5.1 Mapping and description of MS targets regarding reduction of risks and impacts of pesticide use

Article 4 (the National Action Plans - NAPs) of the SUD, in its first paragraph, obliges Member States to set up their quantitative objectives, targets, measures and timetables to reduce risks and impacts of pesticide use on human health and the environment. In addition, the same article foresees that the NAPs shall also include indicators to monitor the use of plant protection products containing active substances of particular concerns (paragraph 2) and on the basis of such indicators and considering where applicable the risk or use reduction targets achieved prior to the application of the SUD, timelines and targets for the reduction of use shall be established.

[31] European Commission (2015), Strategy for agricultural statistics for 2020 and beyond, https://ec.europa.eu/eurostat/documents/749240/749310/Strategy+on+agricultural+statistics+Final+version+for+publication.pdf/9c7787ca-0e00-f676-7a64-7f56e74ec813.

The large majority of Member States have inserted qualitative targets in their NAPs while other NAPs remain vague; as summarised in the table below.

Table 5: Qualitative objectives and targets established by MS in the NAPs

MS	Description of the objectives and targets
AT	Generic objectives and targets presented per obligation. Most of them rely on training and inspection of plant protection equipment in use and promotion of the use of the most modern equipment
BE	Not included as Belgium has defined quantitative indicators in its NAP. See below
BG	I. Reducing the risks and impacts of pesticide use on human health and the environment, including: 1 preventive protection of consumers - by reducing pesticide residues in food of plant origin; 2. reducing the risks from the presence of pesticide residues in food intended for children, as the most vulnerable consumer group; 3. preventing and/or reducing the risks of pesticide residues in drinking water and bottled water; 4. protecting professional users, operators and agricultural workers - by reducing exposure to pesticides; 5. protection of residents and bystanders (occasional residents or passers-by) in areas where pesticides are used, by preventing and/or reducing exposure of those persons to pesticides; 6. the protection of the general public and vulnerable populations - by preventing and/or reducing pesticide risks in public spaces and recreational areas; 7. protection of non-professional users using pesticides on private farms, gardens, yards, etc. II. Environmental protection: 1. preventing and/or reducing pesticide contamination of water and soil; 2. preventing and/or reducing the risks of pesticide residues in water sources - surface water and groundwater; 3. preventing and/or reducing the impact of pesticides on biodiversity, with particular attention to bees and other non-target organisms. III. Promote integrated pest management and alternative approaches or methods, including: 1. Development of integrated pest management systems and alternative approaches or methods for plant protection; 2. Introduction of integrated pest management - through information campaigns and by providing incentives, including financial incentives, to farmers applying the general and/or specific principles of integrated pest management; 3. Encouraging the use of non-chemical alternatives to pesticides where possible.
CY	Targets are set in the NAP, but they are fairly general and may need to become more specific
CZ	CZ has established quantitative targets. See below
DE	DE has established quantitative targets. See below

MS	Description of the objectives and targets
DK	DK has established quantitative targets. See below
EE	The 2019 revised NAP includes quantitative targets. See below
EL	The 2020 revised NAP is presented as the legal text of the Government gazette under the decision No 9269/246316. It includes quantitative targets as follows.
ES	1 -Improve training and information on the sustainable and safe use of plant protection products. For phytosanitary products. 2- Promote research, innovation and technology transfer in integrated pest management and in the use of pesticides. For the integrated pest management and the sustainable use of plant protection products. 3- To promote Integrated Pest Management in order to achieve a rational use of phytosanitary products. For phytosanitary products. 4- Promote the availability of effective phytosanitary products for the control of pests, diseases and weeds, For diseases and weeds, while at the same time respecting health and the environment. 5- To promote techniques that minimise the risk of using plant protection products. 6- To intensify vigilance on the marketing of plant protection products.
FI	The revised 2018 NAP doesn't include any detailed objective as it mentions that "*the objective of the NAP is to reduce the risks of PPP use to human and animal health and the environment. The NAP also aims to advance the introduction of integrated pest management and alternative control methods. Furthermore, the purpose is to reduce dependency on PPPs to the extent justified in terms of the health and environmental risks involved in the use of PPPs*".
FR	France has established a quantitative target. See below.
HR	The NAP provides general objectives aligned to the provisions of the SUD and not very descriptive.
HU	The targets are rather limited to e.g. safe operation of pesticide distribution units; advice should be provided to end-users at the time of sale of pesticide; professional and amateur users use pesticides according to the license document.
IE	The 2019 revised NAP consists of five broad areas: 1. Training, Education, Information Exchange and Data Gathering; 2. Controls on Application Equipment; 3. Controls on Storage, Supply & Disposal of PPPs; 4. Control on use of PPPs in Specified Areas; 5. Integrated Pest Management (IPM). In each of these areas, specific generic qualitative targets are set mainly aiming at assessing the full implementation of the SUD provisions.

MS	Description of the objectives and targets
IT	Italy has established a quantitative target which are not integrated yet in the NAP that dates back to 2012.
LV	The goal of the National Action Plan is to achieve sustainable use of plant protection products, reduce the risks and impacts of pesticide use on human health and the environment and contribute to the enhancement and implementation of integrated pest management and alternative techniques to minimise dependence on pesticide use.
LT	The NAP doesn't include any target in its NAP. Targets and clear objectives are under development.
LU	LU has established quantitative targets. See below
MT	Several generic targets and indicators of progress are listed in the NAP
NL	The NAP is currently under review. A new revised NAP is expected to be published before the end of 2021. The revised NAP will be based on the Implementation Programme for the Vision on Plant protection 2030, including the targets mentioned in that Implementation Programme. Targets are defined on the three strategic goals of the vision: - Resilient plants and cultivations systems; - Linkage between agriculture and nature; and - Negligible emission to the environment and negligible residues on production The targets will be a combination of qualitative and quantitative targets. Quantitative targets are focussed on emission reduction to the environment (residue levels in water bodies).
PT	1-Promote research, innovation and technology transfer to encourage the development and practice of integrated protection as well as sustainable modes of production 2-Enable the universe of professional users 3-Increase the perception of users of plant protection products on the risks and effects of the use of plant protection products 4-Increase the perception of the consumer and public in general on the sustainable use of plant protection products and food security 5-Reinforce the control of pesticide residues in food and decrease the number of incidents by food promoting greater food security 6-Foster adequate use of plant protection products 7-Foster the reduction of exposure during the application of plant protection products 8-Improvement of the use of plant protection products specialising by those who do not hold the proper 9-Increase the perception of non-professional users to the risk associated with the use of plant protection products and improve advise in the act of sale 10-Reduce exposure risks of strange people to aerial application of plant protection products
RO	The 2019 revised NAP includes generic objectives only and the specific objectives follow the requirements of the SUD provisions article per article.
SK	General targets and objectives in line with the F2F targets as the revised NAP has been released in February 2021.

MS	Description of the objectives and targets
SL	• Reduction of sales of problematic substances (Glyphosate and Epoxiconazole at the time) by 100% (prohibition); • Reduction of all PPP sales for professional use by 10% in the period 2018-22; • Increase in number of residue analyses in food and feed by 10% in the period 2018-22; • Increase in share of advisors who complete the basic course by 5% by 2022 as compared to the period 2012-2017 • Reduction of share of infringements in PPP stores by 10% by 2022 as compared to the period 2012-2017 • Established programme for monitoring signs of chronic PPP exposure in professional users by the end of the period of this NAP • Modernisation of PPP application devices - reducing the average age of devices by 2 years by the end of the 2022 period. • Reduction of the proportion of groundwater and surface water samples containing PPPs by 10%, excluding substances representing old loads. • Reduction of the proportion of drinking water samples containing PPPs by 10%, excluding substances representing old loads. • Reduction of the proportion of infringements at inspections of warehouses performed at PPP distributors and users – by 10% compared to the period 2012-2017 • By 2022, specific IPM guidelines are developed for all major crops.
SE	The main focus on reducing risks, residues in water, residues in vegetables, risks for users – no specific numbers in kg active substance/pesticide used. Indicators include sales statistics of products including certain active substances (e.g. diflufenikan, bentazon, glyphosate, MCPA, metribuzin, neonicotinoid), the national risk index for health and environment, national toxicity index.

Source: Compiled by the Consortium based on the analysis of the NAPs and completed by interviews with the NCAs

However, in their initial NAPs, six Member States have included a quantitative target as summarised in the table below.

Table 6: Quantitative objectives and targets established by MS as listed in the NAPs

MS	Description of the objectives and targets
BE	Walloon plan: 50% reduction in the environmental impact for non-agricultural use. 25% reduction in the environmental impact of agricultural use.
CZ	10-15% of pesticide residues in food and water.
DE	DE sets quantitative targets for risk reduction of 20% by 2018 and by 30% by 2020.
DK	40% of the Pesticide Load Indicator while decreasing pesticide taxes.
FR	50% reduction of pesticide use by 2025.
LU	50% of pesticide use (in tonnages) by 2030.

Source: Compiled by the Consortium based on the analysis of the NAPs and completed by interviews with the NCAs

At the time of drafting their initial NAP, only FR and LU have established targets and objectives related to a quantitative reduction of pesticide use when others presented in the table above relate to reduction of risk and impacts.

It should be noted that three countries have now or plan to establish quantitative targets in their objectives.

In Estonia, the NAP lists three quantitative objectives:

- Reducing the proportion of groundwater monitoring stations that exceed pesticide residue limits from 19.7% to less than 10%;
- Maintaining the proportion of samples that have exceeded the limits of residues of PPPs in food of Estonian origin to less of 1%; and
- Maintaining the average number of residues of active substances in a soil sample under 5 active substances detected.

In Greece, the objectives read as follows:

- 2.5% reduction of HRI 2 per year;
- 5% increase of low-risk products (Article 47 of Regulation (EC) No 1107/2009) per year;
- 2% increase of products containing micro-organisms per year; and
- 2% reduction of the percentage of exceedances in the food and feed residue monitoring programmes (national and Community) per year.

This overview of the Member State targets and objectives shows that, as reported in the first Commission report to the Parliament in 2017,[32] Member States have not been ambitious in their objectives and targets. In most of Members States, the NAPs are limited to describe how the SUD obligations (see articles 5 to 15) will be implemented nationally. In a very limited cases, the NAP goes further than the mandatory requirements. The 2018 European Implementation Assessment of the European Parliament (EP)[33] and the European Court of Auditors (ECA) report.[34]

3.1.5.2 Mapping and description of the indicators used by Member States to assess the risks and impacts of pesticides

Over the last three decades, Member States have established national indicators which are being calculated on a regular basis in order to measure the progress in term of reduction of risk and use of pesticides at regional and national levels. In addition, the SUD foresees the establishment of harmonised risk indicators that have to be computed in addition to the existing national indicators. Member

[32] Available at https://ec.europa.eu/food/system/files/2017-10/pesticides_sup_report-overview_en.pdf.
[33] Available at https://www.europarl.europa.eu/RegData/etudes/STUD/2018/627113/EPRS_STU(2018)627113_EN.pdf.
[34] Available at https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=53001.

States have also the possibility to complete the HRIs with novel national indicators (Article 15(1) of the SUD).

This section lists and describes the various main indicators, which are in use at EU and Member State levels.

The Harmonised Risk Indicators (HRIs)

The EC adopted the HRIs as requested in Article 15 of the SUD in May 2019 when Commission Directive (EU) 2019/782[35] establishing harmonised risk indicators to estimate the trends in risk from pesticide use was adopted. Article 15(4) of the SUD requires the European Commission to calculate risk indicators at EU level. Member States are also obliged to calculate the HRIs (Article 15(2) of the SUD). The data to be used for the calculations shall be statistical data collected in accordance with Union legislation concerning statistics on plant protection products, i.e. Regulation (EC) No 1185/2009[36] on pesticide statistics, and other relevant data.

The EU adopted two HRIs:

- The Harmonised Risk Indicator 1 (HRI 1)[37] is calculated by combining the statistics on the quantities of pesticide active substances placed on the market in accordance with Regulation (EC) No 1185/2009 and the information on active substances in accordance with Regulation (EC) No 1107/2009, based on a grouping of the active substances; and
- The Harmonised Risk Indicator 2 (HRI 2) is calculated based on the number of authorisations granted under Article 8(4) of Council Directive 91/414/EEC and Article 53 of Regulation (EC) No 1107/2009, and the categorisation of active substances in accordance with Regulation (EC) No 1107/2009, including if they are low risk active substances, candidates for substitution (CfS), or other active substances (a.s.).

For each HRI, all active substances have been categorised in groups and categories. There are three groups for approved substances. All non-approved active substances are placed in Group 4, Category G. Weighting factors are defined for each group.

[35] Commission Directive (EU) 2019/782 of 15 May 2019 amending Directive 2009/128/EC of the European Parliament and of the Council as regards the establishment of harmonised risk indicators (Text with EEA relevance).

[36] Regulation (EC) No 1185/2009 of the European Parliament and of the Council of 25 November 2009 concerning statistics on pesticides (Text with EEA relevance).

[37] The first Harmonised Risk Indicators were introduced through amendment C(2019)3580(1). Commission Directive (EU) 2019/782 of 15 May 2019 amending Directive 2009/128/EC of the European Parliament and of the Council as regards the establishment of harmonised risk indicators http://data.europa.eu/eli/dir/2019/782/oj .

Table 7: The four groups of active substances used to calculate HRIs

Group	Description of the objectives and targets
1	Low-risk active substances which are approved or deemed to be approved under Article 22 of Regulation (EC) No 1107/2009, and which are listed in Part D of the Annex to Regulation (EU) No 540/2011.
2	Active substances which are approved or deemed to be approved under Article 22 of Regulation (EC) No 1107/2009, and not falling in other categories, and which are listed in Part A and B of the Annex to Regulation (EU) No 540/2011.
3	Active substances which are approved or deemed to be approved under Article 22 of Regulation (EC) No 1107/2009, which are candidates for substitution (CfS), and which are listed in Part E of the Annex to Regulation (EU) No 540/2011.
4	Active substances which are not approved under Regulation 'EC) No 1107/2009, and therefore which are not listed in the Annex to Regulation (EU) No 540/2011 but that can be used by users through emergency authorisation (Article 53 of Regulation (EC) No 1107/2009.

Source: Methodology for calculating harmonised risk indicators for pesticides under Directive 2009/128/EC (2021 Edition)

Table 8: The seven categories of active substances used to calculate HRIs

Category	Link to group	Description
A	1(low risk)	Micro-organisms
B	1(low risk)	Chemical active substances
C	2	Micro organisms
D	2	Chemical active substances
E	3(CfS)	Not Carcinogenic 1A or 1B or Not Toxic for reproduction 1A or 1B or endocrine disruptors
F	3(CfS)	Carcinogenic 1A or 1B or Toxic for reproduction 1A or 1B or endocrine disruptors, where exposure of humans is negligible
G	4 (not approved)	

Source: Methodology for calculating harmonised risk indicators for pesticides under Directive 2009/128/EC (2021 Edition)

For HRI 1, a weighting system is applicable to quantities of active substances per group placed on the market. The factor is 1 for Group 1, 8 for Group 2, 16 for Group 4, and 64 for Group 4.

HRI 2 is based on the number of emergency authorisations granted for plant protection products under Article 8(4) of Council Directive 91/414/EEC and Article 53 of Regulation (EC) No 1107/2009 as communicated to the European

Commission in accordance with Article 53(1) of that Regulation during a reference period. The number of emergency authorisations per group of substances is multiplied by the weighting factor presented above. Both indicators are presented as an index.

The national indicators

This section presents and discusses the different national risk indicators which are being used by Members States in addition to the HRIs.

Literature distinguishes two categories of indicators as follows:

- **Methods with use models** to predict environmental fate and potential risk for human health. Models identify the relative importance of various dissipation pathways, and allow estimation of flux densities, concentrations, residence times and exposure; and
- **Descriptive indicators** which consist of categorical indices of impacts. Generally, this methodology consists of a generic indexing system in which biologically or ecologically significant threshold levels for an environmental variable are used to define categories of impact, hazard or risk.

Therefore, the first approach is to use indicators based on mathematical models that predict the risk trend, and the second one relies on the selection of several categorical indices/descriptive indicators which are measuring the real impacts of the actions in place in order to achieve the reduction of impacts of use of PPP.

Indicators based on theoretical models

Levitan (1997), Hart (1997) and Falconer (1998) are the first authors that present an overview of pest risk indicators known from the literature.[38] They give a short description of each indicator, including a summary of the methodology behind each and the way they are used in practice. The Concerted Action on Pesticides Environmental Risk indicators (CAPER)(1999) builds on this initial research and add several steps.

The following main indicators have been developed over the last 20 years:

1. Treatment Frequency Index (TFI) - Denmark and France
2. Pesticide Load Index (PLI) - Denmark
3. NODU – France
3. PRIBEL - Belgium
4. SYNOPS - Germany
5. Treatment Index (BI) - Germany

[38] CAPER final report, 2000.

6. PRI Nation - Sweden
7. PRI Farm – Sweden
8. NMI3 – the Netherlands
9. CAPER I and II - Belgium

The treatment frequency index (DK & FR), the pesticide load index (DK) and the NODU in France.

The term **Treatment Frequency Index (TFI)** was introduced in 1986 by Denmark. The TFI is a theoretical number of pesticide treatments per ha, based on a standard dose rates of active substances and the amount of pesticides sold yearly. A TFI of 1 is equivalent to one full dosage treatment applied to agricultural land.

In Denmark, the index (known as Frequency of Application – FA) had initially been developed to supervise the success of the politically suggested incentive for pesticides reduction in grain cultivation. In contrast to most other risk indicators for pesticides application, the used algorithm does not contain a factor for toxicity for single active substances. The indicator integrates the information about pesticides application and effectiveness on target organisms about the standard dose, which is looked as a biologically active application dose. This indicator is calculated with relatively few data. It can be calculated with sales figures as well as with data on users.

Denmark complements the TFI with the **Pesticide Load Index (PLI)** indicator for clarification on the question whether divergences of the toxic dose can be explained by changes of the sales figures or by diverging toxicity of the used plant protection products. The reason behind the introduction of complementary elements to TFI is that TFI primarily reflects the consumption of plant protection products and is not considered as valid in order to be able to state the trend in environmental impact or side effects. This is not considered as being sufficient, as the strategy has moved from an objective of reduction of volumes to an objective of reduction of impacts.

Until an indicator for the harmful effects of PPP is developed – which is subject to research activities – TFI and PLI approaches are combined.

To calculate the TFI a broad range of data is necessary, and these input data are not available on a yearly basis in France, therefore the **NODU (*nombre de doses utilisées* – number of doses used)** specific indicator was built. The NODU has now been implemented in France. Because sales figures were available for active ingredients only and not for commercial products, the Danish TFI has been reshaped by the French to estimate treatment frequencies per crop of commercial products.

PRIBEL (BE)

The goal of the first national pesticide programme was to achieve by 2010 (compared to reference year 2001) an impact reduction of 25% in agriculture and 50% for biocides and non-agricultural products. In order to assess the improvements being made, a specific tool complying with the situation was needed to measure the significance of the improvement and how they are contributing to the sustainable use of PPP in agriculture. To that end, the Gent University developed the so-called PRIBEL (Pesticide Risk Indicator for BELgium) indicator.

The PRIBEL indicator is a multi-impact indicator based on the POCER II indicator which is an extension of the POCER I indicator also developed at the Gent University. It assesses at the level of Belgium both the human risk from occupational exposure to pesticides and the risk to the environment from the use of agricultural pesticides. The indicator consists of seven modules: applicator, consumer, surface water, ground water, earthworms, birds, and bees. As the goal of an indicator is to synthetise as much information as possible into a few geographical representations, an aggregation procedure involving several steps (spatial aggregation and aggregation of the active substances over the pesticide groups and the crops groups) is applied.

This approach has the benefit that all the information can be concentrated in global PRIBEL value per compartment for Belgium, but intermediate results are still available for more refined comparisons, e.g. assessment of the impact of a specific pesticide on a single compartment.

The risk indices are calculating considering the (eco)toxicological data of the active substance and the application dose per ha, whilst the frequency considers the number of application cases of one active substance per hectare, the national sales per crop and the national area per crop.

SYNOPS (DE)

SYNOPS (Synoptisches Bewertungsmodell für Pflanzenschutzmittel (synoptic evaluation model for plant protection products) is a computer-aided model aiming to allow the identification of relative changes in PPP-related risks to aquatic and terrestrial ecosystems.

SYNOPS calculates how different representative organisms can get exposed to PPP and relates this exposure to the toxicity for these very organisms evaluated under laboratory standard. The result is a proportionality factor for every measure and for representative organism (SYNOPS-risk index). The bigger the ratio is, the higher is the probability of undesirable events in the environment, or, in other terms, the risk.

Within the National Action Plan SYNOPS is applied on different levels of spatial aggregation. On the one hand SYNOPS is applied on national level to assure the tracking of the risk trends and risk development in Germany. In this case SYNOPS is used on yearly basis with annual sales data of pesticides assuming realistic worst case scenarios for the environmental conditions. This application will be referred as SYNOPS-Trend. On the other hand SYNOPS-GIS is used for regional risk analysis and the detection of hot spots. This implementation of SYNOPS requires more detailed input datasets like field based surveys on pesticide use and extended GIS based datasets on land use, slope, soil types and climate.

Both versions of SYNOPS are based on the same functionalities and procedures to assess the environmental risk on field level. SYNOPS calculates the predicted environmental concentration on daily basis for soil, surface waters and non-target plants. It considers the interception on the crop and the exposure pathways spray drift, surface run-off and drainage and temperature dependent degradation in water and soil. From the daily environmental concentrations the short-term and long-term exposure are derived and the risk potentials are calculated as the ratio of exposure to toxicity (ETR) for three reference species (daphnia, fish and algae) in aquatic systems and two species (earthworm and bee) for terrestrial systems.

SYNOPS-Trend is being used annually since 2005 to track the trend of risk potential of pesticides used in agriculture and horticulture in Germany.

SYNOPS-GIS was used for detail risk analysis of pesticides applied in orchard regions in Germany. Recently it is being used in frame of a pilot hot spot analysis of the risk for small surface water bodies caused by pesticide applications in arable crops in Bundesland Nordrhein-Westfalen.

<u>Treatment Index (BI) – Germany</u>

The BI demonstrates the number of plant protection product applications on an operational area, with regard to a specific crop or a specific company. It takes account of reduced application rates and site-specific applications. In case of tank mixes each plant protection product is counted separately. The data for this indicator stem from the crop-specific company panels for the implementation of the regulation concerning statistics on pesticides, EC no. 1185/2009 (previously NEPTUN-surveys), and the network reference farms.

<u>PRI Nation & PRI Farm (SE)</u>

The Swedish Chemicals Inspectorate has developed two systems intended to track risk trends over time by calculating pesticide risk indicators. Pesticide Risk Indicators at National level (PRI-Nation) and Pesticide Risk Indicators at Farm level (PRI-Farm).

The first system, PRI Nation, was initiated in 1996 with the main objective to monitor impact of pesticide policies established in the national risk reduction programme. It has been in use since 1997 with annual updating and reporting on the national progress.

The second system, PRI Farm, was developed during 2003 and 2004 with the main purpose to follow up pesticide risk trends at individual farms and to compare pesticide risks on different production systems. The aim with PRI-Farm is to use a more realistic approach by defining local exposure conditions. One important aspect is that by using these tools, farmers can check their own progress in relation to risk reduction, which may increase their awareness, interest and participation in the national risk reduction programmes. The work on the PRI-Farm model has been performed in cooperation with representatives of different interest groups such as farmers, industry, authorities and research institutions. Initial tests have been carried out on a number of so called Pilot Farms with the aim to gather experience on practical farm use.

Both models are based on the same approach, where data on hazard and exposure is scored and combined with data on use intensity. The weighting procedure included is based on field data (where available), expert judgements or policy assessments.

The result is aggregated to a single score for each substance or treatment with the intention to indicate environmental and operator health risks respectively. However, the indicator scores or sum does not quantify actual pesticide risks. Instead, the purpose is to indicate trends in potential risks at national level and farm level.

While PRI-Nation is expressed as the nation-wide sum of environment or operator health risk indicators for all substances each year, PRI-Farm provide a risk indicator for each treatment expressed as the indicator sum of a crop or a field on a particular farm.

NMI3 (NL)

The NMI 3 focusses on the emissions to surface water and the related risk to the aquatic ecosystem. The use of pesticides may also lead to contamination and risk to other parts of the environment, such as groundwater, soil organisms and the terrestrial ecosystem.

Although the Dutch policy document contains no additional operational targets for these environmental compartments, the risks are considered in the evaluation as well and therefore the NMI 3 also contains modules for calculating these risk indicators. The NMI 3 includes modules for calculating emission to surface water resulting from atmospheric deposition, spray drift, drainage flow, point sources, and discharge from greenhouses with soilless cultivation and from greenhouses with soil bound cultivation. The model is comprised of a number of simple models, combining a wide range of information about pesticide usage, emission factors, the geographical distribution of crops, surface water, soil and climate properties, and substance properties. Each application in the NMI database is linked to a combination of object treated and application method which determines the emission pathways calculated.

The primary goal of the NMI 3 is to produce a trend line connecting two points of the annual environmental risk at national scale level, at the starting and end year of the policy period 1998-2010. Each point represents the risk indicator outcomes in the years corresponding with farm-based surveys conducted by Statistics Netherlands (CBS). The results can also be used for ranking, for comparing applications of similar type and for visualisation of spatial patterns in calculated emission indicators and risk indicators

POCER-1 and POCER-2 (BE)

The POCER indicator (Pesticide Occupational and Environmental Risk indicator) has been developed at Ghent University for agricultural situations, as a tool for applicators and decision-makers, by calculating the impact of pesticide treatments on the applicator, the worker, the bystander, groundwater, surface water, bees, earthworms, birds, useful arthropods and persistence in soil. A few adaptations in the POCER calculation method can make the indicator useful for non-agricultural conditions. The impact of plant protection products on human health and environment in public services and households can be calculated and the scores can be compared with each other, resulting in an improved pesticide programme.

POCER-2 has been developed to assess the risks of pesticide use in 14 areas (compartments) related to humans, the economy and the environment. Compared to POCER-1 (only 8 compartments), the tool has been improved by adding approaches in the translation of relative risk values into absolute values defined according to the subjective ranking of the importance of the various compartments. The selection of the compartments was made in order to obtain risk information for the sustainability of PPP use. This concept was based on three pillars: human health, natural resources and agricultural interest. For each specific compartment, a pesticide risk indicator was selected. A software was developed to allow an assessment of the risk at various aggregation levels: no aggregation, multiple active substances, multiple times, multiple locations, and multiple compartments.

Descriptive indicators

As mentioned under the introduction of this chapter, there are two opposing approaches. The first one based on theoretical models has been presented in the previous section, the second approach, which is based on the combination of descriptive indicators, is presented in this section. Not all countries have engaged in a research work to develop theoretical indicators. Therefore, they have considered several data sets as possible indicators that could contribute as complementary tools to the theoretical models.

In the following table, a list of such indicators that have been developed by several Member States is provided. Member States and stakeholders that are in favour of using such type of indicators rather than models have indicated that the measurement of such indicators has to be performed on a regular basis in order to assess the trends and the progresses made.

Table 9: Descriptive indicators

Environment and health indicators
Presence of PPP residues in food of animal origin
Presence of PPP residues in feed
Presence of PPP in ground water
Presence of PPP in surface water
Presence of PPP in drinking water
Use of spray drift reduction nozzles (e.g. in % area covered)
Installation of bio beds or other appropriate cleaning places
Integrated Pest Management/Integrated Crop Management implementation rate: – Agricultural area covered by the application of the general IPM principles (comprising those applying ICM, IF) (in %total crop area) – Implementation of voluntary crop specific IPM guidelines (in % area covered compared to total crop production area(s))
Modern machinery in use (such as with cleaning tanks, induction bowl) (e.g. in % of area covered compared to total cropped agricultural area)
Spraying equipment passing the inspection (in % compared to spraying equipment in use)
National register of sprayer operators – number of members and % sprayed area
Number of cross compliance complaints linked to the use of PPPs
Compliance with EQS on EU priority substances linked to Water Framework Directive
MRLs exceedances (%)
Data about law infringement incidences connected with use of PPP, information about inspected PPP application equipment and trained PPP users
Human PPP poisoning incidences
Number of substantiated category 1 & 2 pollution incidents for land, air or water, involving agricultural and non-agricultural pesticides
Population of wild birds and other species (biodiversity)
Information about bee poisoning incidences
Social indicators [39]
Continuous professional development – Numbers of farmers/distributors/advisors holding plant protection training certificates (in % compared to total number of farmers)

[39] An alternative to this list could be the use of indicators developed under the DPSIR (Drivers-Pressures-States-Impacts-Responses) framework that was developed by the EEA to help identifying sustainability indicators. It provides a systems approach for identifying, structuring and representing complex issues in terms of interactions between the system drivers, pressures, states, and responses. Drivers are the environmental and socioeconomic forces of change in the system.

Number of professional users in the non-agricultural area applying the relevant IPM general principles
Container management systems – recovery/collection rate
Continuous rinsing or equivalent techniques of empty containers (rinsing rates (%)
Rapid alert (RASFF) notifications (with regard to MRLs exceedances), which actually lead to produce being either withdrawn from the market or being blocked from entering the market (in % of total alerts) (home grown produce only). Relation (comparison) of above to other food/feed contaminants leading to produce withdrawals in light of RASFF.
Economic indicators
Agricultural production area covered by trained, certificate holders (% compared to crop production area)
Number of farms/holding using remnant purification systems (in % total farms)
Number of viable and registered solutions available for specific pest/disease problems
Registered active compounds per key pest/disease problems
Number of active compounds per key pest/disease problems
Number of economic viable alternative non-chemical solutions available for pest/disease problems
Pest pressures over growing season
Potential harvest losses due to pest pressure
Statistic data about use of PPP
Statistic data about sales of PPP
Pesticide average inputs per crop

Source: Compiled by the Consortium

When using these indicators, the approach is to combine several of them and to measure them at a regular frequency. The trend analysis of this set of indicators shows the progress that is made in term of reducing impact of use of PPP.

Data collection allowed to update the use of national indicators as presented in the table below. The table also indicates whether or not Member States are collecting data recorded by professional user pursuant to Article 67 of Regulation (EC) No 1107/2009.

Table 10: Use of national indicators to measure progress in reduction of risk and impacts or use of pesticides

MS	Use of national indicators	Theoretical indicators	Descriptive indicators	Indicators to measure reduction of use	Indicators to measure reduction of risk as regards human health	Indicators to measure reduction of risk as regards to water protection	Indicators to measure reduction of other risks as regards respect of the environment	National collection of records kept by users pursuant to Article 57 of the PPP Regulation
AT	Yes		X		X	X		No
BE	Yes	X	X					Flanders: only for farmers in the accountancy network (FADN)
BG	Yes		X		X	X	X	No
CY	No							No
CZ	Yes		X	X	X	X	X	Yes
DE	Yes		X	X (Treatment Index)	X (MRLs)	X (SYNOPS GIS)	X (SYNOPS, SPEAR)	No
DK	Yes	X	X	X (PLI -TFI)	X (Pesticide Load Indicator-PLI)	X (Pesticide Load Indicator-PLI)	X (Pesticide Load Indicator-PLI)	Yes
EE	Yes		X	X	X		X	No
EL	Yes		X		X			No
ES	Yes		X		X			Yes
FI	Yes		X					No

MS	Use of national indicators	Theoretical indicators	Descriptive indicators	Indicators to measure reduction of use	Indicators to measure reduction of risk as regards human health	Indicators to measure reduction of risk as regards to water protection	Indicators to measure reduction of other risks as regards respect of the environment	National collection of records kept by users pursuant to Article 57 of the PPP Regulation
FR	Yes	X		X (NODU, TFI)	X (Summary indicator – no acronym)	X (Summary indicator – no acronym)	X (Summary indicator – no acronym)	No
HR	Yes		X	X	X	X	X	No
HU	Yes		X	X	X	X	X	Yes
IE	Yes		X			X	X	Yes
IT	Yes		X	X	X	X		No
LV	Yes		X					No
LT	Yes		X	X	X		X	No
LU	Yes		X	X	X	X (PESTEAUX)	X	No
MT	No							No
NL	Yes	X	X			X (HAIR 2020–NMI-3)		No
PL	Yes		X	X	X	X	X	No
PT	Yes		X					No
RO	Yes		X		X		X	No
SK	No							No
SL	Yes		X	X	X	X	X	Yes

MS	Use of national indicators	Theoretical indicators	Descriptive indicators	Indicators to measure reduction of use	Indicators to measure reduction of risk as regards human health	Indicators to measure reduction of risk as regards to water protection	Indicators to measure reduction of other risks as regards respect of the environment	National collection of records kept by users pursuant to Article 57 of the PPP Regulation
SE	Yes		X	X (National risk index and the toxicity index)	X (National Risk Index)	X (the toxicity index)	X (National Risk Index)	No

Source: Compiled by the Consortium based on interviews with NCAs and national stakeholders

In addition, it should be noticed that, according to Eurostat, nine Member States are making public national statistics on pesticide sales (BE, CZ, DK, DE, FR, HR, NL, RO, and SE).

3.1.5.3 Description of the indicators used by Member States to assess the uptake of IPM by farmers/producers

The second Commission report to the European Parliament issued in May 2020 concludes that very few Member States have put in place a monitoring programme for controlling the uptake of IPM by farmers. According to Article 14(4) of the SUD, it is mandatory for farmers to apply the general principles of IPM on their farm since January 2014. The Council of the European Union, in its conclusions[40], agrees with the Commission's assessment that Integrated Pest Management (IPM) is one of the cornerstones and at the same time one of the biggest challenges of the SUD, requiring more attention by the MS but points out that it may not be achievable to harmonise IPM across all crops and all Member States.

IPM is not a new concept or activity and before the SUD came into force an unknown but significant proportion of farmers (mainly arable farmers) were already carrying out IPM to a greater or lesser extent. However, many farmers did not realise that the measures they had been doing routinely for many years were IPM. The main obstacle to understanding that IPM is being undertaken is that some measures are embedded in farmers' activities as good crop management, but never really considered as IPM in the sense formalised by academics and further in the EU legislation. There was also confusion as to what IPM actually entailed – some incorrectly thought it was a concept that prohibits the use of PPPs. The application of IPM is very site specific so what will work in one farm/field will not necessarily work in another farm/field situation. This may explain why IPM is defined in the form of eight general principles as presented under Annex III of the SUD, to the contrary of organic production which is defined based on a set of specific measures that farmers shall respect to be certified as organic. The main difference between IPM or organic farming is that there is an EU-wide certification for organic, which is not the case for IPM. A certification requires a precise "cahier des charges" because it is a matter of commercial liability. For an IPM certification (and there are some which develop), there is a need for such a precise "cahier des charges".

The French approach for instance is to consider that each farmer has to build its own IPM concept per production type and per field based on the eight principles and considering that the concept has to be adapted when new decisions are taken (e.g. cultivating a new variety which different variety resistance patterns,

[40] Council Conclusions on the report from the Commission to the European Parliament and the Council on the experience gained by Member States on the implementation of national targets established in their National Action Plans and on progress in the implementation of Directive 2009/128/EC on the sustainable use of pesticides. Available at https://data.consilium.europa.eu/doc/document/ST-13441-2020-INIT/en/pdf.

change in cultivation practices). IPM approaches do not have to be considered as static as the different agro-climatic conditions over years, lead to the need to annually adapt the IPM concept. IPM is specific to many parameters of which, but not limited to, the crop, the field, the type of production, and the agro-climatic conditions. A last remark to highlight that IPM has to be considered at the rotation level. For example, the cultivation of a legume crop in the rotation has positive impacts on the following cereal crop such as on nutrition. Therefore, to be fully efficient for annual crops, IPM has to be designed at the rotation level considering all crops included in the rotation over a multi-annual process. All in all, the application of IPM techniques is as wide as the number of agronomical practices at field level. However the IPM concept and the eight principles can be applied everywhere considering, then different techniques selected at field/farm level.

According to the Commission (reference) and the ECA (reference), this leads to the situation that Member States have not converted the IPM general principles into prescriptive and assessable criteria to be applied by users. Therefore, Competent Authorities do not have developed prescriptive and assessable criteria in order to determine compliance with IPM, and therefore there is limited evidence that IPM is systematically applied. Such lack of monitoring system leads also to lack of certainties as regards the uptake of IPM by farmers. Several interviews highlighted that farmers have done significant efforts to adopt IPM and others mentioned that the efforts remain insufficient. The Commission concludes that "*the assessment of the implementation of IPM continues to be the most widespread weakness in the application of the SUD. Consequently, Member States have failed to exploit the significant potential for greater adoption of IPM, including the more widespread adoption of non-chemical pest control techniques*".

In an attempt to monitor uptake of IPM by farmers, a few limited Member States have developed monitoring systems that can be grouped in two main categories as summarised below:

- **<u>Development of a checklist used by external controllers</u>** which takes the form of a list of obligations sorted per IPM principle. These obligations are defined based on the IPM principles listed under Annex III of the SUD. The Belgian and Irish authorities are two good examples to illustrate this approach. The Belgian approach is presented in one of the case studies related to the Pilot Project. Both Member States have developed crop-specific guidelines (two in Flanders, three in Wallonia and a global one in Ireland) which include specific requirements that farmers have to respect to be IPM compliant. About 50% of farmers have already been controlled in Wallonia and 85% in Flanders. The controls are based on information communicated by the farmers and not on verifications in the fields. Such guidelines are adapted, but only at the margin, when required meaning that the requirements are rather generic and not specific enough to adapt to each farmer's conditions. The Belgian authorities have indicated that a large number of checklists are based on generic agronomic practices that farmers shall respect but that they are used to respect for years already and therefore the checklist is not actually a constraint for farmers. These checklists do not include any information on the approach to protect crops and do not provide any information on alternatives that could be used to protect crops against a given pest disease. This is the major difference with the Irish guidelines which are much more prescriptive in that respect.

- **Development of a checklist to support self-assessment by farmers**. Starting from the assessment that IPM is very difficult to monitor at farm level due to its conceptual nature presented above; a few Member States have developed and continue to develop checklists that are distributed to farmers for a self-assessment. The most illustrative approach is the Danish one. Danish authorities have developed checklists that have been communicated to farmers and have been invited to follow these checklists to self-assess their compliance to IPM. For each measure a scoring is given leading to a total number of points over a total of 100. Such final score informs farmers on their level of compliance and highlights the weaknesses of their approaches. Such highlight of weaknesses invites individual farmers to review their approach and IPM concept in order to improve it. To be fully efficient the self-assessments have to be performed regularly and on all the crops a given farmer is cultivating. Danish authorities are not performing external controls on IPM but are promoting such self-assessment by farmers. Germany is also following the general principle of such approach but is requesting farmers to keep on paper their self-assessment as controls can be performed based on such self-assessment. No sanctions are foreseen if farmers cannot produce these filled checklists.

In conclusion, it should be highlighted that following the audit reports performed by DG SANTE, several Member States have recently or are currently reflecting on their national approach to set-up and implement and control of IPM uptake by farmers, at the time of writing of this report.

3.1.6 Member States activities to ensure uptake of IPM at farmer level

Article 14(5) of the SUD Directive states that EU Member States "*shall establish appropriate incentives to encourage professional users to implement crop or sector-specific guidelines for integrated pest management on a voluntary basis. Public authorities and/or organisations representing particular professional users may draw up such guidelines. Member States shall refer to those guidelines that they consider relevant and appropriate in their National Action Plans.*"

In the data collection exercise for this Pilot Project, the team of national experts aimed to gather all existing guidelines, as well as pertinent information about them. These guidelines were assessed and included in the EU-wide database. The present chapter is mostly based on interviews with NCAs, and partially also with national stakeholders, and aims to investigate the Member States' understanding of the SUD Directive's Article 14(5), and also to look into how this article has been implemented and if/how such guidelines have been elaborated. This, and other activities conducted by Member States to ensure uptake of IPM at farmer level are accounted for in the below sections. Firstly, an overview is provided on how/if guidelines have been developed in EU MS. Secondly, it will be investigated what crops/sectors as well as what IPM principles are covered by the guidelines, and the reasons why. Then, the target audience, dissemination efforts, and use of the guidelines will be looked at, in particular to understand their use as regards the control of IPM implementation at farm level. Finally, other tools complementing the guidelines will be discussed.

3.1.6.1 Overview of crop- and sector-specific guidelines

Based on the data collection conducted in the Pilot Project, crop- or sector-specific guidelines have been elaborated and implemented in all EU Member States, except Romania, Luxemburg, and the Netherlands. However, it should be noted that this does not necessarily mean that there are no guidance documents in place as regard crop-specific measures for IPM in these countries. Different types of private and public guidelines co-exist with the "official" ones.

Since Article 14(5) of the SUD does not provide a definition for crop- or sector-specific guidelines, the understanding of what such guidelines actually imply, and the purpose and use of such guidelines, vary across Member States. As a consequence, some interviewees could not provide clear information on the guidelines and in some cases, there were misunderstandings as to what documents were referred to. Indeed, this indicates that there is a need for clear information and further guidance as to what is implied by the crop- or sector-specific guidelines.

In most cases, the guidelines are considered by the NCAs as recommendations or guidance to facilitate IPM uptake among farmers and/or advisors in a voluntary way. Some Member States have established checklists based on the guidelines that are used to verify IPM implementation either by national controls or self-assessment (e.g. BE, IE, DK). Furthermore, a total of three Member States indicated that the guidelines are legally binding documents (BE, HU, HR). In the case of Slovakia, the guidelines that are part of RDP were said to be legally binding to receive rural development support, while crop-specific guidelines developed outside this context for maize are not.

Almost all Member States have developed the guidelines at national level covering the most important cultivated crops on their territory, while in a few cases at regional level (BE, EL and IT). In the case of Italy, general principles are defined at the national level, and are then lowered into the different regional realities through the definition of production regulations. In other cases, regional specificities are taken into consideration even though guidelines are developed at national level (IE, CZ). In the case of Spain, guidelines were elaborated at national level in collaboration with the regional authorities.

Table 11: Overview of sector- and crop-specific guidelines in MS

MS	Geographic level	Type of guidelines	Legally binding
AT	National level	Recommendations for professional users, applied on a voluntary basis	No
BE	Regional level (regional competence but collaboration between the regions)	Practical guides and checklist (used for verification)	Yes
BG	National level	Guidelines for IPM, 47 types of agricultural crops are covered.	Unclear information
CY	National level	NA (no definition provided by NCA)	No
CZ	National level (considering regionalisation by production area for each crop)	Methodological guidelines	No
DE	National level	Tools and considerations how to conduct sustainable crop production. System of support or advice to the farmers. Guidelines are not binding	No
DK	National level	The guidelines are crop-specific cultivating guidelines developed by the main advisory service partly funded by the Environmental Protection Agency. They are not legally binding and can be seen as guidance notes	No
EE	National level	Legal ground is the Plant Protection Act and Regulation of the Minister of	No

MS	Geographic level	Type of guidelines	Legally binding
		Rural Affairs, which is legally binding. Guidance is based on this. Estonian Crop Production Institute (ETKI) guidance (2019) has an addendum in form of check list to verify the measures applied by the farm, and to obtain feedback on strengths and weaknesses of a particular producer	
ES	National level (support of autonomous regions)	IPM Guides Published on the Ministry Web	No
FI	National level	Guidance notes to farmers	No
FR	National level	No specific definition established	No
GR	National/regional level	IPM instructions. Within the guidelines there are minimum requirements for IPM to receive grants	No
HR	National level	Binding documents, technical instructions	Yes
HU	National level	Guide for farmers to put IPM principles into practice, checklist with specific questions for the official inspectors	Yes
IE	National level (some of the variety specific data is more relevant at regional level)	Guidance notes and checklist	No
IT	National/Regional level	National guidelines developed by the Integrated Pest Management Group set up at the Ministry of Agriculture. In addition, Integrated Production Regulations that are binding for producers who decide to join	No

MS	Geographic level	Type of guidelines	Legally binding
LT	National level	Currently, guidance notes for farmers. The new document which is in preparation stage will be a binding document	No (not yet)
LU	NA	No official guidelines in place	NA
LV	National level	25 crop specific IPM guidelines, developed by the Ministry of Agriculture	No
MT	National level	Guidance notes	No
NL	NA	No official guidelines in place	NA
PL	National level	These are optional materials for voluntary use by people using plant protection products. The methodologies are prepared in a simplified (for producers) and extended (for advisers) version. They show how to meet mandatory legal requirements	No – but the acts that they refer to are legally binding
PT	National level	Documents supported by national legislation	No
RO	NA	No official guidelines in place	NA
SI	National level	Official voluntary guidelines	No
SK	National level	Guidance for farmers	Yes/No
SE	National level	Recommendations - a way of clarifying what IPM measures are according to the Board of Agriculture (not connected to control/inspections)	No

Source: Compiled by the Consortium

Focus of the guidelines

Regarding coverage of crops and sectors, it can be said that in general Member States have developed IPM guidelines for the major, or most commonly grown, crops in each respective country. Some of the consulted NCAs mentioned specifically that they developed guidelines for crops of "major economic importance" (BG, HR, IT). In some countries, this is still work in progress. For example, Slovakia started with guidelines for maize as this is the most important crop, while guidelines for arable crops was under development at the time of the data collection. Sweden was working on an updated version of existing guidelines at the time of the data collection that was launched in the autumn 2021. While focus of the Swedish guidelines is on major crops, similar advice exists also for smaller crops through other publications made available by the Swedish Board of Agriculture. In Italy, guidelines are drawn up at national level on crops with economic significance. In a second step, the regions identify what crops are most present on the territory, to create specific integrated production regulations for those crops.

