IPM Decisions

Final Report

Abstract

Crop protection and pest control are major economic concerns throughout Europe. Current decision support systems (DSSs) for farmers provide limited advice mainly because they are region-specific and pest control solutions lack adequate assessment for safety and efficacy. The EU-funded IPM Decisions project intends to create a new and improved DSS integrated with data, tools and resources via a European-wide online platform. Platform users will form an Integrated Pest Management Decisions Network that will include growers, consultants, researchers and agricultural organisations who will develop and disseminate up-to-date solutions for pest management. The project will have a tremendous impact across Europe by improving pest control efficiency and securing better economic returns in agriculture.

June 2019 – May 2024

ipmdecisions@adas.co.uk

Horizon 2020

This project received funding from the European Union Horizon 2020 Research and Innovation programme, under grant agreement number 817617. Views expressed are those of the authors only, and do not necessarily represent those of the European Union or European commission. Neither the European Union nor the European Commission can be held responsible for them.

IPM Decisions

Final Report

Grant agreement number: 817617

Start date of project:	01/06/2019	**End date of project:**	31/05/2024
Deliverable due date:	31/05/2024	**Date of delivery:**	05/07/2024
Classification:	Public		

List of Authors

Company	Author	Contribution
ADAS	Mark Ramsden	Lead author, WP7 content lead
ADAS	Neil Paveley	Contributor
ADAS	Dave Skirvin	WP3 content lead
ADAS	Charles Ffoulkes	WP1 content lead
NIBIO	Berit Nordskog	WP2 content lead
NIBIO	Tor-Einar Skog	WP2 contributor
AU	Niels Holst	WP4 content lead
AU	Lise Nistrup Jorgensen	WP4 contributor
BSB	Nikos Georgantzis	WP5 content lead
Delphy	Harm Brinks	WP6 content lead
SLU	Bjorn Andersson	WP6 contributor
AUA	Ilias Travlos	WP6 contributor

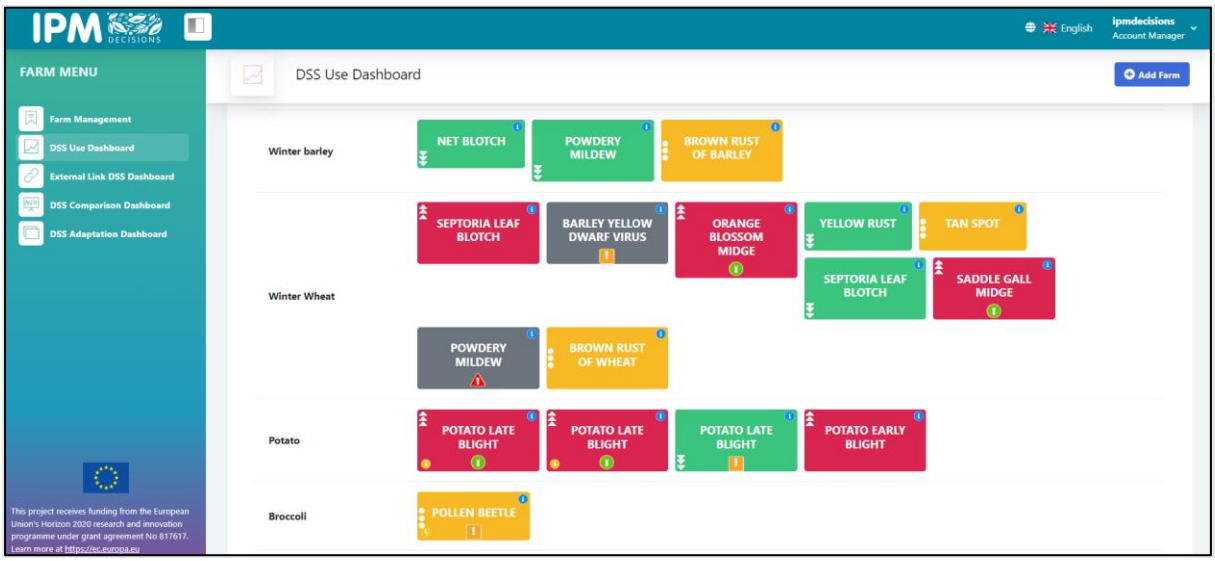
How to quote this document:
Ramsden M.W. et al. (2024). *IPM Decisions – Final report. Deliverable 7.14 of the Horizon 2020 project IPM Decisions (GA number 817617)*, published on the project web site on (2024): (https://www.ipmdecisions.net/documents/?type=deliverables)

Contents

Public Summary

The IPM Decisions project has increased the impact of decision support systems for integrated pest management, through the launch of an open access online IPM Decision Platform https://www.platform.ipmdecisions.net/ and associated resources. Supporting activities have helped quantify the benefits of IPM DSS consultation and identified the barriers and incentives to uptake. Resources have been created to foster DSS innovation, enabling DSS comparison, adaptation, creation, and integration between platforms.

Longevity of the platform has been secured by making the source code open access and lowering the entry threshold for researchers and developers to make their systems accessible to farmers, advisors and other stakeholders.