Portugal has developed guidelines for the most representative cultures, however, also at the request of specific sectors (e.g. avocado). Similarly, in Germany, guidelines were developed in particular for crops where associations are well organised (e.g. sugar beet). In Hungary, two separate guidelines/checklists exist for arable crops and for permanent crops, as these two methods differ importantly. The Czech Republic focused on permanent crops, as well as on vegetables as they are often eaten fresh, with the aim of reducing pesticide residue through the adoption of IP measures.

Concerning IPM principles, most EU Member States have developed guidelines that are focused on the specific aspects and principles of IPM, while other EU MS rather use the guidelines as broader guidelines on integrated production (e.g. BE, HU, MT, IE, AT). In the case of Germany – there is both a more general and a more specific type of guideline. In Sweden, all eight IPM principles are covered, but under four principles (prevention, monitoring, optimisation, and evaluation) as it is believed that these four principles are easier to market. At the time of the data collection, Bulgaria was in the process of updating the guidelines as they did not incorporate all principles and practices of IPM.

Target audience of the guidelines

The target audience of the guidelines in all Member States is mainly focused on farmers, even though the guidelines may also be used by other actors such as advisors or official inspectors. In the example of Hungary, the main audience is farmers, however, a specific checklist has been developed to help official inspectors in their work. Other Member States focus on farmers and advisors, while others target all audiences including farmers, advisors, and inspectors.

Some Member States have developed the guidelines with the main aim to provide sufficiently clear guidance for farmers to use them independently without the assistance of technical advisors. However, even in the case where the guidelines can be used by farmers directly, technical advisors may provide an added value and/or facilitate the adoption of IPM measures. Furthermore, the ability of farmers to use the guidelines independently depends on previous knowledge and education in the field. In some countries, the ability to successfully use the guidelines might also differ from one sector/crop to another.

The French example is rather specific in that context as the national crop-specific guidelines describe the IPM principles and potential approaches per group of crops, and then these national guidelines are linked to other technical guidance documents which are or more regional and local, or more crop type oriented (e.g. carrots produced for the fresh market vs carrots produced for the industry). For the French authorities, the approach was to establish all links between a national document rather generic and the necessary detailed information required at farm and at field levels.

In some EU Member States, assistance from technical advisors is highly recommended (for example, in BG, MT, and FR).

Dissemination efforts

Based on the data collection carried out in the EU Member States, the most common ways of dissemination include making the guidelines publicly available and accessible online, as well as organising specific activities such as training sessions, seminars or conferences to further inform about the guidelines. Some Member States have also disseminated printed versions or brochures at such events.

Furthermore, in some Member States, the mandatory training for professional users of pesticides[41], as well as other official courses related to plant protection, are used to spread information about the guidelines. In AT, IT and DE, consulted NCAs highlighted that information about the guidelines is also spread to the farmers through the advisory services.

Use of guidelines by other actors (verification and control)

As highlighted in previous sections, guidelines are used by a variety of actors, including farmers, advisors and inspectors. As such the use and purpose of the guidelines differ depending on the actor.

In the sense of proper inspection/control plans, more than half of the NCAs indicated that they do not use these guidelines to ensure the implementation of IPM (including CY, SE, DK, FR, IE, DE) while a few countries indicated that they do (including AT, BE, EE, HR, SK, LV).[42]

Different kinds of farm audits are carried out in the EU MS to verify the implementation of IPM at farmer level. In BE (Flanders and Wallonia), the crop-specific guidelines are used for this purpose. In LT, farmers are asked questions related to the implementation of the IPM guidelines at these audits, while in LV, specific manuals have been developed for different crops based on the guidelines. In other countries, the guidelines are used merely as a support tool

[41] Article 4 of the SUD. Training requirements are listed in Annex 1 of the SUD.

[42] It should be noted that there might be discrepancies between this information and the information inserted in the inventory. Due to the lack of definition of guidelines, some NCAs that were consulted where not sure about what documents were referred to.

for the inspections if needed (ES, SE). Some countries have developed specific questionnaires or checklists to verify the implementation of IPM either through control and/or self-assessment (e.g. AT, CY, DE, NL, IE, DK).

In some countries, the verification of IPM implementation is part of the official controls related to the use of pesticides (AT, DE, PT, CZ). This is also the case in SK, where both the implementation of basic IPM requirements, and specific requirements stated in the guidelines, are inspected through questionnaire. In SE, municipalities conduct the controls (assessing risks and needs for control, deciding on type and frequency of the controls). However, guidance to the municipalities is provided by the national competent authority.

Use by other stakeholders

In addition to the interviews conducted with NCAs, national stakeholders were also interviewed about implementation of IPM and the use of sector- and crop-specific guidelines.

The majority of national stakeholders consulted are not involved in assessing the implementation of IPM at farm level, rather this control is conducted by NCAs as has been outlined above. However, a few stakeholders mentioned that they have been assigned responsibilities in this sense, including for example a university in Estonia being involved in work to elaborate IPM questionnaires for control/self-assessment based on the Danish example. Another example are control bodies that are assigned the tasks of carrying out controls for specific certification schemes on IPM (e.g. in IT). Also, it was mentioned that specific research projects are sometimes assigned or tendered, and results are considered to inform regional policies aimed at promoting the adoption of IPM (Emilia Romagna in Italy). In Germany, the Chambers of Agriculture are involved in surveys related to the NAP, including reporting information on the number of publications, number of participants in training courses, number of subscriptions to warning systems, number of consultation hours, etc.

Furthermore, in this context, some interviewees mentioned spraying calendars to follow and field books where to register information about spraying and type of pesticides use, to be able to provide such information in case of audits.

Most stakeholders indicated that they use public crop-specific guidelines, including national guidelines, or guidelines developed by the competent authorities at regional level. However, also other types of guidelines were highlighted, such as those developed by growers' associations, advisory services, research institutions, and for certification schemes. In addition, digital tools such as a specific app, were mentioned in the case of the Netherlands. Indeed, it can be underlined that the sector- or crop-specific guidelines referred to in Article 14(5) of the SUD Directives are not the only existing guidelines in the Member States. A variety of guidelines developed by different actors can be found, providing valuable guidance for farmers and advisors.

In Slovakia, guidelines drawn up by various advisory organisations, were said to provide sufficient information, and where needed it was highlighted that any issues could be solved electronically (through communication with them). In Lithuania, guidelines developed by researchers were highlighted. While the target audience for these guidelines is farmers, it was said that they can also be used by advisors.

Interviews with European researchers that touched upon the subject of crop-specific guidelines indicated two specific issues, including how to reach out to end-advisors and farmers and how to make it possible for them to use the guidelines without being dependent on additional support; and the key issue of IPM regarding the adaptation to local conditions which poses a difficulty also for crop-specific guidelines. Therefore, the need to provide farmers with basic tools to help them design and drive their own solutions adapted to local conditions, was mentioned.

3.1.6.2 Support to stakeholders for implementation of IPM on farms

A few stakeholders of the ones consulted indicated that they had received specific support to implement IPM on farms. Different types of support were mentioned, both at EU, national and regional level.

In regard to EU support, the Rural Development Programme[43] can be highlighted, in particular Measure 10.1 (agri-environment-climate commitments)[44] which guarantees support for farmers introducing integrated production techniques on the farm, Measure 11[45] concerning organic farming, and Measure 2[46] for advisory services, training and cooperation to innovation.

In terms of national and regional support, financial support (e.g. subsidies to pay the extra-costs for purchasing biological control agents, organic cultivation, etc.) was mentioned but also other support such as information, forecasting and warning system services provided for free, as well as other publicly funded research projects, trainings and activities (for example Leaf-Feed project in Hungary for the development of an integrated plant nutrition system).

Also, private support can be highlighted. More cooperation with branch organisations was mentioned in the Netherlands, and in Germany private support is made available by the sugar beet growing associations and related advisory branches (IPM has been mandatory in sugar beet cultivation in Germany for many years pursuant to German legislation). The main support

[43] The rules for rural development spending during 2021-22 are laid out in the CAP transitional regulation, adopted on 23 December 2020. The regulation largely extends the existing rules (initially in place for the 2014-20 period), with some additional elements to ensure a smooth transition to the new CAP, which is due to begin in 2023. More information available at https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development_en#ruraldevelopmentprogrammes.

[44] https://enrd.ec.europa.eu/sites/default/files/rdp_analysis_m10-1.pdf.

[45] https://enrd.ec.europa.eu/sites/default/files/rdp_analysis_m11.pdf.

[46] https://enrd.ec.europa.eu/sites/default/files/rdp_analysis_m2.pdf.

that farmers are receiving in terms of IPM support by the private sector is via their advisory services. Such services are providing technical support to growers in many fields of which agronomy. Finally, pesticides companies in Romania organise, together with distributors, field days and demos, symposia and webinars, presenting various IPM tools to better calibrate the use of pesticides. A similar point was mentioned by Swedish stakeholders: with the growing concern regarding pesticides use, pesticide companies need to find a way of balancing their place in the market.

Complementing tools (by NCAs)

In the consultation with NCAs, interviewees were asked to mention tools that are being used in their countries to promote IPM implementation, in addition to crop-specific guidelines, including legal instruments, financial support measures, technical support measures, trainings, creation of professional networks, as well as other tools. The below table has the purpose of presenting an overview of the measures indicated.

Table 12: Complementing tools for IPM implementation in Member States

<table>
<tr><th>Legal instruments</th></tr>
<tr><td>Most NCAs interviewed had implemented legal instruments to promote IPM implementation.
• Member States have developed legislative measures making it a regulatory requirement to follow the IPM principles.
• In Latvia, IPM elements such as crop rotation, soil tests, fertilisation plan and record keeping are included in the official plant protection controls.
• In Lithuania, implementation is in part supported by the National Agricultural and Food Quality Framework.
• In Bulgaria, a regulation on the maximum residue levels of pesticides in or on foodstuff can be mentioned.
• Mandatory training for licence/renewal of licence for professional use of pesticides, covering also IPM.
• In France taxation and the separation of sales from advice were mentioned, as well as the need for farmers to have two "technical strategic support[47]" every five years.
• In addition, EU instruments, such as GAEC, multiple compliance and agro-technical measures were mentioned as legally binding. Agro-Environmental and climate measures as part of the second pillar of the CAP were mentioned.</td></tr>
<tr><th>Financial support measures</th></tr>
<tr><td>As specified below, a majority of EU Member States have implemented financial support measures to promote IPM and the uptake by farmers. In this context, the agro-environmental measures of the RDP 2014-20 can be highlighted, and in particular measures 10 and 11 relevant for the implementation of IPM paying beyond the obligations and organic farming respectively.</td></tr>
</table>

[47] Each French farmer has at his own costs to get two official technical supports by organisations that will be/are certified by national authorities. Such support aims at train individual farmers on IPM practices based on individual farming practices.

- In terms of national support measures, the following ones were identified in the Czech Republic:
    - Grant title to promote the use of organic preparations (low-risk products)
    - Subsidy to support demonstration farms showcasing IPM compliance, consisting in financial support for e.g. organising events, but also for farming systems with limited use of pesticides
    - Subsidy for organic farming
    - Financial support for F&V as well as vine is provided for integrated production.

- Lithuania provides support to organic farmers for purchasing certified seed. The agri-environment, climate and organic farming measures of the Rural Development Programme (RDP and national measures) were also mentioned.
- In Spain, some autonomous regions provide support for advisory services, also support for using alternative products can be highlighted as well as integrated production (measure 10).
- Financial support of research/knowledge dissemination/pilots by public-private financed programmes was indicated in the Netherlands.
- Support for acquiring specific techniques for precision spraying (within the Danish Ministry of Agriculture).
- In Ireland, Tillage Capital Investment Scheme offers financial support to farmers to help achieve environmental benefits, increasing efficiency and improve competitiveness.
- In Italy, economic compensation is provided to farmers who adhere to the integrated production regulations((supported by measure 10).
- In Portugal, until 2007, financial support measures were implemented for the implementation of IPM, PRODI (integrated production) and MPB (organic) practices(. Following the publication of the Sustainable Use Directive with the obligation to apply the general principles of IPM, support was limited to PRODI and MPB.
- In Austria, financial support is provided for tools for pest monitoring decision-making and for advisory services for IPM (warning service of i.a. Chambers of Agriculture), as well as for promotion of practical trials of sustainable, biological, physical, and other non-chemical methods.

Technical support measures

EU Member States have developed technical support measures to promote IPM and facilitate the uptake by farmers, including advisory services, technical support and workshops, webpages, crop-monitoring reports, and warning systems providing real time data on pests and diseases, research and demonstration projects, and similar measures.

Prognosis and warning systems exist in the majority of countries, making available crucial data either through websites or newsletters. However they do not exist for all pests and diseases.

In addition to the above, both Denmark and the Netherlands have support programmes on specific techniques for precision application and spraying. In Italy, the development of the quality IPM brand SQNPI covering the most important crops cultivated in the country can be mentioned.

Trainings

All Member States (out of the ones consulted) have developed trainings to support the implementation of IPM among farmers. In particular, the mandatory training for professional use of pesticides (Article 4 of the SUD) can be highlighted as this training may also include IPM. In addition to this, workshops and trainings with a full or partial focus on IPM are set-up regularly in some MS. There are also specific trainings for advisors and for inspectors of IPM in place in some countries.

Creation of professional networks

Professional networks have been set up in some EU Member States with the aim of promoting IPM. In this context, different types of networks can be mentioned as follows:

- Networks of farmers' associations in different sectors linking also to research (e.g. in Czech Republic where associations are often linked to private research organisations).
- Networks and/or collaborations of advisors and advisory services (e.g. the national network of certified advisors in Spain).
- Network of inspectors (Slovakia).
- Farm network (DEPHY in France and Germany – see case study)
- H2020 projects and collaborations/networks emanating from such research projects (e.g. NEFERTITI – Hub Bulgaria No 9 "Reducing Pesticide Use in Grape, Fruit and Vegetable Production).

Other initiatives that can be highlighted include the Swedish Plant Protection Council set up by the government to facilitate the implementation of the SUD Directive, a Danish partnership on precision farming including about 100 members, and the creation of professional networks in Ireland in the specific tillage and grassland areas, following training- and stakeholder events.

Other tools

Other measures with the aim of promoting IPM implementation at farm level have been set up in EU Member States, including the following:

- Overall dissemination of key information to advisors and farmers through websites (SK, SE). One such key example is the Integrated Plant Protection, Consultation and Training Information System that has been developed in Lithuania, providing up-to-date information on e.g. on-going trainings, crop monitoring data, maps of the spread of harmful mechanisms, etc. (www.ikmis.lt). Furthermore, in Slovenia, additional staff has been employed to work on knowledge transfer to final users through e.g. small-scale experiments testing alternative methods.
- Research funds dedicated to IPM, including breeding research to provide resilient cultivars, development of DSS, research on particular pest control issues, development and support of tools and uptake of IPM (DE, SE).
- Demo farms and "ambassador farms" (SE, DE, FR) as a way of implementing IPM and disseminating information in parallel.
- Other initiatives to be highlighted include the Ecophyto Plan in France, and the Implementation Programme of the Vision on Plant Protection 2030 in the Netherlands – put in place in September 2020, establishing targets and activities to develop resilient plant and growing systems and strengthen the linkage between agriculture and nature.

Source: Compiled by the Consortium

Complementing tools (by national stakeholders)

In some cases, national stakeholders in the EU Member States have received instructions/mandate by competent authorities to develop tools complementing the crop-specific guidelines, as well as to develop or assist the development of guidelines.

In regard to the development of crop- or sector-specific guidelines, this was highlighted by stakeholders interviewed in Bulgaria, Estonia, Cyprus and Germany. In the case of Germany, associations are in charge of the development of crop-specific guidelines, while in Bulgaria, an agricultural university was involved in the development of existing guidelines as well as in the on-going revisions. This was also the case in Estonia. Furthermore, in some countries (e.g. ES, SE), stakeholders have sometimes been consulted as part of the development of the guidelines.

In addition to crop-specific guidelines, other tools developed include the following:

- **Warning systems, forecasting models, and decision support systems**
  In Austria, monitoring of pests and diseases is in place, as well as application of international forecast models (e.g. ISIP and ZEPP from Germany). Free accessible warning systems have been developed for a wide range of crops.

  Flanders in Belgium has several warning systems in place (for e.g. Potato blight, *Alternaria*, aphid).

  In Latvia, they are developing a network of meteorological stations in orchards, as well as guidelines for optimal spray timing. Testing of the decision support system RIMpro in local conditions is in progress.

  The Chamber of Agriculture in North Rhine-Westphalia, Germany, reported on several initiatives such as a warning service, development and testing of IPM procedures (alternative pesticides, electrical, thermal, mechanical), forecasting models and decision-making support (ZEPP), development and updating of the forecasting systems, tools for risk reduction to assess the risk of pesticides entering the water body.

- **Advisory services**
  In Sweden, advisory services have contributed to the development of IPM specific modules in the context of the publicly financed advisory services – "*Greppa Näringen*" ("Focus on nutrients").

  In the Netherlands, provincial and national education programmes via extension services on the use of existing IPM guidelines have been developed.

In Italy, there is a collaboration between regional authorities and the advisors through which the region coordinates and updates the advisors, and advisory services are provided as part of the Region's integrated public/private system.

- **Information**
  Development of informative tools such as website content on IPM, circulars and notifications following requests by the NCAs were highlighted in several EU Member States (SI, RO, LT, CZ). Also, in some cases, research studies have been commissioned to associations to e.g. investigate biodiversity in differently managed vineyards and analyse benefits of integrated production (CZ). Furthermore, in Portugal, stakeholders contributed to the development of the SUD NAP and improvement of evaluation and procedures, as well as elaboration of standards and notebooks of good practices.
- **Others**
  A variety of tools were developed by stakeholders including colour classification of pesticides based on impact (BE/Flanders), digital tools for farm management including dose calculations, number of treatments, timing, etc. (BE/Flanders), list of specific measures for the most important crops/sectors based on the SUD following request by NCA (NL), adaptations of the dosage of pesticides (SE), certifications including IPM measures in consultation with the government (BE/Flanders), research projects (ES, LT, NL among others).

The tools mentioned above have been disseminated through various channels, including field trials, trainings (theory as well as practical training on the use of tools), field days, seminars, publication of results online or in journals, digital newsletters, presentations, visits to companies, publication of survey results, exhibitions, trade fairs, annual brochures, conferences, annual publication of a guidebook on plan cultivation and plant protection, publications in specialist magazines (among others).

In addition to those, dissemination through warning systems can be highlighted. For example, warning notices sent weekly during season by post, fax or email in some countries (e.g. DE, SE). Advice to farmers via advisory services can also be underlined as an important channel for informing farmers about alternative tools, via direct communications with farmers through sales and consultation.

3.1.7 Classification of Member States as regards their level of implementation regarding IPM related requirements

In the context of the Pilot Project, country fiches were developed for all EU Member States to support the analysis of the typologies of MS as regards IPM implementation. These fiches provide an overview on the current state of the implementation of IPM measures in each country, drawing on the results of the country research and providing some additional contextual information. In particular, the fiches contain the following sections:

- Key statistics of the agricultural sector, providing information on the main crops grown per country, as well as the number and average size of farms.
- Details on the National Action Plan[48], including first publication and revisions (where applicable), as well as an overview of qualitative and quantitative targets.
- Figures with trends on pesticides sales and the HRI indicator, providing data for the time period from 2011 to 2019.
- Details on the implementation of the SUD and IPM, providing an overview of guidelines available in each Member State, information on crop specific practices as well as the IPM principles covered by these practices, and supporting measures in place to incentivise the uptake of IPM practices. Building on the content of the country fiches , the table below provides an overview of the differences in terms of SUD and IPM implementation across Member States, as a result of the data collection exercise performed in this Pilot Project.

[48] Details on the implementation of the NAPs can be found at https://www.europeansources.info/record/directive-2009-128-ec-on-the-sustainable-use-of-pesticides-european-implementation-assessment/.

Table 13: Overview of IPM at Member State level

MS	No of IPM principles covered	IPM principle covered								Taxation systems	Trainings	Professional networks
		1	2	3	4	5	6	7	8			
AT	8	✓	✓	✓	✓	✓	✓	✓	✓	No	Yes	Yes
BE	8	✓	✓	✓	✓	✓	✓	✓	✓	Debated	Yes	Yes
BG	6	✓	✓	✓	✓	✓	✓			No	Yes	Partly
CY	6	✓	✓		✓	✓	✓	✓		No	Yes	Partly
CZ	3	✓	✓	✓						Debated	Yes	Yes
DE	7	✓	✓	✓	✓		✓	✓	✓	Debated	Yes	Yes
EE	7	✓	✓	✓	✓	✓	✓		✓	No	Yes	Partly
EL	5	✓	✓	✓	✓		✓			No	Yes	Partly
ES	8	✓	✓	✓	✓	✓	✓	✓	✓	No	Yes	Partly
FI	5	✓	✓	✓	✓	✓	✓		✓	Abandoned	Yes	Yes
FR	7	✓	✓	✓	✓	✓	✓		✓	In place	Yes	Yes
HR	5	✓	✓		✓		✓		✓	No	Yes	Partly
HU	5	✓	✓	✓	✓		✓			No	Yes	Partly
IE	6	✓	✓	✓	✓		✓		✓	No	Yes	Yes
IT	8	✓	✓	✓	✓	✓	✓	✓	✓	Debated	Yes	Yes
LT	6	✓	✓	✓	✓		✓		✓	No	Yes	Partly
LV	8	✓	✓	✓	✓	✓	✓	✓	✓	No	Yes	Partly
MT	6	✓	✓	✓	✓		✓		✓	No	Yes	Partly
NL	6	✓	✓	✓	✓	✓	✓		✓	Debated	Yes	Yes
PL	8	✓	✓	✓	✓	✓	✓	✓	✓	No	Yes	Partly
PT	8	✓	✓	✓	✓	✓	✓	✓	✓	Debated	Yes	Yes
RO	5	✓	✓	✓	✓				✓	No	Yes	Partly
SE	5	✓	✓	✓	✓		✓			In place	Yes	Yes
SI	7	✓	✓	✓	✓	✓	✓	✓		No	Yes	Partly
SK	2	✓	✓							No	Yes	Partly

Source: Compiled by Arcadia International

3.2 Theme 2: Estimation of the potential to reduce dependency on pesticide use and its key drivers and barriers

3.2.1 Alternatives to chemical pesticides

The question related to the existence of alternative non-chemical solutions to chemical pesticides is key when it relates to the uptake of IPM by farmers. In this chapter, it is first defined what alternatives to chemical pesticides mean highlighting that pesticides can be replaced by other bio products (biocontrol, biopesticides) but also by novel techniques and practices; and also by a mix of techniques, practices or products. Then, the potential of each group of alternatives is assessed, before discussing their availability and barriers for use.

Recital 5 of the SUD mentions that the National Action Plans aimed at setting quantitative objectives, targets, measures, timetables and indicators to reduce risks and impacts of pesticide use on human health and the environment, and at encouraging the development and introduction of integrated pest management and of alternative approaches or techniques in order to reduce dependency on the use of pesticides, should be used by Member States in order to facilitate the implementation of this Directive.

Under Article 5 of the SUD and Article 3(8) of the Regulation (EC) No 1107/2009, non-chemical methods mean alternative methods to chemical pesticides for plant protection and pest management, based on agronomic techniques such as those referred to in point 1 of Annex III, or physical, mechanical or biological pest control methods.

However, the term chemical pesticides is not defined in the SUD but, when interpretating the F2F targets, the Commission has decided to consider that chemical pesticides mean all approved active substances excepted micro-organisms. Several interviewees highlighted that the list of approved active substances contains a few micro-organisms, which are then not considered as chemical pesticides; but also other natural substances which have been purified and sometimes synthetised to respect the technical specification requirements of the approval process under Regulation (EC) No 1107/2009, such as seaweed or seed extracts which are then considered as chemical pesticides. For these interviewees such substances should not be considered as chemical pesticides as their use reduces the risks and negative impacts of pesticides and therefore shall be considered alternatives to chemical pesticides.

The main alternative method groups can be summarised as follows:

- **Tools and techniques to prevent and/or suppress harmful organisms**. This group includes multiple techniques and approaches and includes:
  - The selection of suitable site conditions (area not infested by pest, diseases, or weed; suitable soil types and climatic conditions);
  - The application of crop rotation to reduce the pressure of diseases, pests, or/and weed. If the same crop is planted year after year on the same fields (monoculture), populations of certain pests and diseases can gradually increase. Crop rotation can be an interesting tool for reducing pest/disease pressure especially when long crop rotations are applied (>5 years). In addition to significantly decrease pest pressure, crop rotation has to be planned at a larger scale than just individual fields as pest/diseases easily move from one field to another. Therefore, crop rotation must be reasoned at the level of the farm or the area of production by considering the farming systems present under such area.
  - The use of adequate cultivation techniques (e.g. stale and sterile seedbed techniques, sowing dates and seeding rates (density of seeds), under sowing, closer rows, reduce ploughing (even if ploughing in summer when temperatures are high strongly reduces the presence of weeds) and reduce tillage, mulching, pruning, and direct sowing). Each of these different cultivation techniques must be analysed carefully to identify their usefulness depending on the crops to grow and considering the most important pests and diseases present in the region. For example, the sterile seed bed technique involves cultivating the soil, and then leaving it for a period until an initial flush of weeds has germinated. The grower will then lightly cultivate the soil to destroy the weed cover before the desired crop is planted/sown. Decompaction of the soil also contributes to reducing pest/disease pressure as soil structure also has an impact on biological activity and processes, root development and seed germination and emergence. An early or late sowing date can also contribute to reduce pest pressure and competition as the biological cycle of the pests and diseases is shifted and, therefore, the pest pressure less strong.
  - The use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and plant propagating material. Use of resistant varieties to pest and diseases is a very efficient way to protect the crops. Plant breeding has partly been supporting the development of cultivars with tolerance or resistance to key pests, with an ultimate goal of reducing reliance on conventional

pesticides. New genetic methods and new breeding methods have certainly the potential to help developing new adapted resistant varieties not yet present on the market as traditional breeding techniques is slow in creating such cultivars. The use of certified seed is also recommended as such seed lots have been inspected by official bodies to secure a minimum level of varietal purity (including freedom from weeds), seed germination, vigour and, most importantly, freedom from seed-borne pests and diseases.

- The use of balanced fertilisation, liming, and irrigation/drainage practices based on soil analysis. Soil analysis allows to adapt quantities of fertilisers applied to crop requirement for an optimum crop production. Such approach allows to reduce nutrient losses and leaching to the environment and therefore participate to farm profitability. In addition, a balanced nutrition reduces the risk of crop lodging (for example in cereals) and therefore reduces the use of plant growth regulators that farmers are spraying to avoid any cereal plant lodging. As other examples, nitrogen fertilisation makes the plant somehow more susceptible to initial infections. Irrigation or wet soils may keep and spread the inoculum of water-borne diseases, etc.
- The prevention of the spreading of harmful organisms through hygiene measures (e.g. regular cleaning of machinery and equipment). Machinery can often be responsible for the transport of pests or seed of weeds from field to field or farm to farm. Examples of this are situations like potato cyst nematode or beet cyst nematode being carried from one field to another on soil particles on machinery. Another example is where a combine harvester/baler transports wild oat seeds from one location to another. In addition, good growing and storage hygiene is important to minimise the spread of many pathogens injurious to many crops. Pathogens such as *Erwinia spp.* In potatoes, can be transmitted by debris etc. on boxes. Steam cleaning can eliminate such possibilities. Similarly, cleaning and/or disinfecting growing trays, remains a useful way to reduce the initial source of inoculum. The same principle holds true for storage boxes and trays for all types of crops.
- The protection and enhancement of important beneficial organisms, e.g., through adequate plant protection measures or the utilisation of ecological infrastructures inside and outside production sites. A beneficial organism is any living organism that benefits the growing process, including insects such as pollinators, fungi, viruses, microorganisms, bacteria, other plants than the

cultivated one, and nematodes. By securing the presence of beneficial organisms in the fields by providing suitable living conditions, plants are better protected against pests and diseases.

- **Physical measures (mechanical, thermic, optical)**. Mechanical weed control is certainly a promising practice that can be used in many crops and in particular in permanent crops and annual crops which are seeded/planted in rows. Such techniques can achieve moderate levels of weed control in other crops. New technologies and robots are currently being developed for such mechanical weeding. Such new tools seem to be efficient and allow multiple passes in the same field. The main issue with such tools is their costs which is far too high for a high level of adoption by farmers unless several farmers decide to buy equipment collectively. Manual weeding is often used in conjunction with mechanical methods for weed control is specialty and high value crops such as vegetables. In orchards/vineyards etc., topper/mower for weed control are being used where there is usually a grassed area between each row of trees/vines etc. Crop mulching can serve to reduce the presence of weeds and warm up the soil and vegetation thus encouraging and enhancing growth, then strengthening plants against pests and diseases. However, in some situations the use of a fleece can have a negative impact as it may create conditions for the development of new diseases due to the micro-climate created under the fence at soil level. The use of nets is another physical measure that can be used to protect high value crops, mainly F&V, to prevent entry of insect pests (e.g. flies in cabbages and carrots, birds etc.). However, as with the crop fleeces, new diseases under the net can appear and such nets can't be used in windy areas. Use of optical and sound generating devices such as bangers and kites are primarily used to deter birds from crops. Birds can become accustomed to such devices and so use of such devices requires a change from one method to the other within often a short period of time limiting the usefulness of such approach.

- **Biotechnical measures (pheromones traps, mating disrupting, food traps and attractants).** In recent years, considerable progress has been made using pheromones for mass-trapping, mating-disruption methods for beetle and moth pests associated, mainly, with stored products. Such use of pheromones for stored products can lead to a drastic reduction of chemical treatments during storage, with economic advantages and improvement of food quality. Mating disruption technologies use pheromones in large amounts to confuse males and limit their ability to locate calling females since the goal is to "disrupt" rather than "attract". Such sex pheromones have been successfully used for decades to monitor insect activity patterns e.g. in the insect order *Lepidoptera spp.* (moths and butterflies). Such practices are also widely used in orchards and greenhouses.

- **Precision agriculture – Smart agriculture**. The term refers to the use of several technologies like internet of things, sensors, location systems, robots and artificial intelligence on the farm. The ultimate goal is increasing the quality and quantity of the crops while optimising the human labour used of which reducing the use of pesticide use. Under this group, the non-chemical (i.e. physical) weeding methods can be mentioned which are lying on cultivation tools and robots that remove mechanically weeds from the crops.
- **Biological control and biopesticides** (use of natural enemies, application and release of beneficial organisms, natural substances, use of plant strengtheners/biostimulants of which micro-organisms). The term biopesticides is not defined in the EU legislation[49] but it is widely agreed that it is used to label biocontrol and biocontrol technologies and to make the link with its natural dimension, meaning causing no damage to the environment - or a minimal, non-remanent effect - and no harm to humans and non-targeted animals, nor creating risks for human health (International Biocontrol Manufacturers Association, 2020).[50]

  Depending on the types of living organisms or natural substances used, four categories of technological approaches to biological control are widely agreed:

  - Macro-organisms: invertebrates, such as insects and nematodes used for biocontrol purpose - referred to as Invertebrate Biocontrol Agents;
  - Micro-organisms: viruses, bacteria and fungi as defined in point 15 of Article 3 of Regulation (EC) No 1107/2009;
  - Semio-chemicals or chemical mediators: pheromones; and
  - Natural substances of mineral, plant or animal origin.

  Under this group, the authors proposed to add the category of plant biostimulants which is defined in the new fertilising product Regulation (EU) No 2019/1009[51] that is entering into force in July 2022 and which modifies Regulation (EC) No 1107/2009 as follows: "*a product stimulating plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere: (a)nutrient use efficiency;*

[49] but defined e.g. in the French Rural Code of 6 | Exploring the benefits of biocontrol for sustainable agriculture Institute for European Environmental Policy (2021) Law ("Code Rural et de la Pêche Maritime", article L 253-6). In addition, the Commission proposal to revise the SUD includes a definition of "biocontrol".
[50] International Biocontrol Manufacturers Association - IBMA definition.
[51] Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003 (Text with EEA relevance).

(b)tolerance to abiotic stress; (c)quality traits; and (d)availability of confined nutrients in soil or rhizosphere."

On the basis of the data collected during the interviews and completed by expert judgement from the members of the consortium, the potential for each of these alternative groups to replace chemical pesticides is presented before analysing whether or not such alternatives are existing.

The following table summarises the potential contribution of the above-mentioned techniques, practices, and non-chemical methods to the objective of providing alternatives to chemical pesticides. It highlights the potential of each of these in the future and does not state the actual situation. By doing so this table identifies the most promising future alternatives the current availability of which is then discussed in the next chapter.

Table 14: Assessment of the main technologies and techniques described above as regards their future potential of reducing dependency on pesticide use

Alternatives	Potential reduction of pesticide use	Cost of implementation	Current level of implementation	Long term sustainability
Principle 1 – Prevention and suppression				
Site conditions	Low	Low	Medium	High
Crop rotation				
Crop diversity (crop rotation/sequence)	Medium to high	Low to high	Low to medium	High
Intercropping	Low to medium	Low to medium	Low	High
Under sowing	Low to medium	Low	Low	High
Others (companion cropping)	Low to medium	Low	Low	High
Cultivation techniques				
Stale seedbed	Low to medium	Low	Medium	High
Sowing time	Low to medium	Low	Medium	High
Seed/plant density	Low to medium	Low to medium	Medium	High
Superficial ploughing	Low	Low	Low	High
Non-inversion tillage	Low	Low	Medium	High

Alternatives	Potential reduction of pesticide use	Cost of implemen-tation	Current level of implemen-tation	Long term sustaina-bility
Conservation tillage/direct sowing	Low	Low	Medium	High
Mulching	High	Low	Low	High
Resistant/tolerant cultivars and standard/ certified seed and planting material				
Weed competitive cultivars	Medium	Low	Low	Medium to high
Disease or pest resistant and tolerant cultivars produced through conventional breeding	High	Low	Medium	High
Use of certified seed	Medium	Low to medium	High	High
Disease or pest resistant and tolerant cultivars produced through Genetic engineering & new genomic techniques	High	High	Low	High
Balanced fertilisation, liming and irrigation/drainage practices				
Balanced fertilisation	Low to medium	Low	Low to medium	High
Irrigation	Low	Medium	Medium	Medium
Preventing the spreading of harmful organisms by hygiene measures				
Hygiene measures: cleaning of machinery	Low to medium	Low	Medium	High
Protection and enhancement of important beneficial organisms				
Habitat conditions: hedges, field margins	Medium	Medium	Low	High
Habitat conditions: Enhancing beneficials by improved management	Medium	Medium to high	Low	High
Principle 4 – Biological, physical and other non-chemical methods				

Alternatives	Potential reduction of pesticide use	Cost of implementation	Current level of implementation	Long term sustainability
Biological control: application and release of beneficials and microbials	High	Low to medium	Low	High
Biological control: other natural substances	High	Low to medium	Low	High
Biological control: use of plant strengtheners/ biostimulants	Medium	Low to medium	Low	High
Physical measures: mechanical	High	Low to medium	Medium	High
Physical measures: thermic	Medium	Medium to high	Low	High
Biotechnical measures: pheromone traps	Medium	Low to medium	Low to medium	Medium to high
Biotechnical measures: mating disrupting	Medium	Low	Low	Medium to high
Biotechnical measures: food traps, use of attractants, sexual confusion	Medium to high	Low	Low	Medium to high
SMART/precision agriculture	High	High	Low	Medium to high

Source: Compiled by the Consortium

From the assessment presented in the table above, the following four types of alternatives seem to be the most promising ones in order to reduce the dependency of pesticide use:

- Crop rotation and other physical and mechanical measures (including intercropping, under sowing and companion cropping);
- Use of biopesticides;
- Further development of resistant varieties including conventional breeding and new genomic techniques/new breeding techniques; and
- The development of precision farming and smart agriculture even if such measures are expensive ones.

Crop rotation and crop diversification are important farming practices with most significant impacts in the short and long term. They can clearly have a role in improving soil conditions, water quality, weed management and plant protection systems, biodiversity, and more. Crop rotation is a very old practice. Many different crop rotation schemes have been introduced in the past centuries, to make the crops better adapted to local pedoclimatic conditions. This was done by increasing the number and the complexity of the crops in the rotation cycle, including fallow. During the last decades the diffusion of such practices has been considerably reduced and the number of crops in the rotation has decreased to range between monoculture to 3-4 years maximum, which leads to more pest and disease pressure on the cropping systems. The reduction of crop rotation length was searched for the best economic return by cultivating the two-three most profitable crops for individual farmers. If monoculture of maize is largely implemented in Alsace in France, it is simply because there are no other crops that could bring the same level of revenue for farmers as other crops are less profitable. For the last ten years the agronomic values of implementing longer crop rotations of 6-7 years have been highlighted and longer crop rotations have gained considerations. It is largely agreed by agronomists that crop rotation can help the control of weeds, diseases, and pests. This is also the case with a reduced application or without the use of pesticides, due to an increased crop resistance to pests. Long crop rotations bring other benefits including reduced runoff and soil erosion, improved water conservation, more efficient use of water, enhanced soil carbon sequestration, reduced nitrogen in water (using intermediate crops that can be sold) and increased above-and below-ground biodiversity.

When it relates to reducing the pest pressure, crop rotation has to be considered at several levels, as follows:

- The farmer's individual fields that each have a different history in term of agronomic practices being used on such plot. Therefore e.g. weed pressure is field specific;
- Crop rotation has also to be considered at farm level to adapt to specific farming and cropping practices considering that pests and diseases are moving across individual fields; and
- The area of production has also to be included in the reflexion and development of strategies related to crop protection as the pests and diseases pressure can be largely different from one area of production to the other due to their biological characteristics that make that they are present or not in a given area of production. For example, the European corn borer is not present in all maize production areas but is mainly present in South-Europe rather than in the North.

These three components have to be considered by farmers when building their crop rotation strategy.

The main issues for farmers to change their crop rotation practices, moving from monoculture to long rotations, are mainly economic as such changes of practices involves significant costs:

- It is likely that farmers will have to grow new crops on their farms, meaning that they will have to buy specific equipment for such new crops (seeders, harvesters, etc.), leading to significant investment in material;
- Existing market opportunities have to be considered when selecting crops to be introduced in the crop rotation. When market opportunities are not immediately present, farmers are reluctant to grow a crop they will not be able to sell at high price;
- Introducing new crops on their farm may be perceived as an agronomic risk for farmers that are not used to cultivate such new crops; and therefore do not have all agronomic expertise for an optimal cultivation leading to an optimal revenue; and
- Short-term the introduction of new crops in the rotation will lead to decrease of revenue for farmers that have optimised their rotation for the most valuable crops, and complexity in managing long crop rotations. Flexibility is also required.

These are the main reasons explaining why farmers have difficulties to adopt such long crop rotations. In addition, the importance of crop rotation is still highly underestimated for some researchers, and it proves challenging to create awareness among stakeholders and practitioners, as well as the general public.

Use of alternative products and non-chemical solutions. One of the easiest solution alternatives for farmers will be to replace hazardous chemical substances by non-hazardous ones (the so-called "biopesticides"). However, the biopesticide market is still at an infant stage even if the European biopesticides market is expected to grow by 10-12% during the forecast period (2020-2025). Over the last decade, the major pesticide companies have invested in R&D efforts to develop and market biopesticides and more products and active substances are being approved at the EU level. Before, the market was dominated by smaller companies acting mainly at national level.

Side-by-side another group of products shows large interest in the farming community; these are the plant biostimulants which are products which are re-enforcing the strength of the plants to make them more resistant and resilient to biotic and abiotic stresses.

The progress of the organic industry, the rising cost of chemical pesticides, concerns issues by the civil society, and the increase in awareness about hazards caused by chemical pesticides are the major driving factors for the biopesticides market. It is therefore expected that there will be a shift from chemical pesticides to biopesticides and plant biostimulants in the future. However, the speed of the shift remains unknown.

For the time being, the alternative products suffer from the situation that their spectrum to control pests and diseases is more narrow than chemical pesticides and that, in most of case, their agronomic efficacy is mower. Such situation is decreasing the adoption rate by farmers and producers.

Further development of resistant varieties. Another easy solution for farmers will be to grow varieties resistant to pests and diseases developed through plant breeding. Resistance breeding is an important strategy for reducing crop losses caused by diseases, viruses, and bacteria. Such resistant varieties are already existing in a majority of crops, but resistant cultivars do not cover all pathogens in all crops. Breeding for crop resistance is an environmentally sound method for managing disease and minimising these losses.

Recent advances in genetic and genomic technologies have contributed to a better understanding of the complexity of host–pathogen interactions and have identified some of the genes and mechanisms that underlie resistance. This new knowledge may benefit crop improvement through better-informed breeding strategies that utilise diverse forms of resistance at different scales, from the genome of a single plant to the plant varieties deployed across a given region. Therefore, effectiveness of plant breeding will certainly increase soon with the adoption of recent developments in large-scale phenotyping, genome sequencing, analysis of gene expression, and protein/metabolite abundance even if additional research is needed to increase the understanding of the biology and epidemiology of the causal agents, including host status and virulence, as these have major implications for any breeding program. Only after significant input in improving existing knowledge on both pathogen virulence and plant resistance, resistance breeding will be efficiently accelerated through such novel techniques. Consequently, such plant breeding innovations are rapidly being developed and utilised internationally and across the seed sector, public and private research, plant species and markets.

However, the regulatory framework on some of these new techniques (new genetic techniques) is perceived as constraining by the seed industry in Europe. Regarding mutagenesis breeding the ruling of the European Court of Justice (2018) confirmed that 1) organisms obtained by all means of mutagenesis must be considered to be Genetically Modified Organisms (GMOs) as defined in Article 2(2) of Directive 2001/18/EC (GMO Directive), and 2) the mutagenesis exemption only applies to methods of mutagenesis which have conventionally been used in a number of applications and have a long safety record. Organisms obtained by applying exempted methods are considered GMOs exempted from GMO regulation. Therefore, the EU legislation on biotechnologies is perceived as a major hurdle for investments in new breeding methods-related R&D by the seed industry. Such legal framework may limit the R&D efforts in plant breeding in the EU for developing new disease resistant cultivars.

In conclusion to this section, the analysis presented above clearly shows that alternatives are under development, but it seems that in many cases, economically viable alternatives are not yet available. An analysis of the economic viability of pesticides and their alternatives should consider direct effects on crop production (e.g. yields and quality) and application costs, as well as indirect effects (e.g. short- and long-term effects on soil productivity, biocontrol and health of applicants and bystanders) in the context of the respective agricultural system (e.g. conventional, organic etc.). Important criteria for the choice of alternatives by farmers are further the reliability (i.e. risks) of alternatives in reducing pest damage and required knowledge and machinery in their application. Additional other non-monetised elements, such as easiness of application of a given alternative, are other elements to be considered in such analysis. Such points are disputed between stakeholders where some (mainly NGOs) consider that chemical pesticides can be phased out as alternatives exist and impact of chemical pesticides are too high while others (PPP industry and farmers) highlight that non-chemical economically viable solutions are currently not fully available. On that basis, the experts of the study team investigated on possible indicators that would, to a certain degree, show the level of availability of alternatives to chemical pesticides. Two indicators that may demonstrate the level of presence of alternatives were considered:

- First, the number of minor uses or orphan uses continues to increase. In the F&V sector in France, 42% of the uses are not covered by an alternative to chemical pesticides; and
- Secondly, when considering the comparative assessments that Member States have to complete when reviewing the authorisation of a PPP the active substance of which is CfS pursuant to Article 50 of Regulation (EC) No 1107/2009, the REFIT evaluation of the PPP Regulation concludes that comparative assessments performed up to end of 2019 have not led to a single substitution of chemical pesticides by less hazardous non-chemical alternatives.

In addition, the level of availability of non-chemical alternatives is different across production systems and crops. In greenhouse vegetable production, alternatives are largely available, and these allow to produce without the use of chemical pesticides. Biological control is very well developed and highly profitable in protected environments for greenhouse crops, as well as in many orchards, offering solutions that work technically better than chemical control. In these systems, chemical control often failed because the most important pests had become resistant against the available pesticides. However, it is more difficult to make biological control work in open fields and production systems with short crop cycle. Such situation led to the development of private labels such as "zero pesticides used after flowering" as described in the French case study on tomatoes that can be found in annex to this report. Such situation should not give the impression that alternatives are available in all production systems. The situation in production under greenhouses is promising but it should not give the impression that the same level of use of alternatives is possible in open-field crops.

3.2.2 Costs of implementation of IPM at farm level

Overall, there is a lack of quantitative evidence on the costs of implementation of IPM at farm level and data on the economic costs and benefits of IPM solutions are scarce. As IPM encompasses many principles and practices, as illustrated by the list of general principles of IPM in the Annex III of the SUD, and the variability of production systems and crops all over the EU, estimating the costs of implementing IPM at farm level is very challenging as highlighted in many publications.[52](Waterfield and Zilberman 2012). Moreover, producers often only adopt parts of the spectrum of IPM principles and practices suggested by research and advisory services and, often, do not implement "IPM at 100%". In addition, the baseline on IPM implementation is highly variable, ranging from "almost no IPM" to "ultimate IPM already in place for years". Furthermore, IPM is a dynamic and continuous process, where the different strategies part of IPM are very rarely simultaneously implemented. In addition, some IPM principles may be implemented collectively such as for example pest monitoring that has to be done on individual fields by individual farmers but also at collective level to see evolution of disease and pest populations over a production area (example: SEGES pest monitoring scheme in Denmark). Eventually, the assessment of the costs of stepwise IPM adoption is difficult due to the fact that the efficiency of pest control is often obtained as a result of the complementarities of the different components within the IPM portfolio or spectrum.

Data collected provided by the interviews do not provide robust evidence to be considered for this analysis. Therefore, the answer to this study question relies on literature review performed over the last decade.

To date, the most comprehensive summary of IPM implementation at farm level can be found in the PURE research programme.[53] Previous interesting work was

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[52] For example, G. Waterfield et al., 2012, Pest Management in Food Systems: An Economic Perspective. Annual Review of Environment and Resources 37:1, 223-245.

[53] The on-going PURE project financed by the European Commission FP7 program (Innovative crop protection for sustainable agriculture, www.pure-ipm.eu) aims, amongst other objectives, to produce this evidence with on-station and on-farm data, from six key European farming systems (winter-wheat based rotations, maize-based cropping systems, field vegetable crops, pomefruit, grapevine, and protected vegetables) through the evaluation of a range of candidate IPM solutions from intermediate (solutions easy to implement and scientifically validated) to advanced (solutions in the experimental stage). We here provide a summary of recent experience and data in Europe, although limited, on the cost effectiveness of IPM adoption.

published by Norton and Mullen in the US in 1994 and Fernandez Cornejo in 1998. Although evidence in Europe is growing, albeit slowly, it is currently mostly restricted to ex-ante analysis based on expert judgment, and rarely on quantitative empirical evidence collected directly at farm level.

Inter alia, Pelzer, Fortino et al. (2012), Vasileiadis, Sattin et al. (2011), Mouron, Heijine et al. (2012), Boussemart et al. (2012) propose multi-attribute models to perform *ex ante* assessments of the cost implementation of IPM in various cropping systems. All results summarised in these publications are highly crop- and production system-dependent leading to the difficulties to be conclusive. The main conclusions presented in these publications are presented below:

- Higher labour costs to implement IPM have been recorded. This is especially the case at the beginning of the implementation as farmers have to learn the multiple principles of IPM that they need to implement. Year after year, costs are decreasing. Labour costs are higher for farmers cultivating multiple crops as they have to learn specific IPM principles per crop and production types. Higher costs are particularly observed when farmers are using mechanical weeding techniques which take longer to apply in order to keep the weeds under the threshold;
- Systematic field plot pest monitoring can also take a lot of time, but such costs can be compensated by savings due to treatment only when it is required. Additionally, pest monitoring helps limiting pesticide use to the actual minimal required dosage level;
- Production costs may be reduced with IPM compared to conventional (lower pesticide, fertiliser and irrigation costs);
- The deployment of deployment of reliable cultivars, pest and disease forecasting models, early detection methods, precision spraying employing advanced Global Positioning System, as well as community-based decisions and information sharing, are all approaches that can result in a system net profit within a time frame of 3–4 years. Therefore, economic impacts have to be estimated over a period of time and not limited to a single crop on a single year;
- The impact of IPM on cost depends not only on the impact of the adoption of IPM principles on pesticide use, but also on the cost and agronomic efficacy of alternatives which are variable;
- The use of IPM will lead to reduction of PPP resistance and therefore to cost saving but this is long-term cost saving; and
- Lower selling prices may also be observed when rotation length is increased due to reduced opportunity for alternative cash crops in the rotation.

In most of these publications, the authors have carefully indicated that such conclusions shall not be extrapolated to all crops and cropping conditions and that cost of implementing IPM depends on the specifics of the management of each farm.

Market access and price premium with IPM shall also be considered. This analysis is provided under Theme 3.

3.2.3 Risks of yield reduction

The question related to the risks of yield reduction is of economic nature. Therefore, the findings presented in the previous chapter apply to this one too.

The European Parliamentary Research Service (EPRS) published and in-depth analysis in 2019 titled "Farming without plant protection products - Can we grow without using herbicides, fungicides and insecticide?"[54] The study states that without pesticides, yields will be reduced, depending on the crop, and reductions of between 19 % (wheat) and 42 % (potato) have been reported. The study adds that reductions are higher in regions with high actual production, the latter also as a result of the input of fertilisers, high-yielding varieties, irrigation, etc. It concludes that it is still an open question whether it is possible to reduce the use of PPPs via the implementation of IPM without yield reduction. There are several indications that, for specific crops, a reduction in PPP use is feasible. The general tendency is that a reduction seems possible in the case of (very) high actual PPP use, but not in the case of low use.

Another source of information addressing this issue of risk of yield reduction when implementing IPM may be found in the research work performed in the farm demonstration farm networks such as the DEPHY network in France. Such networks have estimated the risks of yield reduction within the networks when implementing IPM. On a four-year analysis on vineyards on a representative survey of 4;000 vineyards, Lappierre et al. (2021)[55] have estimated the impact of the DEPHY programme[56] on pesticide use and crop yields. The participating

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[54] Available at https://www.europarl.europa.eu/RegData/etudes/IDAN/2019/634416/EPRS_IDA(2019)634416_EN.pdf. This report was a background document to support the debate that will take place during the workshop 'Farming without plant protection products?', 6 March 2019, which contrasts the contents of this report with perspectives from conventional agriculture, the stance of organic farmers and the viewpoint of consumers. This In-depth Analysis has been written by Wannes Keulemans, Dany Bylemans and Barbara De Coninck (CropBiotechnics, Department of Biosystems, KU Leuven), at the request of the Panel for the Future of Science and Technology (STOA) and managed by the Scientific Foresight Unit, within the Directorate-General for Parliamentary Research Services (EPRS) of the Secretariat of the European Parliament.

[55] Lappierre et al. 2021. Providing technical assistance to peer networks to reduce pesticide use in Europe: Evidence from the French Ecophyto plan. Available at https://hal.archives-ouvertes.fr/hal-02190979/file/WP%202019-15_v2.pdf.

[56] The DEPHY farm network, an innovative policy that has provided technical assistance since 2011 to 3,000 volunteer pilot farms enrolled as peer groups. Farmers who choose to participate are enrolled in peer groups made up of a dozen farmers who meet several times a year and to whom the government provides free technical assistance through a dedicated technical engineer. The aim of the program, offered to 1,900 farms in 2011, was to show that decreasing pesticide use while maintaining yields was a feasible objective. In 2016, the French authorities expanded the network from 1,900 to 3,000 farms.

farms were found to use 8 to 22 percent lesser chemical pesticides but at the same time the use of biological products has increased by 24 to 33 percent. This change in practices is mainly driven by the use of biocontrol products as fungicides. It resulted in a reduction in yields for a fraction of enrolled farms while others seem to have maintained their yields, leading to the conclusion that the yield differences were not due to IPM implementation but other agronomic and/or climatic reasons. However, such types of results have to be considered carefully as these results have been achieved within a network of voluntary farms and therefore extrapolating and generalising such results may prove to lead to biased and wrong conclusions.

Additional literature indicates that the focus that growers have on protecting yield has limited the levels of IPM that are practiced. Farmers and growers were reportedly willing to use a high volume of pesticides to protect yields, however, the savings that growers can make by using IPM measures can offset any losses to overall yield [57] and IPM has been shown to sometimes improve yield.[58]

All in all, the results indicate that implementing IPM may not lead to a significant yield reduction in the short term. Such potential reduction is not particularly linked to a given crop, climatic conditions, nor the availability of alternatives. Long-term yield reduction is not known yet. When observed such reduction, leading to a financial loss, may be compensated by a reduction of costs regarding pesticides application. As mentioned above; robust data over a sufficient long period is clearly lacking. In addition, chemical pesticides are easy to use adding to the comfort of the farmer. When implementing IPM, the production systems become more complex and more difficult to manage when chemical PPPs are reduced. The latter will increase the risk while the gain is unclear. This perception of increased risk is a significant barrier for farmers for implementing IPM and reducing chemical pesticide use: are farmers ready to support such risk?

One approach that could incentivise farmers to uptake IPM is the development of insurance schemes. Mutual funds, i.e., farmer-managed no-profit insurance tools cover risks that private insurance companies currently do not (e.g. climatic adversities, such as flooding and damage by wild animals and pests, just before and after the emergence of arable crops). Especially when the damage risk is low, mutual funds cost less than large-scale pesticide use. Indeed, this approach has been implemented for soil insecticides in maize in Italy and has allowed the farmers to uptake IPM in a context of low risk, where the majority of maize farmland does not need to be protected with insecticides at sowing since the

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[57] Way et al. 2000. Integrated pest management in practice - Pathways towards successful application. Crop Protection. 19. 81-103. 10.1016/S0261-2194(99)00098-8.
[58] Heijne et al. 2015. PURE progress in innovative IPM in pome fruit in Europe. Acta Hortic. 1105, 383-390 DOI: 10.17660/ActaHortic.2015.1105.40. https://doi.org/10.17660/ActaHortic.2015.1105.40.

percentage of land with high populations of wireworms (a major soil pest in maize farmland) is often very low (e.g. less than 5% in the Veneto region, an area with large-scale maize production) (Furlan et al., 2017)[59]. Mohring et *al.* (2020)[60] analysed the relation of crop insurance and pesticide use in European agriculture using the examples of France and Switzerland. The paper provides an overview of the research performed on the subject to date and analyse the relation of crop insurance and pesticide use, allowing highlighting differences in crop insurance – pesticide use mechanisms regarding different insurance schemes, agricultural systems and agricultural policies. The authors quantify the association between insurance and pesticide use at the intensive and extensive margin, accounting for simultaneity and interdependencies of insurance-, land- and pesticide use decisions.

The analysis finds a statistically and economically significant association between crop insurance and pesticide use, both in Switzerland and France. In both countries crop insurance is related to choosing more intensive crops with a higher pesticide use. For France it was further found that crop insurance is also related to a higher intensity of pesticide use per hectare. The results indicate that risk management tools are complements for pesticide use, i.e. are associated to a more pesticide-intensive land use and an intensification of pesticide use per hectare. Findings suggest that without insurances, pesticide expenditures would be 6 to 11% lower. Especially in more remote regions in France (Renwick et al., 2013)[61] an explanation might be that insurance makes it more attractive to grow riskier and thus often more intensive crops and grow crops on lands where farming was too risky or not economically attractive before and therefore influences land use choices. The positive association between insurance and pesticide use at the intensive margin in France relates to a risk increasing effect of pesticides. Insurance choice and pesticide use are both determined by farmers' risk preferences, providing some explanations for interactions at the intensive margin.

3.2.4 Link between the level of IPM measures uptake and farmers' characteristics

This section has the purpose of analysing the links between the level of uptake of IPM measures and farmers' characteristics. IPM implementation across the EU differs from one Member State to another, and even from a region to another. While multiple factors play a role in this context, the below sections aim to understand how specific characteristics of the individual farmers may

[59] Furlan, L., B. Contiero, E. Sartori, F. Fracasso, A. Sartori, V. P. Vasileiadis, and M. Sattin. "Mutual funds are a key tool for IPM implementation: a case study of soil insecticides in maize shows the way. IPM Innovation in Europe, Poznan 14–16 January, Abstract book, 159." (2017).

[60] Möhring, N., Dalhaus, T., Enjolras, G. and Finger, R., 2020. Crop insurance and pesticide use in European agriculture. *Agricultural Systems*, *184*, p.102902.

[61] Renwick, A., Jansson, T., Verburg, P.H., Revoredo-Giha, C., Britz, W., Gocht, A., McCracken, D., 2013. Policy reform and agricultural land abandonment in the EU. Land Use Policy 30 (1), 446–457.

affect the extent to which IPM measures are used. First, the links between IPM implementation and the age, level of education, and training will be analysed. Then, the extent to which there is a difference between full-time, part-time farmers and/or contractors will be investigated.

3.2.4.1 Uptake of IPM and farmers' age, level of education, and training

Research has shown that farmers' attitude towards innovation, the environment and health risks play a role regarding the adoption of IPM.[62] Furthermore, the adoption of IPM can be considered as risky due to novelty of certain practices and strategies, as well as the knowledge and experience gap. This perceived risk is considered a significant factor reducing the rate of adoption of new agricultural practices.[63] In this context, the below sections consider in particular age, level of education, and IPM training as factors that may or may not affect farmers' behaviour as regards adoption of IPM measures.

More than half of the stakeholders consulted in the Pilot Project (ca 55%) said that **age of the farmers indeed can be a decisive factor**, implying that the uptake of IPM measures is higher among younger farmers. Reasons that were mentioned for this included openness and innovative minds, as well as better digital skills; in contrast to the older generation being more resistant to change. In connection to this, younger farmers may have access to new networks, and overall have a higher trust in agronomists and advisors. Finally, there might be more awareness among young farmers regarding sustainable farming and the impact of pesticides use on environment, leading to these farmers being more convinced of the need for adopting IPM measures. Interestingly, when looking at organic farming in the EU and age distribution in 2013, farmers younger than 55 represented 61% of the organic sector, while only 45% of the conventional sector.[64]

However, on the other hand, several stakeholders were not convinced of age being a decisive factor. It was underlined that independently on the age group, farmers may be, for example, conservative or innovative. Furthermore, it was highlighted that it is rather a genuine interest of the farmer in crop cultivation and in how to improve the cultivation, as well as values and principles, that will affect the uptake of IPM measures. One interviewee highlighted that where there is a genuine interest for crop cultivation and the land, this is often transferred from one generation to another and does not depend on age. In

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[62] Science for Environment Policy, European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol (2014), accessible at: https://ec.europa.eu/environment/integration/research/newsalert/pdf/factors_affecting_farmers_adoption_integrated_pest_management_394na2_en.pdf.

[63] Lefebvre, M., Langrell, S. R. H., & Gomez-y-Paloma, S. (2014). Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, 1107. DOI:10.1007/s13593-014-0237-2.

[64] European Commission (2016), Facts and figures on organic agriculture in the European Union, accessible at: https://ec.europa.eu/agriculture/rica/pdf/Organic_2016_web_new.pdf.

addition, other factors to consider were mentioned such as the characteristics of the farm, the sector, experience, training and knowledge.

In regard to whether education is a decisive factor affecting IPM uptake, more than half (ca 57%) of the consulted stakeholders agreed with this. Higher education results in a better knowledge about both IPM as such, but also about the motivations for implementing IPM measures and techniques – whether this is done independently or with the help of advisors, and about the different impacts and results of organic vs. conventional farming. Farmers having received higher education may also be more open to new technologies and adapt to e.g. new digital tools more swiftly. However, also here, several other factors are to be considered as well.

Some evidence was found in the literature, indicating that level of education is one of several factors indeed affecting IPM implementation.[65] Furthermore, participation in IPM training programmes leads to a better understanding of IPM among farmers.[66]

For those stakeholders that did not consider education as a decisive factor, it was mentioned that many older or less educated farmers implement IPM measures without being aware that it is IPM, as several IPM principles are merely good farming practices. Practical experience and accumulation of know-how may play a more significant role than education or training. Finally, the genuine interest of the farmer, wanting to create good conditions for crops to grow was again put forward, as well as the consideration for each specific situation and setting.

In addition to the consultation with national stakeholders, NCAs across all EU MS were asked about **to what extent farmers are trained to use IPM measures.** Article 5(1) of the SUD states that Member States shall ensure that all professional users, distributors and advisors have access to appropriate training by bodies designated by the competent authorities (including both initial and additional training). Subsequently, Article 5(2) establishes that Member States must put in place a certification system and designate the competent authorities responsible for the implementation. Such certificate must provide evidence of sufficient knowledge by undergoing training or by other means. The subjects of such training are further outlined in Annex I of the Directive and includes *inter alia* notions on IPM strategies and techniques.

When asked about **to what extent farmers are trained to use IPM measures**, several NCAs referred to this mandatory training. However, the set-up of this training and the extent to which IPM is covered, differ from one

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[65] Surendra K Dara, The New Integrated Pest Management Paradigm for the Modern Age, *Journal of Integrated Pest Management*, Volume 10, Issue 1, 2019, 12. https://academic.oup.com/jipm/article/10/1/12/5480541?login=false.

[66] Jayasooriya H. J. C., and M. M. M., Aheeyar, 2016, Adoption and factors affecting on adoption of integrated pest management among vegetable farmers in Sri Lanka, Procedia Food Sci. 6: 208–212.

country to another. Other initiatives mentioned in relation to IPM training, were online meetings with farmers, advice and advisory package (BG), training courses (LT), and specialised monthly magazines (CZ). In Lithuania, IPM is traditionally part of the general agricultural education and various trainings exist that are focused on new technologies and innovation. In Slovenia, applicants for subsidies under the RDP for IPM fruits, vegetables and vine, receive training, while other farmers are generally less trained.

While the above sections are based on contributions from national stakeholders and NCAs mostly based on assumptions, some tendencies can be identified. Overall, age and level of education of the farmers seem to have a potential effect on the level of uptake of IPM measures. Indeed, those factors may affect the farmers' attitudes towards innovation and sustainability, which according to the literature is key for IPM adoption. However, there are various factors acting together, including for example characteristics of the farm, of the sector, as well as level of interest, knowledge, and experience of the farmer. Therefore, looking at one factor in isolation, such as age or level of education of the farmers, is not sufficient.

3.2.4.2 Differences between full-time, part-time farmers and/or contractors, regarding IPM uptake by farmers

For the understanding of this question, part-time farming is interpreted as holdings where the agricultural activities imply a partial activity of the farm manager, both in terms of time allocated and income. It can thus be considered that the farm manager divides his time between farming and another economic activity. In this context, it can be highlighted that according to Eurostat data from 2013, managers of small farms tend to put in less working time than those of bigger farms. Ca 23% of farmers with less than 5 ha of agricultural land work full-time on the farm, while 82% of farmers with 100 ha or more, work full-time.[67] Therefore, it can be considered that smaller farms (less than 5 ha), which constitute about two-thirds of EU farms,[68] often are part-time farms.

Research has found that farmers perceive lack of time and competing goals as obstacles to adopting IPM measures.[69] This is a crucial consideration when looking at potential differences regarding IPM implementation between full-time and part-time farmers, as well as contractors, as available time is a key distinction between those farmer types.

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[67] European Commission (2018), Eurostat, Farm structures, accessible at: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/farming/documents/farm-structures_en.pdf.

[68] Eurostat (2018), Farms and farmland in the European Union – statistics, accessible at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics#cite_note-1.

[69] Kvakkestad, Valborg, Åsmund L. Steiro, and Arild Vatn. 2021. "Pesticide Policies and Farm Behavior: The Introduction of Regulations for Integrated Pest Management" *Agriculture* 11, no. 9: 828. https://doi.org/10.3390/agriculture11090828.

The in-depth interviews with national stakeholders showed than less than half of consulted stakeholders (ca 35%) though that there is such a difference. However, this may also be linked to the fact that stakeholders were not aware of any specific data related to this and could therefore only provide assumptions. Some stakeholders believed that there might be a difference, implying overall that full-time farmers have a better uptake and agricultural contractors the lowest. However, this is not the main reason that will determine IPM uptake, but merely one of several factors that impact farmers' agricultural strategies.

Part-time farmers will have other activities on the side, and thus the time allocated to farming activities, of which learning about IPM techniques and approaches, might be limited. Furthermore, this may also affect the overall knowledge, interests, and efforts of the farmer, required for IPM implementation. Also, the possibilities of affording investment costs for e.g. new equipment, may be limited for a part-time farmer. Interestingly, similar reasons were mentioned by interviewees who believed that part-time farmers may have a better uptake of IPM practices than full-time farmers. Since they have (potentially) another job they might be less concerned about yields and open to take more risks, thus switching to adopting IPM measures. It was also mentioned that part-time farmers might use less pesticides to lower production costs.

Regarding full-time farmers, this group is often highly concerned about the quality of their produce, as it is their primary source of income. Therefore, they are willing to put in more efforts, and also have more time to acquire the knowledge needed. They might be more eager to search for alternatives and improve monitoring skills at their farms. On the other hand, it could also be considered that full-time farmers are more prone to increase their reliance on pesticides as a form of insurance, being reluctant to take on risks. Furthermore, IPM practices require continuity – which may be easier for full-time farmers compared to part-time. From an economic point of view, full-time farmers will be more likely to implement IPM techniques if the remuneration (market as well as financial incentives granted by support measures, and additional remuneration through supply chain contracts) is worth the additional cost.

Another consideration that came through in the interviews, was farmers' consideration for the land that they are cultivating, and that overall, a farmer who owns the land will be more considerate and use less pesticides. According to this reasoning, contractors would thus be less focused on investing in soil fertility, biodiversity and long-term strategies. Rather, as their tasks is to keep the crops healthy, they want to limit any risk (and thus use more pesticides). Of course, this may also depend on the relationship with the landowner and any guidance and instructions provided. However, overall contractors seem less likely to use IPM measures as it may not be cost-effective for them, also requiring more time.

It is a difficult task to establish whether there is a difference regarding IPM uptake between different types of farmers (full-time, part-time, and contractors), as a variety of factors come to play. While consultations with national stakeholders identified several aspects to consider (e.g., time availability, financial capacity, risk-taking), many of those can be applied to the different farmer types. For example, the limited amount of time of a part-time farmer may result in a higher uptake of IPM measures. Similarly, the additional time availability of a full-time farmer may lead to a higher uptake. Finally, it should again be highlighted that also other factors interact and affect the implementation of IPM. Some that were mentioned in the interviews include: ownership of machinery, the characteristics of the final product and/or the market expectations and requirements, principles and values, as well as genuine interest of the farmer.

3.2.5 Link between the level of IPM measures uptake and crop characteristics

The use of pesticides is determined by several factors, including the type of crop, the management of the farm, the range of pests and diseases affecting the crop in that specific environment as well as economic factors such as the added value of the crop itself and the prices. Consequently, measures that succeed at reducing pesticide use vary greatly depending on the underlying reason to why pesticide is used in the first place.

The aim of this study question is to understand which aspects related to the crop and pest characteristics play a role in the reduction of pesticide use and, consequently, in enhancing or constraining the potential to extend the implementation of IPM across new areas and crop typologies.

Certain crops appear as more suitable to undergo a reduction in pesticides use, due to both internal as well as external factors.

Crops are exposed to a wide spectrum of antagonists and pathogens, including bacteria, fungi, oomycetes, viruses, nematodes, and insects, which can result in the occurrence of the disease. Pests and diseases can lead to a partial or total reduction in plant productivity, thus affecting both the economic sustainability of the farming activities and food availability and prices.

In absence of PPPs, global crop losses due to pests and diseases range between 30% and 50% **depending on the crop (DAFM)**.[70] This result suggests that intrinsic but also extrinsic features linked to the crops result in differences in terms of reduction of yield observed when pesticides are reduced.

[70] Department of Agriculture, Food and the Marine, Ireland https://www.pcs.agriculture.gov.ie/aboutus/aboutpesticides/whydoweneedpesticides/.

The severity of plant diseases is also dependent on the plant immune system and the plant-pathogen interactions. Plants have a complex system of defence against pests that include structural defence mechanism and later cellular defence mechanism. The structural defence mechanism consists of structures which exists in the plant even before the occurrence of the pathogen.

Cuticular wax, consisting of cutin and wax deposited on the leaf, acts as a physical barrier and helps preventing the retention of water on the surface thus limiting the germination of spores. Another element of defence is the epidermal cell wall that may directly prevent or make difficult the entry of pathogens in the plant. When pathogens penetrate in the pre-existing barriers of the host there are post-infectional structural mechanisms that help blocking the infection.

One of them is the histological defence mechanism that blocks the flow of toxic substances and the further spread of pathogens through the formation of cork layers, abscission layers and tyloses. At cellular level, the presence of natural sheath resulted by the inward stretching of the cell wall can delay the penetration of fungi in the host. In addition to the mentioned structural mechanisms, plants adopt biochemical processes of defence through inhibitory antimicrobial substances both before and after the infection (e.g. phenols, saponins, cynogenic glycosides, phytoalexins, etc).

These mechanisms can differ from crop to crop and have naturally evolved basing on the pests present in their growing environment. Since the defence mechanism varies with the crop type, what constitutes an effective plant protection product, including pesticides, may vary according to the crop itself.

As a result, certain crops, may or may not behave as "host", i.e. show susceptibility to pathogens. This variability can be crop-specific, but also cultivar specific, resulting in the occurrence of resistant varieties within the same crop. It is important to note that, even within the same crop, there is a certain degree of variability that it is linked to the physiological status of the plant, i.e. plants belonging to the same species/cultivar showing different behaviours vis-a-vis pests. In fact, the use of resistant varieties is included among the IPM principles and, thus, considered an important tool to achieve the reduction of pesticides needs and use. Yet, the availability of resistant variety remains unequal across crops, and the performance of such resistant varieties may vary greatly thus affecting the effectiveness of such tools.

Some of the **national stakeholders interviewed underlined the importance of plant breeding to develop pest resistant varieties**, thus reducing the yield loss caused by pests and diseases. Resistance breeding is an environmentally sound method for managing diseases[71] and consists in the selection of parental plants with the best genetic potential to obtain plants with desired characteristics.

Alongside the "internal factors" (i.e. crop/variety choice, defence mechanisms, physiological state) there are a number of external factors that define the degree to which the use of pesticides can be reduced, and alternatives can be implemented. These factors are mainly linked to the price of PPPs and their added value for the crops, which influence the willingness of farmers to invest in alternative methods which might require a higher investment in capital and human resources. As a general principle, the higher the added value to the crop is (e.g., ornamental), the higher the chances are that the farmers will undertake more sophisticated pest control methods, e.g., use of sexual pheromones.

The combination of such internal and external factors can be ultimately used as a proxy to reflect the different degree IPM measures are taken across crop systems.

The interviews performed suggest that the need and dependence on pesticides are extended to all crops, and their application remains necessary, especially for some ornamentals (i.e., flowers – because of high qualitative standards requested by the consumer), fruits and vegetables such as cabbage, tomato, flower bulbs, oilseeds, olive, sugar beet, vines, Brussels sprout, and lettuce. For some of these crops (such as vines and olives), IPM techniques and practices have become widespread, often due to their higher economic value. **Farmers tend to avoid alternative products and techniques for crops characterised by a low financial margin**. Moreover, some means of biological control can be risky, expensive, due to a bigger number of applications, or less efficient and require specific weather conditions (i.e., temperature and humidity) to be effective when applied on the crops.

For some vegetables (e.g., maize and field beans) **mechanical weeding techniques can be a valid method of control through which** reduce the number of treatments requiring dangerous chemical products. Still, mechanical weeding such as hoeing and harrowing can be limited in certain conditions, especially on slopes where machinery cannot be used, thus limiting the application of this practices in some areas.

In addition to weeding, **cultivation in a protected environment** such as greenhouses**, results in a significant reduction in the use of pesticides**. This is due to the possibility not only of controlling some of the environmental factors within the crop (i.e. temperature, humidity, light, nutrients, weeds

[71] Nelson, R., Wiesner-Hanks, T., Wisser, R. *et al.* Navigating complexity to breed disease-resistant crops. *Nat Rev Genet* 19, 21–33 (2018). https://doi.org/10.1038/nrg.2017.82.

etc..), but also the possibility of using certain beneficial products and insects for the pest control.

The way the crop is cultivated also affects the use of pesticides. Respondents report that crops grown on large, homogeneous plots (wheat, barley, maize, sunflower, sugar beet, oil seed rape, soybean, etc.), are more difficult to protect without using pesticides**.** In fact, if on one hand cultivating genetically uniform monoculture crops can lead to a better efficiency and earnings, on the other hand it can increase susceptibility to attacks from both diseases and insects[72]. The influence of crop-specific characteristics, methods of cultivation, and value on the market on the potential reduction of pesticide use is confirmed by the Italian case study "Alien Stop", where mechanical methods of crop protection, namely insect nets, are used on fruit cherry trees, apple trees and pear trees as defence from insects, thus reducing the incidence of pests and diseases. According to the study, the use of nets as a mechanical mean of protection can reduce the use of chemical treatments of around 80-90%.

Finally, pesticides are classified by the WHO in groups depending on their use and provide hazard level[73]. WHO distinguishes four main categories:

- Insecticides;
- Herbicides;
- Fungicides; and
- Rodenticides.

When discussing these groups, respondents to the interviews underline how there are more alternatives to fungicides than for insecticides, suggesting that **crops affected by fungi could be more easily managed through IPM**. Some diseases and insects such as stem mining pests in oilseed rape, aphids, *Lice lanosi* and *Tanymecus dilaticollis*, are considered difficult to manage without chemical control due to a lack of valid alternatives, while other diseases caused by insects such as Cabbage pod midge and Corn rootworm (controlled through crop rotations), spider mites (controlled biologically with *Phytoseiulus persimilis*[74]), allow the implementation of integrated control strategies.

3.2.6 Cooperation and communication between stakeholders

This chapter explores the different aspects related to cooperation and communication between stakeholders in the context of IPM, ranging from the

[72] David Andow, The extent of monoculture and its effects on insect pest populations with particular reference to wheat and cotton, Agriculture, Ecosystems & Environment, Volume 9, Issue 1, 1983, Pages 25-35, ISSN 0167-8809, https://doi.org/10.1016/0167-8809(83)90003-8.

[73] The WHO Recommended Classification of Pesticides by Hazard and guidelines to classification, 2019 edition, https://www.who.int/publications/i/item/9789240005662.

[74] David A. Raworth, Control of Two-spotted Spider Mite by Phytoseiulus persimilis1 1Pacific Auri-Food Research Centre Contribution #652, Journal of Asia-Pacific Entomology, Volume 4, Issue 2, 2001.

existing collective actions and their efficiency to marketing initiatives that support and encourage the reduction of pesticide use. Moreover, it also investigates the purchase habits and preferences of farmers vis-à-vis phytosanitary products, alongside the awareness of the availability of registered products including alternative ones.

3.2.6.1 Efficiency of collective actions

Farmers' organisations and collective actions may benefit the implementation of sustainability practices, including those addressed to the reduction of use of pesticides. However, the contribution of collective actions might differ between sectors and crop productions. This chapter aims at identifying the collective actions put in place and their benefits in terms of pesticides use reduction, as well as understanding how cooperation and collective initiatives differ among crop productions and have evolved in different countries.

The below sections will first identify the collective actions aiming at reducing the dependency on the use of pesticides, and then assess whether such collective actions differ across different crop systems, and finally explore whether and to what extent collective actions increased across EU countries over the past years.

The implementation and effectiveness of collective actions to reduce the use of pesticides might depend, to a certain extent, on the type of crop system. The interviewed stakeholders, however, show a divergent opinion on that, though some country level examples are provided. Likewise, the interviewed stakeholders show a divergent opinion on the trends of collective actions in their countries, for which there is a lack of up-to-date aggregated data. Among the competent authorities interviewed, about half of respondents confirmed that such initiatives exist (from Belgium, Bulgaria, Croatia, Czech Republic, Latvia, Slovakia, Netherlands, Germany, Spain, Ireland, Italy, Sweden, Austria, Denmark), while the remaining respondents answered negative, and five did not know.

The interviewed competent authorities, national stakeholders and researchers identified several actions which are (or can be) undertaken in a collective form, as follows:

- Collective purchase (e.g., machinery necessary to implement alternative production methods). In that context the CUMAs;[75]
- Marketing actions (e.g., labelling and certification schemes);
- Bargaining along the supply chain (e.g., contracts with retailers);
- Developing new systems (e.g., resistant cultivars, warning systems and damage thresholds);

[75] Farmers union to collectively buy equipment. CUMAs are existing in France and Belgium only.

- Coordination with value chain partners (e.g., for replacing chemical input with low-risk input and making use of decision support systems and more robust varieties);
- Monitoring of pests and diseases (on landscape level);
- Interventions financed under Operational and Rural Development Programmes, (CMO market organisations and 2 Pillar of the CAP);
- OPs implement interventions directly targeted to IPM techniques (e.g., promoting the use of use of *Bacillus thuringensis*, sexual confusion, etc);
- Collective learning, peer-to-peer learning and transfer of knowledge (including showcasing and farmers' workgroups);
- Communication and dissemination (e.g., inform civil society what farmers are doing in the implementation of new technologies and good practices);
- Link and support to advisory services;
- Provide advisory services;
- Citizens collective initiatives (e.g., pesticide-free municipalities alliance) and NGOs' (e.g. WWF, Greenpeace) with benefits in increasing the attention of public opinion and policy;
- Establishing networks and links with research projects (e.g., collaboration with researchers to disseminate the research outputs and new technologies to farmers); and
- Promote digitisation, provision of data and forecasts.

Overall, research shows the potential of cooperation to improve the effectiveness of collective farming practices.[76] The literature explains that, on the one hand, cooperative pest management is effective in extending the benefits of reduced pesticide use at regional scale, whereas on the other hand smaller and locally based cooperative forms might be more easily undertaken by farmers.[77] A strand of research demonstrates that, for example, the use of herbicides is more effective at cooperative level than at single-farm scale.[78] In any case, collective actions appear also to have an effect on the farmers' behaviour, i.e., the single farmer's decision of whether to adopt alternative practices can be more influenced by those around the farmer than by farmer's characteristics.[79] Accordingly, a comparative analysis of five EU countries carried out in 2011, reveals that collective approaches seem to increase the

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[76] J. Sherman, J.M. Burke, D.H. Gent, 2019. Cooperation and coordination in plant disease management. Phytopathology, 109 (2019), pp. 1720-1731, DOI:10.1094/PHYTO-01-19-0010-R.

[77] Stallman H., James H., 2015. Determinants affecting farmers' willingness to cooperate to control pests. Ecological Economics, 117(2015):182-192. https://doi.org/10.1016/j.ecolecon.2015.07.006.

[78] Evans J., Williams A., Hager A., Mirsky S., Tranel P., Davis A., 2018. Confronting herbicide resistance with cooperative management. Pest Management Science, 74(11):2424-2431. https://doi.org/10.1002/ps.5105.

[79] Bell A., Zhang W., Nou K., 2016. Pesticide use and cooperative management of natural enemy habitat in a framed field experiment. Agricultural Systems, 143(2016):1-13. https://doi.org/10.1016/j.agsy.2015.11.012

effectiveness of pesticides action plans, especially when all relevant stakeholders (including research and extension services) are brought together.[80]

Based on research, much of the benefit from collective action and cooperation is linked to increased learning processes and knowledge exchange. In recent years, a growing strand of literature has casted light on different agricultural knowledge systems in Europe, with special regard to farmers' social networks[81], knowledge spillovers,[82] group learning,[83] and peer-to peer learning (i.e., learning-from-others).[84] Such processes can include learning actions to reduce the use of pesticides, such as the implementation of novel techniques and innovative technologies. However, the scientific literature on the specific case of pest management learning processes is still poor, though growing.

A relevant support to collective actions can be provided by the implementation of operational programmes (OP) by producers' organisations, as set up by the Regulation (EU) No 1308/2013. OPs are established to promote the implementation of market oriented and agro-environmental measures to foster a sector's overall sustainability. Among the various interventions that might be undertaken depending on the specific case, OPs are required to implement agro-environmental actions, which can include measures to reduce pesticide use and dependency. Likewise, OPs are often functional to set up certification and quality schemes, which can include IPM schemes.

Moreover, producers' organisations can be aimed at adhering (or setting up) certification schemes. In 2010, a study identified 427 certified schemes existing, of which 56 voluntary schemes relate to integrated crop and integrated pest management principles. Fruits and vegetables are by far the crops mostly concerned by IPM certification;[85] in fact, cooperatives in the sector have been

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[80] Barzman M., Dachbrodt-Saaydeh S., 2011. Comparative analysis of pesticide action plans in five European countries. Pest Management Science, Wiley, 2011, 67 (12), pp.1481 - 1485. DOI:10.1002/ps.2283.
[81] Skaalsveen, K., Ingram, J., Urguhart, J., 2020. The role of farmers' social networks in the implementation of no-till farming practices. Agricultural Systems, Volume 181, May 2020.102824. https://doi.org/10.1016/j.agsy.2020.102824.
[82] Vroege, W., Meraner, M., Polman, N., Storm, H., Heijman, W., Finger, R., 2020. Beyond the single farm – A spatial econometric analysis of spillovers in farm diversification in the Netherlands. Land Use Policy, (99):105019. https://doi.org/10.1016/j.landusepol.2020.105019.
[83] Prager, K., Creaney, R., 2017. Achieving on-farm practice change through facilitated group learning: Evaluating the effectiveness of monitor farms and discussion groups. J.Rur.Stud., 56(2017) :1-11. https://doi.org/10.1016/j.jrurstud.2017.09.002.
[84] Schneider, F., Fry, P., Ledermann, T., Rist, S., 2009. Social Learning Processes in Swiss Soil Protection—The 'From Farmer - To Farmer' Project. Hum Ecol (2009) 37:475–489. DOI:10.1007/s10745-009-9262-1.
[85] Areté Consultants (2010) Inventory of certification schemes for agricultural products and foodstuffs marketed in the EU member states: Data aggregations. Report prepared for the European Commission DG Agriculture. http://ec.europa.eu/agriculture/quality/certification/inventory/inventory-data-aggregations_en.pdf. Accessed 11 June 2014.

proactive in promoting IPM principles-based practices and innovative techniques across Europe.[86]

The implementation and effectiveness of collective actions to reduce the use of pesticides might depends to a certain extent on the type of crop system. The interviewed stakeholders, however, show a divergent opinion: half of respondents believe that a difference between crop systems does exist, while the remaining respondents answer otherwise or do not know the answer. Furthermore, among the NCA interviewed, about two-thirds of respondents stated that a difference in collective actions across crop systems does exist (from Belgium, Bulgaria, Croatia, Czech Republic, Latvia, Slovakia, Slovenia, Netherlands, Germany, Spain, Ireland, France, Italy, Portugal, Sweden, Austria), while less than one-third answered otherwise, and four did not know. Some examples were provided by the interviewees. For instance, in the Netherlands, cooperation exists mainly on edible and fresh products, although also in the production of ornamentals cooperation is increasing. In Spain, some special crops like tobacco and lupulus are more because of the limited number of producers and the high value of the production. In Italy, main collective actions arise from the fruit and vegetable and wine sector, whereas in Sweden the fruit sector, sugar beet and starch potatoes productions are more cooperative. In Germany, special crops require a higher level of knowledge and cooperation. Beyond the influence of context specific socio-economic and cultural factors, the number of producers characterising a sector and the value of the production might partially explain these cross-sectoral differences.

The interviewed national stakeholders show a divergent opinion on the trends of collective actions in their countries. Less than half respondents perceive an increasing trend in the number and size of collective actions, while other respondents suggest otherwise or declare to not have enough knowledge about it. Likewise, among the competent authorities interviewed, only one-third respondents indicated a positive trend in collective actions (from Belgium, Bulgaria, Croatia, Slovakia, Spain, Ireland, Italy, Austria), against two-thirds suggesting a negative trend or lack of knowledge about it. No official statistics exist about trends on the number of collective and cooperative actions aimed at reducing the use of and dependency on pesticides. The most recent study on producers' organisations[87] shows that in 2017, the EU accounted for 3.434 recognised organisations. This study, however, does not consider the non-recognised organisations, which are likely to be numerous. The opportunity to

[86] Damos P., Colomar L., Ioriatti C., 2015. Integrated Fruit Production and Pest Management in Europe: The Apple Case Study and How Far We Are From the Original Concept? Insects 2015, 6, 626-657; doi:10.3390/insects6030626.

[87] European Commission, 2019. Study of the best ways for producer organisations to be formed, carry out their activities and be supported. Final Report. https://op.europa.eu/en/publication-detail/-/publication/2c31a562-eef5-11e9-a32c-01aa75ed71a1.

have actions to reduce pesticides implemented in collective form is therefore very broad.

3.2.6.2 Marketing initiatives as regards reduction of pesticide use

The production activity carried out by farmers can be conducted either in the form of individual entities or through vertical and horizontal forms of aggregation. Specifically, through horizontal organisation in the form of producer organisations, farmers aim to benefit from, for example, greater bargaining power, the achievement of economies of scale, production planning, and the collective adoption of specific agronomic practices. This question investigates the link between aggregative forms of agricultural production and the reduction of pesticide use.

In order to answer the study question, this was split into two sub-questions discussed with national stakeholders, as follows:

- Are there producer organisations/companies that market products with reduced pesticides use in your country? and
- Are there differences concerning the collaboration and communication regarding different crops?

Agricultural activity has a range of specific attributes that distinguish it from other economic sectors and that have direct implications for its organisational forms.

First and foremost, agricultural activities are dependent on nature and its biological and climatic factors, which results in a lack of control over certain aspects of production such as planning, monitoring, and supervision[88]. The marketing of agricultural products in today's global context exposes the farmer to various challenges such as price volatility, lack of economies of scale, high transaction costs in accessing markets, and concentration of downstream and upstream firms in the supply chain that puts farmers in a disadvantageous position when negotiating terms of trade or setting up contractual relations.

Several studies show that cooperative organisations in agriculture can address these issues thanks to their ability to economise on transaction costs, develop countervailing power,[89,90,91,92] practice contingency pricing via patronage

[88] Schmitt, Günther (1993). Why Collectivization of Agriculture in Socialist Countries Has Failed: A Transaction Cost Approach.

[89] Bonus, H. (1986). The Cooperative Association as a Business Enterprise: A Study in the Economics of Transactions. Journal of Institutional and Theoretical Economics (JITE) / Zeitschrift Für Die Gesamte Staatswissenschaft, 142(2), 310–339. http://www.jstor.org/stable/40750872.

[90] Staatz, John, (1987), Recent Developments in the Theory of Agricultural Cooperation, Journal of Agricultural Cooperation, 02, issue , number 46204, https://EconPapers.repec.org/RePEc:ags:joagco:46204.

[91] Hansmann, H. (1988). Ownership of the Firm. Journal of Law, Economics, & Organization, 4(2), 267–304. http://www.jstor.org/stable/764924 .

[92] Hansmann, H. (1996) The Ownership of Enterprise. Belknap Press of the Harvard University Press, Cambridge.

refunds, making quality control and decision making less costly, improve the efficiency and organisation of individual farms, and strengthen their bargaining power in the value chain.

The EU has fostered the development of institutionalised forms of cooperation between farmers (horizontal cooperation) and between farmers and other actors of the agri-food chain (vertical cooperation). With the adoption of Regulation (EU) No 1308/2013 ("the CMO Regulation"[93]), the EU laid down a legal framework common to all agricultural sectors for the setting up and the recognition of POs (producers organisations) and associations of producer organisations (APOs), as a form of horizontal cooperation at the primary production level, on the top of other existing forms of cooperation between producers (e.g. cooperatives).