Executive Summary

Decision Support Systems (DSS) are valuable resources for farmers and advisors looking to advance their holistic IPM strategies. DSS include simple treatment thresholds, pest risk models driven by weather variables and systems which account for a combination of risk factors. The scope of the platform includes DSS for invertebrate pests, weeds and plant pathogens of all outdoor crops in Europe. The IPM Decisions project did not develop new DSS, it is providing a platform for delivery of DSS and providing resources to enable development and testing of new DSS. Three dashboards are supported in the platform, for specific user groups:

- 'Use Dashboard' – enables farmers and advisers to find and run IPM DSS relevant to their crops and pest pressures.
- 'Comparison Dashboard' – enables comparisons of risk outputs from two or more DSS.
- 'Adaptation Dashboard' – enables researchers and DSS providers to change the internal parameters of public domain models, to adapt them to their local circumstances.

Developers can integrate their DSS with the IPM Decisions platform or can consume climate data and/or DSS models through Application Programming Interfaces (APIs).

- **Full integration:** The DSS would be accessed by farmers and advisers, free of charge, through the Platform user interface. The risk algorithms would be either embedded into the Platform or the DSS would be developed to comply with the data standards of the Platform. The DSS developer does not therefore need to create a user interface and the Platform provides direct access to users.
- **Partial integration:** DSS providers wishing their system to be seen by a wider audience, would provide IPM Decisions Platform users with access to simplified pest risk information (e.g. regional level risk predictions), through an API. Users who are interested in accessing the full functions of a DSS would then be directed to developer's own DSS interface through a link.
- **Service consumer:** Established DSS which are delivered to farmers and advisers through the DSS developer's own user interface, can use resources (such as European weather data) from the Platform as input data, via an API or web service.
- **Click through link:** Farmers and advisers can click on a link in the Platform to access the DSS through the DSS provider's own web site and pay wall. The links will be context sensitive, so will be visible to farmers and advisers in a dedicate 'DSS Links' dashboard.

IPM Decisions project outputs

- The IPM Decisions Platform (https://www.platform.ipmdecisions.net/) was launched across Europe, fulfilling the original vision for the project. The platform provides:
  - Dynamic open access IPM Decisions Risk Maps
  - Farm Management area – for adding Farm locations and selecting DSS.
  - DSS Use Dashboard – for consulting selected DSS.
  - External Link DSS Dashboard – for selecting and linking to third party DSS sites.
  - DSS Comparison Dashboard – for comparing outputs from up to 5 DSS or comparing a DSS with previous year outputs.
  - DSS Adaptation Dashboard – for adapting some parameters of existing DSS.
- More than 50 DSS for priority pests have been integrated into the Platform.
- Plans have been developed for Platform longevity beyond the end of the project.
- A dedicated Weather Service API has been created, providing sufficient information for a client to be able to connect to and get information from a range of weather data sources, in order to run IPM DSS integrated into the IPM Decisions Platform.
  - *Weather service source code: https://github.com/H2020-IPM-Decisions/DSSService*
- A dedicated DSS Service API has also been created, enabling external exploitation of select DSS integrated with the IPM Decisions Platform.
  - *DSS Service source code: https://github.com/H2020-IPM-Decisions/WeatherService*
- An online tool, IPM DSS Metadata file editor, has been developed to support integration of IPM DSS with the IPM Decisions Platform.
- A DSS Factory has been created, to support innovation and application of updated and novel systems across Europe.
- Methods have been developed for evaluating the value and impact of IPM DSS.
- Seven pest and climate observation data sets have been made freely available for reuse.
- Several open access publications demonstrating the validity of IPM DSS have been supported.
- Assessment of the impact of increased uptake of DSS in Europe show significant potential for reducing pesticide inputs while maintaining profit margins.
- The main identified barriers to the adoption of DSS for all farmers in Europe were the lack of trust in DSS and the feeling that they lack the knowledge to use such systems.
- The main barrier identified among farm advisors across Europe was poor access to marketing information about DSS.
- A typology for user-specific selection of DSS for IPM in Europe has been created, and used to develop freely accessible online tool called IPM Adviser (https://ipmadviser.ijs.si/) was launched in 2024, supporting users in finding appropriate IPM DSS.
- Three rounds of multi-actor workshops were completed between Dec 2019 and March 2022. These took place across 12 countries, engaging with over 700 participants.
- Stakeholder engagement across Europe helped prioritise key crop:pest combinations where decision support would be valuable (Table 3.3).
- IPM Decisions jointly coordinated two international Conferences in Brussels: the FarmDemo Conference in 2022 and the IPM Conference in 2024.

1 Introduction

The IPM Decisions has delivered a pan-European on-line platform for integrated pest management (IPM) decision support systems (DSS). It was funded under SOCIETAL CHALLENGES – Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy, in response to the call to H2020-SFS-2018-2; Stepping up integrated pest management (Part A)[1]. As part of the Farm to Fork Strategy, there are two non-legally binding pesticide reduction targets, namely a 50% reduction in the use and risk of chemical pesticides and a 50% reduction in the use of more hazardous pesticides. The Commission will continue to publish each year updates on progress at EU level towards these Farm to Fork pesticide reduction targets.

Farming must address the key challenge of increasing production of affordable food to meet global demand, whilst minimising environmental impacts. Crops affected by invertebrate pests, weeds or diseases (collectively 'pests') are less productive and plant protection products pose an environmental hazard. IPM Decisions has accelerated uptake of farm Decision Support Systems (DSS) to achieve impacts aligned with the principles of Integrated Pest Management (IPM). The project aim and objectives were:

Project Aim: Increase the impact of decision support systems for integrated pest management.

Objective 1: Increase user access to, and uptake of, IPM DSS.

Objective 2: Quantify the benefits of using DSS.

Objective 3: Foster DSS innovation through the Platform, to secure longevity of impact.

Our Vision

No pesticide wasted, through optimal pest management and targeting of treatments.

Our Mission

Provide the agricultural community with easy access to services, tools and resources that support and promote holistic integrated pest management.

Our Purpose

Increase user access to, and uptake of, IPM services, tools and resources.

Through maintenance and growth of the IPM Decisions Platform and integration of IPM DSS and data.

Quantify and promote the benefits of using IPM DSS and related services, tools and resources.

Promoting the Platform and associated resources within target communities.

Foster innovation to secure adaptive growth.

Engage with the agricultural community to ensure the Platform and associate resources and data remain accessible, transparent, relevant, and trustworthy. Supporting further research and development of new products and services.

[1] European Commission Horizon 2020 call: Stepping up IPM

IPM decision support can play a key role in reducing the need for treatment with plant protection products (PPPs) and targeting treatment according to need; thus reducing the use and risk of PPP under the Farm to Fork strategy. Reducing pesticide use requires both a reduction in need for pesticides (through non-chemical practices) and that pesticide treatments are applied according to the reduced need. Our sister project 'IPMWORKS' (101000339) addressed Part B of the call for 'Stepping Up IPM' and focused predominantly on reducing the need for pesticides. 'IPM Decisions' focused on ensuring treatment is according to need. The resulting IPM Decisions platform is designed to deliver a diverse range of DSS, including simple treatment thresholds, pest risk models driven by weather variables, and systems which account for a combination of risk factors. The scope of the platform includes DSS for invertebrate pests, weeds and pathogens (referred to collectively as 'pests') of all outdoor crops in Europe. The project did not develop new DSS, rather it created a platform for delivery of DSS and providing resources to enable development and testing of new DSS.

There are some strong examples of IPM DSS being widely used in some countries, but on-farm uptake is far from universal. Key constraints on IPM DSS uptake are listing in Table 1.1, along with how the IPM Decisions platform was designed to address these limitations:

Table 1.1 Key constraints on IPM DSS uptake, and project response to address them.

Constraint on IPM DSS uptake	How IPM Decisions is addressing the constraint
Unaware of available DSS	Creating single marketplace platform
DSS are not user friendly	Bespoke dashboards for each type of user
Benefits of DSS are unclear	Quantifying benefits
DSS are insufficiently risk-averse	Presenting supporting data
DSS do not reflect multi-pest pressures	Enabling new DSS and combinations of DSS
Unwilling to trust DSS outputs	Presenting supporting information
Lack of support in using DSS	Creating an IPM Decisions Network

1.1 IPM Decisions Consortium

The IPM Decisions consortium brought together renowned leaders in their fields with a mix of multidisciplinary interests and expertise to deliver the project objectives Figure 1.1. The balance between public sector and industry participants provided a strong 'route to market' for open-access and commercial DSS.