Most POs in the EU pursue the aim of promoting the use of environmentally sound cultivation practices and production techniques. According to the CMO regulation, Producer organisations' (POs) are entities that have been formed on the initiative of producers in a specific sector to pursue one or more specific objectives[94] and that are controlled by producers. Among the objectives listed in Article 152 of the CMO regulation, the one dedicated to promoting, and providing technical assistance for the use of environmentally sound cultivation practices and production techniques is of particular interest for POs in the EU. A study shows that more than 50% of POs in the beef and veal sector pursue the promotion and assistance for environmentally friendly practice, and thereby contribute to sustainable use of natural resources or climate change mitigation.[95]

The literature presents studies which point to the importance of reduction of non-chemical pest control methods linking them to PO membership. Abdulai (2019)[96] reports in his study that cooperative membership plays a role in raising the use of sustainable practices by focusing on integrated pest management technology.

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[93] Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007, OJ L 347, 20.12.2013, p. 671.

[94] Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R1308.

[95] European Commission (2018) Study on Producer Organisations and their activities in the olive oil, beef and veal and arable sector.

[96] Owusu, Victor & Abdulai, Awudu. (2019). Examining the economic impacts of integrated pest management among vegetable farmers in Southern Ghana. Journal of Environmental Planning and Management. 62. 1-22. 10.1080/09640568.2018.1517085.

Other authors such as Deng et al. (2021)[97] study whether and to what extent agricultural cooperatives contribute to reducing environmental impacts of agricultural production. Their findings suggest that agricultural cooperatives play an important role in improving agricultural sustainability helping farmers to adopt eco-friendly technologies and access environmentally friendly inputs with more affordable prices, promoting organic production and enhancing sustainable use of material inputs. They also observed an increase in farmers' willingness to adopt safe production behaviours, and a decrease in chemical fertiliser and pesticide application rate of cooperative members.

Ciagnocavo et al. (2018)[98] analysed family farming in Spain finding out that collective responses to the use of chemical pesticides in controlling pests and diseases have been led predominantly by the cooperative sector. They also note that implementing IPM practices could not have been made possible without the guidance, assistance and technical support offered by cooperatives.

Organic POs are recognised as promoters of IPM practices in the EU.

A striking example of farmers' organisation marketing products with reduced use of pesticides is the one of organic farmers' cooperatives. The importance of organic POs/cooperatives is confirmed by the investigation conducted across the EU with national stakeholders. Most national stakeholders interviewed (80%), confirm that there are POs/companies marketing products with reduced use of pesticides in their country and that most of these are POs/companies of organic farmers.

Other certification labels with reduced use of pesticides exist (e.g. Prodi, LMR, SNQ, VVAK, Global GAP[99] etc.) but they do not have the same visibility as the organic label.

Another form of cooperation that promotes the reduction of pesticides is the vertical cooperation between farmers and retailers. Some of the respondents reported that some retailers (e.g. ALDI, LIDL, Hofer, Spar, Billa, Iglo, Elbe-Obst, MPB, Hrvatsko Sunce etc…) impose the reduction of pesticides in their contracts with farmers, probably thanks to a change of needs on the consumer side.

In terms of sectors, national stakeholders report that the adoption of IPM practices is generally spread in the EU fruit and vegetables sector, especially for products such as apples, hops, rice, potatoes, and vines.

The literature does not offer substantial indications concerning the link between organisational forms of agri-businesses and the level of collaboration and

[97] Deng L, Chen L, Zhao J, Wang R (2021) Comparative analysis on environmental and economic performance of agricultural cooperatives and smallholder farmers: The case of grape production in Hebei, China. PLOS ONE 16(1): e0245981. https://doi.org/10.1371/journal.pone.0245981.

[98] Giagnocavo, C.; Galdeano-Gómez, E.; Pérez-Mesa, J.C. Cooperative Longevity and Sustainable Development in a Family Farming System. *Sustainability* 2018, *10*, 2198. https://doi.org/10.3390/su10072198.

[99] https://www.akkerbouw-van-nu.nl/gewassen-teelt/gewassen/teeltsystemen-en-keurmerken/.

communication on IPM practices per crop. However, the distribution of POs per agricultural sector gives us an overview of those crops for which a higher number of producer organisations is observed. This distribution can be used as a proxy to observe on which crops there is a greater interest of farmers to collaborate and transfer information, including information on sustainable cultivation practices that follows the IPM principles.

According to a survey conducted across the EU in 2017,[100] more than 50% of recognised POs and Associations of Producers' Organisations (APOs) in the EU are in the Fruit and Vegetable sector. Within the F&V sector, the product categories that see a major collaboration between farmers are "Olive oil and table olives", followed by "Wine", "Cereals", "Tobacco", and "Rice".

The interviews performed with the national stakeholders provide an insight on the level of collaboration and communication on IPM practices between farms at crop level.

Overall, the most profitable crops are those for which there is a higher degree of cooperation and exchange of information. For some crops such as fruit, tomato, sugar beet, pepper, cereals, and oilseed the degree of cooperation and sharing of information is higher compared to other sectors. In these sectors, the strategies for the reduction of pesticides and the application of IPM practices for these crops is consolidated and already in place.

A different scenario is observed for other crops, namely ornamentals, zucchini, watermelon, and melon where the lack of knowledge leads to a lower level of collaboration and share of information concerning IPM practices.

3.2.6.3 How are farmers buying their PPPs?

To investigate the characteristics of the PPPs market and farmers' behaviour in PPP usage, the accessibility of PPPs by farmers and farmers' awareness and knowledge of PPPs specific usage are analysed.

The analysis of the study question builds on the available literature focusing on how the farmers behave when using PPPs. Moreover, it makes use of two questions discussed with interviewed national stakeholders:

- Extent to which farmers know all registered products they can use for a given use; and
- Extent to which farmers have access to all available products.

Changes in legislation are a key factor to explain the behaviour of farmers. The use of pesticides in the European agricultural sector is regulated through the EU Directive, 2009/128/EC on sustainable use of pesticides (SUD) and the

[100] European Commission (2018) Study on Producer Organisations and their activities in the olive oil, beef and veal and arable sector.

Regulation (EC) No 1107/2009 regarding placing plant protection products on the market. The directive requires the European Member States to develop training activities targeting occupational exposure to pesticides and communication material aimed at residents and bystanders.

A study by Kvakkestad et *al.* (2021)[101] finds that Norwegian farmers' self-reported knowledge of IPM increased after the introduction of the SUD, and 41% of farmers stated that they use IPM to a greater extent than before the SUD was introduced. These results demonstrate that mandatory IPM requirements have been a successful strategy for increasing farmers use of IPM in Norway. At the same time, the study advocates for clearer IPM provisions and increased intrinsic motivation for IPM among farmers that will reduce the risks from pesticides further.[102]

Many scholars have underlined that farmers' adoption of more sustainable production methods deviates from pure profit maximization. Agri-environmental policy instruments' design within a pure neoclassical economics paradigm, based on profit maximization, may be insufficient in reducing negative environmental externalities from farming[103]. Farmers' adoption of more sustainable practices is affected by farmers' personality,[104] farming objectives and intrinsic motivations,[105,106,107,108] norms and behaviour within the farming community and the wider society.[109,110]

The degree of knowledge of PPP depends on the farmer typology. For example, dairy farmers often do not know about the PPP because they have a more specialised knowledge about cattle and less focus on crop production. On the contrary, arable farmers are more aware of IPM since they are supported by suppliers and are familiar with the specialised informative material (e.g., websites and dedicated applications). Furthermore, there is extensive access and information about the products for conventional farmers and production,

[101] Kvakkestad, V., Steiro, Å.L. and Vatn, A., 2021. Pesticide Policies and Farm Behaviour: The Introduction of Regulations for Integrated Pest Management. Agriculture, 11(9), p.828.
[102] ibidem.
[103] Dessart, F.J.; Barreiro-Hurlé, J.; van Bavel, R.M. Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. Eur. Rev. Agric. Econ. 2019, 46, 417–471.
[104] Austin, E.J.; Deary, I.J.; Willock, J. Personality and intelligence as predictors of economic behaviour in Scottish farmers. Eur. J. Personal. 2001, 15, 123–137.
[105] Arbuckle, J.G., Jr.; Morton, W.L.; Hobbs, J. Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. Clim. Chang. 2013, 118, 551–563.
[106] Greiner, R.; Gregg, D. Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments: Empirical evidence from northern Australia. Land Use Policy 2011, 28, 257–265.
[107] Greiner, R.; Patterson, L.; Miller, O. Motivations, risk perceptions and adoption of conservation practices by farmers. Agric. Syst. 2009, 99, 86–104.
[108] Reimer, A.P.; Thompson, A.W.; Prokopy, L.S. The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. Agric. Hum. Values 2012, 29, 29–40.
[109] Burton, R.J.F.; Kuczera, C.; Schwarz, G. Exploring farmers' cultural resistance to voluntary agri-environmental schemes. Sociol. Rural 2008, 48, 16–37.
[110] D'Emden, F.H.; Llewellyn, R.S.; Burton, M.P. Factors influencing adoption of conservation tillage in Australian cropping regions. Aust. J. Agric. Resour. Econ. 2008, 52, 169–182.

but far less for farmers working with organic productions. Often farmers' knowledge is limited and insufficient to support decision-making on how and when to use the products, with some farmers unable to follow market changes and product names. Such limited knowledge is reduced in those contexts in which farmers are obliged to attend courses about pesticide use and obtain certificates, and all professional users are trained.

Moreover, aspects of farms, such as size and type of cultivation have an influence on pesticide usage.[111] Aspects such as farmer tenure, income reliance, existing knowledge and resources may further impact pesticide use[112]. For example, farmers who rely on their farms for 50% or less of their income may need greater regulatory or information-based instruments to stimulate use of IPM[113]. Some authors suggest considering farm and farmer characteristics when designing actions to reduce the usage of pesticides in order to enhance their effectiveness.[114] For instance, farmers with little knowledge about IPM and lack of resources should be targeted with specific actions since they require more information and economic based instruments such as training and subsidies to overcome the lack of knowledge.[115]

Furthermore, farmers' behaviour is related to the experience about the efficiency of pesticides and the perception of the damage to the health derived by the pesticide's usage. In fact, farmers are willing to replace conventional with bio-pesticides when the former is perceived as inefficient on pests and as damaging farmers' health. At the same time, farmers are willing to pay a higher price for bio-pesticides when they consider that the conventional ones negatively affect their health.[116] Then, if a product has worked farmers like to use it again and therefore, they may not know of any alternatives to that product, nor do they see any need to know any alternatives.

Overall, **farmers have all the instruments to acquire knowledge about pesticides**, through manuals, apps and portals on the web, and the available and recommended products are published by the official advisory services in print media and on the Internet. The access of farmers to all products available in the market is facilitated by national databases established by MS, where all

[111] Lee, R., den Uyl, R. and Runhaar, H., 2019. Assessment of policy instruments for pesticide use reduction in Europe; Learning from a systematic literature review. Crop Protection, 126, p.104929.
[112] Wilson, C. and Tisdell, C., 2001. Why farmers continue to use pesticides despite environmental, health and sustainability costs. Ecological economics, 39(3), pp.449-462.
[113] Ibidem.
[114] Manner, M. and Gowdy, J., 2010. The evolution of social and moral behavior: evolutionary insights for public policy. Ecological economics, 69(4), pp.753-761.
[115] Tey, Y.S., Li, E., Bruwer, J., Abdullah, A.M., Brindal, M., Radam, A., Ismail, M.M. and Darham, S., 2014. The relative importance of factors influencing the adoption of sustainable agricultural practices: a factor approach for Malaysian vegetable farmers. Sustainability science, 9(1), pp.17-29.
[116] Petrescu-Mag, R.M., Banatean-Dunea, I., Vesa, S.C., Copacinschi, S. and Petrescu, D.C., 2019. What do Romanian farmers think about the effects of pesticides? Perceptions and willingness to pay for bio-pesticides. Sustainability, 11(13), p.3628.

registered products are listed and presented, and by farmer's magazines showing "product comparison" and promoting alternative.

National stakeholders agree that farmers know the products they use. Nevertheless, their knowledge is sometimes too generic, and farmers do not have specific information about the products they use. There is definitely a need for training for farmers in terms of evaluating the alternatives to the usual used products. Usually, farmers know that the tools and products exist, but they do not know the names or what dosages to use. Many farmers therefore get help from either independent or selling advisory services to adapt the choice of products according to the needs and conditions.

Advisory services, associations, promotion campaigns, and training are fundamental to filling the farmers' specific knowledge gap and sharing information about new PPPs and their applications.

If farmers have a good consultant, this is more likely not to be the case. Good consultants are essential to evaluate the products in terms of both environmental and economic sustainability.

In Article 5(1) of the SUD, the training of advisors is considered as one measure to reduce the risks associated with pesticide use. Article 3(3) of the directive considers an 'advisor' as any person who has acquired adequate knowledge and advises on pest management and the safe use of pesticides, in the context of a professional capacity or commercial.

Based on a survey distributed to the total population of Danish agricultural advisors, Pedersen et al. (2019)[117] conclude that there are differences between the recommendations given on pesticide use from Danish independent agricultural advisors compared to recommendations given by advisors with an economic interest in selling the pesticides (supplier affiliated advisors from chemical companies and agricultural companies). In general, most advisors always/often recommend a lower dose to the farmer than the maximum dose stated on the label. However, the study shows that supplier-affiliated advisors are less likely to recommend lower doses. Such results are found in other contexts (i.e., US) with Lichtenberg and Berlind (2005)[118] farmer survey findings regarding soybean producers in two Maryland (US) counties, where soybean producers using independent advisors for scouting had significantly lower

[117] Pedersen, A.B., Nielsen, H.Ø., Christensen, T., Ørum, J.E. and Martinsen, L., 2019. Are independent agricultural advisors more oriented towards recommending reduced pesticide use than supplier-affiliated advisors? Journal of environmental management, 242, pp.507-514.
[118] Lichtenberg, E. and Berlind, A.V., 2005. Does it matter who scouts? Journal of Agricultural and Resource Economics, pp.250-267.

pesticide demand than soybean producers using chemical dealer employees or scouting themselves.[119]

The role of associations and distributors is precious to promote information on new products and their correct use. The involvement of large producer cooperatives in the sale of farming inputs contributes to effective dissemination of information and know-how.

The usage of new products is limited by farmers' conservative behaviour that sticks to their traditional distributors of products. Limited access to some products may be related to the division on the market where the large chemical companies will sell some products to different distributors. This means that when farmers need to change from one product to a more effective one, they might need to change distributor/business partner. This is considered as an obstacle to the diffusion of all and new products. In some cases, exclusive agreements on the market create advantages for some companies, but as a consequence, it creates problems for the farmers as it becomes challenging to access some products if they do not change distributor/business partner.

3.2.7 Knowledge transfer

This section introduces the main tools that have been implemented at Member State level in order to transfer knowledge among farmers. Then, Theme 4 (see Section 3.4) presents strategies on how to encourage and promote change in the approaches towards pesticide use and will formulate specific strategies on how to scale up good practices.

The large majority of Member State authorities have reported the use of pest monitoring systems which are presented in the table below together with the prognosis systems and models being used.

Table 15: Pest monitoring programmes per Member State

Member State	Description or link
AT	Warning services have been developed at the agricultural chambers: https://warndienst.lko.at/ and at AGES: https://www.warndienst-pflanzengesundheit.at/warndienst/. https://rebschutzdienst.at/.
BE (Flanders)	https://lv.vlaanderen.be/nl/landbouwbeleid/landbouwbeleid-eu/steunmelding/werkingssubsidie-voor-waarnemings-en#.
BE (Wallonia)	Networks organised by technical institutes (e.g., CARAH) that published bulletins when the pressure of pest disease requires a treatment.

[119] Pedersen, A.B., Nielsen, H.Ø., Christensen, T., Ørum, J.E. and Martinsen, L., 2019. Are independent agricultural advisors more oriented towards recommending reduced pesticide use than supplier-affiliated advisors? Journal of environmental management, 242, pp.507-514.

Member State	Description or link
BG	Pest monitoring is mainly carried out by BFSA and the information is summarised in the form of monthly plant protection bulletins distributed to farmers. The Plant Protection Act Art. 8. (1) indicates that the Executive Director of BFSA shall annually by 31 January approve a list of economically important pests of agricultural crops by administrative-territorial units - districts. The pests included in the list shall be subject to systematic and permanent surveillance. In Regulation No 14 of 2016 - " Art. 11. (1) The pests included in the list of economically important pests shall be subject to systematic and permanent observations on their occurrence, distribution, density and degree of attack on agricultural crops. (2) Systematic and continuous surveillance shall be carried out by: 1. plant protection inspectors of the Regional Directorate for Food Safety by conducting route surveys in representative crops and plantations in agro-ecological areas and/or by observations in forecast fields; 2. farmers by carrying out mass and route surveys of the areas they manage.
HR	Performed by advisory services which became parts of the Ministry of Agriculture.
CY	Pest monitoring performed by national experts based on field surveys and monitoring with traps (olive fruit fly, Mediterranean fruit fly, godling moth, red scale, European grapevine moth).
CZ	Monitoring of pests (http://eagri.cz/public/app/srs_pub/fytoportal/public/#rlp|so|diseases), diseases (http://eagri.cz/public/app/srs_pub/fytoportal/public/#rlp|so|diseases), prognosis of pests (http://eagri.cz/public/app/srs_pub/fytoportal/public/#rlp|so|diseases), prognosis of diseases (http://eagri.cz/public/app/srs_pub/fytoportal/public/#rlp|so|diseases) are at a high level in the Czech Republic. Methodologies are extensively listed on the Plant Medicine Portal. Monitoring and forecasts for a wide range of diseases and pests are carried out by the staff of ÚKZÚZ and published on the maps of the Plant Health Portal and by the state administration. This is then joined by research institutes or private organisations (for example, the Kluky test station near the town Písek carries out monitoring for money - http://www.zskluky.cz/). A combination of state monitoring and private monitoring.
DK	There is a large number of warning and pest monitoring systems. These are not hosted by the authorities but by SEGES or Universities. The Danish EPA has over the years supported the development and evaluation of such systems.
EE	ETKI Pest Monitoring system
FR	A national network called réseau "épidémiosurveillance is in place in France for 10 years. Farmers monitor their field and report back to a

Member State	Description or link
	coordinator who then publish a so-called "Bulletin de Santé du Végétal - BSV" that is then distributed to farmers at a very high frequency depending on the pest/disease pressure. The network is funded by authorities and the national Ecophyto plan. It has a budget of 6 Mio EUR (significant decrease of 35% over the last 3 years). A total of 15,000 Fields is monitored each week by 4,000 farmers which have been trained to perform such pest monitoring. The budget reduction has concerned the non-agricultural areas for which monitoring has been stopped. Such monitoring is extremely expensive and doesn't not allow a reduction of pesticide use but rather an improvement of efficiency in the spraying and in the control of diseases.
DE	all plant protection services have regional surveillance networks. They are the basis of information for the weekly warning services and crop protection information.
EL	Agricultural alerts at www.minagric.gr.
HU	There are forecast system operated by the Hungarian Chamber of Professionals and Doctor of Plant Protection (MNMNK), the Hungarian Chamber of Agriculture, and different private companies.
IE	Teagasc has periodic updates on pests for different crops groups & Met Eireann issues blight warning and environmental advisories on spraying opportunities.
IT	Each Region and Autonomous Province has its own surveillance / forecasting systems which are also conveyed through official websites. Such networks can be completely public or include both public and private systems.
LV	The State Plant Protection Service is an institution responsible for the establishment of a pest control/forecasting network in Latvia, see the map: http://noverojumi.vaad.gov.lv/karte.
LT	Lithuanian Agricultural Advisory Service has developed very good tool for farmers, which is available as one of the electronic services : https://www.lzukt.lt/electronic-services/ By logging into the IKMIS system, visitors are promptly informed about the spread of harmful organisms in various agricultural crops in all regions of the country. This system publishes catalogues of plant protection products, diseases, pests and weeds that help identify a disease or pest more quickly and make it easier to choose plant protection products registered in Lithuania. See www.ikmis.lt.
MT	Surveillance is done by MAFA-AGR and MCCAA. No networks as such.
NL	Pest surveillance/forecast networks (decision supporting systems) in the Netherlands are private initiatives, mostly for (fungal) diseases and aphids/trips.

Member State	Description or link
PT	DGAV, as a national phytosanitary authority, defines and coordinates more than 60 phytosanitary surveillance programs, which include also quarantine pests and diseases, aiming at their early detection, and when they detect their control.
SK	National monitoring of pests (CCTIA and NAFC). Central Control and Testing Institute in Agriculture, private networks for fruit growers, wine growers and pesticide distribution companies.
SL	Forecasting network functioning under the auspices of the public plant protection service, which in turn belongs under the Administration for Food Safety, Veterinary Sector and Plant Protection.
ES	Each autonomous regions as their own surveillance network. For example, in Catalonia there are seven warning stations for different crops (fruit trees, vines, hazel trees, citrus, olive trees, vegetable crops, rice, cereals) according to territorial distribution. The technical staff of the Plant Protection Service prepares these warnings based on pest and disease monitoring and field experiences in collaboration with the technicians of the Plant Protection Associations (ADV).
SE	Prognosis and warning system are developed and implemented by the Board of agriculture) for agriculture and horticulture. SLU follows some activities to monitor insects that can work as vectors for virus through traps (sugfällor). In terms of networks, advisory groups, facebook groups etc. are sharing information and what has been observed in the fields. Newsletter/weekly reports via digital channels drafted and disseminated by the Regional Plant Protection Centre (Växtskyddscentralen) (Board of Agriculture) during the season. Also published on the website. Weekly meetings in different parts of the country led by the Regional Plant Protection Centre (Växtskyddscentralen) – for advisory services and trade. Reporting on what has been observed in the fields. In this context, day trips also organised in the field to look at different trials – different parts of the country. While this is not IPM specific, but as IPM implies cultivation, strategies and cultivation adaptations – it is relevant.

Source: Compiled by the Consortium

The analysis of these pest monitoring and prognosis systems shows a large variability in terms of actors and intensity of activities across Member States. All have declared that the bulk of the activities is to monitor pest and diseases on the major crops. In the largest majority of cases, there is no monitoring on weeds as it is much more complicated to monitor weeds than pest and diseases. In addition, the flora present in fields is rather farm and field specific as it largely depends on the cultivation techniques and fertilisation regimes that have been applied by farmers over a long period of time.

Large progresses have been reported by national authorities and stakeholders in the pest monitoring networks and the information potentially available to farmers has increased exponentially. This is mainly due to the use of digital tools and electronic data-recording and reporting systems. In many countries, the bulletins are sent to farmers via SMS and emails.

However, several authorities have reported that a trend to reduce budgets of pest monitoring and prognosis systems is observed. In Hungary, the national forecast network was operated by the Plant Protection Authority. Due to the lack of resources and the continuous downsizing of staff and tasks, this task was terminated, and it was not outsourced to another institution. In France, the budget of the "réseau d'épidémiosurveillance" has been reduced by 30% in 2019-2020.

Farmers are usually supported by agricultural advisors and extension services that provide advice on crop protection and other agronomic practices. Such services can be provided by public or private actors. In most of cases, farmers can get agronomic support from different sources (cooperatives, chambers of Commerce, Chambers of Agriculture, traders, PPP industry sale force, etc). Several Member States (AT, CZ, DE, EE, FR, IT, HU, LV, SK, SL) have established rules or policy measures aiming at separating advisory services from sales of pesticides. In Germany, there have always been independent official state advisory services, which are very effective. In contrary to other EU countries, they have not been privatised. In addition, the retailers of the pesticide producers also offer advice. In addition, there exist also a number of private advisors or advisory enterprises who also advise farmers independently from pesticide sales. The pesticide industry is not allowed to advise directly. A manufacturer does not market its products directly to users (farmers), but rather through, for example, agricultural dealers and their advisors. The question is how independent the land trade advisors are. In Spain, the official advice from the plant protection services is independent. In Ireland, Teagasc is independent and does not sell products, but many others have built advisory services around product sales). France has introduced a new law as of January 2021 to separate advice from pesticide sales. Operators that were used to combine sales to advice had to decide on the activity they wanted to continue. In the largest majority of cases, operators have decided to continue selling pesticides and therefore such entities cannot provide any agronomic crop protection support. The effectiveness of such measure in reducing pesticide use has still to be demonstrated.

The most promising approach to transfer knowledge at farm level and across farmers is certainly the set-up of farm networks (see the DEPHY farm network and the case study on farm network in Germany – Chapter 4). The network of DEPHY demonstration farms was put in place in 2010 and has already been through three different phases of recruiting farms: in 2011 with the launch of the first 1,200 farms, in 2012 with the growth to 1,800 farms and opening the network to all types of farms, and finally in 2016-17 with the growth to 3,000 farms. Spread out all across France, the DEPHY farms cover all of the large segments of French agricultural production: Crops, animal agriculture, viticulture, arboriculture, legumes, horticulture and tropical crops. Included in these farms are 120 farms of agricultural high schools and 710 conversion or organic farms. Drawing upon the experiences of the French farm network DEPHY and other pre-established national farm networks, the H2020 IPMWORKS project, that started in 2020, will build a European farm network with a two-fold objective: to demonstrate IPM strategies, which use small quantities of pesticides, and to promote the adoption of such strategies via knowledge exchange and peer-to-peer learning among farmers.

3.2.8 Other drivers and side effects that can facilitate the reduction of dependency on pesticide use and side effects

Beyond the drivers enquired within the analytical framework, there could be further (potential) drivers emerging from social, economic, environmental and legal dimensions that might play a role in reducing the farmers' dependency on pesticides use. Among the others, the MS taxation system can influence pesticide use and should be investigated. The study question aims at casting light on other drivers (existing or to be developed) and their role in reducing pesticides dependency.

To answer the study question, it is necessary to first identify further social, economic, legal and environmental drivers that could facilitate the reduction of dependency on pesticide use. Second, to narrow the lens down on PPPs' taxation systems by understanding which countries have introduced such systems, and whether and to what extent these systems are effective.

3.2.8.1 Identified drivers across social, economic, legal, and environmental dimensions

A number of social, economic, legal and environmental drivers (existing or potential) that can contribute to the reduction of pesticide use were identified by interviewed national stakeholders, competent authorities and researchers, as shown in the table below.

Table 16: Identified drivers across social, economic, legal, and environmental dimensions

ECONOMIC	SOCIAL
• Emergence of cost-effective alternative to pesticides. • Financial incentives and new funding support instruments. • Increasing pesticides prices and farmers' income trends. • Decreasing costs for alternative products driven by increasing demand. • Decreasing price of technologies. • Increasing availability of pesticides alternatives.	• Consumers' attitude and behaviour. • Digitalization. • Generational renewal, aging and gender. • Farmers' knowledge and training.
LEGAL	**ENVIRONMENTAL**
• Improving monitoring systems. • Setting up mandatory regulations. • Developments in the CAP and PPP policy, F2F strategy may be a booster. • Future potential alignment between mandatory IPM principles and international trade agreements. • Smoother registration process for low-risk plant protection products. • Area-based PPP prohibition. • Compensation payments for obligations under protected areas. • Formalise certification schemes. • Taxation.	• Environmental conditions and climate evolution. • Climate change and increased pest pressure. • Trend of biodiversity losses. • Increased resistances. • Development of green spatial planning to increase biodiversity.

Source: Compiled by the Consortium

Regarding drivers within the **economic dimension**, the key driving force of pesticides' use reduction falls at the crossroad between the availability of alternatives and the balance between alternatives and conventional pesticides' prices. No pesticides' reduction can be undertaken unless there are alternatives available on the market. The development of new alternatives and technologies, as well as the reduction of their prices, might drive further implementation of IPM measures. The reduction of alternatives' prices might be driven by an increasing demand by producers. On the other side, high prices of conventional products (either due to high demand by producers or taxations in place), combined with increasing accessibility to alternatives, may act as a driver (or a trigger) of pesticide use reduction as well. This trend, though, is not taking place at present. On the background, an important economic driver is represented by the set of subsidies in place, which amount, and setting may likely evolve in future.

On the **social dimension**, the interviewed stakeholders, competent authorities, and researchers converged on the driving role of consumers' awareness, attitude and behaviour. This is in line with, for example, the consumers' willingness to pay for organic products, which is strongly guided by environmental and sustainability concerns[120]. Research shows that a higher share of organic consumers value food pesticides risk higher than food benefits compared to the share of conventional consumers (70% against 53% of consumers, respectively), which can be a driver of "pesticides free" food choice. Nonetheless, in both categories of consumer, a majority (between 61 and 69%) is not fully aware of the regulatory standards for pesticides in food, assuming that in principle no pesticides should be present in food.[121]

As suggested by national stakeholders, an increased understanding by consumers about integrated production would be beneficial. At present, consumer perception is limited to two options: no crop protection like organic, and crop protection like conventional. But also integrated production contributes to sustainability. Increasing consumer knowledge about the differences between low-residue and non-residue products may help foster consumers' influence on IPM uptake. To this end, better labelling, communication and education (including schools) may be useful strategy to improve consumers' knowledge.

Interviewed researchers put special emphasis on training and information exchange. The increase in farmers' knowledge and skills is clearly a driver of pesticide use reduction. During the last few years, the literature has growingly demonstrated the contribution of learning processes and knowledge exchange

[120] Katt F., Meixner O., 2020. A systematic review of drivers influencing consumer willingness to pay for organic food. Trends in Food Science & Technology, 100(2020):374-388. https://doi.org/10.1016/j.tifs.2020.04.029.

[121] Koch S., Epp A., Lohmann M., Bol G., 2017. Pesticide Residues in Food: Attitudes, Beliefs, and Misconceptions among Conventional and Organic Consumers. J.Food.Prot., 80(12):2083–2089. https://doi.org/10.4315/0362-028X.JFP-17-104.

to sustainable and resilient farming systems,[122] and in farming practices and innovations.[123]

Digitalization might also be a driver of pesticides' reduction, as suggested by national stakeholders. This might be because digitalization can increase the diffusion of information and knowledge across consumers and producers. Accordingly, recent research suggests digitalization-induced changes in, for example, farmer-advisor relation[124] and knowledge exchange.[125] Yet, little is known about the actual impact of digital technologies on the use of pesticides.[126] Likewise, evidence of digitalization impact on consumers is divergent and, for instance, research found that both positive and negative effects can be expected by the consumers' use of social media.[127,128] This divergency might depend on the market segment (food category), which adds complexity to the issue.

It was also pointed out the role of generational renewal, aging and gender in driving pesticides' use. The literature reports clues of a young farmers' attitude towards more sustainable practices,[129] but not much on the gendered environmental attitudes. Yet, scientific evidence on these factors is poor.

On the **legal dimension**, developments in the regulatory framework will certainly influence pesticides' use. A few aspects that might be relevant drivers within the regulatory context have been highlighted by interviewed stakeholders and competent authorities. For example, attention was paid to the alignment between the IPM principles as applied within the EU, and third countries' regulations, which make evident the role of future international trade agreement. Moreover, the introduction of new elements might contribute to help policy drive pesticides' use reduction, such as setting up mandatory regulations and a structured monitoring system, smoothing registration processes for low-

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[122] Sumane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., des Ios Rios, I., Rivera, M., Cheback, T., Ashkenazy, A., 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. Journal of Rural Studies, Volume 59, April 2018, Pages 232-241. https://doi.org/10.1016/j.jrurstud.2017.01.020.

[123] Thomas, E., Riley, M., Spees, J., 2020. Knowledge flows: Farmers' social relations and knowledge sharing practices in "Catchment Sensitive Farming". Land Use Policy, 90, 104254. https://doi.org/10.1016/j.landusepol.2019.104254.

[124] Eastwood, C., Ayre, M., Nettle, R., Dela Rue, B., 2019. Making sense in the cloud: Farm advisory services in a smart farming future. NJAS - Wageningen Journal of Life Sciences, Volumes 90–91, December 2019, 100298. https://doi.org/10.1016/j.njas.2019.04.004.

[125] Michels, M., Fecke, W., Feil, J.H., Musshoff, O., Pigisch, J., Krone, S., 2020. Smartphone adoption and use in agriculture: empirical evidence from Germany. Precision Agriculture (2020) 21:403–425. https://doi.org/10.1007/s11119-019-09675-5.

[126] Phillips, T., Klerkx, L., McEntee, M., 2018. An Investigation of Social Media's Roles in Knowledge Exchange by Farmers. Conference Paper at 13th European IFSA Symposium, 1-5 July 2018, Chania (Greece).

[127] Simeone M., Scarpato D., 2020. Sustainable consumption: How does social media affect food choices? Journal of Cleaner Production, 277(2020):124036. https://doi.org/10.1016/j.jclepro.2020.124036.

[128] Sogari G., Pucci T., Aquilani B., Zanni L., 2017. Millennial Generation and Environmental Sustainability: The Role of social media in the Consumer Purchasing Behavior for Wine. Sustainability 2017, 9(10), 1911; https://doi.org/10.3390/su9101911.

[129] European Young Farmer Survey: Building a Sustainable Sector. European council of young farmers. https://wordpress.ceja.eu/wp-content/uploads/2019/09/CEJA-Delaval-Survey.pdf.

risk and alternative products, defining pesticide-free area to be compensated through subsidies and, lastly, formalizing IPM certification schemes. Importantly, it was mentioned by national authorities the possibility to develop further taxation systems (shifting towards environmental taxation), also including the opportunity to differentiate VAT based on PPPs' level risk, and the introduction of the "name&shame" principle that is becoming more and more accepted.

Regarding the **environmental dimension**, the main concern arisen from experts and interviewed stakeholders is the impact of climate change on the environmental conditions within which pests and diseases develop. Change climate conditions might lead to increasing pests' pressure. Accordingly, the literature highlights that such threat exists worldwide at large scale.[130] A study in the USA, for example, estimates an increase in pesticides' costs by 70% by 2100,[131] which may come with increased use of pesticides. This effect is linked to changes in temperature and CO_2, but also to the potential reduction of natural enemies,[132] which has also been suggested by experts. In addition, stakeholders remark the importance to keep focusing of emerging resistances.

Taxation systems, therefore, might help drive pesticides' use towards less-dependent patterns. In theory, an optimal tax system should allow a use of pesticide up to the level at which pesticides' use is more costly (economically, socially, environmentally) than beneficial. Taxes can also stimulate innovation and adoption of alternatives by farmers, and provide resources to support, for example, research and investments and, finally, cover the costs of their collection. Despite appealing in theory, the practical application of a taxation system is challenging, that is why at present only a few countries in the EU have implemented similar schemes.[133]

However, about two-thirds of the national stakeholders underlined that no such system is in place in their countries, or at least they are not aware about it. More precisely, competent authorities explained that a specific taxation system is implemented in Sweden, Denmark and France, whereas similar systems exist in Belgium and Germany. The implementation of such a system is under consideration in Italy and Portugal.

[130] Pathak T.B., Maskey M.L., Rijal J.P., 2021. Impact of climate change on navel orangeworm, a major pest of tree nuts in California. Science of The Total Environment, 755(1):142657. https://doi.org/10.1016/j.scitotenv.2020.142657.
[131] Koleva N., Schneider U., 2011. The impact of climate change on the external cost of pesticide applications in US agriculture. International Journal of Agricultural Sustainability, 7(3):203-216. https://doi.org/10.3763/ijas.2009.0459.
[132] Thomson L., Macfadyen S., Hoffmann A., 2010. Predicting the effects of climate change on natural enemies of agricultural pests. Biological Control, 52(3):296-306. https://doi.org/10.1016/j.biocontrol.2009.01.022.
[133] Lefebvre M., Langrell S., Gomez y Paloma S., 2015. Incentives and policies for integrated pest management in Europe: a review. Agron. Sustain. Dev. (2015) 35:27–45. DOI 10.1007/s13593-014-0237-2.

Accordingly, the Pesticide Action Network (PAN) Europe[134] identified and described four taxation models across EU member states. The table below synthetises these findings. Besides, regarding the VAT, some countries applied low rates, including for example Poland, Portugal, Romania, Slovenia, Spain, Cyprus, and (partially) Belgium.

Table 17: Existing and debated PPPs' taxation systems in Europe as identified by PAN Europe

Country	State	Description
BE	Debated	In the 1990s, in Belgium a regulatory proposal was drafted but finally was not approved. Currently, Belgium is undertaking research to evaluate the actual utility and effectiveness of a tax on pesticides.
CZ	Debated	The Czech Republic set up the objective to analyse the possibility of introducing economic instruments (e.g., a sales tax on PPP) in the NAP.
DK	In place	The first taxation scheme was set up in 1996 based on ad valorem taxes on the highest wholesale price. In 2013, a new tax scheme was introduced and is paid on pesticides according to how large the impacts from the pesticides are on health, nature, and groundwater based on a combined index. The revenues of the tax are returned for agricultural and environmental purposes.
FI	Abandoned	Finland introduced a fee on pesticide use in 1988, with the purpose to finance control and registration. However, the fee was abandoned in 2006.
FR	In place	France introduced the first taxation system in 2000, then modified in 2009 and, more recently, in 2018. The pesticide tax is paid by pesticide buyers and collected by pesticides sellers and aims to provide the water agencies more resources to encourage conversions to organic farming has been the main aim of this tax reinforcement.
DE	Debated	In 2015, German government proposed the introduction of an ad-hoc taxation system based on the Norwegian model. The proposed taxation would be paid by the industry or, alternatively, the wholesalers.

[134] https://www.pan-europe.info/issues/pesticide-taxation.

Country	State	Description
IT	In place	In 2000, Italy set up a flat tax of 2% to all pesticides manufactured and sold that are classified has having certain health risks and/or toxicity to aquatic organisms.
NL	Debated	In the Netherlands several pesticide tax debates took place. At the end, these led to the denial of a proposed taxation because of the relatively high organisational effort, the low elasticity of demand, and the higher burdens for domestic producers as well as leakage through import.
Norway	In place	Norway was the second country in Europe introducing a tax on pesticides in 1988. In 1999, the tax was changed into a differentiated scheme and now consists of a base rate and an additional rate.
ES	In place	In 1984, Sweden was the first country in the world introducing a taxation of pesticides based on volumes sold. The original system imposed a tax of SEK 4/kg, which was then then increased in 2015 up to 34 SEK/kg. The Swedish government consider a revision of the existing taxation scheme.
Switzerland	Debated	A long-standing debate is still taking place since the 1990s, but the Swiss authorities argued in favour of more effective measures such as cross-compliance, registration guidelines, or agri-environmental measures. As opposite to this authority, there is some public and political pressure to further promote a reduced application of pesticides.

Source: Compiled by the Consortium

In those countries where the system is applied, the evaluation of the effectiveness is diverging. Throughout the interviews, it was generally pointed out that national stakeholders could not give an opinion on the effectiveness of such taxation systems, except one from Germany who explained that it is not effective because not mandatory. Likewise, most of the competent authorities could not answer, except six respondents, of which five argued about the limited impact of the system, and one instead confirmed a relevant positive impact (Denmark). In Sweden, for instance, the system is based on the amount of product used. This might cause higher costs when pest pressure is particularly high because the farmer will need to save his/her production anyway, even in the case of organic farming because organic products are used in higher quantity. Unlike, in France the tax system does not seem useful in term of reducing pesticide use, but taxes collected through the taxation system funds the Ecophyto plan. In Flanders it is argued that collected funds are used for minor purposes, whereas in Germany it is not very effective as it is not mandatory. In this regard, the NAP could improve the system.

Denmark remains the most positive example in the interviewees' opinion, especially considering the re-use of collected funds for promoting alternative farming practices. Nonetheless, research on Danish farmers highlights that, despite some large reductions of pesticide use after the tax reform in 2013, the system has not reached the reduction forecasted in ex-ante assessments. This might be (partially) due to a farmers' behaviour characterised by a strong production-oriented attitude that shows a weaker response to market-based instruments.[135]

One of the main argumentations behind the non-effectiveness of taxation is the higher cost for farmers. Research in Germany compared the impact of pesticide taxation and a green nudge treatment and finds that, while a tax would reduce the amount of pesticides used, it would also imply a substantial profit loss.[136] This aspect might lead to setting up a low-level tax to avoid impacting farmers' income. Accordingly, the literature finds that the overall effectiveness of PPPs' taxation is limited mainly due to low tax levels, and that differentiated taxes are superior to undifferentiated ones in reducing pesticides' use.[137,138] Higher tax levels may increase their effectiveness, but there is divergence on the effective tax level to be applied. For instance, further investigation reveals that Norwegian farmers would be relatively insensitive to a 100% increase in the price of pesticide (i.e. herbicides and fungicides).[139]

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[135] Pedersen A., Nielsen H., Daugbjerg C., 2020. Environmental policy mixes and target group heterogeneity: analysing Danish farmers' responses to the pesticide taxes. Environmental Policy & Planning 22:5, 608-619, DOI: 10.1080/1523908X.2020.1806047.

[136] Buchholz M., Peth D., Mußhoff O., 2018. Tax or Green Nudge? An Experimental Analysis of Pesticide Policies in Germany. Discussion Paper No. 1813, Georg-August-Universität Göttingen. http://hdl.handle.net/10419/190685.

[137] Böcker T., Finger, R., 2016. European Pesticide Tax Schemes in Comparison: An Analysis of Experiences and Developments. Sustainability 2016, 8, 378; doi:10.3390/su8040378.

[138] Finger R., Möhring N., Dalhaus T., Böcker T., 2017. Revisiting Pesticide Taxation Schemes. Ecological Economics 134, http://doi.org/10.1016/j.ecolecon.2016.12.001.

[139] Vatn A., Kvakkestad V., Steiro A.L., Hodge I., 2020. Pesticide taxes or voluntary action? An analysis of responses among Norwegian grain farmers. Journal of Environmental Management 276 (2020) 111074. https://doi.org/10.1016/j.jenvman.2020.111074.

Table 18: More detailed information on taxation systems

Denmark	France	Norway
Tax base		
Excise duty Volume of active substances sold according to categories of environmental risks, expressed as the pesticide load indicator: Human health risk Environmental degradability and accumulation Environmental toxicity on non-target organisms	Excise duty Volume of active substances sold, grouped according to their risk profile: Carcinogenic, mutagenic or impact on human reproduction Ecotoxicity Aquatic toxicity Price-based tax, similar to VAT Value of pesticide sale VAT reduction for PPPs used in organic production	Excise duty Volume of active substances produced or imported, grouped into categories according to human health and environmental risks (low, medium, high)
Tax rate		
Fixed base tax per kg of active substance: DKK 50 Differentiated tax based on criteria: DKK 107 (multiplied by the compiled load indicator)	Rates depending on risk category between EUR 0.9 and EUR 9 per kg of active substance 0.9% of the selling price without VAT 0.1% for biocidal products 10% VAT rate instead of 20% VAT for regular products for organic production	NOK 25 per hectare multiplied by a category weighting factor and a standard area dose for the pesticide Higher factors for pesticides sold to non-professional consumers Parameters are defined at the approval of a pesticide
Imposition point		
Pesticide distributor or importer	Pesticide distributor or importer	Pesticide distributor or importer
Revenue generated		
DKK 520 million (EUR 70 million) per year on average between 2014 and 2017	EUR 400 million	NOK 50-65 million (EUR 5-6.5 million)
Use of revenue		
Fully reimbursed to the agricultural sector through lowering of agricultural land property tax, support of organic farming, administrative services, green growth measures as defined in NAP	Funding of the ECOPHYTO program. Used for other agricultural measures including NAP and promotion of organic farming and balancing costs of water operators	Part of the overall state budget

Source: Compiled by the Consortium

Pesticide taxation is probably the most efficient way to achieve reduction in pesticide use but, in order to be effective, taxes have to be set at a sufficiently high level, and further compensation could be considered. High tax level can be lowered by other economic inducements, such as subsidies for organic farming, were introduced.[138] Other economic incentives can be applied such as the remuneration of environmental services through voluntary contracts subsidising low-input practices. While Swiss authorities argue that other measures are more effective than pesticide taxation, the literature highlights potential benefits brought by combinations of different tools, including taxation schemes.[140] Therefore, the effectiveness of pesticide taxation may increase in combination with other instruments.