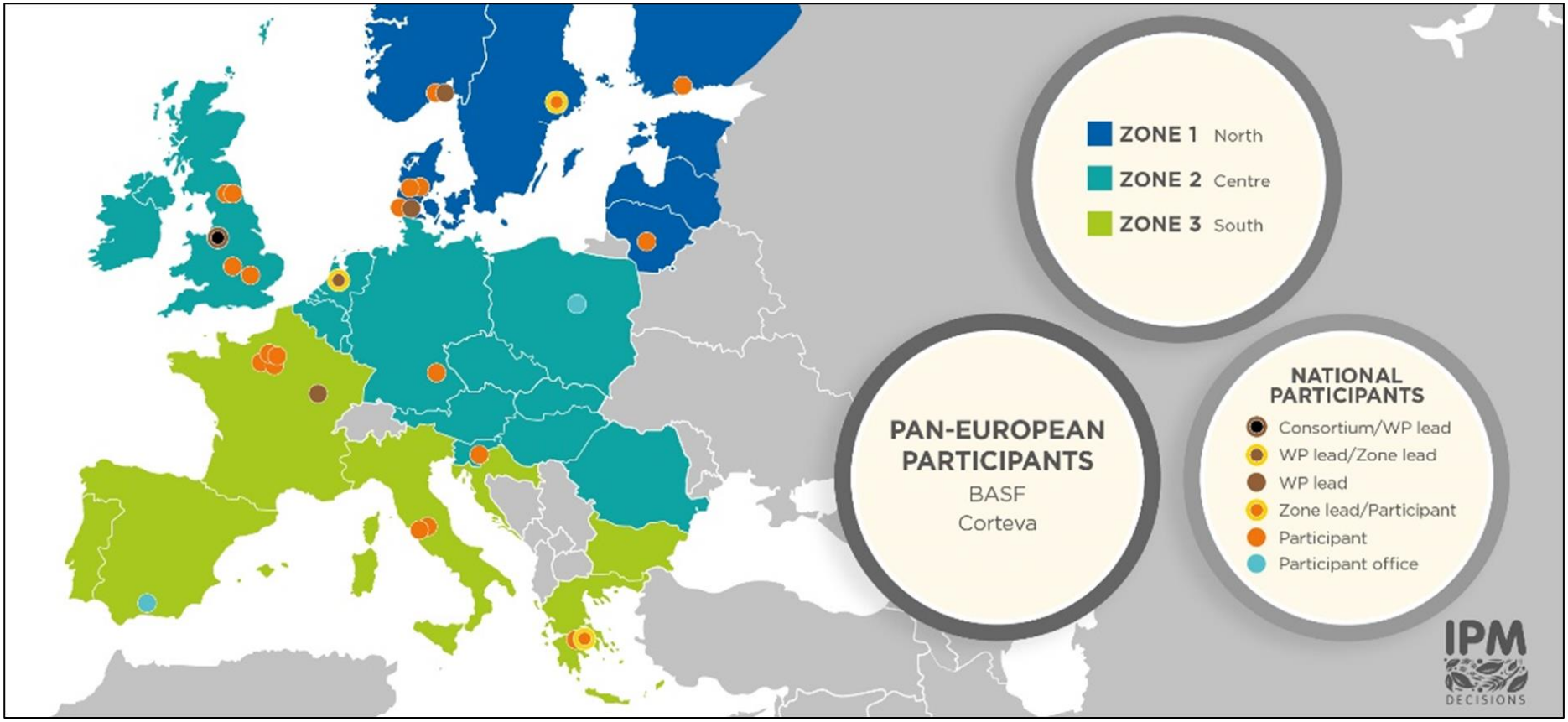


Figure 1.1 The distribution of consortium participants across Europe.

#	Participant organisation (short name)	Expertise relevant to IPM and decision support
1	RSK ADAS Ltd (**ADAS**)	Applied research in IPM and DSS development, and stakeholder networks
2	Aarhus University (**AU**)	Strategic/applied research in sustainable pest management and DSS development
3	Agricultural and Horticultural Development Board (**AHDB**)	National industry levy organisation for knowledge transfer. Met. network and DSS provider
4	Agricultural University of Athens (**AUA**)	Basic/applied agricultural science research and knowledge transfer
5	Bavarian State Research Center for Agriculture (**LfL**)	Knowledge and service centre for agriculture. DSS provider
6	Burgundy School of Business (**BSB**)	Business school with expertise in applied social science in the agriculture sector
7	Perm. Assembly of the Chambers of Agriculture (**APCA**)	Farmer led organisation delivering technical advice and field demonstrations. DSS provider
8	Coldiretti (**Coldiretti**)	Farmer organisation to enhance the value of agriculture through innovation
9	DELPHY (**Delphy**)	Advisory services and technical innovation for agriculture.
10	Engineering – Ingegneria Informatica S.p.A. (**ENG**)	Software development and services, including for the agriculture and supply chain sectors
11	Jozefa Stefana International Postgraduate School (**MPS**)	Bridging research and industry: information technologies and knowledge-based applications
12	Lithuanian Research Centre for Agric. and For. (**LAMMC**)	Public institute for applied research and knowledge transfer. Advice and DSS provider
13	Natural Resources Institute Finland (**Luke**)	IPM research and integration of farm management software and DSS
14	National Institute of Agronomic Research (**INRA**)	Research and open-source software for models of plant/pest/pesticide interactions
15	IPM CONSULT (**IPM Consult**)	Develops and supplies online DSS for integrated weed management
16	The Norwegian Institute of Bioeconomy Research (**NIBIO**)	Research and development of DSS systems being integrated across Scandinavia/Baltic states
17	Norwegian Meteorological Institute (**MET Norway**)	National meteorological service, represented in international meteorological organisations
18	Rothamsted Research (**RRES**)	Agricultural research institute developing and delivering models and DSS
19	Swedish University of Agricultural Sciences (**SLU**)	Plant protection research, advice and DSS provider
20	SEGES (**SEGES**)*	National agricultural advisory organisation. Knowledge transfer and DSS provider
21	BASF Plc (**BASF**)	Multi-national plant protection products development, manufacture and stewardship
22	GAIA (**GAIA**)	Cooperative owned organisation delivering technical innovation, met. network and DSS
23	FERA Science Ltd (**FERA**)	Translational science, developing and delivering a suite of DSS
24	Health and Safety Executive (**HSE**)	National authority for pesticide regulation and implementation of SUD
25	CIRAD – Agricultural Research for Development (**CIRAD**)	Research for Mediterranean region, development of models, open-source software
26	Corteva Agriscience (**Corteva**) as Dow AgroScience	Multi-national plant protection products development, manufacture and stewardship
27	The Danish Environmental Protection Agency (**DEPA**)	National authority for pesticide regulation and implementation of SUD

**Replaced during the project by SEGES Innovation P/S*

1.2 Interactions between IPM Decisions and IPMWORKS

IPM Decisions and IPMWORKS are H2020 sister projects, both funded in the frame of the topic: SFS-06-2018-2020 - Stepping up integrated pest management.

In addition to IPM Decisions, the EC commissioned a complementary project 'IPM***WORKS***' to increase uptake of IPM. IPMWORKS set up on-farm IPM demonstrations across Europe, including in-field demonstrations of DSS in association with the IPM Decisions Platform. This substantially strengthen the practical impact from IPM Decisions. The leadership teams from the two projects worked together to maximise synergy. Common partners were included in the consortium, leading significant WPs to ensure consistency of the activities in both projects (ADAS, INRAE and DELPHY).

Project Title: An EU-wide farm network demonstrating and promoting cost-effective IPM strategies

Project Acronym: IPM*Works*

Grant Agreement number: 101000339

Coordinator: Nicolas Munier-Jolain, INRAE

Along with the promotion of organic farming, integrated pest management (IPM) is one of the tools for low-pesticide-input pest management. IPM is based on prevention and non-chemical control to enable reduced reliance on pesticides. This approach is tested by very few pioneer farmers throughout Europe; the majority of European farmers rely heavily on pesticides with major environmental and societal impacts. The EU-funded IPMWORKS project is promoting the adoption of IPM strategies. An EU-wide network of farmers progressing further in IPM practices will help to show other farmers the benefits of holistic IPM. They are demonstrating low reliance on pesticides with better pest control, reduced costs and enhanced profitability. The project is also organizing training and producing training material.

IPM Decisions and IPM***WORKS*** are complementary; IPM Decisions focusses on delivering IPM DSS through an online Platform, and engagement with a network of DSS users/stakeholders. IPM***WORKS*** focusses on field demonstration of IPM (i.e., holistic IPM, of which DSS is one component) through a network of farmers/advisers.

1.2.1 Long-term aims for interactions between the two projects.

The project coordinators and management executives of the two projects agreed aims for interactions between IPM Decisions and IPM***WORKS***. These aims focus on the challenging long-term task to make the Networks and the Platform from the two projects self-sustaining after the projects end.

1.2.2 Inter-project communication

- Management executives of the two projects remained distinct throughout the duration of both projects.
- Work package leaders in common across the projects were responsible for tactical information sharing and decisions across the two projects.
- Project coordinators (on behalf of their respective project management groups) interact on strategic decisions, where there are joint consequences.
- Both projects published a common article in Open Access Government (OAG) in May 2021 contributing to raise the awareness of EU policy makers on the significance of the adoption of IPM to reduce pesticide use in Europe, and the role of the digital tools and networks of Demo farms to support the general adoption of holistic IPM. Article available here: https://www.openaccessgovernment.org/integrated-pest-management/112485/
- Project coordinators and work package leaders were invited, as appropriate, to each other's annual project meetings, to give mutual updates on progress in each project.

1.2.3 Collaborations during the projects

- IPM***WORKS*** and IPM Decisions, together with NEFERTITI, an H2020 Farm Demo project, co-organised a Policy Dialogue event in Belgium on May 10 and a Farm Demo conference in Brussels on May 11 (see WP6 & WP7). The aim of these two co-organised events were both to showcase the Farm Demo network and the IPM Decisions platform, but also to kick-off the joint efforts to find practical and financial solutions able to support the long-term sustainability of both the IPM***WORKS*** network of Demo farms and the associated digital tools (IPM resource Toolbox and IPM Decisions platform.
- Following the success of the H2020 Farm Demo Conference, IPM***WORKS*** and IPM Decisions co-organised a further IPM Conference in Belgium on 14 May 2024.
- Several demonstrations and case studies have been conducted in IPM***WORKS*** on the use of IPM DSS. The IPM Decisions platform was demonstrated to the IPM***WORKS*** consortium.
- An API was created to link the IPM Decisions platform to the IPM***WORKS*** Toolbox, such that all DSS integrated into the IPM Decisions Platform are now described automatically as a Toolbox resource.
- The approach taken to estimate the impact of scaled up uptake of DSS across Europe was based on a meta-analysis of DSS use in IPM***WORKS***.

2 IPM Decisions – Approach

The Platform has been designed such that users engage with the Platform through dedicated Dashboards; a set of web pages each with a user-friendly graphical interface that allow the farmer and adviser users to select both the DSS that they wish to run, and the data to be used as input to the DSS. Depending on the specific DSS being used, the inputs could include, for example, meteorological data, and observations about the crop and pest density. The flow diagram below (Figure 2.1) illustrates the components of the Platform and their connections.