3.2.8.2 Application of the 'polluter pays' principle?

The civil society might influence the pesticides use and, consequently, act as a driver. This could occur, for example, through society putting pressure on the political debate and policymaking and/or through the consumers' choice which might re-orient (or contribute to re-orient) the market. As such, the civil society owns a potential to drive the use of pesticides by farmers and should be considered. This societal aspect includes the potential application of the 'polluter pays' principle, which could act as a driver too. This study question aims at understanding whether and how the civil society drives the use of pesticides, and whether taxing externalities (the "polluter pays") could be an effective tool to align pesticides' use with societal expectations and policy goals.

Based on the interviews, half of the national stakeholders and researchers consider the influence of civil society relevant. Among the other stakeholders, nine suggest that the influence exists but it is not significant yet. Only one respondent affirmed that the influence does not exist at all. Among competent authorities, the opinion is more divergent, resulting in two-thirds of respondents that answered positive, whereas two answered that their influence is limited, and the rest did not have an opinion.

One of the respondents' main argumentations points to the evidence that civil society can play a critical role in the general acceptance or not of the use pesticides. Changes in this public perception can create drivers for farmers and/or retail to change their attitude towards the use of pesticides. Farmers would be more inclined to look for alternatives. This role can be expressed by a higher willingness to pay for more sustainable products and/or through pressure onto the political debate and decision-making.

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[140] Lee R., Uyl R., Runhaar H., 2019. Assessment of policy instruments for pesticide use reduction in Europe: Learning from a systematic literature review. Crop Protection 126 (2019) 104929. https://doi.org/10.1016/j.cropro.2019.104929.

Research captures the increasing societal concerns in Europe regarding the use of pesticides and related risks[141]. Accordingly, advocacy organisations' initiatives are growing in the EU to mobilise the citizens' support.[142] On the other hand, consumers' choice and behaviour influence the food supply and, therefore, the farmers' behaviour, also in terms of pesticide use, though this might be limited to certain groups of consumers. In fact, scientific literature explains that consumers' willingness-to-pay is driven by environmental and health concerns to a great extent.[143]

Nevertheless, interviewees provided a series of considerations about relevant, potential constraints that might hinder the influence of civil society. First of all, the product price remains a key factor in purchase behaviour and consumer demand, which cannot be avoided. The extent to which consumers can influence farmers' behaviour will be limited within the boundaries of purchase possibilities. Some components of the society might not be willing or able to pay high prices.

Secondly, a critical limitation factor is the quality, type and amount of information reaching consumers and citizens. In this regard, education and media play a role in consumer awareness and behaviour and, therefore, could be a factor enhancing the societal influence on sustainability. In general, consumers are becoming aware and more informed about sustainability issues.

Besides, the societal influence on pesticide use is limited by climatic and regional circumstances, and the type of cultivation and technical systems and the availability of effective and affordable non-chemical alternatives, which imply an unavailable and necessary use of pesticides.

A fully sustainable production system (e.g., fully organic production) might compromise the food self-sufficiency of Europe (i.e., reduced yields), which in turn represents a constraint to the extent to which consumers can push on sustainability itself. Research demonstrates that a gap between conventional production and pesticide-free farming systems such as organic exists in terms of crop yields, though such difference varies depending on the type of crop[144].

Alongside the direct influence of civil society on pesticides' use, other instruments can be set up to ask polluters compensate the higher social and environmental costs affecting the whole society. To this end, in 1972 the OECD

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[141] Schaub S., Huber R., Finger R., 2020. Tracking societal concerns on pesticides – a Google Trends analysis. Environ. Res. Lett. 15 084049.
[142] Tosun J., Varone F., 2020. Politicizing the Use of Glyphosate in Europe: Comparing Policy Issue Linkage across Advocacy Organizations and Countries. Journal of Comparative Policy Analysis: Research and Practice. https://doi.org/10.1080/13876988.2020.1762076.
[143] Katt F., Meixner O., 2020. A systematic review of drivers influencing consumer willingness to pay for organic food. Trends in Food Science & Technology, 100(2020):374-388. https://doi.org/10.1016/j.tifs.2020.04.029.
[144] De Ponti R., Rijk B., van Ittersum M., 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems, 108(2012):1-9. https://doi.org/10.1016/j.agsy.2011.12.004.

introduced the **polluter-pays principle**. The polluter-pays principle implies the internalisation of negative environmental externalities through the transfer of the expenses of pollution prevention and public control measures on the polluters. Polluters, therefore, are incentivised to avoid environmental damage and are held responsible for the pollution that they cause.[145]

Among the interviewed actors, opinions about the feasibility and potential implementation of the polluter-pays principle are divergent. Only one-fourth of national stakeholders consider this principle a possible strategy, while half of stakeholders suggest that this principle is not feasible or not effective in the current conditions. Among the competent authorities interviewed, about one-third stated that this strategy is possible, while another one-third argued that it is not feasible, at least under current conditions. However, initiatives (partially) based on this principle already exists in some countries (25 on the existing and debated PPPs' tax systems in Europe).

A number of argumentations underpin the interviewees' opinion. In the first place, a critical factor is the increasing price to pay, and who is going to pay it. It was argued by national stakeholders that regardless of who pays the extra costs, the impact might be negative. For example, taxes imply higher costs, which in turn might be reflected in higher prices to be paid by consumers. In case of extra cost to be paid by consumer, important part of population might choose for more unhealthy diet.

Alternatively, in case of extra cost to be paid by farmers, this might impact farmers' income and local productions. Indeed, research demonstrates potential significant profit losses under pesticide taxation. A further relevant suggestion by national stakeholders underline that such principle cannot be implemented when alternatives to pesticides are not available. Farmers might not be able to pay, and it would be unfair to let them pay when alternatives are not available. Even though these solutions fulfil the polluter pays principle, the income reduction in the agricultural sector caused by a tax is one of the key hurdles for acceptance of such measure[146]. Lastly, in case of extra cost to chemical companies, these may decide to leave the EU market and, consequently, European products might be replaced by cheaper imports.

Behind the "who pays" question, there is an overarching issue that has been raised by stakeholders, that is: *who is the polluter*? The interviewed competent authorities wonder whether the polluter should be referred to the producer or

[145] European Court of Auditors, 2021. The Polluter Pays Principle: Inconsistent application across EU environmental policies and actions. Special Report NO.12. https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=58811.

[146] Finger R., Möhring N., Dalhaus T., Böcker T., 2017. Revisiting Pesticide Taxation Schemes. Ecological Economics 134 (2017) 263–266. http://dx.doi.org/10.1016/j.ecolecon.2016.12.001.

the user of pesticides. A definition of the polluter is a necessary pre-condition and likely, stands at the core of the polluter-pays principle.

The policy debates taking place across the EU (e.g., Germany and the Netherlands) claimed the inelasticity of pesticides' demand as a major reason to not introducing a pesticide tax. In fact, an important requirement for effectiveness and efficiency of pesticide taxes is the demand's sensitivity to price. Research provides relevant observations in this regard. Firstly, the elasticities depend on the type of agricultural system and, therefore, pesticides' use reduction should differ across different systems. Secondly, elasticities are time-dependent, meaning that the demand of pesticides in the short-run is less elastic because time is needed to implement new practices or technologies. Thirdly, elasticities depend on the type of pesticide. In particular, herbicides appear more elastic because mechanical alternatives are available. Thus, lower tax rates are required to reduce herbicide use.

As opposite to the polluter-pays principle, one of the interviewed stakeholders suggest the approach of the "not-polluter rewarded" principle. Behind this suggestion there is the idea that it could be better to motivate farmers to apply alternatives and provide them with tools and knowledge. Accordingly, competent authorities underline that financial incentives can be more effective than taxations.

3.2.8.3 Effects of introducing other beneficial practices for soil and water through ecosystems

Agro ecosystems are characterised by different dimensions, i.e. physical, chemical, biological and anthropic, which are intimately linked and virtually impossible to separate. Due to such intrinsic features, the implementation of measures that bring improvements to one of these areas, often results in benefits arising in other dimensions. Examples include the improvements in soil biota that can follow the reduction in pesticide use through IPM measures, thus positively affecting the overall soil quality and ultimately nutrients cycles[147]. A burgeoning literature also explores the effects of inadvertent pesticides leakage into water bodies[148] and their persistence, suggesting that a reduction in use of the latter can positively affect water quality.

The aim of this section is to investigate whether there is a link between IPM practices and practices for soil and water conservation, and what is the nature of this relationship. In fact, it is important to consider these relations to identify

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[147] Lamichhane, J.R., Pesticide use and risk reduction in European farming systems with IPM: An introduction to the special issue, Crop Protection (2017), http://dx.doi.org/10.1016/j.cropro.2017.01.017 . Available at URL: https://hh-ra.org/wp-content/uploads/2021/02/Lamichhane-Pesticide-use-and-risk-reduction-in.pdf.
[148] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Agri-environmental_indicator_-_pesticide_pollution_of_water.

eventual barriers to adoption of IPM practices by farmers as well as to leverage on the synergies.

In order to investigate this, three sub-questions were set up, in order to reflect on different aspects as follows:

- Can positive effects (complementarities) or trade-offs be observed between goals like pesticide reduction and soil conservation? If yes, which ones?
- Extent to which future restrictions of the use for fertilisers, as planned in the F2F strategy, will help reduce the dependency on pesticide use? and
- Beneficial effects on ecosystem services from reduced pesticide use

Soil conservation entails a wide range of practices aimed at preserving the physical, chemical and biological quality of soil. Examples of soil conservation practices include:

- No-till or minimum tillage (as opposed to more invasive practices such as mouldboard ploughing);
- Mulching, or 'the application of a protective cover of plant residues or other suitable material;
- Use of cover crops;
- Soil amendment, using organic amendments; and
- Reduced inputs of synthetic/chemical fertilisers.

Interestingly, although the goal pursued may differ, some of the above-mentioned practices also represent staples of the IPM approach. Specifically, several of those practices are also listed among the cultivation techniques aimed at "Prevention and suppression" (IPM Principle 1, e.g. superficial ploughing, non-inversion tillage, conservation tillage and mulching). That being so, a first level of synergies between the goal of pesticide reduction (through IPM) and soil conservation can be already identified in the sense that both can be achieved through a set of similar measures.

Soil conservation practices have proven to generally have positive effects on pest pressure and reduction of pesticide needs, but negative effects can be observed as well. Numerous studies have been performed on the influence of soil management practices vis-a-vis pest management, e.g. studies on the impact of conservative tillage methods on pest population as well on pesticide concentrations and fate.

Alyokhin et al.[149] performed a review to identify the effects on pest dynamics and management, both positive and negative as well as direct and indirect, that occur when soil conservation practices are performed in high-input agricultural systems such as potato and onion cultivation.

Overall, literature shows that the beneficial effects on reducing pest pressure that arise from soil conservation practices are linked to both direct (direct effect on the population of pests as well as that of natural enemies) and indirect (overall better health status of the crops) mechanism associated to such practices. Evidence collected in the literature suggest that the overall increase in complexity in agricultural ecosystems that can be achieved by soil conservation practices (i.e. through less disturbed soils and higher organic matter content) creates an environment that is overall less conducive to outbreaks of herbivorous insect pests.

Based on this review, the table below provides examples of positive and negative effects identified.

Table 19: Examples of positive and negative effects

Soil conservation practice	Positive effects on pest management	Negative on pest management
No-till or minimum tillage	Provision of more complex habitat compared to conventional tillage, due to: - leaf litter accumulation - increase in numbers of their natural enemies/biological control agents which enjoy additional resources in the form of alternative prey and shelter.	Possible increase in economically important weeds that can also create a reservoir for vectors of viruses, such as for PVY and its aphid vectors as well as for IYSV and its thrips vectors. Weed control is usually more difficult, often resulting in increased use of synthetic herbicides.
Mulching	Suppression of weeds by preventing the light necessary for their emergence and growth, and occasion-ally through its allelopathic properties. Reduced ability of some harmful insects (and insect-transmitted viruses) to identify host plants, or	Living mulch could represent a reservoir for harmful insects (including insect-transmitting insects), fungi and other pests.

[149] https://onlinelibrary.wiley.com/doi/epdf/10.1111/eea.12863.

Soil conservation practice	**Positive effects on pest management**	**Negative on pest management**
	to move between host plants within the field. Increase in natural enemy population, thus improving biological control. The physical or chemical properties of the mulch may contribute to pathogen and insect pest suppression, i.e. due to release of secondary plant compounds). For insect vectors, living mulches may act as a sink for non-persistent viruses: With most non-persistent viruses, including PVY, aphids stop being infectious after a few probes on a healthy or unsusceptible plant forming the mulching.	
Use of cover crops	Creates more stable and diverse biological communities with a more complex network of nutrient and energy flow due to increased amount of residue on the soil surface (thus improving soil structure) and increased natural enemy populations.	Cover crops can serve as a bridge between growing seasons for polyphagous pests (acting as a reservoir as it is the case with mulch), especially in areas with warmer climates where their lifecycles are not interrupted by winter diapause.
Soil amendment and use of organic amendments	Favourable environment for the growth of cultivated crop plants as well as favourable organisms. Improved overall soil health, including abundance, diversity, and activity of soil-dwelling organisms.	High soil quality is likely to favour at least some species of soil-dwelling insect pests.
Reduced inputs of synthetic fertilisers	As excessive amounts of nitrogen fertiliser have been associated with greater pest and disease problems, due to softer tissues.	Excessively reduced fertilisers inputs could result in lower natural defences in the crops.

Soil conservation practice	Positive effects on pest management	Negative on pest management
Mycorrhizae	Positive effects on plant growth and fitness due to: - supplying resources used by crop plants to synthesise defensive compounds. - triggering plant defence signalling pathways.	

Source: Compiled by Arcadia International

Fewer studies have been conducted on the effects of more specific IPM practices *on* soil conservation. As it has mentioned before, there is a direct link between certain IPM measures under Principle 1 "Prevention and suppression" and soil protection/conservation. These are not specifically or traditionally pest-management practices *per se* and can be rather defined as agronomic practices which are aimed at maintaining a balanced and resilient agro-ecosystems, thus also contributing to soil conservation. That being so, the link between other IPM measures, i.e. associated to more specific IPM principles, is less direct or less investigated.

As a principle, certain concentrations of pesticides are known to potentially have numerous effects on the soil system, including on effects on:

- Soil microbial activity (crucial for the nutrients cycle);
- Soil enzymes; and
- Availability of certain nutrients.

That being so, all the approaches that can lead to a reduction of pesticides use, including IPM measures, can supposedly mitigate such threats. In this context, IPM could play a role in positively (yet indirectly) contribute to soil quality and conservation. However, there are lesser studies investigating the direct link between highly specific IPM practices (e.g. biological control etc) and soil conservation, and most of them focus on the biological dimension of soil health/quality rather to chemical and physical properties.

National-level stakeholders identified a number of mutually favourable links between the goals of pesticide reduction and soil conservation, even if a few respondents suggested that no relationship is known. As interviews usually provide insights that are more general and less "practice-specific" as compared to the literature explored, the exact cause-effects pathways linking the two goals were not explored in detail during interviews.

Most interviewees deem the increase in biodiversity associated with soil conservation as contributing to decrease pests' pressure on crops and, consequently, the need for using pesticides. At the same time, they also mentioned how increased biodiversity associated to reduced pesticide can ultimately lead to increased quality of water and increased fertility of the soil.

With respect to National Competent Authorities, the views on this topic are more controversial, with some cases where no complementarity was seen and others where specific trade-offs were mentioned. Notably, this stakeholder group rather focused on the externalities that the reduction of pesticides can bring on water and soil, including:

- Preservation of organic matter and soil biota, including beneficial microorganisms, in the soil;
- Positive effects on soil quality and mitigation of soil erosion in agricultural systems where the use of herbicides is limited, in favour of cover crops and living mulches; and
- Mitigation the risk of soil and water contamination, due to adsorption to soil particles (i.e. localised contamination) as well as to inadvertent drift of pesticides in water bodies (i.e. more large-scale contamination).

Nonetheless, specific trade-offs between the two objectives have been mentioned by CAs, especially with respect to tillage. In fact, although soil conservation practices tent to favour minimum or no-tillage, this could result in limiting the tools to effectively control soil borne diseases as well as weeds. Moreover, the reduced use of herbicides pursued by IPM might translate in an increased reliance on tillage and ploughing, which is not in line with the principles of soil conservation.

Behavioural studies could shed light on the combined adoption by farmers of measures targeting pesticide reduction and soil and water conservation. Beyond the ecological aspects underlying the links and synergies between these different areas and the extent to which different agronomic measures influence each other's outcomes, there is also a behavioural component when it comes to the adoption of measures that tackle pesticide reduction *in combination* with measures targeting water/soil conservation. In fact, there could be a behavioural bias suggesting that farmers that already adopt environmentally friendly practices may be more inclined to and, thus, likely to adopt additional environmentally beneficial practices, thus further scaling up the benefits on soil and water resources.

Over the last decades, researchers have increasingly studied the factors that influence farmers' adoption of environmentally sustainable practices, including studies from the JRC on the behavioural factors that influence the adoption of environmentally sustainable farming practices.[150] In fact, judging by the burgeoning literature on this topic, the behavioural perspective appears as a particularly warranted approach to evaluate voluntary adoption of measures vis-à-vis the respect to mandatory requirements.

Nonetheless, most studies focus on the behavioural factors playing a role in the uptake of single measures or in single areas. The behavioural components of environmentally friendly farming practices have been put in a policy-oriented context in a recent behavioural science study[151] from the JRC. Results from this study suggests that the more mandatory requirements placed on farmers, the less likely they are to make additional voluntary contributions. Although not directly or explicitly linked to the relation between measures targeting pesticide reduction and other environmental measures, these findings may shed light on the extent to which farmers already subjected to the mandatory requirements of the green architecture of the CAP may be inclined to adopt and endorse further environmentally beneficial practices.

Leveraging on such synergies, both at technical and behavioural level, appears as particularly interesting from a policy perspective, in that it can support the design of policy that can achieve different goals simultaneously and with enhanced results.

Synergies in the achievements of targets related to both pesticides and fertilisers can be sought. Fertilisation and pest managements are both important variables within agricultural systems. In the context of the Green Deal, measures have been defined to significantly reduce the use and risk of chemical pesticides, as well as the use of nutrients, potentially leading to reduction of fertilisers use. As regard the latter, a Green Deal target set out in both the EU Biodiversity Strategy for 2030 and the F2FS concerns the reduction of nutrient losses (nitrogen and phosphorus) by at least 50% by 2030, while ensuring that there is no deterioration in soil fertility. According to the EC, this target will reduce the use of fertilisers by at least 20% by 2030.

Although those goals and targets are virtually independent on one another, synergies in their achievements could be sought. One opportunity to do so is represented by digital and precision farming, i.e the use of new tools combined with real time data and smart farming application methods. The tools and opportunities of smart agriculture could be capitalised and used to optimise the pesticide use alongside nutrient inputs, as also described in IPM Principle 6, "Pesticide selection".[152]

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[150] Available here.
[151] Available at URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC123832.
[152] Specifically, IPM Principle 6.3, "Precision agriculture and spraying".

The synergy between these targets is already listed among the technical solutions identified in the different Green Deal documents to achieve climate, environment and health targets and goals.[153] Specifically, the tools mentioned to simultaneously tackle both types of targets, i.e. pesticide and fertilisers reduction refer to:

- Precision farming & fast broadband internet access across rural areas; and
- Farm sustainability tools for nutrients.

Although the high relevance of such approaches towards both goals, it has been estimated that precision farming alone is most likely insufficient to reach the targets (-50% of more hazardous pesticides, -20% fertilisers, -50% nutrient losses). However, by using several precision farming solutions together, there is the possibility of reducing pesticide use by around 10-20% (see the inventory of practices, techniques and technologies as presented under Annex 1) and fertiliser use by 10%. As a drawback to this approach, it needs to be reminded that the adoption of precision farming technologies requires broadband coverage and new equipment.[154]

Further research efforts are needed to disentangle the links between crop nutrition and pest management. Beyond synergies in terms of policy and targets, the extent to which those two elements influence each other at agronomic level is not very well explored. As mentioned above, balanced nutrition is also included in the IPM Principle 1, "Suppression and prevention". From one hand, insufficient fertilisation can affect the susceptibility of plants to insect pests by affecting plant tissue nutrient levels. In fact, research shows that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and biological properties of soils, achievable through an adequate nutrient supply to crops. On the other hand, an excessive use of fertilisers can cause nutrient imbalances and, thus, lower pest resistance. Moreover, as it is the case for most agronomic practices, climatic and crop specificities shall be considered.

Moreover, the selected influence of organic vis-à-vis inorganic fertilisation on pest management is still to be explored. That being so, more studies comparing pest populations on plants treated with synthetic versus organic fertilisers are needed. In fact, better understanding of the underlying effects of how and why organic vs inorganic fertilisation appears to improve plant health may lead us to

[153] https://www.europarl.europa.eu/RegData/etudes/STUD/2020/629214/IPOL_STU(2020)629214_EN.pdf.
[154] https://www.europarl.europa.eu/RegData/etudes/STUD/2020/629214/IPOL_STU(2020)629214_EN.pdf.

new and better integrated pest management and integrated soil fertility management designs.[155]

Interview findings mainly focus on the trade-off that a reduction in fertilisers use might bring, including an increase in pesticides needs. The connections between these two areas were explored in interviews as well, mainly focusing on the physiological relation between nutrition, plant defence and consequently pest management. However, as the nature of this judgment criteria is highly technical, several national level stakeholders expressed no opinion on this topic, mainly due to lack of knowledge. Nevertheless, the following points have been raised, rather focusing on the negative effects that a reduction in fertilisation can have on pest management, i.e.:

- Possible detrimental consequences in reducing fertilisers linked to a reduction in vigour and, hence, defences; and
- Widely spread use of high-input varieties, that need a high rate of fertilisation; for the latter, a reduction of fertilisers could lead to a sub-optimal physiological state, leading both to lower yields but also increased vulnerability to crops.

National Competent Authorities also highlighted the fact that the nature of this study question is highly technical, thus challenging to provide contribution to. The main points mentioned by this stakeholder group revolved around, as was the case for the national level stakeholders, the possible trade-offs that a reduction in fertilisers could bring on pesticide use, including:

- Possible increase of pesticide use linked to the increased vulnerability of crops in a suboptimal that could result from a reduction in fertilisers use;
- Behavioural factors that could induce farmers to use more pesticide to mitigate and compensate for the reduced yields that could follow a reduction in fertilisers used; and
- Potential issues arising from the possible restrictions of substances such as copper, which is often included in the compositions of both fertilisers and plant protection products, it was also suggested that the answer to this question is crop/cultivar dependent.

Alongside those potential trade-off, Competent Authorities also underlined the need to consider the regulatory framework provided by the Nitrates Directive, and that optimizing the dosage of fertilisers according to the topical/specific soil

[155] Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystemshttps://www.sciencedirect.com/science/article/pii/S0167198703000898?casa_token=32Annw7OXZsAAAAA:QlrR9NlqLKhCZ8DG7H7-0G69S8V2AFjwVUI5ozNjaEzUMxwM6lWBFqpnMj3DwzZnSRTZddx3MmY.

conditions can represent the key to harmonise the use of fertilisers without hampering the physiological status and defence capacity of crops.

According to the Millenium Ecosystem Assessment,[156] ecosystem services (ES) can be defined as "*the benefits people obtain from ecosystems*". These can be classified into:

- **Provisioning services**, such as food, water, timber, and fibre;
- **Regulating services**, that affect climate, floods, disease, wastes, and water quality;
- **Cultural services** that provide recreational, aesthetic, and spiritual benefits; and
- **Supporting services** such as soil formation, photosynthesis, and nutrient cycling.

It is clear that agricultural landscapes provide a number of ecosystem services ranging from the production of food and other raw materials to the contribution to regulatory (e.g. water and climate regulation) and cultural (e.g. aesthetic value and recreation) services.[157] Moreover, the ES concept has been considered in European policy in several EC communications.[158]

Numerous studies use ecosystem services as a framework to assess the impact of pesticides. Although the (reduction of) pesticide use might potentially affect all those four dimensions, the scope of analysis in this report will mainly focus on those ES which might appear as more directly linked to pesticide use, i.e. regulating and supporting services, in line with the approach followed by Nienstedt et al. (2021)[159] to determine specific protection goals for environmental risk assessment of pesticides.

As a general principle, ES can be supplied at their maximum level by ecosystems only when all the elements within the ecosystem are at their optimal state and interact in a balanced manner. That being so, any major disturbance to one or more elements of the (agro) ecosystem may result in a reduced supply of ES by the latter. In this context, approaches that encourage and support the

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[156] https://www.millenniumassessment.org/documents/document.356.aspx.pdf.

[157] https://www.sciencedirect.com/science/article/pii/S0048969711005821?casa_token=eGoLuyAcVcYAAAAA:6qlHrWBwu9CKBVeGNvv_xac9xfx38XmBn8DAXnmAPYJkjATvHaGyH7r_lJ_5pnklHth9ud0Z2_U.

[158] EC (European Commission), 2006, Communication from the European Commission. Halting the loss of biodiversity by 2010 — and beyond. Sustaining ecosystem services for human well-being. COM(2006) 216 final, 22.5.2006 (2006), pp. 1-15; EC (European Commission), 2011,Communication from the Commission: our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM(2011) 244 final, 3.5.2011 (2011), p. 17.

[159] Karin M. Nienstedt, Theo C.M. Brock, Joke van Wensem, Mark Montforts, Andy Hart, Alf Aagaard, Anne Alix, Jos Boesten, Stephanie K. Bopp, Colin Brown, Ettore Capri, Valery Forbes, Herbert Köpp, Matthias Liess, Robert Luttik, Lorraine Maltby, José P. Sousa, Franz Streissl, Anthony R. Hardy (2021) Development of a framework based on an ecosystem services approach for deriving specific protection goals for environmental risk assessment of pesticides, Science of The Total Environment, Volume 415, Pages 31-38, ISSN 0048-969. https://doi.org/10.1016/j.scitotenv.2011.05.057.

complexity within the agro ecosystems, including IPM measures, have the potential to positively act on the provision of ES. As an example, the increased biodiversity that is promoted by certain IPM measures (e.g. keeping the pest density below certain economically viable thresholds, as opposed to completely eradicate it) renders the agro-ecosystem more resilient and balanced, which is crucial for the delivery of ES.

However, the relative provision of different ES categories by a "natural" ecosystem could somehow differ from what is expected in terms of performances from an agro ecosystems, where the provisioning ES (e.g. provision of food through the cultivation of crops) is a highly desired and prioritised ES. That being so, the potential benefits that the approach promoting a reduction of pesticide use could bring is intimately dependent on the extent to which they affect the yield. Nonetheless, when agro eco-systems are holistically assessed, e.g. considering also regulating ES (e.g. beneficial effects on nutrient cycles via positive effects on the soil biota), approaches to agricultural management such as IPM appear as very promising.

The analysis provided to this topic by stakeholders solely focused on the segment of ecosystem services related to "regulating services", and thus focusing on the impact on water and soil resources. Furthermore, given that the notion of ecosystem services is somewhat technical and not always well-known among stakeholders, the arguments mentioned by interviewees often refer to the influence of a reduced pesticide use on the ecosystem themselves, rather than on the *ecosystem services.*

National-level stakeholders reiterated points raised already when inquired about the links between reduction of pesticides use and preservation of soil and water resources (elaborated in the first judgment criteria), underlining the benefits that a reduction in pesticide use can bring to the ecosystem, i.e.:

- Increased biodiversity at all levels, notably pollinators, natural enemies of crops' pests, and microorganisms (yet considering that a reduced use of herbicides may imply a need to practice more tillage, which in return might have negative impacts on soil microorganisms);
- Preservation of the soil and water bodies, in terms of improvement of physical, chemical and biological fertility of the soil as well as water quality;
- Improved air quality; and
- Less disturbance to beneficial organisms such as Mycorrhizal fungi, thus bringing improvement in water absorption and nutrients by crops.

When inquired about this topic, NCAs mentioned similar arguments as compared to national level stakeholders, focusing on the impact on the regulating ES, alongside general positive effects on the ecosystems themselves. In addition to this, it has also been mentioned that the reduction in pesticide use could bring benefits in terms to climate change mitigation and improved landscape, i.e. including cultural and aesthetics services.

3.3. Theme 3: Assessment on how public policies, private certification schemes, and other strategies are contributing to the reduction of the dependency on pesticide use

3.3.1 Factors affecting the different implementation of IPM across Member States by cropping system

Research for the Pilot Project and the analyses in previous sections suggest that the implementation of IPM varies across Member States. Arguably, there are two dimensions of implementation, for which there are differences between the EU Member States:

1) The mode or approach selected by Member States how certain elements of IPM are implemented; and
2) The degree to which certain elements of IPM are implemented at Member State level and to what extent there is an uptake of these IPM elements.

The Overview Report on the Sustainable Use of Pesticides from DG SANTE[160] and the related country audit reports highlight several differences in the implementation of IPM across Member States. For example, they showcase that while all Member States have developed crop- or sector-specific guidelines by now, there are differences in who develops these (see also Table 25 above), and the degree to which they cover the crops grown in each country. As the country specific audit reports suggest, the coverage of these guidelines ranges between e.g. about 40% of UAA in Greece to almost all UAA in Austria and Poland (99%, 98% respectively). The reports also suggest that control systems vary significantly across countries.

Implementation of IPM might also differ based on the definition Member States employ to establish compliance with rules on IPM. The Overview Report suggest that the approaches of Member States differ profoundly. For example, the report concludes that in Denmark, implementation of and compliance with IPM is assumed based on the fact that the country achieved its targets on the reduction of pesticide use, while other countries perform surveys (Poland) or introduce reporting requirements for users (the Netherlands) to establish the degree to which IPM is implemented.

Differences in the mode of implementation of IPM can mostly be explained by differences in the legal and political circumstances of the EU Member States. For example, the structure of Member States (unitary vs. federal) is among factors determining the responsibilities for IPM and its implementation within the respective countries. In federal countries such as Germany and Belgium, greater responsibilities lie with their regions. Further, path-dependencies, the legal

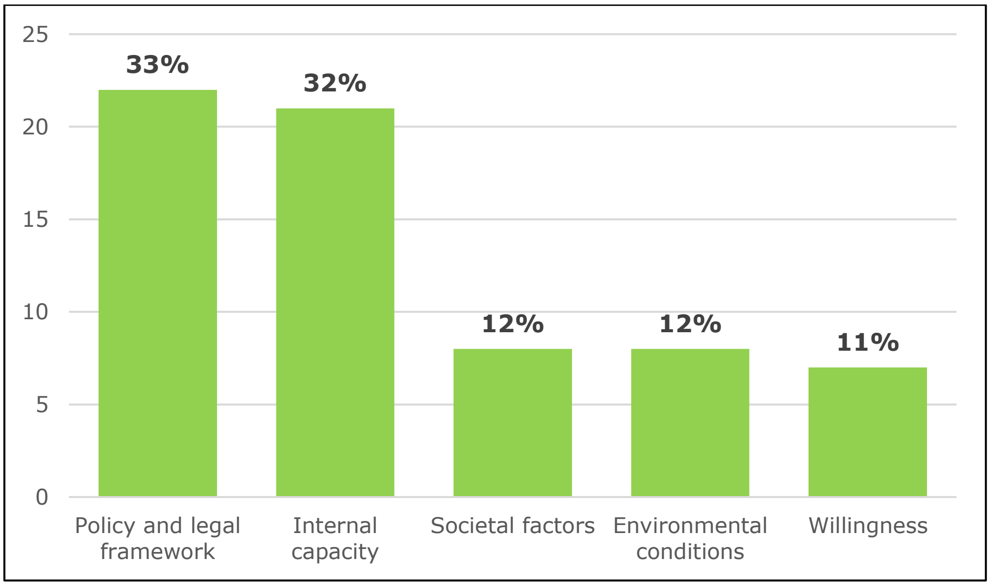
[160] https://ec.europa.eu/food/audits-analysis/overview_reports/act_getPDF.cfm?PDF_ID=1070.

systems and the set-up of related policy fields all influence the way Member States implement IPM.

With regards to the degree to which IPM is implemented, a recent journal article explores and identifies major "roadblocks and adoption barriers".[161] Exploring factors across the globe, the authors establish six factors that affect the implementation of IPM. They raise concerns that a lack of knowledge at farmer level and their risk aversion prevents the uptake of new non-chemical approaches to crop protection. The authors further see vested interests and the lobbying by large producers of conventional crop-protection measures as another factor that influences policymaking and weakens efforts by policymakers to implement IPM further. Further, policy itself is seen as a factor that determines the degree to which IPM is implemented. For example, for the EU, the authors take the view that the operationalisation and control procedures are lacking which thus reduces the effectiveness of the mandatory measures on IPM. Finally, the article argues that research itself needs to take a more holistic approach to develop new and promising IPM measures that can be implemented.

The findings from the article echo the views and observations shared by interviewees during the country research for this project. Asked about their views if and why there are differences in the implementation of IPM across Member States, interviewees shared reasons that can be clustered in five large groups (see figure below).

Figure 15: Interviewees' views on differences in the implementation of IPM



Source: Compiled by the Consortium

[161] See Deguiene et al. (2021), Integrated pest management: good intentions, hard realities. A review, Agronomy for Sustainable Development, 41:38. Available at: https://link.springer.com/content/pdf/10.1007/s13593-021-00689-w.pdf.

Most frequently, interviewees cited factors linked to the policy and legal framework as influencers of the different implementation of IPM. In particular, they see administrative burden and legal obstacles as factors that hinder implementation and might lead to differences between countries. Also, the different availability of alternatives to chemical products and availability of support services are mentioned as factors that can explain variation. Almost as many interviewees consider that the reasons for differences in the implementation of IPM lie with farmers ('internal capacity'). They argue that many farmers lack the necessary understanding, awareness, knowledge, and/or resources to implement IPM further. Several interviewees point out that especially smaller farms struggle to implement IPM as it is costly to get familiar with the processes and farmers cautious to try new methods that might reduce their yield. Yet, there are also several interviewees that question the willingness of farmers to implement IPM and cite existing traditions as a factor that might lead to differences in the implementation across Member States.

Apart from these factors, interviewees also suggest that societal factors play a role. Awareness for environmental issues or lack therefore across Member States might determine whether farmers feel pushed to implement IPM measure more consistently, while higher demand for sustainable products in some EU Member States might create greater incentives for farmers to reduce the use of conventional pesticides. Finally, the interviewees acknowledge that independent of all these factors which can be influenced, environmental aspects also play a role in the implementation of IPM. They point towards the differences in climatic and environmental conditions within and across Member States, which lead to differences in the pests, farmers have to address and differences in the crops grown.

3.3.2 Role of authorities as regards IPM implementation or awareness

Following the implementation of the SUD, EU Member States are obliged to ensure necessary conditions for implementation of IPM by professional users, access to information and tools, as well as advisory services related to IPM. While individual farmers may be hesitant to adoption of IPM measures due to various reasons such as lack of interest and/or knowledge, technical difficulties, reluctance to changing habits, or increased risks, national-level efforts to promote the implementation of IPM are central.[162]

This chapter has the aim of discussing possible roles of the national competent authorities across the EU regarding implementation and awareness of IPM. Based on desk research and data gathered from in-depth interviews with national stakeholders and NCAs, three different aspects could be identified in

[162] Helepciuc F-E, Todor A (2021) Evaluating the effectiveness of the EU's approach to the sustainable use of pesticides. PLoS ONE 16(9): e0256719. https://doi.org/10.1371/journal. pone.0256719.

this context including information dissemination measures, financial support, and regulatory instruments/control of compliance.[163] These three aspects will be further discussed below.

The first role au authorities is related to the placing of PPPs on the market. Since the enforcement of Directive 91/414/EEC, the EU has continued to improve and review its legal framework for placing PPPs on the market. Today Regulation (EC) No 1107/2009 concerning the placing of plant protection products on the market has introduced a new legal framework in Europe for the assessment and approval of active substances and for authorisations of plant protection products containing them. Among the main provisions introduced: a full harmonisation for risk assessment, decision making, strict criteria for approval of active substances, the substitution principle to be applied to the substances identified as candidates for substitution, incentives for low risk active substances, the zonal system for the assessment and authorisations of plant protection products and the mutual recognition of such authorisations with strict deadlines. Several publications have indicated that Regulation (EC) No 1107/2009, and in particularly the authorisation process, have been instrumental is reducing risk and impacts of pesticides. This is also translated in the evolution of the HRI 1 which clearly shows a decrease of risk and impacts of pesticides.

The role of authorities to provide information, training, advice and tools was underlined by consulted stakeholders. This is **useful both to achieve a change in mentality among farmers, convincing** them about the benefits of transferring to a more sustainable agricultural system, as well as to facilitate such transfer for the farmers. It was also said that IPM as a farming system should be further discussed, rather than only specific IPM techniques and methods. Demonstration farms are valuable measures in terms of knowledge exchange between farmers, advisors, and researchers, and for the dissemination of IPM methods among farmers.[164] Also, statistics, scientific results, IPM databases for farmers, and technical advice, were put forward as useful tools to be provided by the authorities.

In this aspect, the mandatory training for professional users of pesticides, including also IPM, as per Article 5 of the SUD, can be mentioned. While this training is highly valued in the Member States, it could be further improved and developed, with a further focus on IPM, also including discussions on values and principles. In addition, the inclusion of IPM principles as a mandatory module in agricultural education, but also in universities and high schools, could lead to further knowledge about IPM. The development of such training modules or

[163] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.

[164] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.

programmes could be developed in collaboration with farmers' organisations to also include good agricultural practices.

In addition to the farmers, two other groups are important to emphasise in this context: **advisory services and the general public.** The role of advisors would benefit from being further developed. In particular, available services are not large enough in some countries. Furthermore, state-funded advisory services are needed to drive the use and development of IPM practices, independent from, and complementary to advisory services selling pesticides.[165] Advisors depending on sales of pesticides might not provide advice targeting IPM practices as this would reduce their sales. The general public on the other hand needs to be informed through awareness raising activities both online (internet campaigns, social media), as well as offline (e.g. field demos, press, advertisement). A general strengthening of cooperation and coordination of dialogue between farmers, public, advisory, and science would only be beneficial.

Another key aspect of the authorities' role regarding IPM implementation are incentive-based instruments such as taxes or subsidies. Indeed, the transfer towards a farming system based on IPM may imply certain risks of e.g. reduced yields and quality, as well as additional costs. To encourage farmers efforts to make this transfer and to ensure a more secure economy, it is important to provide them with financial support. As IPM implementation is a slow process, it is important that authorities provide long-term support to ensure progress and direction. Research has indicated that incentive-based measures should be designed so as to encourage the adoption of IPM as a system, rather than providing incentives for the adoption of single or crop-specific practices.[166] Furthermore, the funding of research and support to producer organisations for resources to plan and support IPM, were also mentioned. Compensation and subsidies could be provided in the form of lower prices for biological alternatives or funds for using specific agricultural practices or alternative methods enabling the reduction of pesticides. In this context, interviewees mentioned both CAP and other EU policies, as well as national level funding.

Another point to be mentioned under this aspect is the **marketing of products from IPM cultivations**, while this has not always proven to be successful, there are some interesting initiatives in place. For example, the SQNPI (*Sistema di Qualita Nazionale Produzione Integrata*) by the Ministry of Agriculture in Italy

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[165] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.

[166] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.

and the and the HVE (*Haute Valeur Environnementale*[167]) in France. In the case of SQNPI, it gives producers access to public subsidies (through Measure 10 and 3.1 of the RDP) when showing compliance with the regional IPM guidelines developed by national and regional authorities. Indeed, similar certifications already exist in Italy at regional level (Emilia Romagna, Tuscany, Veneto), while SQNPI is a national certification scheme.[168] HVE is structured in three levels and aims to limit external inputs such as pesticides and fertilisers. The certification schemes are structured in three levels, where Level 2 implies the adoption of techniques with low environmental impact, and Level 3 ensures a low dependency on inputs and a measurement of environmental performance thresholds in regard to biodiversity. Such certification schemes may provide added value to the products sold as well as a correct application/improved implementation of IPM rules. Furthermore, producers may receive financial support for their efforts either through a price premium on the products sold, or subsidies for production costs. However, in comparison to organic products, it may be difficult for consumers to grasp what the IPM principles imply, while the set of organic rules is easier to fully understand. While research has shown that there is a willingness to pay for reduced exposure to pesticide risk in general, marketing IPM products is complicated as there is no clear commitment regarding the reduction of pesticide use, and the variety of principles covered by the term IPM may be confusing.[169]

The role of authorities to enforce legislation and check compliance is of obvious importance, even though this should come together and be combined with other aspects encouraging IPM implementation. In terms of actual audits at farm level, this is being done in different ways across the Member States, from self-assessment to actual controls carried out by inspectors, or a combination. Moreover, interviewees highlighted the importance of establishing proper targets related to IPM through the NAPs as well as ensuring that the implementation of such targets is monitored. Indeed, a special report by the European Court of Auditors published in 2020, provided recommendations to enable IPM enforcement, including i.a. to ensure that Member States convert the IPM principles into practical and measurable criteria, and that these criteria are verified at farm level.[170] The Commission replied: "*As of 01 January 2014, professional users of pesticides shall apply IPM general principles, listed in Annex III of the SUD. Criteria for assessment of IPM implementation are of importance for the authorities to apply during inspections at farm level to*

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[167] Haute Valeur Environnementale, https://hve-asso.com/.
[168] SQNPI, https://www.ccpb.it/en/blog/certificazione/integrated-crop-management-national-quality-system-sqnpi/.
[169] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.
[170] Sustainable use of plant protection products: limited progress in measuring and reducing risks (2020), Special Report, European Court of Auditors.

conclude on compliance or non-compliance. In its 2017 report to the EP and the Council, the Commission pointed out that enforcement of IPM in the Member States still needs to be improved. Implementation and enforcement of IPM is an aspect systematically covered during audits to Member States. Any weaknesses identified result in issuing recommendations to Member State authorities, and these are systematically followed-up to ensure that adequate corrective actions are taken by the authorities." Finally, regulation on chemical pesticide use was also put forward, and it was said that in some cases products should be available under certain conditions only, rather than banned completely.

To conclude it should be noted that the three categories of policy instruments that have been discussed should work together in order to ensure efficiency as regards IPM implementation and awareness.

3.3.3 Extent to which market preferences or public opinion influence the reduction of dependency on pesticide use

Consumer concerns related to pesticides have appeared as a major issue in recent decades. This regards both the perceived risks to human health through pesticide residues in food, as well as negative impacts on the environment. An EFSA-initiated Eurobarometer study focusing on food safety perceptions in 2019, showed that 39% of respondents were concerned about pesticide residues in food.[171] Growing awareness among the general public and consumers is an important development needed to achieve IPM implementation across the EU even if MRL annual monitoring performed at national and European levels shows a high level of compliance (>95% of samples respect the MRL).

This chapter aims to understand whether the public opinion may have an impact on the IPM measures implemented by farmers, and thus on the reduction of dependency on pesticide use, and if so, to what extent and through what actions. Secondly, consumers' potential to influence agricultural practices through their purchasing decisions is discussed. Finally, consumers' willingness to pay for products coming from a system using less pesticides, will be analysed, as well as whether the price premium connected to such products reach the producer.

3.3.3.1 Impact of public opinion on IPM measures

According to several stakeholders interviewed, public opinion may have an impact on the agricultural measures applied by farmers, including IPM measures, however, only to a limited extent. One obstacle identified in this regard was the public's limited awareness and sensitivity to the concept of IPM (compared to organic farming). Through the analysis of interview data, two

[171] European Parliamentary Research Service (2021), The future of crop protection in Europe, accessible at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656330/EPRS_STU(2021)656330(ANN2)_EN.pdf.

ways for the public opinion to influence agricultural measures implemented at farm level, were identified: influence through impact on the political debate and agenda; and influence through consumer behaviour.

In the case of public opinion influencing the political debate, decision-making and national policies, this has shown to have an impact, e.g. in the case of glyphosate. Public opinion may influence through media (articles, blogs, social media) as well as through the representation by NGOs that are involved in the relevant field. NGOs with an interest in crop protection are in most cases environmentalists (e.g. Pesticides Action Network PAN, Greenpeace) and often support more stringent regulations.[172] Such NGOs sometimes intervene in the political debate and also in the formation of the public opinion. Furthermore, other important stakeholders in the supply chain, such as retailers, are important. Any negative news related to the use of pesticides may have an important impact on farmers.