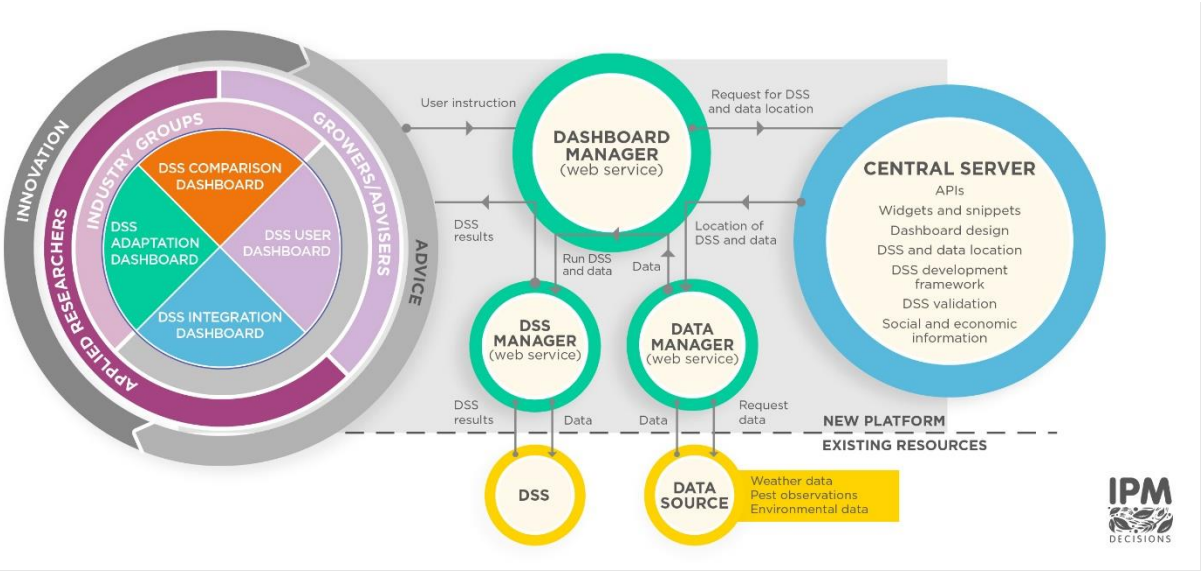


Figure 2.1 Overview of the IPM Decisions Platform.

2.1 Ensuring the platform will deliver what users need (WP 5 and 6)

Platform design was undertaken based on the experience of project partners in delivering online platforms and decision support systems, and an interactive feedback process with target end users through three rounds of stakeholder workshops across 12 countries in Europe. These stakeholder workshops also facilitated survey feedback forms, collecting data on the barriers and incentives to the uptake of IPM DSS. These stakeholder workshops and questionnaires confirmed that the constraints on DSS uptake identified in the proposal were widespread across Europe. Some key differences between potential users were also identified; differing by country and by type of user (farmers, adviser or researcher). Differences between users are being addressed by designing specific 'dashboards' for each user type, through which users will interact with the platform to obtain the services they need. For example, the farmer and adviser dashboard will provide a simple 'click and go' route to find and run IPM DSS to identify key pest risks to their crops. Regional differences in user needs are related to differences in major crops/pests and the degree of on-line skills. Key pests were addressed by prioritising DSS for integration on the platform for different zones across Europe. Ensuring accessibility was addressed during a second round of workshops, which obtained feedback from potential users on drafts of the dashboards.

Findings from stakeholder workshops and questionnaires in 2020, 2021, and 2022 fed back directly into software design of the platform and open access publications detail the findings.

The stakeholder workshops also acted as a foundation to the projects stakeholder network, which was expanded to including key influencers in the industry who could increase the impact of the project post-launch of the Platform. Engagement with other EU projects (particularly our sister-project IPM*WORKS*) identified and utilised synergies to increase joint impact.

2.2 Building the platform (WP 2 and 3)

A catalogue of IPM DSS (compiled in WP4) defined the inputs (e.g. weather variables and pest observations) and outputs (e.g. charts and text describing pest risk) which the platform software needed to support. Engagement with target end users shaped the platform specifications. Two aspects were agreed early in the project:

1) Four levels of interaction between DSS and the platform were defined to suit different types of DSS. These four levels range between full integration (where the users interact with the DSS through the dashboard interface of the platform) through to a simple link to an existing DSS website. Application programming interfaces (API) enable communications between the DSS and the platform.
2) The platform was intended to be open access and the ethos is that as many DSS as possible should also be open access. However, the DSS are not owned or operated by the project consortium, so the degree of access for each DSS is facilitated through the use of API, which do not require access to the underlying algorithms or data in order to provide services to users.

A process has been defined for DSS integration, from the point of agreement with a DSS provider, through to public release of the functioning DSS on the platform. Tasks and responsibilities have been defined for each step in the process. Prioritisation of DSS for integration was guided by what DSS are available and have DSS providers interested to engage with the platform, and by prioritisation of pests for different zones of Europe - based on a user survey.