Influence through consumer behaviour will be further discussed below, however, consumers' demand for sustainable and environmentally sound agriculture indeed constitutes a way of influencing agricultural practices. This has been seen in the trends and demand for organic food products. Farmers have to adapt to what the consumers want, and their behaviour can therefore play a decisive role. However, while consumers often are in favour of a limited use of pesticides, they also want a good price and high-quality products. Currently, not all consumers are willing/able to pay a price premium for IPM products.

3.3.3.2 Influence of consumers' purchasing decisions on agricultural practices

As mentioned above, consumers may impact agricultural practices at farm level as farmers need to adapt to consumers' requests and behaviour. There is generally a growing interest for organic and sustainable products, healthy foods, as well as short supply chains. When reflecting upon whether purchasing decision may impact agricultural practices in general, the growing interest for organic products and the increasing organic production show that this is indeed possible.

However, in many cases the impact that consumers' purchasing decisions may have, is limited as price remains a decisive factor for most consumers. In several countries, only a minority, or part of the population will pay a premium price for e.g. organic products. As regards IPM, influence might be even more limited due to difficulties in marketing this kind of products. Situated in between organic

[172] European Parliamentary Research Service (2021), The future of crop protection in Europe, accessible at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656330/EPRS_STU(2021)656330(ANN2)_EN.pdf.

and conventional, the consumer's understanding of IPM might be limited. Especially when seen among the various labels available on the market. Also, being based on various principles, it is not clear for the consumer what an IPM label covers.[173] In addition to this, the verification of IPM is also more complex. However, there are certification schemes in place such as SQNPI in Italy, IP-SUISSE in Switzerland, and the international scheme Global GAP which also covers IPM.

Another aspect is that the consumers generally care for the cosmetic appearance of products, in addition to taste and price.[174] However, a change of attitude towards buying secondary food products was reported by an interviewee in Sweden. While this was in the context of avoiding food waste, it is an interesting trend as it could reduce the need to use certain pesticides used for appearance and marketability.

3.3.3.3 Consumers' willingness to pay and price premiums

The focus of this section is twofold – in a first step, **consumers' willingness to pay (WTP)** for products coming from agricultural systems using less pesticides is analysed. In a second step, it will be investigated whether the **price premium for such products**, if any, goes all the way back to the production stage and reaches the producer.

Research has found that there is a WTP for reduced exposure to pesticide risk in general, and for organic products in particular. However, it remains unclear how products complying with other certifications such as IPM, are recognised and valued by consumers.[175] A study from 2012 regarding the WTP for apples (organic/IPM/regular) in four EU countries, concludes that the WTP for organic apples is highest, while the WTP for IPM apples is higher than for apples coming from a regular cultivation. However, consumers are not always ready to pay a premium for such products. Another study looking at the WTP of US consumers regarding tomatoes and apples labelled as "sustainable production", has shown that WTP may be limited because the information is vague.[176]

[173] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f.

[174] Yue, C., Alfnes, F., & Jensen, H. H. (2009). Discounting spotted apples: investigating consumers' willingness to accept cosmetic damage in an organic product. Journal of Agricultural and Applied Economics, 41, 29–46; Roosen, J., Fox, J. A., Hennessy, D. A., & Schreiber, A. (1998). Consumers' valuation of insecticide use restrictions: An application to apples. Journal of Agricultural and Resource Economics, 23(2), 367-384.

[175] Marianne Lefebvre, Stephen R. H. Langrell, Sergio Gomez-Y-Paloma. Incentives and policies for integrated pest management in Europe: a review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2015, 35 (1), pp.27-45. ff10.1007/s13593-014-0237-2ff. ffhal-01284266f; Pascale Bazoche, Frank Bunte, Pierre Combris, Eric Giraud-Heraud, Alexandra Seabra-Pinto, et al. Willingness to pay for pesticides' reduction in European union: nothing but organic? 2012. ffhal02807216.

[176] European Parliamentary Research Service (2021), The future of crop protection in Europe, accessible at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656330/EPRS_STU(2021)656330(ANN2)_EN.pdf; Tonsor, G. T., & Shupp, R. (2009). Valuations of 'sustainably produced' labels on beef, tomato, and apple products. Agricultural and Resource Economics Review, 38, 371–383.

According to several interviewees, there is a limited segment of consumers that is willing, and have the possibility, to pay a higher price for these products. This segment is confined to consumers with a higher income and awareness/knowledge about these issues. When looking at WTP, it is important that the consumer is aware of what the labels imply and what costs the production requirements for such labels cost the producer. As mentioned above, this is a difficulty for IPM labelled products or products coming from agricultural systems using less pesticides. There is a lack of concrete targets and indicators that can be marketed to the consumer, and the fact that there is a variety of principles may lead to confusion as well as to different "IPM" labels representing different approaches.

The WTP also varies from one EU Member State to another. In the example of Sweden, the area for organic cultivation is no longer increasing, while an important share of the cultivated land is organic – in comparison to the average in other EU MS. This implies indeed that there is a willingness to pay for more sustainable products. However, trends change and currently the demand for locally produced/made in Sweden is more important than organic. Overall, the WTP will also depend on the purchasing power in each of the EU Member States and also varies across different demographic segments and with time.[177] Furthermore, it can be noted that there is a difference between WTP and actual purchasing behaviour: consumers may be favourable to buying e.g. organic products, but as regards the eventual purchase, price remains the deciding factor. Finally, other factors will also affect the consumer behaviour, such as the reputation of the related product brand. Also, the willingness to pay may differ from one product to another.

In the context of the stakeholder interviews, data was collected on the **price premium** for these products, to understand whether this premium actually reaches the producer. It was said that in many cases, the producers are not sufficiently rewarded for their efforts and profitability is low due to the higher production costs. Some of the consulted stakeholders believed that the price premium rather goes to the retailers. In this context, it should also be considered that the structure of the markets is not the same in all EU Member States. For example, in Slovenia, primary produce is mostly sold through markets rather than through retail, and in Lithuania there is a preference for short supply chains (markets and farms), which ensure the price premium reaches the producer. A European Commission study on organic supply chains from 2016, concludes that the distribution of added value differs greatly within and between supply chains, as well as across countries. Distribution of added

[177] European Parliamentary Research Service (2021), The future of crop protection in Europe, accessible at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656330/EPRS_STU(2021)656330(ANN2)_EN.pdf.

value seemingly depends on the structure and characteristics of the specific supply chains (e.g. level of integration, product innovation), as well as on power relations between the supply chain actors.[178]

3.3.4 Contribution of the EU policies and CAP to reducing the dependency on pesticide use

This chapter provides an overview of policy measures aiming to reduce the dependency on pesticide use. Firstly, the so-called EU pesticides package is presented. This is followed by a section focused on the CAP and its impacts on the reduction of dependency on pesticides use, including IPM uptake. Finally, other relevant policies that contribute to reducing the dependency on pesticide use are presented as well as a number of suggestions for future policies identified through the stakeholder interviews.

3.3.4.1 EU Pesticides package

The term "reducing dependency of pesticide use" is not defined in the EU legislation. However, it is understood that, by implementing IPM in all farms, the volume of chemical pesticides being used will decrease, even if chemical pesticides are not excluded from IPM. Therefore, the term can be simplified by "reducing synthetic or chemical pesticide use".

The new political targets set by the European Commission through the Green Deal (see Section 3.3.4.3 below) are the continuation of a growing corpus of European legislation (the "pesticides package") that has tried to address the issues linked to the harmful impacts of plant protection products application since many years. The pesticides package includes two main legal framework which are both aiming to reduce dependency of pesticide use:

The main contributor to a reduction of dependency on pesticide use is the overarching **Directive 2009/128/EC on sustainable use of pesticides** (the SUD). Article 1 of the SUD clarifies the two objectives of the SUD, namely to (1) reduce the risk and impacts of pesticides, and (2) implement IPM in order to reduce the dependency of pesticide use. Therefore, the reduction of the dependency is not a direct but an indirect objective of the SUD. It is by promoting the implementation of IPM and the use of alternatives to chemical pesticides, that reduction of dependency will/may be observed. Article 14(4) indicates that as of January 2014, IPM shall be implemented by all professional users, of which the farmers. Six years after the requirement for farmers to implement IPM, it is difficult to assess that a reduction of dependency of pesticides has been achieved. Member States' efforts to implement IPM are largely unknown as IPM implementation is not controlled in a large majority of Member States, partly due to the lack of robust control mechanisms. In June

[178] European Commission (2016), Distribution of the added value of the organic food chain, accessible at: https://orgprints.org/id/eprint/31990/3/sanders-etal-2016-Distribution-of-the-added-value-EUCommission-FinalReport.pdf.

2022, the European Commission adopted its proposal for a new Regulation on the sustainable use of Plant Protection Products (SUR), including i.a., rules that ban pesticides is natural areas, encourage the reduction of pesticides through the use of IPM and alternatives to chemical pesticides.

Another key contributor to the objective of reducing pesticide use is **Regulation (EC) No 1107/2009 on the placing of plant protection products on the market**. As for the SUD, this regulation has not any direct objective in relation to the reduction of pesticide use; but it largely contributes to achieving the Farm-to-Fork target objectives namely the reduction in the use and risks of chemical pesticides (see Section 3.3.4.3 below). The renewed program of approval of active substances which is in place since the entry into force of the Directive 91/414/EEC[179] has led to the withdrawal of more than 600 actives substances, the most hazardous one, out of a total of 1,100 in a 20-year period. All in all, volumes of pesticide use have not decreased over the last decade but the hazardous profiles of products being used have evolved as chemical/synthetised pesticides with high hazardous properties have been replaced by less-hazardous substances and products.

A third main potential contributor to a reduction of pesticide use is **the EU organic farming** policy. Under the Green Deal's Farm-to-Fork Strategy, the European Commission has set a target of "at least 25% of the EU's agricultural land under organic farming and a significant increase in organic aquaculture by 2030". To achieve this target, the Commission has developed an action plan for organic production in the EU. Under Axis 3 of the plan (organics leading by example: improving the contribution of organic farming to sustainability), actions aiming at "developing alternatives to contentious inputs and other plant protection products" are foreseen. Synthetised pesticides are not allowed for use in organic production but non-synthetised ones, such as copper sulphate, are allowed. This leads to situation where the TFI is higher in organic production fields than in conventional fields mainly due to the fact that alternatives to synthetised pesticides, when available, are used at higher dosage.

The last main legislation that could lower the volumes of pesticides being used is **Directive 2009/127/EC with regard to machinery for pesticide application.** Recital 2 highlights that "the design, construction and maintenance of machinery for pesticide application play a significant role in reducing the adverse effects of pesticides on human health and the environment". The Directive thus contributes to the objective of reducing the dependency of pesticides use. In addition, the correct use of well-calibrated sprayers and compulsory inspection of sprayers currently in use can be a useful measure in order to achieve better control of PPPs. Results from EU members with extensive experience on this subject, new proposals from EU members

[179] The predecessor of Regulation (EC) No 1107/2009.

without it, and results from a wide survey conducted across the EU, show this initiative as one of the most reasonable and profitable in the whole pesticide application process. The average pesticide use-reduction potential resulting from regular control is estimated to range from 5 to 10%. Usually, the monetary savings corresponding to such reductions exceed inspection and repair costs to the user.[180]

These four legislations presented above clearly show that each of them has an impact in reducing risk and/or use of chemical pesticides as demonstrated by the evolution of the HRI1 over the last decade; and therefore, also contributing to the reduction of risk on chemical/synthetised pesticide use.

3.3.4.2 Impacts of the past and current CAP on the reduction of dependency of pesticide use and IPM uptake by farmers.

The CAP is under a transition period as a political agreement has been reached on 25 June 2021 by the European Parliament and Council on the new CAP Post-2020, and since endorsed by EU Agriculture Ministers at their meeting on 28 June 2021. The new regulations have been published in December 2021 (the main texts being regulations 2021/2115, 2116 and 2117) and will apply as of January 2023.

Therefore, this section will first discuss the contribution of the past and current CAP to reducing the dependency on pesticide use before presenting in detail the IPM toolbox which has been designed and proposed for the 2023-2027 period in the PAC Post-2020.

Several research papers addressing this question have been analysed in a meta-analysis by the European Court of Auditors. In its 2020 report,[181] the ECA concludes that "The common agricultural policy does little to help enforce IPM". While recognising that the current CAP includes instruments that can support farmers' sustainable use of PPPs, ECA also acknowledged that the CAP toolbox seems not to be complete enough to support IPM uptake by farmers then leading to the reduction of dependency of pesticide use. The back-to-back evaluation and impact assessment study on the SUD, that will be published in spring 2022, also make the same conclusions.

The Commission replied: "The Commission considers that the current CAP does not do little but on the contrary, helps enforce IPM at farm level. The instruments quoted by the ECA and a number of other instruments available to Member States are and will be in the future relevant and effective for the sustainable use of pesticides and IPM. Under the direct payments, the CAP "greening" scheme includes a minimum share of biodiversity area but also crop

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[180] Gil E. 2006. Paper presented during the 2006 ASAE Annual meeting. Available at https://elibrary.asabe.org/abstract.asp?aid=20632.
[181] Available at https://www.eca.europa.eu/Lists/ECADocuments/SR20_05/SR_Pesticides_EN.pdf.

diversification, which are both relevant for the IPM. Rural development policy also supports restrictions of pesticides due to the implementation of the Water Framework Directive. In addition to investments in respective equipment, the CAP also supports knowledge transfer and information actions as well as advisory services for farmers, including the promotion of IPM. The cooperation between farmers, researchers and advisory services, promoted through the European Innovation Partnership (EIP AGRI), is also important and may cover innovative ways to reduce the use of PPPs and implement IPM. The CAP also includes the regulatory framework for organic farming (12.6 mio ha in 2017), with possible financial support under rural development. Organic production applies specific principles and sets requirements going beyond the principles of IPM, which among others requires crop rotation and severe restriction on which PPPs maybe used. Farm advisory services may also offer advice on organic farming. The proposal for a future CAP consolidates these contributions on the sustainable use of PPPs and IPM. It furthermore proposes to include in the future conditionality the most relevant parts of the IPM principles, in particular crop rotation and requirements for biodiversity areas, as well as the other relevant provisions of the SUD. Importantly, the Commission proposes better integration of the system for advising farmers and better integration with research and knowledge transfer from the CAP networks. With Pillar I eco-schemes and Pillar II management commitments, Member States will also have much more flexibility than in the current period 2014-2020 to better tailor the support of practices of sustainable use of pesticides and IPM taking account of their own particular needs assessments."

Eventually, the analysis of the current tool developed by the Commission shows that the various tools aiming at promoting IPM uptake are measures that could affect the reduction on dependency of pesticide use. GAEC 8 on crop rotation is an example of such indirect measure and the decision on the implementation of crop rotation adapted to the local conditions is let to the Member States.

The Post-2020 CAP measures, which will be implemented as of 1 January 2023, constitute a new step forward aiming at supporting IPM uptake. The new CAP will benefit from a new architecture, shortly presented below. The new CAP has more instruments relevant for pesticides use than only conditionality, eco schemes, AECM (now called "Management commitments") and market measures. Tools such as Farm Advisory Services, RD support for investments, cooperation and EIP, advice and training, mutual funds and LEADER can also be used to support IPM uptake at farm level. Also the research Horizon 2020 and Horizon Europe programs have devoted significant resources on IPM. Finally the organic legislation, while not part of the CAP Plans *stricto sensu*, is quite relevant and a branch of the CAP.

As regards pesticides, Pilar I of the future CAP (annual management, EAGF), direct payments and market interventions, is based on two main instruments.

First, the **enhanced conditionality** contributes to establishing the foundation of the CAP's "green architecture" with links between payments made to farmers and EU and national legislation and area management with respect to climate, water, soil, biodiversity, and health. The new enhanced conditionality goes beyond the current level of cross-compliance (see below) and applies to all holdings receiving direct payments and area or animal -based rural-development payments. The scope of conditionality is based on both Statutory Management Requirements (SMRs) and Standards for Good Agricultural and Environmental Conditions (GAECs) all requirements mandatory for farmers.

Conditionality is a sanctioning tool. In case of non-respect of the SMR and GAEC obligations, reduction of the CAP payments can be applied.

The main changes are as follows:

The SUD is a new SMR (coded SMR 13) and four obligations are concerned:

- Article 5(2) on training and certification of professional users;
- Article 8(1) to (5) on inspection of equipment in use;
- Article 12 with regard to restrictions on the use of pesticides in protected areas defined on the basis of the Water Framework Directive and Natura 2000 legislation; and
- Article 13(1) and (3) on handling and storage of pesticides and disposal of remnants.

Article 14 on IPM obligations was not formally included in the scope new conditionality because it concerns general principles, while conditionality is about concrete and precise farming practices. Moreover the relevant elements of the IPM principles are already translated into farming practices through the GAEC and SMR framework (e.g. crop rotation is a GAEC standard) and Member States must consider their implementation of the SUD when defining their GAEC standards. The concrete farming practices eventually developed by Member States for IPM are therefore in practice under the scope of conditionality.

Most of them may have an indirect impact on IPM uptake and the reductions of risk and use of pesticides such as:

- GAEC 1: Maintenance of permanent grassland based on a ratio of permanent grassland in relation to agricultural area;
- GAEC 2: Appropriate protection of wetland and peatland;
- GAEC 3: Ban on burning arable stubble, except for plant health reasons;
- GAEC 6: Tillage management reducing the risk of soil degradation, including slope consideration;
- GAEC 7: No bare soil in most sensitive period(s);

- GAEC 9: Minimum share of agricultural area devoted to non-productive features or areas, retention of landscape features, ban on cutting hedges and trees during the bird breeding and rearing season, and as an option, measures for avoiding invasive plant species; and
- GAEC 10: Ban on converting or ploughing permanent grassland in Natura 2000 sites.

All these measures have the potential to impact agronomic practices and therefore can be considered as IPM measures.

Two GAECs are more directly related to IPM uptake:

- GAEC 4: Establishment of buffer strips along water courses has the main objective to protect river courses against pollution and run-off where it is forbidden to use pesticides and fertilisers; and
- GAEC 8: Crop rotation at farm level. Details of the GAEC on which crop rotation to respect have to be decided at Member State level. Member States have also the possibility to adapt this GAEC to insert diversification measures under conditionality.

Secondly, **eco-schemes** that are obligatory for Member States and voluntary for farmers create possibilities to reward farmers for actions improving climate and the environment, which go beyond the baseline as established by the enhanced conditionality. Arguments are provided to further enlarge their potential and coverage.

Pillar I also includes other funding mechanisms that could be interesting for IPM uptake and in particular the **sectorial interventions and the operational programme (OP) funding**. To date, such intervention was limited to a few CMO sectors (only F&V). The new CAP offers Member State the possibility to fund in environmental measures to all CMO sectors. In their national strategic plans, Member States have to decide which CMO sectors will be subject to co-funding under POs. In the new CAP, at least 15% of funding for operational programmes in the F&V sector must be spent on actions for environment and climate compared to 10% in the 2013-2020 CAP.

Under **Pillar II** (multiannual management, EAFRD, rural development interventions and national co-financing), the main change in the Rural Development policy is to be dealt, as for Pillar I, with the new delivery model (from compliance to performance). With respect to its core principles and its coverage, there are only limited changes. The agri-environment, climate and other management commitments have a special focus on environment and climate.

The main characteristics of and differences between Pillar I eco-schemes and Pillar II payments for environment, climate and other management commitments are presented in the table below.

Table 20: Characteristics and comparison of Pillar I eco-schemes and Pillar II payments for environment, climate and other management commitments

Schemes for the climate and environment – Eco-schemes (Pillar I)	Environment, climate and other management commitments (Pillar II)
Mandatory for MS, voluntary for farmers	Mandatory for MSs. Voluntary for farmers
Yearly, not co-funded	Multi-year (5-7 years for management commitments), co-funded
>=25% of direct payments budget	>=35% of the EAFRD budget for environment and climate measures
Payments to genuine farmers	Payments to farmers and other beneficiaries
Payments per ha eligible to direct payments	Payment per ha (not necessarily eligible to direct payments)/animal
Annual (or possibly multiannual)	Multiannual (5 to 7 years or more) under contractual commitments
Calculation of the premia; Compensation for cost incurred/income foregone, or incentive payment: top-up or basic income support (amount to be fixed and justified by MS)	Calculation of the premia: Compensation for cost incurred/income foregone
Examples of measures supporting IPM uptake that could be funded under eco-schemes: - Rotation or Diversification - Support to conservation agriculture without pesticides: rotation, no ploughing, soil cover, cultivation techniques, etc - Maintenance of organic farming - Establishment of non-productive areas on agricultural land	Examples of measures supporting IPM uptake that could be funded under Pillar II: - Reduced or ban of use of pesticides - Use of Integrated Pest Management beyond the obligations under the SUD - Longer multiannual rotation and diversified crops - Payments for investments for pesticides management and localised spraying - Payments for training and advice - Conversion to organic farming, etc… - Investments for precision spraying equipment - Contributing to advice, cooperation and monitoring systems - Harvest assurance

Source: Completed by the Consortium based on European Commission documents

The two schemes can be combined together.

During the negotiations of the Post-2020 CAP, stakeholders have been invited to comment on the Commission proposal. While acknowledging that DG AGRI considers that the toolbox addresses correctly IPM uptake; it is now up to Member States to include such measures in their NSP. Stakeholders also recognise the progress made in terms of available measures aiming at reducing use and risk of pesticides but several of them have indicated that very little progress seems to have been done. The remarks and critics made during the interviews read as follows:

- Not targeting enough reduction of pesticide use. As in the current CAP, the Post-2020 CAP includes provisions that are too general and specific enough to IPM uptake;
- No measures promoting seed treatment;
- Farmers can be encouraged to use more sustainable and innovative technologies, and follow IPM as much as possible, but the economic cost is important for farmers to survive and be able to keep producing without having to close down the farm;
- EIP-AGRI which can also play an important role under Pillar 2 is not used enough;
- The optimal strategy would be to support farms with tools (knowledge and financial) that they can adapt to their specific circumstances. The CAP partly fails to support such local conditions;
- The CAP may fund tools that have proven to be efficient such as e.g. resistant varieties and biocontrol products; and
- Any change in the business costs money and implies a risk, so it needs to be compensated and this is also not considered enough by Member States.

An additional issue is of legal nature. As Article 14 of the SUD makes that some IPM practices are mandatory for farmers as of January 2014. CAP subsidies may be granted for measures beyond the obligations.

Most, if not all, of the remarks that have been collected through interviews were commenting the new financing schemes and were not addressing the complementary tools supporting research, knowledge transfer and uptake of IPM by farmers and advisory/extension services. Member States have the obligation to provide advisory services to farmers and fund advisory services through the Farm Advisory Services (FAS). Such tool should have the objective to be of great support to train farmers on IPM principles. All IPM measures that will be funded as part of the CSP shall be supported through FAS activities.

3.3.4.3 Extent to which the F2F reduction targets are integrated into the proposed CAP reform

This section first presents the objectives of the European Green Deal and its strategies, of which the Farm to Fork Strategy before discussing the extent to which the F2F reduction targets are integrated into the CAP reform.

Following the presentation of the European Green Deal[182] as its central vision for a sustainable EU economy, the European Commission has adopted several strategies for which pesticide use is relevant. These set the scene for the future of the food system, protection of biodiversity, organic production and pollution in general. In more detail, the following strategies shape the policy context:

The Farm to Fork Strategy[183] presents a framework for a sustainable food system in Europe ranging from food production to consumption and waste prevention together with a roadmap of key regulatory and non-regulatory initiatives. Crucially, it sets two reduction targets for the use and risk of chemical pesticides for 2030. The first is an overall target of 50% reduction in the use and risk of chemical pesticides,[184] while the second one aims at halving the use of more hazardous pesticides.[185] Both these targets are measured against a baseline of the average of the years 2015-2017. The strategy also sets targets for organic farming on 25% of the agricultural area in 2030. The reduction targets of the Farm to Fork Strategy are further mentioned and detailed in the action plans on Organic Production[186] and Towards Zero Pollution.[187]

The Biodiversity Strategy[188] specifies the EU Green Deal in the area of conservation and restoration of healthy and resilient ecosystems, habitats and species. Key considerations are the greening of urban and peri-urban areas and reducing pollution of environmental compartments. In addition to the targets from the Farm to Fork Strategy and with an objective to reverse the declining trend in pollinators, the Biodiversity Strategy aims to reach 10% of agricultural areas in high-diversity landscape features,[189] and to eliminate the use of pesticides in sensitive areas such as urban green areas.

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[182] European Commission, "The European Green Deal," *European Commission*, vol. COM(2019), 2019, https://doi.org/10.1017/CBO9781107415324.004.
[183] European Commission, "A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System," 2020.
[184] All pesticides falling under Regulation (EC) 1107/2009, except microorganism.
[185] Defined in footnote 13 of the Farm to Fork Strategy as active substances classified as candidates of substitution or subject to cut-off criteria.
[186] European Commission, "Action Plan for the Development of Organic Production" (European Commission, 2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022R0720.
[187] European Commission, "Pathway to a Healthy Planet for All. EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'" (European Commission, 2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827.
[188] European Commission, "EU Biodiversity Strategy for 2030.," vol. COM(2020), 2020. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827.
[189] For example ponds, hedge rows, buffer strips or fallow land.

The Farm-to-Fork and Biodiversity strategies targets for pesticide reduction certainly constitute a main driver for a reduction of pesticide use, reflecting a desire in Europe to reduce the impact of excess inputs into agricultural systems, and thus minimise the negative impacts on the environment and human health. IPM is designated in the Farm-to-Fork strategy as "one of the main tools in reducing the use of, and dependency on, chemical pesticides in general, and the use of more hazardous pesticides in particular".

The objective of reducing the risk and use of pesticide use by 50% has to be considered as a combined objective, meaning that the objective is not to reduce use by 50% and risk by an equal 50% but rather to combine risk and use in a single objective and then a single indicator. Several stakeholders have indicated that reducing the risk can oppose to reducing the use as the risks can be decreased by substituting hazardous substances with low-risk or less hazardous substances and then volumes of sue will not be reduced; the other way around, volume of use can decrease but not the risk based when using more hazardous substances.

Therefore, achieving the two pesticide use targets of the F2F will be measured based on two indicators. The first indicator (F2F1) of 50% use and risk reduction of chemical pesticides will be measured using the Harmonised Risk Indicator 1 (HRI1) methodology, but excluding micro-organisms (viruses, bacteria, etc) and using a different baseline. As with HRI 1 the indicator is an index, with a baseline set as average sales 2015-2017. Hence, it is not built on absolute values or kg of sales, rather the change observed in each Member State, with weightings applied to the different groups of active substances.

The second F2F target introduces a use reduction target of 50% for the more hazardous pesticides.[190] The indicator to measure progress will be based on the sales of active substances that belong to Group 3 (candidates for substitution), with average sales in 2015-2017 as the baseline value. As for HRI1 and F2F1, the indicator is an index and only reflects change in Member States, not actual volumes of sales.

The European Farm-to-Fork and Biodiversity strategies follow from the EU Green Deal and include the European Commission's approaches to environmental issues. They should guide the orientation of several related policies. However, these strategies are not legislation and thus not binding documents. The expectation was that CAP would significantly contribute to the targets of these strategies. However, the draft policy framework for CAP reform in 2018

[190] More hazardous pesticides are plant protection products containing active substances that meet the cut-off criteria as set out in points 3.6.2. to 3.6.5 and 3.8.2 of Annex II to Regulation (EC) No 1107/2009 or are identified as candidates for substitution in accordance with the criteria in point 4 of that Annex.

preceded these strategies and, as such, do not explicitly take into account of the Green Deal objectives and targets.[191] However, the Commission considered that it is needed to adapt the proposed CAP framework to the Farm to Fork objectives was minimal and that no major changes were deemed necessary in the EU legislation. On the other hand, both the European Parliament and the Council of the EU voted, in October 2020, against the explicit inclusion of the strategies' targets in the Post-2020 CAP period (2023-2027). While the Post-2020 CAP does not explicitly integrate these objectives in the text, the reform is compatible with the Green Deal, as explained in the Staff Working Document 93 Final of 2020, "Analysis of the links between CAP reform and Green Deal".[192] It thus has the potential to accommodate the European Green Deal's ambitions.

3.3.4.4 Other policies that contribute to the reduction of dependency of pesticide use

This section first provides an overview of policy measures – other than the CAP – that contribute to reducing the dependency on pesticide use. Secondly, a number of suggestions for future policies identified through the stakeholder interviews are presented.

In addition to specific legislations that have been presented in the above sections, several environmental EU legislations have an indirect impact on the reduction of dependency on pesticide use. Directives on environmental protection (on water: Directive 2000/60/EC, Directive 1008/105/EC, 2006/118/EC, Directive 98/83/EC, Directive 91/271/EEC, on wild birds: Directive 79/409/EEC, on natural habitats: Directive 92/43/EEC). When assessing each of these directives on environmental protection, the Water Framework Directive (Directive 2000/60/EC, short: WFD) is the most relevant policy piece. It is most frequently referenced and all stakeholders that responded on a relevant relationship between the WFD and the objective of reducing pesticide use considered this the most important directive in the area of environmental protection, as it aims to reduce pesticide concentration in water bodies and groundwater.

In addition, the Natura 2000 – the network of protected areas stretching across the EU to ensure long-term survival of valuable and threatened species and habitats under the EU Birds Directive and the EU Habitats Directive may contribute to reducing the use of pesticides when banning the use of pesticides from vulnerable areas.

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[191] Guyomard H, Bureau JC, Chatellier V, Détang-Dessendre C, Dupraz P, Jacquet F, Reboud X, Réquillart V, Soler LG, Tysebaert M. 2021. European Parliament - The Green Deal and the CAP: policy implications to adapt farming practices and to preserve the EU's natural resources.
[192] https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2020)93&lang=en.

However, the relationship between these legal frameworks and strategies; and their contribution to a possible reduction of dependency on pesticide use is not clear. Only indirect effects may be identified.

Some Member States have also developed national strategies and policies aiming at reducing the use of pesticides. The table below presents the national level policy measures that were put forward, as well as some additional tools and strategies.

Table 21: Overview of national policy measures collected during the interviews

- BE - Flemish Protein Strategy promoting durable animal and plant protection as well as (new) protein sources, and the Flemish Green Deal stimulating production of sustainable food.
- IT - Decrees at regional level (by regional governments) in Italy, e.g. authorisation to use glyphosate as herbicide has been withdrawn through these decrees in some Italian regions.
- NL - Future vision crop protection 2030, towards resilient plants and cultivation systems, as well as its implementation programme.
- SE – national environmental objectives about inter alia increasing the organic cultivation. Clear effect of this have been seen, leading to a reduced use of pesticides.[193]
- SE, PT – certification schemes encouraging cultivations using less pesticides, or certain types of flour or crops working within an environmentally friendly concept through labels such as KRAV and Svenskt Sigill, or through specific brands such as Lantmännens vänligare vete (cultivation concept "Climate and nature" launched in 2015 with the objective of lower climate impacts and with increased consideration for the environment and nature). In Portugal, the MPB for organic products, and the PRODI for integrated production were mentioned.
- FR: national Ecophyto strategy aiming at reducing pesticide use by 50% by 2025 (and corresponding legislations).

3.3.5 Extent to which private sector schemes affect the use of pesticides. What is their extension potential?

Certification schemes impose a series of measures to be undertaken by farmers producing under such schemes or belonging to certain POs/cooperatives. These measures might include practices contributing to reducing the use of pesticides. In this case, such practices could be considered for their potential and extended over other farms, sectors and/or regions. Successful practices provided by certification schemes can be a driver towards reduced dependency on pesticide. This study question, therefore, aims at determining whether such practices are

[193] Sveriges Miljömål, https://www.sverigesmiljomal.se/environmental-objectives/.

provided by certification schemes, identifying them, defining success factors, and evaluating the extent to which they can be extended.

In order to answer this study question, it is necessary to identify and describe concrete examples of reduction of dependency on pesticides use by farmers and their organisations through private certification schemes, to assess the extent to which such good practice can be extended and identify factors of success.

Private certifications are not required to show compliance with legal requirements and, therefore, remain voluntary. Commission Communication 2010/C 341/04 distinguishes between certification schemes employing third-party attestation, and self-declaration schemes that operate on the basis of a label or logo (often registered as a trademark) without involving any certification mechanism. The latter schemes are not certified and rely on the producer's self-declaration or through selection by the scheme owner. By reverse, where legislation exists, claims must consider and be consistent with such standards refer to them (e.g. if a scheme is making organic farming claims, it must be based on Regulation (EC) No 834/2007 about organic production and labelling of organic products). Among the others, certification schemes' purpose, requirements and claims can cover environmental protection issues, which in turn can include measures for the reduction of pesticide use.

Regulation (EU) No 1308/2013 established the possibility to set up operational programmes by POs to promote farmers' cooperation towards implementation of specific interventions. Among the various interventions that might be undertaken depending on the specific case, OPs are required to implement agro-environmental actions, which can include measures to reduce pesticides' use and dependency. Likewise, OPs are often functional to set up certification and quality schemes.

Regulation (EC) No 889/2008 lays down the rules for organic schemes that are directly related to a restricted/reduced use of certain chemicals and inputs, including synthetic pesticides.

As highlighted by the interviewed stakeholders and competent authorities, there is a number of schemes linked to the reduction of pesticide use. Specifically, these schemes refer mainly to organic productions and other IPM and eco-labels. Moreover, OPs might be functional to set up quality labels other than those at the EU level to add value based on the agro-environmental interventions undertaken.

Based on their experience, stakeholders suggest some practices that can be successfully implemented under certification schemes and operational programmes (OPs) interventions, such as the implementation of decision support systems, mechanical weed control, sexual confusion of parasites and pheromones, beneficial insects, inter-row cultivation, crop rotation and precision irrigation.

Organic production and IPM schemes are specifically addressed to the implementation of agro-environmental actions, including reduction of pesticides use. Organic production rules prohibit the use of synthetic fertilisers, herbicides and pesticides by promoting alternative practices like crop rotation, non-GMO resistant varieties, and natural pest control. IPM schemes encompass the IPM principles but, in fact, are required to propose and set up additional agro-environmental targets beyond the IPM principles. However, most IPM certification schemes are private business-to-business, where adoption of IPM practices is a requirement for market access.

The number of producers adhering to certification schemes, as well as consumption of food produced under these labels, have increased over the past decades especially for organic farming, and is expected to keep growing in future. The Farm to Fork Strategy establishes aspirational targets to increase agricultural land managed as organic farming at least up to 25% by 2030. Also, a number of volunteer schemes and niche labels (e.g. mountainous farming) are emerging across the EU regions and markets. The table below some examples of IPM schemes.

Table 22: Examples of IPM certification schemes in the EU

Name	Country	Type	Description	Source
Producción Integrada	Spain	B2C	Each Spanish region has developed its own scheme for integrated production, which include the IPM principles. These schemes are covered by the "Real Decreto 1201/2002, de 20 de noviembre" and compensated as an agri-environmental measure by the Rural Development Programmes of Comunidades Autonomas of Spain (EC Reg. 1974/2006).	PURE, 2015
Certification environnementale des exploitations agricoles	France	B2C	This scheme was created in 2010 at consists of three certification levels, which partially cover the IPM principles.	PURE, 2015
Fruitnet	Belgium, Spain, New Zealand, South Africa	B2C	Private scheme based on the principles of Belgian law on integrated production in fruit production (Arrêté du Gouvernement flamand du 26 mars 2004).	PURE, 2015
IP SUISSE	Swiss	B2C	IPSuisse is a swiss certification scheme focused on Integrated Production based on three levels of	PURE, 2015

Name	Country	Type	Description	Source
			certification. In 2014, 20000 farms are certified: 15250 livestock farms, 4500 cereal producers (24000ha), 250 seed rape producers (950ha).	
GlobalGAP	EU	B2B	Private sector body that sets voluntary standards for the certification of agricultural products based on Good Agricultural Practices (GAP), which cover IPM principles.	PURE, 2015
SQNPI Sistema Qualità Nazionale di Produzione Integrata	Italy	B2C	A certification scheme that aims to enhance the agricultural vegetable productions obtained in compliance with regional regulations of integrated production. The scheme is supported for payment as an agri-environmental measure of Rural Development Programmes of the Italian Regions (EC Reg. 1974/2006).	ReteRurale[194]

Source: Compiled by the Consortium

Likewise, organic production is growing in the EU. The organic crop area has increased by 46% between 2012 and 2019, whereas the number of organic farmers has increased by 15% in the period 2013-2016. Instead, IPM certifications are still few in the EU, and most of them are private business to business given the IPM requirements in certain markets.

The organic, IPM and other volunteer ecological schemes purposively address the need for increased uptake of sustainable practices, including those related to pesticide reduction. A study carried out in 2010 identified 427 certified schemes existing, of which 56 voluntary schemes (B2B and B2C) referring to IPM principles. These have been developed by retailers and producer organisations, and regard mainly the fruits and vegetables sector.

For other peculiar schemes, such as mountainous farming, the link with reduced use of pesticides is weak, though existent (e.g., grazing livestock implies lower use of chemical fertilisers and pesticides). However, the diffusion of these schemes is limited to farms in mountainous areas that are generally less pesticide dependent. Besides, research revealed that most of the mountainous

[194] http://www.reterurale.it/produzioneintegrata.

labels' sales names and brandings belong to individual stakeholders regarded as a person or a company,[195] which further constrain the possibility to extend these certifications.

By focusing on schemes rooted into formal regulations, organic farming certainly provides a promising pathway towards a reduced dependency on pesticide use. Firstly, the number of organic producers is increasing across Europe. Second, consumption of organic food is increasing as well, and often comes with higher sale prices[196]. Third, so far organic farming is specifically supported by policy measures under CAP – Pillar 2 (Rural Development measures), whereas in some Member States organic production is functional to access to further subsidies (e.g., greening payments under CAP – Pillar 1). As described in the proposal for the new CAP post-2020, support to organic farming will continue in future and it will be funded also by the first pillar of the CAP under the eco-schemes. Fourth, the capacity of advisory services to guide farmers through organic production is increased and supported by policy measures, notably under CAP - Pillar 2 and for the future CAP also by the eco-schemes under Pillar I. Drawing upon these elements, organic farming shows good premises and represents an opportunity for expanding the producers' adherence to more sustainable production models and, in turn, decreasing the use of pesticides.

Among private certification schemes, IPM is specifically aimed at increasing the uptake of good practices by combining the higher costs of production with access to sustainability-oriented consumer segments and, eventually, higher sale prices. Under this assumption, IPM schemes might be a promising tool at national or regional level to expand the uptake of good practices. Yet, a few schemes have been set up across Europe.

So far, IPM practices have allowed producers to get into specific markets, but without a premium price.[197] Both interviewed stakeholders and the literature highlight the part taken by the consumers in driving the potential of certification schemes. While the consumers' attitude to and willingness-to-pay for organic food has been increasing until now, demand for IPM certified products appears weaker.

A reason behind the low demand of IPM might be the difficulty in communicating complex decision models, also due to the varieties of principles covered by IPM which could in turn lead to a multiplication of labels. Currently, the market appears saturated by a high number of schemes and labels raising

[195] Santini F., Guri F., Gomez y Paloma S., 2013. Labelling of agricultural and food products of mountain farming. Joint Research Centre, Report EUR 25768 EN.
[196] Janssen, M. and U. Hamm (2014) Governmental and private certification labels for organic food: Consumer attitudes and preferences in Germany. Food Policy. DOI: 10.1016/j.foodpol.2014.05.011.
[197] PURE, 2015. Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management. Deliverable 1.5 - Cost-benefit analysis of IPM solutions. https://ecophytopic.fr/sites/default/files/2020-10/D1.5_vfinal.pdf.

environmental sustainability, which is likely to contribute to increase complexity and consumer confusion and misunderstanding (Canali, 2011).

Scientific research on the issue is contentious. A strand of literature shows that IPM is perceived closer to conventional production than to organic. Accordingly, the consumer willingness-to-pay is much higher for organic products than for IPM ones.[198,199] On the other hand, other literature[200] demonstrates higher substitution between IPM and organic than with conventional, but the market share of IPM drops when the price difference between IPM and organic is reduced. Such trade-off might hinder the potential to expand good practices through IPM schemes, though this is due to the increasing market strength of organic products, which are a pathway for reducing pesticides' use as well.

Volunteer schemes, however, suffer from a regulatory constraint that impede to recognise the application of IPM under these "not official" labels, and they are required to certify farming practices that go beyond IPM, which might hinder (to some extent) the producers' adherence to such ecological schemes and, therefore, a potential increase in good practices' uptake. This aspect might assume relevance considering the growing emergence of ecological schemes in Europe and worldwide. Marketing integrated pest management products is not an easy task, in the absence of official label at the European level.[201]

Adherence and potential of certification schemes depends on the trade pattern. The market orientation determines whether a certain producer/organisation is interested in producing and marketing products under certification schemes. This is particularly evident for those sectors exporting to non-EU countries where such schemes could not be recognised, or the local market does not value these types of productions. The interviewed experts, for instance, highlight the cases of cereal and feed production in Denmark and, more generally, the case of the Netherlands that is a great exporter. This aspect could be extended to other exporting countries, such as Italy, Spain and Germany.

Most IPM certification schemes are business-to-business, where adoption of IPM practices is a requirement for market access. In Europe, end-consumers have low awareness about benefits of IPM, and hardly identify IPM products. This might (partially) explain why the retailers, that often ask producers to provide IPM-compliant products, do not create a market segment specific to IPM.

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[198] Bazoche, P., F. Bunte, et al. (2013) Willingness to pay for pesticides' reduction in EU: nothing but organic? European review of Agricultural Economics. 41(1):87-109.
[199] Marette, S., A. Messéan, et al. (2012) Consumers' willingness to pay for eco-friendly apples under different labels: Evidence from a lab experiment. Food Policy. 37:151–161.
[200] Coralie Biguzi, Emilie Ginon, Sergio Gomez-y-Paloma, Marianne Lefebvre, Stephan Marette, Guillermo Mateu, Angela Sutan, Consumers' preferences for integrated pest management: the case of tomatoes, presented in EAAE conference 26-29 August 2014, Ljubljana and submitted to Food Policy.
[201] Lefebvre M., Langrell S.R., Gomez y Paloma S., 2015. Incentives and policies for integrated pest management in Europe: a review. Agron. Sustain. Dev. (2015) 35:27–45. DOI 10.1007/s13593-014-0237-2

However, low awareness might be challenged through improved communication, above all considering that consumer choice for IPM products seems to increase when these consumers get access to information on IPM. Communication to consumers, therefore, appears to be a crucial action to be taken in order to increase the potential of IPM schemes and, in turn, extending the uptake of good practices by farmers. Retailers may play a role in communicating IPM to consumers, rather than limiting IPM as a market-access tool.[202]

Advisory services might be important in providing producers with figures to help farmers make an informed choice, including adherence to a scheme. As pointed out by interviewed stakeholders, a further element of success is the availability of knowledge and prepared advisors to support farmers and smooth the transfer of sustainable practices, including adherence to certification schemes. The education of farmers, hence, is key. Information should be easily accessible by farmers, in terms complexity and time demand for learning. This includes more research on the topic, also considering technologies and precision agriculture, and how this innovation applies to the context specificities.

3.4 Theme 4: Strategies on how to scale up good practices throughout the EU

In order to analyse this theme – *Strategies on how to scale up good practices across the EU*, data was gathered from both national stakeholders, such as advisors and researchers, as well as NCAs. This analysis was also based on literature review and a workshop that took place on the 10th of January 2022. Strategies on how to scale up good practices are explored in the below sections by looking at the presence of independent advisory services, networking opportunities and EU platforms for knowledge transfer, as well as tools that are in place with the aim of transferring knowledge. Also, the CAP instruments will be explored to see how they may contribute to scaling up good practices.

3.4.1 Presence of independent advisory services at regional level

This chapter has the purpose of investigating the presence of independent advisory services at regional level. Advisory services play a key role in the encouragement of change, and in favouring the use of new methods and technologies. To explore this topic, the presence of independent advisory services at regional level was discussed with national stakeholders and NCAs in the in-depth interviews conducted. The below sections first discuss the concept

[202] PURE, 2015. Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management. Deliverable 1.5 - Cost-benefit analysis of IPM solutions. https://ecophytopic.fr/sites/default/files/2020-10/D1.5_vfinal.pdf.

of "independent" advisory services and their importance, then the presence of such advisory services in the Member States is analysed.

First of all, it is necessary that the concept of "independent" advisory services is defined. A report[203] from the SCAR-AKIS Strategic Working group, that explored the "Future of Advisory Services" refers to the criteria for being an advisor. It states that an advisor should be impartial and not promoting specific products or technologies, as well as capable of improving the ability to change. As mentioned by many national stakeholders, advice must be impartial, trusted, simple and farm tailored. In the specific case of IPM, advisors must integrate a vast amount of specific knowledge, therefore the suitability of the advisor must be considered. The interviews reinforce the fact that farmers value advice that is reliable and based on research or something that can actually be "seen". As an example, research-based advice is considered an independent and impartial advice, on the other hand advice coming from private organisations connected with the pesticide industry, which can have a commercial interest, is seen as "non-independent". However, there are different types of advisors – non-independent and independent - with an important role on IPM adoption and they should all be considered in any analysis. The concept of non-independent and independent must also be further debated. In fact, many types of organisations play a role in the advisory services system: public or governmental, research and universities, farmer-based, non-governmental and private or commercial organisations.

During the workshop it was asked to the participants what they considered an independent advisor. The contributions focused on being independent from pesticides or plant protection products sales, as well as other market chains. It was also mentioned that an independent advisor should look after different sources of information, have technical knowledge and a close relation with the farmer, providing tailored and profitable advice.

This analysis of the independence raises the question of whether there should be an independence validation, through training and certification. An advisor's wallet, that included this validation as well as a possible rating from the farmer could be a possible strategy for what concerns this question of independence.

The answers to the in-depth interviews show that in many Member States, the presence of independent advisory services is considered to be limited. However, it is not always possible to know what the respondents intended by "independent" at the time of the answers. The fact that in some countries there are contrasting answers, shows that the question, or the concept, may have been misunderstood. Nevertheless, the analysis of the conducted interviews

[203] https://ec.europa.eu/eip/agriculture/sites/default/files/policy_brief_on_the_future_of_advisory_services_scar_akis_06102017.pdf.

shows that most of the advisory services are public, provided by governmental bodies, but research institutes and smaller private companies also play an important role.

Members States such as Greece, Romania, Hungary, Slovakia, Latvia, Malta refer that the presence of such advisory services is very limited. At the same time Belgium, France, Poland and Spain are considered to have a high extent of independent advisory services.

Belgium suggests that independent advice comes from research and practice centres, while on the other hand, the Italian advisory services coming from governmental bodies and regional structures were considered dependent.

Latvia and Czech Republic refer that lack of funding or public support is a reason for the limited extent of the presence of independent advisory services. In this way many of the existing advisors are commercially oriented.

The H2020 I2connect project has a database of advisory services that is being built and that in the future may be an important tool to evaluate the presence of independent advisory services at regional level.

3.4.2 Networking of advisory services

The below sections aim to understand the extent to which advisory services' networking is sufficiently developed to allow transfer of knowledge from advisors across MS. In this context, existing projects, collaborations and initiatives are discussed, and potential barriers are explored.

In order to foster cooperation between Member States and exchange practices and making use of the EU-wide databases, the advisory services' networking must be sufficiently developed.

There are many platforms, projects and other initiatives building and connecting the network of advisors. For example, the H2020 projects I2connect, FAIRSHARE and Agrilink, the EUFRAS association (European Forum for Agricultural and Rural Advisory Services) and the SEASN (South-eastern Europe Advisory Service Network) organisation, as well as initiatives like the SCAR (Standing Committee on Agricultural Research) committees, as well as supporting initiatives such as the strategic working groups like the SWG SCAR-AKIS.

In the interviews conducted, the national advisory services were often mentioned (Lithuania, Netherlands, Germany, Bulgaria, Latvia, and others), that sometimes work together with representatives from other countries, for example the Chamber of Agriculture of North Rhine Westphalia with representatives from the Netherlands and Germany.

EUFRAS is a European level organisation, founded in 2013, that works as a network for rural advisory services. It is designed to play an advocacy role for the members addressing particularly EU-Institutions in the field of agricultural politics and rural development. With EUFRAS, there is now a contact on a European level for questions regarding agricultural policies and rural advisory services. Members of EUFRAS include public and private advisory services as well as institutions whose work focus on supporting farming families, agricultural organisations, local groups and individuals involved in agriculture or rural development that address current and emerging problems.

The I2connect project is connecting advisors in agriculture and forestry. It aims to fuel the competencies of advisors that support and facilitate interactive innovation processes. I2connect uses existing advisor networks and experiences of success to create a broader network and momentum of change. In the I2connect website there is an inventory of advisory organisations and advisors in 30 countries, which allows users to search for advisors or organisations by name, organisation, city, country, scale of intervention and sector related field of expertise.

The AKIS (Agriculture Knowledge and Innovation Systems) is a concept that describes knowledge and innovation systems in agriculture, defining how people and organisations join to promote mutual learning and generate and share knowledge. It was created to ensure that relevant people get connected, and that knowledge is shared between everyone who uses and produces it, across the EU. The PROAKIS project described the different AKIS in different countries, and the most effective ways for creating connections and supporting knowledge flows.

In addition, the EIP-AGRI Network, together with the National Rural Networks, have an important role on building a network of advisory services.

Some barriers mentioned were that advice has to be regionally adapted, and sometimes EU level advisory services, or resources and tools created in local projects and initiatives, are limited to regions and specific countries, and therefore it is difficult that advisors use them in their specific situations. The language barrier was also mentioned again: between advisors, the language sometimes limits the knowledge transfer.

Overall, there are very few answers on the question whether there are sufficiently developed advisory services to allow knowledge transfer from advisors to advisors and between countries, reflecting the lack of the dissemination of these platforms and initiatives.

3.4.3 EU related projects aiming at knowledge transfer on IPM

This chapter looks at existing EU related projects with the aim of increasing knowledge transfer on IPM. Various projects are in place and are listed and described in the below sections. Then, added value as well as potential barriers related to such projects are discussed.

In the EIP-Agri database, many EU related projects aiming at knowledge transfer on IPM can be found. Many of these are multi-actor projects and some are thematic networks. The list that follows includes projects with different characteristics: some have a broader theme, like NEFERTITI and IPMWORKS, others more specific, for example IWMPRAISE that focuses on weed management or OPTIMA that is crop specific. Other crucial differences in these projects are the targeted audience: some focus on farmers, others are more oriented towards researchers and other stakeholders, and some have a multi-end user approach. The strategy for approaching farmers and transfer knowledge can also be different: some develop a network of demonstration farms, while others simply disseminate results through more traditional tools.

Table 23: EU related projects aiming at knowledge transfer on IPM (Source: CORDIS and EIP-Agri)

Name of the EU related project	Short Description	Year of conclusion
C - IPM	The major objective of Coordinated-IPM was to contribute to research defragmentation by coordinating national IPM research and extension efforts as well by pooling existing resources.	2016
EMPHASIS	Effective Management of Pests and Harmful Alien Species - Integrated Solutions	2019
WINETWORK	Network for the exchange and transfer of innovative knowledge between European wine-growing regions to increase the productivity and sustainability of the sector	2017
nEUROSTRESSPEP	Novel biocontrol agents for insect pests from neuroendocrinology.	2019
PonTE	Pest Organisms Threatening Europe.	2019
MyToolBox	Safe Food and Feed through an Integrated Toolbox for Mycotoxin Management.	2020
MycoKey	Integrated and innovative key actions for mycotoxin management in the food and feed chain.	2020
XF-ACTORS	Xylella Fastidiosa Active Containment Through a multidisciplinary-Oriented Research Strategy.	2020
TROPICSAFE	Insect-borne prokaryote-associated diseases in tropical and subtropical perennial crops.	2021
IWMPRAISE	Integrated Weed Management: PRActical Implementation and Solutions for Europe.	2022
MUSA	Microbial Uptakes for Sustainable management of major bananA pests and diseases.	2021
INNOSETA	Accelerating Innovative practices for Spraying Equipment, Training and Advising in European agriculture through the mobilization of Agricultural Knowledge and Innovation Systems.	2021
RUSTWATCH	A European early-warning system for wheat rust diseases.	2019
VIROPLANT	Network for the exchange and transfer of innovative knowledge between European wine-	2017

Name of the EU related project	Short Description	Year of conclusion
	growing regions to increase the productivity and sustainability of the sector.	
OPTIMA	Optimised Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables.	2021
FF-IPM	In-silico boosted, pest prevention and off-season focused IPM against new and emerging fruit flies.	2023
SuperPests	Innovative tools for rational control of the most difficult-to-manage pests (super pests) and the diseases they transmit.	2022
PRE-HLB	Preventing HLB epidemics for ensuring citrus survival in Europe.	2023
IPM Decisions	Stepping-up IPM decision support for crop protection: will create an online platform that is easy to use for the monitoring and management of pests.	2024
SMARTPROTECT	SMART agriculture for innovative vegetable crop PROTECTion: harnessing advanced methodologies and technologies.	2022
DiverIMPACTS	Diversification through Rotation, Intercropping, Multiple Cropping, Promoted with Actors and value-Chains towards Sustainability.	2022
NEFERTITI	Networking European Farms to Enhance Cross Fertilisation and Innovation Uptake through Demonstration.	2022
IPMWORKS	An EU-wide farm network demonstrating and promoting cost-effective IPM strategies.	2024

Source: Compiled by the Consortium

The H2020 EU projects like IPMWORKS, NEFERTITI and IWMPRAISE are ongoing projects that have a well-established strategy for knowledge dissemination, not only at EU level but also at national, regional and local level. As their main audience is the farmers and farm advisors, they encourage change through a vast range of communication activities such as demonstration events or field days that involve farmers and other stakeholders at local level as well as cross-visits (demonstration events focused on exchange between Member States).

Many of these projects are in close relation, cooperating and learning from each other. For example, IPMWORKS has NEFERTITI, IPM Decisions, SmartProtect and ENDURE as partner projects. IPMWORKS is also learning from the experiences of the French farm network DEPHY, a flagship action of the French "Ecophyto" plan, which aims at a reduction of 50% of the phytosanitary products use in France, by 2025.

In particular, IPMWORKS is building an EU-wide network of farmers, with hubs of pioneer farms in different regions and sectors. These hubs will progress further in the adoption of IPM, through peer-to-peer learning and joint efforts, as well as demonstrate good practices to other farmers. The project also includes the creation of a resource toolbox to provide easy access to IPM resources for both internal and external stakeholders. Throughout the project one of the work packages is responsible for designing and proposing strategies, advice and training for a long term exploitation of the Farm Demo Network, even after the project ends, for a successful adoption of IPM in the EU.

The IWMPRAISE project is also aiming at knowledge transfer, in this case related to Integrated Weed Management (IWM). The project is looking for barriers in the uptake of IWM good practices and will develop and optimise novel alternative weed control methods. For knowledge exchange and results dissemination, a toolbox of validated IWM tools will be created as well as online information, educational programmes, and other dissemination tools. Farmer field days will be held and there will be exchange with rural development operational groups dealing with IWM issues.

From the interviewed national stakeholders, part of them (approx. 40%) answer that they do not have any knowledge or cannot mention any EU related project aiming at knowledge transfer on IPM (for example in Bulgaria, Cyprus, Hungary, Slovakia, Romania and Poland). Many of these interviewees answer that if there are such projects, they are insufficient or inefficient. On the other hand, countries like Spain, Germany, Netherlands, Belgium, Estonia and Slovenia reported specific EU related projects or mentioned that these projects exist and are important for technical knowledge transfer for farmers. Some of the projects mentioned were IPMWORKS, NEFERTITI, C-IPM, IPM Bligh 2.0, ENDURE and Internet of Food and Farm.

"Interreg projects" were also mentioned several times as a way to exchange knowledge. This was mentioned by Poland, Czech Republic, Belgium and Spain. However, only two specific examples were given: in Czech Republic, an Interreg project with Austria (Interreg South Moravia) and between Spain (Northeast) and France (South).

Some interviewees refer to these EU projects as a good strategy to encourage change in practices, by favouring new methods and technologies. These projects promote the exchange of new insights between farmers and other actors, in study days or demonstration activities. In these activities farmers can actually see effects on pesticide reduction and this is far better way of transferring technical knowledge than giving them reports to read. The national stakeholders that answered that these projects are well implemented also mention that these projects promote cooperation and knowledge exchange between countries, as well as at national level.

It is also stated that even if a lot of knowledge has been developed and knowledge transfer is intense, there is a lack of comprehensive information in a single database. This can also be confirmed as there are many projects with similar themes and similar objectives that end up with their results scattered.

The lack of robust answers, i.e. with concrete examples of EU projects that the interviewees are aware of, may be caused not only by the weak dissemination and communication of these projects, but also because of the interviewees targeted. It was mentioned that in some cases, EU related projects tend to be developed repeatedly by a specific consortium that may be detached from practice.

3.4.4 MS initiatives and programmes to foster knowledge transfer across MS

This chapter explores different MS initiatives and programmes in place with the purpose of fostering knowledge transfer across the Union. First, existing initiatives and programmes are identified and explored. Then, the added value of such initiatives is discussed and the extent to which these initiatives constitute successful strategies for sharing good practices is analysed.

Out of the interviews conducted with National stakeholders, NCAs and EU level associations, only approx. 21% gave answers with examples of initiatives and programs. Many interviewees had no knowledge of initiatives or programmes and other referred that these programmes are limited and not sufficiently developed. It was also stated that, in some cases, only a small percentage of stakeholders participates in these initiatives, which are not able to reach the vast majority of farmers and other organisations.

Several H2020 projects were mentioned, such as C-IPM, OPTIMA, ENDURE, PURE, DIVERImpacts, IPM Decisions and IPMWORKS. Initiatives like Interreg projects were mentioned by Belgium, Czech Republic and Poland but there were no specific examples highlighted. Regional initiatives, such as the NORBARAG collaboration between the Nordic Baltic countries, were also mentioned.

One of the most mentioned initiatives, even if in different questions in the interviews (by Austria, Germany, Portugal, Netherlands, Croatia, Hungary, Estonia and Slovakia) is the Better Training for Safer Food (BTSF). BTSF, launched in 2005, is a European Commission training initiative to improve the knowledge and implementation of EU rules covering food and feed law, animal health and welfare, as well as rules on plant health and plant protection products. It includes training courses, training material library, published reports, calls for tender as well as contact details for BTSF National Contact Points. Stakeholders in different positions and fields participate in BTSF: Plant Protection Services, Control organisms, policymakers, NCAs and advisors.

From 2006 to 2019, BTSF had around 2050 events with more than 77 000 participants. In e-learning courses, from 2014 to 2019, there were 29 272 participants. The BTSF training includes topics like Integrated Pest Management, Plant health surveys and control over pesticide application equipment. The platform is in continuous development, introducing and improving topics over time. Some of the most recent topics are Organic farming, Official Controls Regulation and Biocidal and PPP evaluation systems. One of the limitations of the BTSF academy platform is the language barrier.

Another initiative mentioned was the ERA-NET, that works under H2020 but is a funding instrument focused on 'topping-up' funding of single joint-calls for transnational research and innovation and increasing the share of funding that Member States dedicate jointly to challenge driven research and innovation agendas. Interviewees refer to this initiative as smaller than H2020 ones, and as referred to in the projects and platforms, the platforms supporting these initiatives tend to no longer exist.

The ERIAFF network (European Regions for Innovation in Agriculture, Food and Forestry) has as main objectives the facilitation of the integration of European policies in favour of innovation in the areas of agriculture, food and forestry, the improvement of the performance of the European Innovation Partnership for Productivity and Sustainability in Agriculture, by acting as facilitators of information flows and relationships between stakeholders in their Regions and across the EU, and the development of interregional innovation projects and EIP AGRI Operational Groups. Thus, ERIAFF is promoting knowledge transfer in several ways. One specific example is the S3 platform, that assists EU countries and regions to develop, implement and review their Research and Innovation Strategies for Smart Specialisation (RIS3).

EUFRIN was also mentioned as a programme or initiative for exchange in the field of research. EUFRIN is an informal, voluntary organisation of university departments and research institutes that specialise in research, development, and extension on temperate fruit crops, based in countries of the European Union, Switzerland, and Eastern Europe.

Another initiative mentioned by the interviewees was the International Organisation for Biological Control (IOBC) and its Regional Sections. This organisation encourages collaboration in promoting feasible and environmentally safe methods of pest and pathogen control.

3.4.5 EU platforms on knowledge transfer on IPM

The below sections analyse the extent to which EU platforms exist to exchange knowledge across MS. EU platforms are considered a key element for facilitating knowledge exchange. While fostering cooperation between Member States, these platforms allow the exchange of practices and tools between researchers, innovators, farmers, advisors, policymakers and other stakeholders. Below, such EU platforms are explored and described. Then, their potential added value, barriers and possible improvements are discussed.

On a first level, the EIP-AGRI (agricultural European Innovation Partnership) can be considered an EU wide platform or network to foster competitive and sustainable farming and forestry. It was launched in 2012 to contribute to the

European Union's strategy 'Europe 2020' for smart, sustainable and inclusive growth. This EU level partnership brings together innovation actors (farmers, advisors, researchers, businesses, NGOs and others) in agriculture and forestry. This network of interactive innovation is funded by Rural Development programmes (RDPs) or the EU research and innovation programme "Horizon 2020" and its key "building blocks" are Operational Groups, Multi-actor projects and Thematic Networks. The EIP-AGRI also creates Focus Groups that bring together experts, including farmers, to collect and summarise knowledge on best practices in a specific field. For example, on topics such as "IPM practices for soil-borne diseases"[204] (2015) and "IPM for Brassica".[205]

The European Rural Networks' Assembly, which is the main governance body of EIP-AGRI, since 2015, includes several sub-groups. The permanent Sub-group on Innovation for agricultural productivity and sustainability is one of them. The objectives of this sub-group include supporting the implementation of the EIP-AGRI in Rural Development Programmes, identify common issues, problems and good practices and cooperation with National Rural Networks to support innovation.

On a second level there are platforms, created by EU funded projects, which aim at sharing knowledge on IPM. For example, the IPM Decisions project is creating an online platform targeted for farmers and advisors, for the monitoring and management of pests. This platform will include a large range of existing Decision Support Systems for specific regional conditions.

Another project building a platform for knowledge transfer on IPM is SMARTPROTECT. The platform is a freely and easily accessible repository where end-users, such as farmers and advisors, have access to innovative IPM methodologies and technologies. It is also possible to contribute to the Platform's content by suggesting solutions to be incorporated and uploaded.

Other specific platforms for knowledge exchange on IPM are being built in projects such as IPMWORKS and IWMPRAISE.

National Knowledge platforms are being built as well, as they have a key role in the good functioning of the AKIS system. One example is the TITRIS platform in Lithuania, coordinated by the Lithuanian Agricultural Advisory Services. TITRIS is a free, open-source system in both Lithuanian and English, that collects, publicises and compiles data on applied research and results for the development of sustainable agricultural production.

In the undertaken interviews, some other platforms were mentioned, for example the ENDURE platform that, unlike other platforms and many project websites that end up no longer being available at the end of the project, remains

[204] https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_focus_group_on_ipm_practices_for_soil-borne_diseases_final_report_2015.pdf.
[205] https://ec.europa.eu/eip/agriculture/en/publications/eip-agri-focus-group-ipm-brassica-final-report.

functional. The national stakeholder interviews also mentioned EIP-AGRI and some H2020 funded projects as platforms for knowledge exchange on IPM. Associations and organisations like IOBC, IBMA, Copa Cogeca and EUFRIN were also referred as "platforms".

However, similarly to the interview question related to EU projects, many interviewees had no knowledge on EU platforms for knowledge transfer on IPM, which seems to show that in some way these platforms are reaching a limited audience, or at least not the audience questioned.

In common, these IPM knowledge exchange platforms target mainly farmers and advisors, even if they also include other stakeholders in the value chain. They foster cooperation between Member States, by producing, collecting and sharing information and by linking countries or regions and agricultural sectors. However, the information resulting from these multi-actor projects and Thematic Networks end up scattered between different platforms, with information that is hard to identify, especially when the projects end, and the platforms are no longer available.

Therefore, to reinforce the cooperation between Member States, these platforms, including the national ones and EU projects, must be connected in order to find a platform at European level, with open access, where resources can be found easily and preferably by using national languages, as this tends to be a barrier, especially in the countries where English is not widely used and when interacting directly with the farm community.

3.4.6 Potential tools aiming at transferring knowledge across MS

This chapter aims at identifying and exploring potential tools with the aim of transferring knowledge across EU Member States. Diverse types of tools at EU, national, and regional level, are described below, followed by an analysis of potential barriers and ways to overcome such barriers.

From the stakeholders interviewed comes the idea that, if there are tools for transferring knowledge across MS, they are not well known or not sufficiently disseminated. However, a small number of the interviewees identify H2020 projects, and other initiatives and platforms, this time as tools, such as: GO projects, Interreg projects, IOBC, ENDURE, BTSF, ERA-NET and AKIS.

As already indicated, the IPM Decisions project is creating an online platform targeted for farmers and advisors, for the monitoring and management of pests. This platform, if well maintained and updated, can be a potential tool for farmers and advisors to have access to knowledge existing across the MS, in this case related to Decision Support Systems for IPM.

Another potential tool, but which is also not launched at the time of writing this report, is the IPMWORKS toolbox. This tool will include resources directed to farmers, advisors, researchers, and policymakers, such as pest management and advanced IPM strategies, coming from farms across different MS. The platform is planned to be launched in 2022.

Other projects that were already mentioned, have produced, or are producing, tools for knowledge transfer on IPM, such as SMARTPROTECT, IWMPRAISE or C-IPM.

Other examples of tools for exchange of practices and knowledge were round tables, at both national, regional and EU level. Collaborations between universities, researchers, advisory and farmers associations were also identified as potential tools for knowledge transfer between Member States.

To improve knowledge and research transfer, the national stakeholders mention different kinds of tools that they would like to see, such as consistent and standardised rules (Austria), detailed guides and leaflets (Romania), international cooperation platforms to transfer knowledge for the sector that integrates strategies from different countries (Sweden) and centralised information in general. The example of Denmark was highlighted, where there is an institute for knowledge exchange and communication, that gathers research, universities, practice, and industry/agriculture in a digital infrastructure. Interviewees also mention that they would like to see more initiatives and programmes that could provide an economic incentive for farmers to reduce pesticide use (Bulgaria) and more investment and funds for agricultural research programs, especially for technological research (Lithuania).

Some stakeholders refer to tools used by advisory services, with all the IPM information centralised. Some of these advisory services relate to institutions in other countries, also creating an exchange between MS. One of the examples is a tool referred by Lithuanian Advisory Services: IKMIS is an innovative digital tool for integrated plant protection information, consulting, and training. It is made available by the Lithuanian Research Centre for Agriculture and Forestry and the information in the database is obtained directly from the database of the State Plant Service. Even if this is not a tool focused on transferring knowledge at EU level it is also available in English.

Another example of a tool used at national level but that could be disseminated or used as an example in other MS, is the Inagro crop protection application, which gives information about natural enemies and PPP (and their risk for the environment) using pictures from the pests.

In Spain, the TRIANA (Integrated Treatments in Andalusia in Agriculture) tool was developed by the Plant Health Service (Junta de Andalucía) and is used at regional level.

The FarmDemo project, in close relation with NEFERTITI, AgriDemo-F2F, PLAID and IPMWORKS developed tools, such as resources and guidelines, to enhance peer-to-peer learning through farm demonstration as a way to scale up the uptake of innovation and good practices. This tool helps to improve the organisation of demonstration events at farms.

Some of the barriers mentioned were that these tools sometimes do not reach the main target: the farmers. For this to happen, advisors must reach the farmers, or farmers have to be involved in projects in order to access these tools. Another problem mentioned is that some tools may not apply in all MS, as the local conditions in the MS have a significant variation and therefore IPM cooperation is not always easy to achieve. Another problem is the huge amount and fragmentation of tools.

Regarding these barriers there is a clear need of pulling together information from EU projects and national resources. To achieve this, research information and existing tools have to be aggregated to make them relevant and useable at the local level. There is also a clear need to better link the research community to advisors in order to produce usable tools.

3.4.7 Implementation of CAP instruments

The below sections aim to explore the CAP instruments and their potential as regards reducing the dependency on pesticide use. In a first step, CAP instruments and their adoption at national level are discussed. Then, transfer knowledge across agricultural types is analysed, focusing on conventional vs. organic practices.

It should be highlighted here that as National Strategic Plans for the new CAP 2023-27 were still under development during the data collection and analytical phase of the Pilot Project, information related to upcoming CAP instruments is limited.

3.4.7.1 Implementation of CAP instruments to effectively reduce the dependency on pesticide use

To analyse the CAP instruments that could effectively reduce the dependency on pesticide use, three questions were asked in the in-depth interviews with national stakeholders and NCAs: 1) how CAP instruments have been integrated in National Strategic plans; 2) the extent to which the National Strategic Plans (NSP) and 3) the SUD National Action Plans (NAPs) have been aligned and the extent to which MS have planned to update their NAP based on new opportunities provided by the CAP reform.

As at the time of the interviews the National Strategic Plans were still under development and were not available publicly, many questions in the interviews remained unanswered. Therefore, it is very difficult to propose a strategy on how to implement CAP instruments effectively to reduce the dependency on pesticide use. Nevertheless, the new green architecture proposed in the CAP reform, while providing for differentiated adoption between MS, will necessarily strengthen the instruments that contribute to reduce the dependency on pesticide use.

A recent study evaluated the CAP's impact on knowledge exchange and advisory services[206] by analysing the 2014-2020 CAP instruments and measures that have direct (and indirect) effects on knowledge exchange, advisory activities and innovation in the agriculture and forestry sectors and in rural areas. It concluded that CAP instruments and measures contribute to Member State Agricultural Knowledge and Innovation Systems (AKIS) but concern only a small part of the Member States AKIS.

In this report all four CAP instruments were considered relevant. In particular, the measures and instruments concerned in the analysis included three measures of the" Regulation (EU) No 1305/2013" (Rural Development – Pillar 2) that directly support knowledge transfer, innovation and advisory services: knowledge transfer and information actions (Measure 1), advisory services, farm management and farm relief services (Measure 2), and cooperation (Measure 16), notably supporting Operational Groups and their pilot projects. The "Regulation (EU) No 1307/2013", which refers to direct payments (Pillar 1) includes the greening topics and practices, such as crop diversification, maintenance of permanent pasture, ecological focus area, and fostering knowledge exchange on these topics.

As mentioned in the study, during the 2007-2013 period, several Member States or regions used advisory services supported by the EAFRD to provide for the implementation of the Farm Advisory System (FAS) (Flanders in Belgium, Estonia, Italy but also Lithuania, Malta, Portugal, Slovakia and Scotland in the United Kingdom). In these Member States/regions, it is difficult to isolate the effect of the FAS without Rural Development support. Several other Member States, with a strong AKIS as well as a pre-existing and diversified advisory landscape, consider that the FAS had little impact. It was implemented within their existing advisory services, without additional tasks or funding (Austria, Wallonia in Belgium, Germany, Denmark, France, the Netherlands, Poland, Luxemburg).

The study compared the period of 2007-2013 to 2014-2015 and stated that, in Rural Development Programmes, "the framework has prominently expanded to include many new activities such as information and demonstration activities or visits and exchanges at farm level (sub-measures 1.2 and 1.3)". As mentioned before, such activities have the capacity to foster a holistic approach of the farm and may cover topics such as the economic and environmental approach of the

206 https://op.europa.eu/en/publication-detail/-/publication/e75ab09a-7719-11eb-9ac9-01aa75ed71a1/language-en.

farm and also including the FAS topics like the principles of integrated pest management (Article 14 Directive 2009/128/EC).

The study concluded that CAP instruments and measures contribute to the strengthening of Member State Agricultural Knowledge and Innovation Systems (AKIS), even if concerning only a small part of the Member States AKIS, and to the access of advisory services, contributing to the development of activities that can foster the reduction of pesticide use. However, as stated in the study, and understood by the analysis of the in-depth interviews, it is complicated to quantify the contribution of these measures, especially attending to the diversity of countries and regions.

The study also developed recommendations that could be considered to contribute for the reduction of dependence of pesticides use, such as:

1. Develop an integrated vision of MS AKIS;
2. Strengthen coherence between CAP instruments and measures and MS AKIS;
3. Maintain and develop the EIP AGRI;
4. Foster information flows between advisors, farmers, and researchers;
5. Maintain training and knowledge support for advisors and encourage MS to link funding of advice to training of advisors;
6. Foster holistic advisory services in response to farmers needs including topics of public interest;
7. Increase the ability of all farmers to access advisory services and promote them while enabling approaches to evolve;
8. Place more emphasis upon the 'hard to reach' with CAP funding;
9. Improve 'targeting';
10. Support knowledge exchange, advice and innovation methods based on new technologies;
11. Reduce administrative burden; and
12. Revise and specify data collection of monitoring indicators.

3.4.7.2 Transfer of knowledge across agricultural types (conventional vs. organic production)

In the interviews conducted, many stakeholders and NCAs (Latvia, Germany) refer to knowledge that has been transferred from both organic to IPM and IPM to organic, and that is widely used, such as mechanical weeding, use of beneficial organisms and catch crops, biodiversity measures, reduced tillage practices, etc. They also point out that there is a need for learning on both sides and that not only organic farming practices should be praised and valued, as such practices also need to improve in terms of performance.

National stakeholders' answers mention that it is possible to integrate experience from one type of agriculture to the other through practical advisory, and technical experts operating in the field (Austria, Cyprus, Italy), for reciprocal transfer of knowledge.

Finding common problems and complementary themes and approaching them on both ways is also valuable. Many stakeholders, for example in Portugal and Lithuania, suggest that in the future both agricultural types will be complementary and, in some ways, merged. For that, there are departments that work together (agroecology) and studies that integrate both types of agriculture.

Joint education and cooperation: workshops, seminars, training, field days and demonstrations with comparative tests; exchange of experiences between farmers, projects in which both groups work together; research at farm level; use of success stories (Romania, Slovenia) because farmers apply what they actually see that works (Slovakia), what "convinces" them (Germany).

There is an emphasis on the importance of providing advice that is reliable and effective, that is, based on research and provided with figures. Farmers will only accept and apply alternatives that they can actually "see" working and that bring some economic advantage. The consumer interest is also mentioned as something farmers consider as much as economical results.

For this to happen, research and knowledge must be disseminated. Many MS use tools such as social media, newsletters, websites, farmer forums and meetings, technical bulletins, trainings, demonstrations and other communication channels in order to inform farmers on research results. Close collaboration between researchers and academic community and practice (farmers and advisors) is also referred by the stakeholders interviewed, for example through regular meetings to exchange ideas. Other tools used include smartphones, new devices, and other new technologies. Researchers also focus on writing technical articles, participation on conferences and close cooperation on various research projects.

The NCAs have similar views. They also mention an education system with emphasis on cooperation through trainings, workshops, round tables between the stakeholders, model farms and practical demonstrations with direct knowledge transfer from farmers with experience. Some of the NCAs also mention other measures which are helping the MS to transfer knowledge from different agriculture types: e.g. subsidies for certain measures (for example for mechanical control of weeds) and other incentives and support through CAP instruments (Latvia).

Regarding the improvement of the knowledge and research transfer, NCAs suggest a better connection of stakeholders (mainly farmers and researchers) and dissemination of results from both types of production.

In many ways, most of the strategies suggested, for example demonstration projects referred to before, such as IPMWORKS, NEFERTITI and DiverIMPActs, seem to be promoting cooperation between organic and conventional farming.

Whereas this transfer is happening in most countries, and boundaries between both types of agriculture seem to be blurring, some limitations are pointed out. It is mentioned in countries like Bulgaria that situations of tension between organic production and non-organic production are common, which cause difficulties in integrating both types of agriculture. Another limitation referred to is that organic farming is well recognised while IPM products do not have consumer recognition, as well as a certification system. Even with willingness to learn from each other, the fear of the unknown and possible risks seems to be a barrier to knowledge transfer.

Other limitations include the lack of funding in national research projects which cause an imbalance between research and knowledge transfer and in turn is causing a decrease in the interest of the researchers, which sometimes are working on the same level of farm advisors, resulting in a lack of quality and independent research. International and EU level projects do not consider some specific aspects such as local climatic conditions and crop varieties, and this is an obstacle for agricultural knowledge dissemination.

3.4.8 Final remarks on how to scale up good practices throughout the EU

To conclude the analysis of Theme 4 – *Strategies on how to scale up good practices across the EU*, impactful strategies at EU, national and regional level identified during the data collection and analytical phase are further discussed and highlighted in the below sections. The aim here is to make some preliminary conclusions of the above sections and put forward concrete and practical examples that could provide added value in the context of knowledge transfer, and also ways to improve existing initiatives.

The below table provides an overview of identified strategies and their level of application.

Table 24: Strategies identified and level of application

	Strategies identified	European level	National/ Regional level	Local level
Demonstration farms	Demonstration and model farms	☐	☐	☐
	Extend the existing networks of demonstration farms	☐		
	Increased budget for demonstration farms	☐	☐	
Trusted advisors support	Create a sense of community and transmit it to the farmer	☐	☐	☐
	Close interaction with farmers and building trust			☐
	Bottom-up approach	☐	☐	☐
	Continuous training of advisors		☐	☐
Dissemination	Translated resources	☐	☐	
	Discussion and study groups	☐	☐	☐
	Improved use of social media	☐		
	Webinars	☐	☐	☐
	Engagement of key stakeholders that can disseminate knowledge nationally	☐	☐	
	IPM policy makers community	☐	☐	
IPM Toolboxx	Strategical DSSs based on benchmarking	☐		
	Coordinate the various initiatives on the topic	☐	☐	☐
	EU wide data base of farm level IPM practices	☐		
Nudging strategies	Promote IPM not only with technical knowledge but also normative and social aspects			☐
	System to reduce the impact of risk taking		☐	☐
	Reduce bureaucratic burden	☐	☐	

Source: Compiled by Consulai

Demonstration and model farms (EU Projects and CAP instruments): demonstration and model farms have a major role in the spreading of good practices and innovative methods and technologies. It was suggested the creation of the status of "experimental farm". These farms would feed the IPM practices and tools database and would receive support (subsidies and other) in return. The need for increasing the budget for demonstration farms was identified, not only for supporting these farms but also to extend the existing networks of demonstration farms to all Member States and regions (for example the IPMWORKS network). It is also important to consider cross-visits as a demonstration event on model farms, but in this case focusing on the knowledge exchange between MS.

Advisory services play a key role in promoting lower dependency of pesticides use. During the workshop it was highlighted that the training of advisors and a close and trusted technical support are strategies to assure that good practices reach and are adopted by farmers. A scheme of continuous training of advisors was suggested, to increase the knowledge and practical skills (focusing on a holistic view of IPM), as well as normative and social aspects for the adoption of good practices, for example on farmer behaviour or IPM advising methods. It was also mentioned that such training scheme should be mandatory and that there should be a standardised approach to education of advisors on IPM. Building trust with farmers is also a key strategy for encouraging change. It was stated that trust and close interaction helps dealing with risk aversion or with a case of "failed advice", which is sometimes inevitable on the topic of IPM. Creating a sense of community, for example in farmers' associations, or in the networks of demonstration farms in EU projects, promotes interaction and trust, and enhances cooperation and adoption of good practices. In the case of projects with farmers, these should start with a bottom-up approach, for example interviews with the farmers, to understand their needs and focus on that.

The dissemination of results from projects, or tools and good practices could be encouraged by the translation of these resources, because using local language is considered important for guaranteeing the use and adoption by farmers. Discussion and study groups (possibly integrated with demonstration farms), as well as webinars in local language were suggested as strategies for good practices to reach more stakeholders, in particular farmers. The improved use of social media could also be a strategy for projects, initiatives, and knowledge to reach more audience. Many projects are already using platforms such as LinkedIn, Twitter and YouTube for sharing events, results, and good practices in general. The engagement of key stakeholders that can disseminate knowledge nationally is also very important to improve the dissemination of good practices for farmers. This can be done by involving such stakeholders in projects and initiatives. Another strategy that is considered relevant for the dissemination of IPM related topics is the development of an IPM policymakers' community with members from all MS, which is already being conducted in the IPMWORKS project.

Knowing that there is a vast variety of resources and tools in websites, toolboxes and platforms, a coordination of the various initiatives on the topic was suggested, therefore creating links between key websites and toolboxes at MS level and EU level. This could lead into the EU-wide database of farm level IPM practices which could include the description of the tool (including adaptability to local conditions), in several languages and links to examples where this is used, for example projects where such practice was used in a demonstration event with videos of testimonies (the "human" aspect for decision making) or other resources such as case studies and discussions on the topic. If the tools are based on model farms practices, they should include information on effectiveness and cost-efficiency, as well as possibility to do a benchmark on possible DSSs. There should be crop- and pest specific toolboxes adapted at regional/local level. The promotion of these toolboxes should happen at regional level across the Member States.

Other strategies for scaling up good practices across the EU refer to using not only the technical and economic aspects of IPM but also normative and social aspects. On this point, farmer behaviour must be considered, to use the right methods of promotion. A national system for reducing the impact of risk taking, where farmers would feel they are taking lower risks when adopting good practices, was suggested as a strategy that could increase the effectiveness of the promotion and adoption of practices that reduce the use of pesticides. A lower bureaucratic burden of the National and EU instruments related with the adoption of good practices, and more specifically of the CAP instruments related to IPM, could also promote the adoption of good practices. These are just some examples of nudging strategies – a set of principles from behavioural economics and psychology that could be applied to promote the adoption of IPM without restricting farmers' options or significantly increasing the economic incentives in the sector.

It was not possible to make an analysis of the CAP Strategic Plans in the different Member States, due to the timetable of the CAP reform process, however, it remains important to highlight the importance of strengthening some of the instruments available to scale up good agricultural practices in Europe. On one hand, through eco-schemes (Pillar I), there will be the possibility of enhancing a set of practices that contribute to increase efficiency in the use of inputs and maximise ecosystem services provision, beyond the obligations. On the other hand, through the instruments of Rural Development (II Pillar), there should be, in addition to possible support with the agri-environmental commitments for IPM practices beyond the obligations and promotion of measures to support the training of advisors and the creation of Demo Farms, and to ensure an effective demonstration of results and a real knowledge transfer to farmers.

The below table provides an overview of impactful strategies identified per study question.

Table 25: Impactful strategies for each study question

Study questions	Impactful strategies
How to encourage a change in current agricultural practices and promote lower dependency on pesticide use	• Demonstration and model farms • Continuous training of advisors • Discussion and study groups • Webinars
How to foster cooperation between Member States	• Extend the existing networks of demonstration farms • Translated resources • Improved use of social media • Coordinate the various initiatives on the topic • EU wide data base of farm level IPM practices • IPM policymakers' community
How to implement CAP instruments effectively to reduce dependency on pesticide use and how to ensure coherence with other incentives	• Increased budget for demonstration farms (cooperation to innovation) • Support continuous training of advisors in this topic
How to improve knowledge and research transfer among sectors and how to integrate it into conventional farming when it decreases the use of pesticides	• Demonstration and model farms • Discussion and study groups • Continuous training of advisors • Webinars

Source: Compiled by the Consortium

When comparing the identified strategies with the study questions of this theme, it is clear that many of these strategies have a broad level of intervention and can be an answer to more than one question. It is the case of Demonstration farms that may encourage changes in practices while promoting farmer-to-farmer learning that can include integration of practices from different types of agriculture production (for example conventional and organic).

For encouraging a change in current agricultural practices and promote lower dependency on pesticide use, the most impactful strategies identified were the creation of demonstration/model farms, the training of advisors and discussion and study groups, as well as webinars, for knowledge exchange.

Regarding the cooperation between Member States there were many impactful strategies identified: extension of the existing networks of demonstration farms; translating resources such as tools from websites and existing toolboxes, improving the use of social media (for disseminating results or events, for example), coordinating the various initiatives on the topic, from websites of projects and at MS level, use the EU database of farm level IPM practices and the creation of an IPM policymakers community with members from all Member States.

On the implementation of CAP instruments to reduce dependency on pesticide, although the analysis is very limited because of the lack of concrete contributions from the interviews and the workshop, the main strategy identified is supporting continuous training of advisors.

Regarding the question on how to improve knowledge and research transfer among sectors and how to integrate it into conventional farming when it decreases the use of pesticides, some impactful strategies were identified: demonstration and model farms with networks of demonstration farms that include both organic and non-organic model farms, discussion and study groups with stakeholders from both types of agriculture, training of advisors, that integrates knowledge from holistic IPM and good practices from organic farmers, for example and webinars that also integrates knowledge from both agricultural systems.

In summary, it is not possible to identify one single strategy that answers to all these study questions and the main question "how to scale up good practices throughout the EU". All the topics addressed (advisory services and its networking, EU related projects and initiatives, platforms and tools aiming at knowledge transfer and CAP instruments) are interlinked and there are therefore strategies proposed that relate to several of the topics.

4. Case studies

This section presents the abstracts of the 12 case studies conducted in the context of the Pilot Project.

The use of crop specific guidelines for controlling implementation of IPM at farm level in Belgium.

Building on the national food safety monitoring activities, the regional Belgian authorities have developed an IPM monitoring approach based on crop specific guidelines. Such monitoring is currently used in routine by external and independent organisations. The annual results show a high level of compliance leading to the conclusion that IPM is correctly implemented in Belgium.

A collective initiative initiated by vegetable farmers to reduce dependency on pesticide use: the Brittany case in France.

Vegetable growers from North-Brittany have set-up a collective approach to reduce dependency on pesticide use through their association of producer organisations (APO) - CERAFEL. This multi-year initiative aims to produce and market the main vegetables produced in the area (cauliflowers, artichokes, shallots, onions in open fields and tomatoes in greenhouses) under a label created by the APO named "Zero pesticides after flowering". Vegetable growers substitute pesticides with a range of management practices and alternative products to chemical pesticides. The program builds on regional R&D efforts funded by the APO and additional regional technical centres such as the Chambers of Agriculture of the region Bretagne. First, the overall structure of the fresh vegetable sector in Brittany is presented. Then, the history and development of the initiative is described. Following, the current situation and the results achieved since the launch of the initiative are presented. Eventually, the forthcoming activities foreseen by CERAFEL to further develop their initiative with the objective of a complete phasing-out of chemical pesticides in the coming decade are described.

A large-scale pesticide-free wheat production program in Switzerland.

The Swiss producer organisation IP-SUISSE introduced a pilot program for non-organic pesticide-free wheat production in 2018/19, which then opened to all producers in 2019/20. The program aims to reach a large-scale adoption of 20-50% of Swiss wheat production - and is the first of its kind in Europe. Farmers in the program substitute pesticides in wheat production with a range of integrated pest management practices. They are compensated with a price premium and a federal direct payment. The program builds on a long-standing extensive wheat production program of IP-SUISSE which has a market share of around 50% of Swiss wheat production. This case study describes the history and development of this extensive and pesticide-free production program. Following, the case study investigates adoption barriers and hurdles for farmers adoption, effects of the program on pesticide reduction, farmers' incomes, and consequences for the development of sustainable wheat production practices and technologies in Switzerland. Finally, the potential for pesticide use reduction through non-organic pesticide-free production programs for other crops and countries is discussed.

ADVID – Vine and Wine Cluster in the Demarcated Douro Region in Portugal.

This case study focuses on the activity carried out by ADVID, which is an association created in 1982, which aims to contribute to the modernisation of Portuguese viticulture, in particular the Demarcated Douro Region, and, consequently, contribute to improving the quality and profitability of Portuguese wines and vineyards. The Association was created by the initiative of a group of companies linked to the production and trade of wines from the Demarcated Douro Region (namely Porto wine), who understood that it was important to have a structure that would ensure the transfer of knowledge from academia to the field, and that knowledge was not only concentrated at the level of the R&D entities existing at the time. The initial concerns of the association were related to the need to promote a continuous source of information, to support the technical decisions of the associates, namely regarding new land systematizations, vine mechanization, work rationalization, and choice of vegetative material. These first actions later gave rise to the implementation of integrated pest management programmes and more recently to integrated production, an essential tool for quality production that is safe for the consumer. As a result of its journey and importance, ADVID was recognised in 2009 as the Managing Body of the Douro Region Wine Cluster, in 2017 as the Managing Body of the Vine and Wine Cluster, and in 2018 was awarded the title of Collaborative Vine and Wine Laboratory.

IPM implementation in rice in Spain.

The selection of this case study was based on a set of distinctive factors: 1) it is an extensive crop developed in a particular territory due to the need of compatibility with a Natural Park (Donaña), 2) there is a historical experience of 23 years of IPM practices, 3) there is an enormous adherence by farmers to IPM in the crop and 4) there is an organisation (Federation) which aggregates the provision of IPM services to over 60% of farmers in the region.