2.3 Enabling testing and evaluation of the benefits of IPM DSS (WP 4)

Testing of DSS usually involves comparing predictions of pest risk against observational data of pest prevalence. However, predictive value does not necessarily translate into economic return and farmers are more likely to use a DSS if there is evidence for improved economics. Large losses for a low frequency of false negative predictions can outweigh many small gains from true predictions. Work package 4 developed methods for economic analysis of DSS and applied those methods to a set of contrasting pest/crop systems. To enable this analysis, data sets of pest observations were obtained across many sites and seasons. The work has explored the extent to which existing observational dataset of pest density (for example, from

efficacy field trials) can be used to evaluate the benefits of DSS. The work has shown that such data have limitations for such evaluations but have the advantage of being readily available and less costly than bespoke DSS testing experiments.

A statistical tool was developed to evaluate the quality of pest risk guidance from a given DSS. The tool is documented in a paper submitted to a peer-reviewed journal for open access publication: *A framework for evaluating the value of agricultural pest management decision support systems.* The likely impacts of widespread uptake of DSS on pesticide use were estimated for different sectors of European agriculture. The uncertainty around the estimates was substantial, due to gaps in observational data needed for parameter estimation. Nevertheless, the analysis indicated that potential impacts of DSS uptake would be substantial.

The socioeconomic impacts associated with the use of IPM DSS in wheat, potato, and grape production were evaluated. Our analysis shows that using IPM DSS can provide economic benefits for farmers by reducing the treatment frequency index, thus lowering overall cost of production and total pesticide usage.

2.4 Project management (WP 1 and 7)

The Project Management Executive (PME) provided communication between work packages (Figure 2.2); monitored risks, ensured ethical compliance (e.g. with GDPR), assessed the provenance of DSS, and tracked the schedule of project deliverables. The PME also coordinated communications with DSS providers interested to integrate their DSS on the platform. Terms and conditions have been created for users of the platform and DSS providers, focussing on issues of liability and confidentiality of data.