Over the years it has been possible to significantly reduce the number of phytosanitary treatments on rice crops and to implement a set of agricultural practices that encourage a reduction in the application of inputs and an increase in the ecosystem services provided by rice growers in the Seville region.

The RoboWeedMaps initiative in Denmark.

RoboWeedMaps is a weed management product chain that covers the entire process from weed registration and identification to application of herbicides or mechanical treatments. The product chain includes components developed over the last 30 years of research in integrated pest management in Denmark and was developed to a full product chain in the RoboWeedMaps project funded by Innovation Fund Denmark from 2017-2020. The project has demonstrated an average saving in costs of 33 € per ha, equal to 57-73 % for different crops. Significant improvements were also demonstrated for environmental indicators with 24 – 52 % improvements for Treatment Frequency Index and 6 – 95 % improvements for Environmental load index. The potential of site-specific treatment compared to field-specific treatment was also tested, but only for one weed species. The results here showed a further reduction of 88 % in herbicide use. Even though the product chain has been demonstrated successfully, further improvements are needed. Most notably, the hierarchical botanical model should be improved from identifying monocots and dicots to deliver information about the family, genus and ultimately species of the weeds The case study on RoboWeedMaps is relevant for the Pilot Project as a state of the art set of tools supporting farmers in applying IPM. The decision support system part of the chain has shown promising possibilities for application in other parts of Europe.

ALIEN.STOP in Italy.

The project ALIEN.STOP investigates the use of multifunctional nets to successfully control several key insects of fruit orchards, such as the codling moth and the threatening brown marmorated stink bug. Results of the numerous experimental trials performed suggest that the nets are a successful mean to control a wide range of harmful insects, also showing a wide range of positive side-effects including protection from extreme weather events (e.g. hail and extreme rain) as well as birds attacks. Further research is required to investigate the influence of the nets on agronomic and physiological aspects, such as pollination and fruit ripening, as well as to optimise the technique thus reducing the associated costs.

IPM in Chrysanthemum with the focus on thrips control in the Netherlands.

In this case study, three individual projects that focussed on the use of natural enemies in the integrated control of thrips in greenhouse grown Chrysanthemum were investigated.

Use of natural enemies in Chrysanthemum is not very straight forward. Though predatory mites and pirate bugs can establish themselves in Chrysanthemum, their effectiveness as a biological control agent of thrips is dependent on the timing of their introduction in the crop, the additional food available and conditions in the greenhouse. Nevertheless, there is great potential for developing a successful system for use of predatory mites and pirate bugs in the control of thrips in this crop. Further research is required to optimise conditions under which these natural enemies will best establish themselves, and to determine under practical conditions if their use can be combined with other biological control agents and potential chemical control methods that prove necessary to control severe infestations or infections of other pest or diseases.

IPM in Quebec.

This case study aims to investigate how Quebec in Canada has worked to implement IPM in Quebec over the past years, starting off with the first Phytosanitary Strategy in 1992. This was followed by a refocused strategy in 1997 which included an objective to increase IPM adoption. Barriers to IPM uptake are discussed, as well as how to overcome them. Finally, the case study looks at future developments in this field in Quebec, as well what the EU can learn from past and on-going activities.

Fruchtkalk in Bulgaria.

The case study is aimed at shedding light on the effectiveness and success of an integrated pest management (IPM) measure called Fruchtkalk. The case study will attempt to explore the best practices and also to investigate relevant problems of the implementation of Fruchtkalk as IPM measure on national level in Bulgaria.

The product Fruchtkalk was introduced in Bulgaria through a partnership between Balkan Bio Frukt Ltd. and the German firm Schneider Verblasetechnik . The product has been used widely as a fertiliser and plant protection product due to its status as a basic substance, by conventional and bio producers of berry, vine and horticulture crops in Bulgaria.

The case study identifies and considers challenges around the application of Fruchtkalk and the perceivable difference between the views of producers and national authorities on the use of Fruchtkalk.

The German model project "Demonstration Farms for Integrated Pest Management".

The German model project "Demonstration Farms for Integrated Pest Management" was set up to speed up the process of knowledge transfer and actively engage in knowledge exchange between growers, advisors, and researchers. The main goals were the implementation and demonstration of IPM on selected farms, the analysis of indicators for IPM implementation and exchange on the acquired knowledge and information of a wider audience. The project achieved a sound implementation and improvement of IPM practices. Depending on the crop and regional conditions, it is possible to reduce pesticide use in case-specific approaches. In arable crops preventive measures such as adapting crop rotation, choice of resistant or tolerant varieties, tillage or sowing times as well as monitoring and the use of decision support systems were improved. The close collaboration with the state advisory services is essential for the uptake of IPM at field level.

Biological agents to reduce herbicide use in Lithuania.

The objective of the project successfully implemented by the Lithuanian Chamber of Agriculture together with researchers from Botany Institute, Nature Research Centre was to address the problems of improving soil quality, reducing the use of nitrogen fertilisers, and increasing the yield and quality of production in order to increase crop efficiency and resource sustainability. The project envisaged to increase the profitability of farms by reducing the use of nitrogen fertilisers, maintaining, or even improving the yield of production thanks to a new generation of microelements and improving (restoring) soil structure and product quality with the help of microorganisms. The results are showing very good effect of using biostimulants products, especially in cereals.

This project is planning to explore the potential of an innovative biostimulants product, BioGel, a preparation made from biohumus (Vermicompost) and water containing free amino acids of plant origin, macro (N, P, K), micro (Mg, Mn, Fe, Zn, Cu, B, Fe) elements, vitamins (B1, C, B2, A, E, PP), humic acids, and enzymes.

The results of the planned research will provide new scientific information and further develop knowledge on the effects of biological agents on the growth and development of cereal and bean crops and will help farmers to choose environmentally friendly plant protection products. However, due to the fact that the project has just started, concrete results on the action of the Biogel product in reducing pesticide use by strengthening the defence of plants are not available yet.

5. General conclusions and recommendations

This section presents the key findings and conclusions of the Pilot Project. In addition to summarising findings for each of the four themes that pay particular attention to presenting the barriers linked to IPM uptake by farmers, it includes references to the case studies.

Theme 1: Identification and assessment of effective practices and technologies to reduce dependency on the use of pesticides in the European Union

One of the first major output of the Pilot Project is the development of an inventory of IPM practices, techniques and technologies. More than 1300 examples were identified across Member States to reduce dependency on the use of pesticides, leading to the creation of an EU-wide database that includes all these examples.

In the European Union a large variety of individual cropping practices and crop protection techniques are widely adopted, which in their combination constitute the implementation of IPM. However, due to the high number of crops cultivated and the diversity of cropping situations in Europe and therefore the various combinations of practices, added to the fact that research and development is in constant evolution in this area, it is impossible to present a complete list of IPM solutions.

Therefore, examples presented in the EU-wide database have to be seen as inspirational examples within each of the eight IPM principles as outlined in Annex III of the SUD, rather than being exhaustive.

The EU-wide database was established gathering 35 generic types/groups of practices, techniques (e.g., crop rotation) and technologies (e.g. weeding robots) illustrated by about 1300 national examples from across all the Member States, covering the general principles of IPM, a variety of production types and crops. **Each type/group of practices has been assessed as regards its potential to contribute to the reduction of dependency of pesticide use, its cost for implementation and its overall effectiveness (see table below)**. It is important to understand that this effectiveness can vary significantly depending on crops and local context. This is highlighted through the presentation of national examples.

Alternatives			Potential reduction of pesticide use	Cost of implementation	Current level of implementation	Long term sustainability
Principle 1 – Prevention and suppression						
	Site conditions		Low	Low	Medium	High
	Crop rotation					
		Crop diversity (crop rotation/sequence)	Medium to high	Low to high	Low to medium	High
		Intercropping	Low to medium	Low to medium	Low	High
		Under sowing	Low to medium	Low	Low	High
		Others (companion cropping)	Low to medium	Low	Low	High
	Cultivation techniques					
		Stale seedbed	Low to medium	Low	Medium	High
		Sowing time	Low to medium	Low	Medium	High
		Seed/plant density	Low to medium	Low to medium	Medium	High
		Superficial ploughing	Low	Low	Low	High
		Non-inversion tillage	Low	Low	Medium	High
		Conservation tillage/direct sowing	Low	Low	Medium	High
		Mulching	High	Low	Low	High
	Resistant/tolerant cultivars and standard/ certified seed and planting material					
		Weed competitive cultivars	Medium	Low	Low	Medium to high
		Disease or pest resistant and tolerant cultivars produced through conventional breeding	High	Low	Medium	High
		Use of certified seed	Medium	Low to medium	High	High
		Disease or pest resistant and tolerant cultivars produced through Genetic engineering	High	High	Low	High

Alternatives			Potential reduction of pesticide use	Cost of implemen-tation	Current level of implemen-tation	Long term sustaina-bility
		& new genomic techniques				
	Balanced fertilisation, liming and irrigation/drainage practices					
		Balanced fertilisation	Low to medium	Low	Low to medium	High
		Irrigation	Low	Medium	Medium	Medium
	Preventing the spreading of harmful organisms by hygiene measures					
		Hygiene measures: cleaning of machinery	Low to medium	Low	Medium	High
	Protection and enhancement of important beneficial organisms					
		Habitat conditions: hedges, field margins	Medium	Medium	Low	High
		Habitat conditions: Enhancing beneficials by improved management	Medium	Medium to high	Low	High
Principle 4 – Biological, physical and other non-chemical methods						
	Biological control: application and release of beneficials and microbials		High	Low to medium	Low	High
	Biological control: other natural substances		High	Low to medium	Low	High
	Biological control: use of plant strengtheners/ biostimulants		Medium	Low to medium	Low	High
	Physical measures: mechanical		High	Low to medium	Medium	High
	Physical measures: thermic		Medium	Medium to high	Low	High
	Biotechnical measures: pheromone traps		Medium	Low to medium	Low to medium	Medium to high
	Biotechnical measures: mating disrupting		Medium	Low	Low	Medium to high
	Biotechnical measures: food traps, use of attractants, sexual confusion		Medium to high	Low	Low	Medium to high

Alternatives		Potential reduction of pesticide use	Cost of implementation	Current level of implementation	Long term sustainability
	SMART/precision agriculture	High	High	Low	Medium to high

Source: Compiled by the Consortium

In addition to the database, the 12 case studies also led to a number of tangible examples of practices and techniques used in IPM, studied more into depth. For example, the RoboWeedMaps initiative in Denmark, the use of multifunctional nets to control key insects on fruit orchards in the Italian project ALIEN.STOP, the use of natural enemies in the integrated control of thrips in greenhouse grown Chrysanthemum in the Netherlands, or the basic substance Fruchtkalk used as a fertiliser and plant protection product in Bulgaria. Other case studies highlighted the importance of applying IPM in a holistic way, using a variety of IPM practices addressing the eight principles (e.g. in the case study on rice in Spain). Eventually, the case studies also studied how agricultural economic organisations (e.g. producer organisations, cooperatives) or authorities initiated approaches aiming at reducing dependency of pesticide use via IPM.

Member States developed a wide range of activities to ensure uptake of IPM at farmer level, including the development of crop- and sector specific guidelines; training and information activities; providing warning systems, forecasting models.

The Pilot Project has mapped the crop- and sector specific guidelines developed by Member States and aimed at ensuring IPM uptake in accordance with Article 14(5) of the SUD. This led to the creation of a second inventory in the EU-wide database which focuses on such level guidelines.

As the SUD does not provide a clear definition of such guidelines, the development of crop specific guidelines has been initiated via various approaches depending on how Member States have interpreted the requirement from Article 14 of the SUD which are perceived as vague and not prescriptive enough. Therefore the Pilot Project found first that a plethora of tools and materials is produced by in Member States, but yet not all of them are formally considered or classified as guidelines. Such variety of public and private guidelines, often referred to as **cropping guidelines co-exist with those officially recognised crop-specific guidelines by public authorities** in the context of Article 14(5) of the SUD.

Second, when considered as crop-specific guidelines by NCAs, such documents provide descriptions including coverage of crops, coverage of IPM principles, target audience, and whether they are used for controls by authorities or not.

Generally, the aim of the guidelines is to provide guidance to farmers, while in a limited number of countries they are also used for the monitoring and control of IPM implementation (as is demonstrated by the case study in Wallonia, Belgium). In most cases they are not legally binding. The inventory of crop-specific guidelines, as reported by NCAs, is included in the EU-wide database.

In addition to said guidelines, the Pilot Project recognised the efforts made by Member States to promote and disseminate these crop specific guidelines including i.a. training and information activities.

Pesticide use data can be one source of information assessing the effects of IPM on the dependency on pesticide use. However, current data on pesticide use as collected by EUROSTAT are fragmented, which does not allow for an overall assessment of trends in their actual use.

To date, Member States are only required to report data to Eurostat every five years, and they are relatively free in their approach for such data collection but need to address the representative crops. As a consequence, Eurostat data on pesticides use provides data for a limited number of country-crop-year combinations only. Such fragmentation is an issue that is addressed in the context of the revision of the European agricultural statistics system leading to the proposal of a new framework Regulation agricultural input and output (SAIO) to be adopted in 2022. The aim is a better coherence the revised SUD and in the drafting of a delegated act addressing record-keeping of pesticide use (foreseen under Article 67 of Regulation (EC) No 1107/2009).

Data on pesticide sales (in tons) are arguably a good proxy for the actual amount of pesticides used if data series of three to five years are considered. However, such proxy does not provide sufficient details on the intensity of pesticide use in individual crops.

Despite the fact that farmers act as economic operators and only purchase pesticides on demand, it cannot be excluded that to some degree pesticides are also purchased to be kept as a stock for future use. Although there are cases, where pesticides are purchased by farmers and kept as stock, sales can be correlated to the actual use of pesticides when considered across a 3 to 5-year time span. After an increase in sales between 2011, and 2016 to a peak of 371,000 tonnes of active substances, sales in the EU-27 decreased steadily until 2019 by almost 10% to 336,000 tonnes of active substances. Over the whole period of time, the distribution of sales of active substances across different groups stayed very stable. Fungicides account for the largest share of sales (approx. 43%), followed by herbicides (33% of annual sales). Insecticides (10% of annual sales) and other products (excluding plant growth regulators and molluscicides) account for the remaining share of annual pesticides sales.

The majority of Member States set out targets on pesticide *risk* reduction, while only one Member State defines a target on pesticide use (pesticide sales) reduction.

Over the last three decades, Member States have established national indicators which are being calculated on a regular basis in order to measure the progress in term of reduction of risk and use of pesticides at regional and national levels. In addition, in 2019, the Commission established harmonised risk indicators (HRI 1 and HRI2) (Commission Directive (EU) 2019/782) that have to be computed in addition to the existing national indicators. Member States have also the possibility to complement the HRIs with novel or existing national indicators (Article 15(1) of the SUD). The recent computation of these harmonised risk indictors has demonstrated that, overall, progress has been achieved in reducing the risks and impacts of pesticide use even if large variability across Member States is observed.

When it relates to the qualitative and/or quantitative targets set by Member States in their National Action Plans (NAP) in accordance with Article 4 of the SUD, the Pilot Project confirms the conclusions of previous studies (evaluations of the SUD by the EP and the EC, Commission reports on enforcement and implementation of the SUD, the ECA report on the SUD, etc.) that the large majority of Member States have inserted targets, being qualitative or quantitative, on pesticide risk reduction in their NAPs. France is the only Member States which has yet established a quantitative target aiming at reducing by 50% pesticide use by 2025.

Country fiches on the implementation of IPM measures point at a great variety of the uptake and implementation choices of IPM across EU Member States

Country fiches have been developed for all EU Member States. These fiches provide an overview on the current state of the implementation of IPM measures in each country, drawing on the results of the country research and providing some additional contextual information. In particular, the fiches contain information on key statistics of the agricultural sector, details on the National Action Plans, including an overview of qualitative and quantitative targets and feature figures with trends on pesticides sales and the HRI indicator, providing data for the time period from 2011 to 2019. Finally, the fiches provide details on the implementation of the SUD and IPM, such as an overview of guidelines, information on crop specific practices and supporting measures in place to incentivise the uptake of IPM practices.

Theme 2: Estimation of the potential to reduce dependency on pesticide use and its key drivers and barriers

Diverging views exist on the availability of alternative solutions.

The Pilot Project shows that promising alternative solutions may exist but that these are still at development level. Such alternatives have costs but also benefits. In addition, many stakeholders have indicated that farmers are looking for economically viable alternatives, leading to difficulties on how to assess their viability. Another major issue inhibiting to the uptake of alternatives is the lack of long-term information on the economic, environmental and social costs and benefits.

The most promising types of alternatives in order to reduce the dependency of pesticide use are crop rotation when considering long-rotations (more than five years), use of biopesticides, further development of resistant varieties using any types of breeding techniques; and the development of precision farming and smart agriculture (digitalisation, robotics). However, the cost for implementation and the required knowledge to implement and adapt techniques to field conditions related to several of these techniques is comparably high leading to a potential low uptake of such technologies by farmers if not financial compensation is provided.

In most of cases, the agronomic effectiveness of alternatives is lower and, therefore, often, a mix of alternatives must be combined. A single practice will, in many cases, not be sufficient in ensuring pest control. Alternative measures in most cases have to be employed in combination. As a last resort, chemical pesticides may be employed if the approach does not sufficiently reduce pest damage below the economic threshold.

Such conclusions are reinforced by the conclusions of the ECA 2020 report on the sustainable use of pesticides which highlights that "non-chemical" methods are evolving, but the number of low-risk PPPs is low. Such conclusion also leads to an issue of uptake by farmers as the overall crop management with alternatives is becoming more sophisticated than the conventional use of chemical pesticides.

Other views indicating that multiple alternatives to chemical pesticides are existing have been expressed during the Pilot Project.

In order to better assess the availability of alternatives, the Pilot Project proposes two indicators to estimate the number of alternatives available to farmers and invite the legislator to further develop such indicators, or develop others, in order to have a more precise view on the situation.

The costs of implementation of IPM at farm level vary considerably from one cropping system to another and from one technology to the other and also regionally.

Such cost will then depend on the IPM solution. Substituting a chemical pesticide by an alternative biopesticide with the same agronomic efficiency has nearly no cost. However, when the IPM solution relies on a series of tools of which mechanical weeding and other smart agriculture practices, the investment costs and risks may be too high for a farmer to invest in such equipment and, in such cases, collective investments should be sought (e.g. through CUMA, machinery sharing by farmers or contractors or agricultural economic organisations) to reduce the costs per hectare. IPM also relies on i.a. pest monitoring which requires to acquire knowledge on pest recognition or the deployment of centralised services dor pest control, the use of treatment thresholds (if available) and management and many other activities.

Similarly, the level of uptake and the potential of adopting IPM measures varies according to the characteristics of the crop. The different applicability of IPM practices across crops translates into a different potential reduction of pesticides. Such characteristics can be intrinsic to the crop (e.g. genetics, availability of varieties resistant to specific pests and diseases) as well as external (e.g. high gross margin). The methods of cultivation and the different marketing channels also play an important role on the adoption of IPM practices. For instance, cultivation of crops in protected environment (e.g. greenhouses) allows the adoption of biological control techniques or climate regulation that wouldn't be effective in open field.

Another element to consider when assessing the suitability of the crops to be managed with IPM techniques is the environment in which they are cultivated. In some territorial contexts, agricultural operations using chemical products can be replaced by mechanical means (e.g. mechanical weed management dependent on crop, soil type, precipitation, and landscape features).

The Pilot Project concludes that **implementing IPM does not lead to a significant yield reduction short term under optimal regional conditions and low pest pressure**. Such potential reduction is not particularly linked to a given crop, climatic conditions, nor the availability of alternatives. When observed such reduction, leading to an economic loss, may be (partly) compensated by a reduction of costs regarding pesticides application. **However, robust historical data over a sufficient long period is clearly lacking**.

In addition, using chemical pesticides without considering the IPM intervention hierarchy is easier adding to the flexibility of the farmer. When implementing IPM, the production systems become more complex and with more management operations when chemical PPPs are reduced. The latter will increase the risk while the economic gain for individual farmers is unclear. Therefore, this **perception of increased risk is a significant barrier for farmers for implementing IPM and reducing chemical pesticide use**: are farmers ready to support such risk under such unpredictable situation?

While there are links between the level of IPM measures uptake and farmers' characteristics, a variety of factors act together in influencing agricultural practices used. The Pilot Project identified tendencies indicating that the age and level of education of farmers may indeed have a potential effect on the level of uptake of IPM measures. These factors may affect the farmers' attitudes towards innovation and sustainability, which are both key for IPM adoption. However, there are various factors acting together, including for example characteristics of the farm, of the sector, as well as the level of interest, knowledge, and experience of the farmer. Therefore, looking at one factor in isolation, such as age or level of education of the farmers, is not sufficient.

The same applies to whether there is a difference between full-time and part-time farmers as regards IPM uptake. The Pilot Project enabled the identification of several aspects to consider in this context such as time availability, financial capacity, long-term planning and risk-taking. On the one hand, it can be argued that full-time farmers would therefore be more likely to have a better IPM uptake as farming is their main activity to which they allocate an important amount of time and effort. On the other hand, part-time farmers may be more prone to e.g. risk-taking as their income is not solely dependent on the farming activities whereas on the other hand, their expertise can also be lower, or they depend on contractors conducting the management operations. Of course, this will depend on the other income of the part-time farmer, and thus also here a number of factors need to be accounted for.

Collective approaches promote farmers' learning about and uptake of better pest management practices (including IPM). Generally, IPM is more effective at landscape or production area levels (e.g. pest monitoring shall be done at production area level). Operational programmes set up by producers' organisations might be a useful tool to foster reduction of pesticide use dependency. The interviewed stakeholders suggested several actions that can be undertaken in a collective form and outlined the potential of cooperation to improve the effectiveness of collective farming practices. A relevant support to collective actions can be provided by the implementation of operational programmes by producers' organisations. **Collective approaches seem to increase the effectiveness of pesticides action plans,** reducing costs and allows for extending the benefits of reduced pesticide use at regional scale, whereas pest management is more effective at cooperative level than at single-farm scale. Also, **collective actions appear to have an effect on the farmers' behaviour**, i.e., the single farmer's decision of whether to adopt alternative practices can be more influenced by those around the farmer than by farmer's characteristics.

Much of the benefit from collective action and cooperation beyond its positive effects on pest management on a landscape level is linked to increased learning processes and knowledge exchange. Such processes can include **learning actions to reduce the use of pesticides, such as the implementation of novel techniques and innovative technologies.** However, the scientific literature on the specific case of pest management learning processes is still poor, though growing. Further, **such cooperation might allow sharing of costs and risks of investments in novel machinery and equipment** beneficial for the implementation of IPM.

Agricultural cooperatives and certification labels constitute the most relevant marketing initiatives promoting reduced pesticides' use, although adoption of IPM practices, cooperation and exchange of information varies significantly among sectors.

Agricultural cooperatives play an important role in improving agricultural sustainability helping farmers to adopt novel technologies. Beyond the role of cooperatives, certification labels also constitute marketing initiatives that can foster the reduction of pesticide use. A great wealth of certification labels linked to reduced use of pesticides exist (e.g. Prodi, LMR, SNQ, VVAK, Global GAP etc..) both at EU and national level; yet, they do not have the same visibility as the organic label.

Farmers' awareness and knowledge on pesticides and alternative products varies significantly among sectors. IPM is knowledge intensive, and farmers do not always have means to access such knowledge.

Stakeholders agree that farmers know the products they use, and they have at their disposal the instruments to acquire knowledge about pesticides, based to the availability of national databases of products, apps, websites and magazines and other promotional material. Nonetheless, the Pilot Project suggest that farmers specialised in crop production manifest a bigger awareness on alternative products typologies and application as compared to farmers whose main activity revolves around livestock production and which grow crops as a secondary activity.

Further training and demonstrations on the use of alternative products are key because the lack of farmers' specific knowledge on commercial product and dosage. In this context, independent advisory services, associations, promotion campaigns, and training are fundamental to filling this specific knowledge gap. The German case study provides a successful example of "IPM demonstration farms" to speed up knowledge transfer to farmers and exchange between growers, advisors, and researchers. The DEPHY network, part of the Ecophyto programme in France, is another key example on how to build and disseminate knowledge The experience demonstrated that, depending on the crop and regional conditions, it is possible to reduce pesticide risk and use in case-specific approaches, and that state advisory services are essential for the uptake of IPM at field level.

Knowledge transfer takes place within Member States through pest monitoring networks, agricultural advisors and farm networks.

Pest monitoring systems and decision support systems are available in the large majority of Member States. Most of them aim to monitor economically relevant pests and diseases on the major crops, while there is less on weeds since this is more complicated to monitor. The intensity of activities and types of actors involved is variable across Member States. However, several NCAs reported that a trend to reduce budgets for pest monitoring and prognosis systems is observed, and in Hungary the national forecast network was terminated due to lack of resources. European initiatives such as the project IPM Decisions aim to counteract such developments and provide access to a large variety of decision support systems.

Agricultural advisors and extension services play an important role in providing advice on crop protection and agronomic practices. Again, the set-up varies between Member States. For example, in Germany, there exist independent official state advisory services, while in some other countries, they have been privatised. Furthermore, private advisory services exist, as well as retailers of pesticide producers that also offer advice. In the case of retailers or agricultural dealers, the independency of the advice may be questioned. Several Member States have established rules or policy measures aiming at separating advisory services from sales of pesticides. In France, a law was introduced in 2021 to separate sales of pesticides from advice. The first major observation on the impact of the measure shows that the large majority of pesticides distributors and retailers (>90%) have decided to keep their sale activities and cease their advisory activities.

Another initiative that has shown to be successful as regards knowledge transfer at farm level, is the set-up of farm networks. The case studies on the DEPHY network in France and farm networks in Germany provide examples of good practice. Also, the case study on wine in the Douro region in Portugal provides an example of a strong network, as well as important links between research and the field. Another valuable example is the H2020 project IPMWORKS which is the first example of a Pan-European network.

From an economic perspective, the key driving force of pesticides' risk and use reduction falls at the crossroad between the availability of alternatives and the balance between alternatives and conventional pesticides' prices and their economic risks.

Pesticide use reduction can be achieved if there are viable alternatives available on the market which show similar degrees of effectiveness as compared to conventional products. The development of new alternatives and technologies, as well as the reduction of their prices, might drive further implementation of IPM measures. An important economic driver is represented by the set of subsidies in place, whose amount and setting may likely evolve in future.

Pressure from civil society, is a key potential drivers of pesticide use reduction. Although not direct purchasers or users of pesticides, civil society can influence pesticide use patterns. This role can be expressed either through higher willingness to pay for more sustainable products, thus influencing market patterns, or through pressure onto the political debate and decision-making. However, there are potential constraints to the driving role of consumers, notably linked to the product price (key factor in purchase behaviour and consumer demand) and the quality, type and amount of information reaching consumers and citizens. In fact, albeit a general interest among consumers in reducing pesticide use.

Results of the pilot projects suggest that consumers awareness of IPM remains jeopardised and lower as compared to awareness of organic management. Better labelling, communication and education (including schools) may be useful strategy to improve consumers' knowledge about IPM and its role in reducing dependency on pesticides use.

Digitalisation might also be a driver of pesticides' reduction, as it can increase the diffusion of information and knowledge across consumers and producers. Accordingly, recent research suggests digitalisation-induced changes in, for example, farmer-advisor relation and knowledge exchange. This is highly relevant in the context of increasing farmers' knowledge and skills, which is clearly a driver of pesticide use reduction. Yet, little is known about the actual impact of digital technologies on the use of pesticides.

Taxation systems and tools such as the polluter pays principle might help drive pesticides' use towards less-dependent patterns, however their practical application results challenging.

Examples of taxation systems also include the opportunity to differentiate VAT for PPP based on risk level, the application of the polluter pays principle and the introduction of the "*name&shame*" principle.

However, one of the main argumentations stakeholders bring forward regarding such tools is related to the fact that farmers' demand (and use) for pesticides would not be significantly affected by the application of such systems, as (effective) alternatives are still scarce and are rather knowledge intensive. As a result, the expected impact of taxation systems in reducing dependency from pesticides remains unclear.

With respect to the polluter pays principle, stakeholders suggest that it might lead to higher costs of production that, in turn, might lead either to reduced farmers' income, or higher selling prices to pay by consumers. As a result, opinions on the feasibility and potential implementation of the polluter-pays principle are divergent. Lastly, a clear definition of the "polluter" (i.e. the pesticide producer or user) is a necessary pre-condition and likely stands at the core of the polluter-pays principle.

Leveraging on synergies between reducing pesticides use and pursuing other goals such as nutrient management, soil conservation etc. can support the design of policy that can achieve different goals simultaneously and with enhanced results.

With respect to soil conservation, numerous soil conservation practices have proven to generally have positive effects on pest pressure and reduction of pesticide needs. However, examples of negative effects can be observed as well, e.g. difficulties to replace chemical weeding with mechanical systems when implementing a minimum/no-tillage soil management systems.

Synergies can also be identified in the ambitions of the F2F targets related to both reduction of pesticides use and reduction of nutrient losses, the latter ultimately leading to reduce fertilisers use. These synergies have been already highlighted among the technical solutions identified in the European Green Deal to achieve climate, environment and health targets and goals. One opportunity to do so is represented by digital and precision farming, i.e the use of new tools combined with real time data and smart farming application methods.

Theme 3: Assessment of how public policies, private certification schemes, and other strategies are contributing to the reduction of the dependency on pesticide use

The different level of implementation of IPM practice depends on several factors of legal, behavioural, environmental nature as well as different degree of knowledge and resources.

Research, including the findings from the Pilot Project, suggests that there are notable differences in the degree of implementation of IPM across Member States of the EU. It seems that a significant percentage of farmers is not applying the intervention hierarchy that should be required under IPM, where chemical pesticides should only be used as a last resort. For instance, seed treatments are frequently applied. Differences in the interpretation of legal requirements, differences in agricultural practices, climatic conditions, capacity constraints and vested interests are among the reasons research cites as explanatory factors for the variation in implementation.

Interviews performed in the scope of the country research for the Pilot Project support the findings of previous research. Policy and legal frameworks are key enablers for the implementation of IPM in Member States. The exact set-up can set positive or negative incentives for the implementation. An example of a policy framework supporting the uptake of IPM practices by farmers is given in the case study performed in Quebec, where policies to reduce pesticides use in the agricultural sector and to increase the adoption of IPM by farmers are in place since 1992.

A second factor considered as an important variable explaining the difference in implementation of IPM is capacity. Lack of capacity, knowledge, or resources in some Member States severely limits the ability of farmers in these countries to implement IPM measures. This, in turn, suggests that the availability of support measures and advisory services can play an important role, linking this factor back to the policy and legal framework.

In addition, tradition, environmental conditions, and the general willingness of farmers to implement IPM measures are yet other factors that might partly explain the difference in implementation across Member States.

The crucial role of authorities as regards IPM implementation or awareness mainly takes the form of information and dissemination measures; financial support; and regulatory instrument and control of compliance.

The role of national competent authorities in the EU Member States is crucial to promote the uptake of IPM and the awareness of the concept. The data collection activities conducted in the Pilot Project identified three different aspects related to the role of the NCAs in this context:

- Information and dissemination measures;
- Financial support; and
- Regulatory instrument and control of compliance.

Information and dissemination measures are useful for awareness raising and to achieve a change in mentality among farmers. Successful examples of this are training initiatives and demonstration farms, as well as various tools such as databases, warning systems, decision support systems, advice, and statistics provided by the authorities. While farmers are mostly concerned by these measures, also advisors and the general public are relevant. The case study on the German demonstration farms for IPM can be highlighted here, set up to enable knowledge transfer between grower, advisors and researchers.

Financial support to support the farmers in their transition towards a more sustainable farming systems has shown to be central. Such transition may imply certain risks including yield- or quality reduction, as well as additional costs. To encourage farmers efforts to make this transfer and to ensure a sufficient and stable income from crop production, it is important to provide them with financial support. Another aspect of this is the marketing of products from IPM cultivations which sometimes consist in both public subsidies for the production, as well as a price premium (as showed in the case study on IP-SUISSE and the pesticide-free wheat programme). This case study also highlights the key enabling role of food-supply chain actors in implementing durable and large-scale changes in current pest management practices.

Control of compliance is done differently in different MS and may consist in actual farm audits carried out by inspectors, self-assessments conducted by the farmers, or a combination of the two. In this context, the establishment and implementation of proper targets related to IPM is of high importance as this would make the control of compliance more effective, compared to the current situation.

Finally, the three categories of policy instruments outlined here should work together in order to ensure efficiency as regards IPM implementation and awareness.

Market preferences or public opinion may influence the reduction of dependency on pesticide use, however, only to a limited extent.

Public opinion can impact agricultural measures, even if only to a limited extent, due to e.g. the general public's limited awareness of IPM and various co-existing factors. Impact can be reached through two main channels – impact on the political debate and agenda via media (blogs, social media, articles) or representative key stakeholders such as NGOs, retailer or consumer organisations; or through consumers' behaviour and purchasing decisions.

There is a general and increasing interest among consumers for sustainable and healthy food, which is positive for the development of organic production but also for IPM production and cultivation. However, price remains a decisive factor and in many EU Member States it is only a small part of the population that buys these products. Another limiting factor is the consumer's preference for high quality products often with care for the esthetical appearance in addition to taste. Regarding IPM, difficulties related to marketing have been observed, linked to a limited understanding of these products as they are situated in between organic and conventional. Also, it is not always clear to the consumer what the different principles cover. This said, there are some successful examples of IPM products. One such example can be found in the case study on IP-SUISSE, a pesticide-free wheat production programme in Switzerland, where farmers in the programme substitute pesticides with a range of IPM practices.

Research has found that there is a willingness to pay (WTP) for reduced exposure to pesticide risk in general, and for organic products in particular, through purchase and consumption. However, it is unclear whether products complying with other certifications such as IPM, are recognised and valued by consumers. The lack of concrete targets and indicators related to IPM that can be marketed to consumers and the variety of principles may lead to confusion among consumers about what an IPM label implies and thus what they are paying for. Overall, the WTP depends on the purchasing power in each EU Member State and varies across demographic segments and with time. Furthermore, other factors such as brand, price and the type of product, play a role in affecting the consumers' purchasing decisions. Regarding the price premium, stakeholder consultation performed in the context of the Pilot Project showed that many stakeholders believe that producers are not sufficiently rewarded for their efforts and that the price premium does not always reach the farmer. This differs of course depending on the structure of the market and supply chain in the different EU Member States.

Contribution of the CAP to reducing the dependency on pesticide use. The consultation that took place during this Pilot Project leads to the conclusion that stakeholders consider that **CAP toolbox and instruments have been useful in promoting and support beyond the obligations the uptake of IPM by farmers but only to a limited extent.** Most of the comments were commenting the financing schemes and were not addressing the complementary tools supporting research, knowledge transfer and uptake of IPM by farmers and advisory/extension services (e.g. FAS). Member States have the obligation to provide advisory services to farmers through the Farm Advisory Services (FAS). Such tool should have the objective to be of great support to train farmers on IPM principles.

The **new CAP toolbox has been enriched by several tools that could help Member States to fund IPM uptake**, but this remains the decision of the Member States authorities to activate measures. At the time of drafting this report (January 2022), the Member States proposals were not yet publicly available.

Several public and private schemes target, among other management practices, a reduction in the use of pesticides.

Organic farming and zero pesticides are promising and have shown large-scale potential for reduction – in-between solutions (IPM labels) with reduced use are hard to market.

Private certification schemes promoting reduction of pesticide exist but are hard to market due to relatively low demand and awareness among consumers to the exception of the F&V sector.

The potential of private schemes in reducing pesticide use seems hindered by relatively low demand and awareness by consumers of management schemes other than the organic one. When it comes to private certification schemes, only a few schemes have been set up across Europe, mainly in specialty crops (F&V). In the French case study, for example, vegetable growers belonging with a producer organisation (AOP CERAFEL) have set-up a multi-year initiative to reduce dependency on pesticide based on the use of a “Zero pesticides” label. Besides, operative programmes might be functional to set up quality labels other than those at the EU level to add value based on the agro-environmental interventions undertaken.

While the consumers’ attitude to and WTP for organic food has been increasing until now, awareness of the merit of IPM as production system appears weaker among consumers. Communication of IPM is complex, also due to the varieties of principles covered by IPM. Other peculiar schemes, such as mountainous farming, show a weak link with reduced use of pesticides, and the diffusion of these schemes is limited to farms in mountainous areas (less pesticide dependent) and belongs to individual stakeholders.

Theme 4: Strategies on how to scale up IPM knowledge and good practices throughout the EU

While the role of independent advisory services can be considered important regarding the reduction of pesticide use, the set-up and types of advisors vary significantly across Member States, as well as their presence at regional level.

The analysis of the in-depth interviews conducted in the project indicate that the extent to which independent advisory services are present at regional level is very diverse from Member State to Member State. However, it is clear that in many Member States there is limited presence of advisory services. These services should support farmers and encourage change by giving advice that is impartial, trusted, simple and farm tailored.

There are many types of advisors (public sector, research institutes, farmer-based organisations, and private sector), with different roles and needs. Between Member States, the distribution of the different types of advisors also differs. These actors can be independent or non-independent, both playing an important role in IPM adoption, however, the concept and level of independency must be further discussed.

Several initiatives exist aiming to build networks of advisors across Member States, however, language remains a barrier to knowledge transfer in some countries, as well as the importance of adapting IPM practices to local conditions.

Many initiatives and projects have been building and connecting the network of advisors across the EU, such as the EIP-AGRI, the EUFRAS and SEASN associations and projects like I2connect and Agrilink. The BTSF programmes also provides training and support in this field.

Collaborations between MS and their advisory services were also mentioned as a strategy that has been developing the network of advisors and the AKIS systems in the EU.

Language is still considered a barrier to what concerns the networking and transfer of knowledge between MS. Knowledge exchange is also limited by the fact that the tools, methods, and resources applied in each MS may not be applicable throughout the EU, since advice should be locally adapted, in particular in the topic of IPM.

A lot of information is being produced and disseminated by these projects, but there is a lack of comprehensive information in a single database, which causes the information to be scattered across websites, social media and other platforms.

About 40% of stakeholders interviewed could not identify relevant projects and initiatives related to this topic, which may indicate that the dissemination of these projects is not reaching a large majority of stakeholders involved in the topic or can be a consequence of the stakeholders targeted in these interviews.

EU related projects seem to be working well in scaling up good practices throughout Europe, however, this is not happening equally in all MS, as many stakeholders have no knowledge of such projects. The strategy of dissemination and communication of the projects and their results has been in continuous improvement, with projects that focus on thematic demonstration networks, and on the farmer, therefore reaching more farmers and being more efficient in promoting IPM.

A lot of platforms have been created to promote knowledge exchange on IPM, at different levels (European, National and local levels) and by different types of stakeholders (advisory services, research institutes, H2020 projects, etc.). European and World associations and organisations are also mentioned as "Platforms" for knowledge transfer. Such platforms must be able to develop a better link between research and farmers/advisors, translating scientific knowledge into farm practices. There is a need for building synergies between platforms to enhance the transfer of knowledge and to prevent information and tools from being scattered. A platform easily found, using national languages and with open access would also reach a wider audience of farmers and other key stakeholders, while also enhancing the cooperation between MS.

Potential tools aiming at transferring knowledge across MS were identified, however, further integrating and coordinating information and tools from different resources could lead to a usable tool reaching more farmers.

Some tools have been developed with the aim of transferring knowledge on the topic of IPM. This goes from GO projects, H2020 projects, European level organisations to more locally developed tools, for example by National plant health services.

As in other topics, most stakeholders interviewed could not identify relevant tools. However, national guidelines, toolboxes from European projects, round tables and collaborations between universities, advisory services and other players were stated as relevant tools for knowledge transfer across the EU.

In order to reach more farmers and enhance the transfer of knowledge across MS there is a need for integrating information and tools from EU projects, national and local resources, therefore having a relevant and useable tool at the local level.

CAP instruments were considered relevant for advisory services and knowledge exchange (as NSPs were under development at the time of the Pilot Project, a full analysis of the new CAP could not be conducted).

CAP instruments are considered relevant for the development of advisory services and knowledge exchange; however, it is not possible to make a clear analysis of how these instruments can be implemented to effectively reduce dependency on pesticide use because the NSP were still under development at the time of the analysis.

Knowledge from both types of agriculture (conventional and organic) should be integrated as both sides have much to learn from each other, however, some barriers were identified, for example the fact that IPM is not so well recognised because it does not have consumer recognition or a certification system.

The interviewees mention instruments such as an education system with emphasis on cooperation through trainings, workshops, round tables between the stakeholders from different backgrounds (conventional and organic), model farms and practical demonstrations with direct knowledge transfer from farmers with experience. Other instruments such as subsidies to specific measures like mechanical weed control are also mentioned.

Overall conclusions - barriers and drivers linked to IPM uptake

The Pilot Project allowed to identify a series of key barriers and drivers to the full/optimal exploitation of the IPM techniques which will, in turn, lead to reduction of dependency from pesticide use.

Key drivers	Key barriers
Pressure from civil society and **policy developments** promote and drive transitions to more sustainable agriculture. Pesticide use has become a topic of the societal debate and civil society may act as a driver through e.g. putting pressure on the political debate and policymaking and/or through consumers' choice contributing to a re-orientation of the market. **Collective actions** increase the effectiveness of pesticides action plans, reducing costs and allows for extending the benefits of reduced pesticide use at regional scale, whereas pest management is more effective at cooperative level than at single-farm scale. Also, collective actions appear to have an effect on the farmers' behaviour, e.g. by incentivising farmers to adopt alternative practices by mirroring other virtuous farmers. **R&D efforts have a significant potential** in developing new methodologies, models and equipment, as well as in creating knowledge and innovations covering a large number of crops. Some areas of focus include knowledge on pest biology, improved methodologies on pest monitoring, prediction models, and the development of new farming models. Moreover, industry has to further invest in biopesticides, new farming equipment, robotisation, and digitalisation. **The presence of a dense network of independent advisory services** is a key driver in IPM uptake as knowledge needs to be communicated to producers.	**Lack of availability of alternatives to conventional practices.** Promising alternative solutions (biopesticides, techniques and technologies) may exist but are often still at development level. Moreover, the effectiveness of such alternatives is generally lower as compared to conventional products. This results in an additional effort by the farmers that need to combine several techniques, thus requiring advanced know-how. **The regulatory framework for placing alternative products on the market remains too cumbersome.** Time for registration continues to increase. **Economic risks of substitutes vs. chemical pesticides**. Cost for implementation for several of these techniques remains high, also in the view of the combined applications of IPM techniques, as mentioned above. Collective purchases of equipment or contract solutions may be an option to tackle those costs. **Potential lacking (market) compensation for farmers to change practices** (towards more costly/risky) – IPM certifications hard to market. Need to establish new supply chains to cope with longer crop rotations.

Key drivers	Key barriers
The development of certification labels and private schemes developed by agricultural economic organisations boots the reduction to the dependency of pesticide use even if such developments are, for the time being, mainly limited to the F&V sector. **Policies need to play the role of "sticks and carrots"** to allow a smooth transition to IPM. Effective and efficient policies require a better understanding of farmer decision-making processes. **Promotion campaigns and training** are fundamental to filling this specific knowledge gap and boost the uptake of on-farm IPM practices. **Generational renewal** shall be used as a lever to change cropping practices towards a more sustainable agriculture in the EU. **Taxation systems** may be effective if they are precise and support a specific policy (e.g. risk reduction) and at the same time generate budget which enables farmers to switch to other practices or alternatives. Taxation system also requires the availability of alternative methods and measures.	**Lack of knowledge among farmers and uncertainty about effectiveness and efficiency of substitutes** among farmers can hamper the uptake of IPM practices by farmer, thus potentially slowing down the process of reducing pesticide use dependency. IPM is more knowledge-intensive than crop protection based on the use of chemical pesticides and many farmers do not have this knowledge nor do they have access to advisor who have it. In many cases alternatives, such as biological control agents, are host specific, require exact timing and specific conditions for their application. **The difficulties in estimating the long-term societal and environmental costs** of pesticides use limit the development of IPM uptake as the long-term risks of pesticide use are not well known (nor anticipated) nor have the long-term effects of IPM on the control of diseases, pests and weeds been widely studied, i.e. there is a lack of documentation of the long term effects/impacts of IPM on sustainability components.

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KF-08-22-240-EN-N

Publications Office
of the European Union

DOI: 10.2762/457165
ISBN: 978-92-76-53692-5