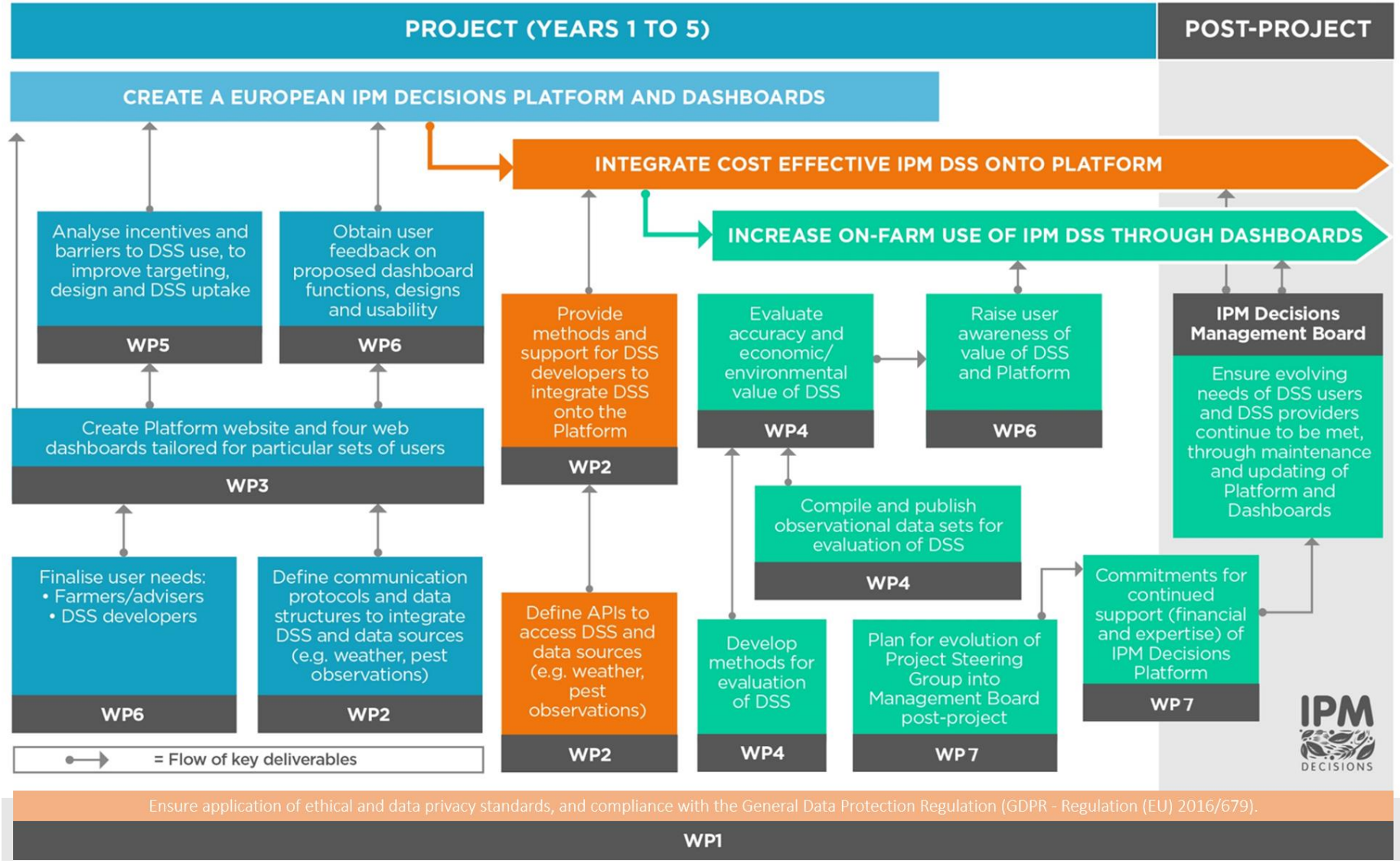


Figure 2.2 Schematic diagram showing key deliverables from work packages generating impact through the IPM Decisions Platform

3 IPM Decisions – Project Implementation

The IPM Decisions project consists of a consortium coordination and project management and ethics reporting work package (WP1&7), four research and technology work packages (WP2-WP5), and one dissemination and technology transfer work package (WP6) (Figure 3.1).

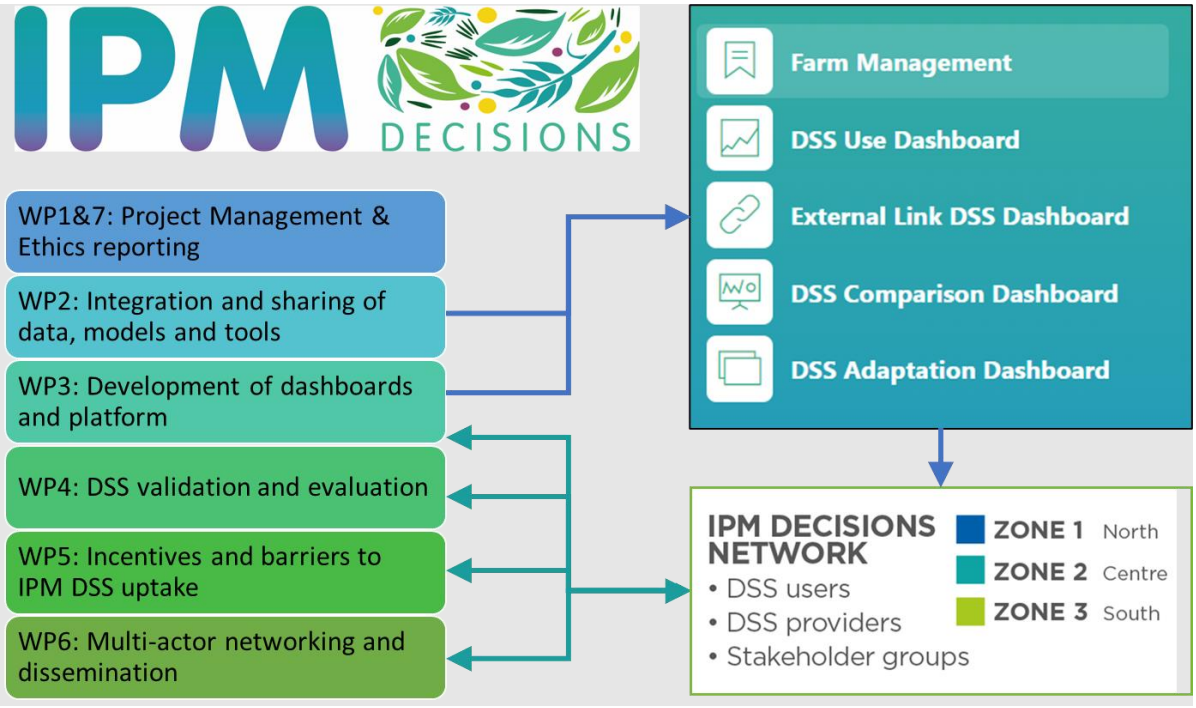


Figure 3.1 Interactions between the IPM Decisions work packages, the platform resources, and the associated IPM Decisions Network.

IPM Decisions Work Packages

WP1&7	Project Management and Ethics Reporting	ADAS
WP2	Integration and sharing of data, models and tools	NIBIO
WP3	Development of dashboards and platform	ADAS
WP4	DSS validation and evaluation	AU
WP5	Incentives and barriers to IPM DSS uptake	BSB
WP6	Multi-actor networking and dissemination	DELPHY

3.1 Project management and coordination, and Ethics reporting (WP1 & WP7)

Project partners

ADAS (Lead), AU, AUA, BSB, DELPHY, NIBIO, and SLU

Project objectives addressed by this work package.

Work Package 1 and 7 facilitated delivery of all project objectives, with the overall objective to coordinate the project and to implement all necessary legal, financial and administrative management. Work Package 1 facilitated compliance with appropriate ethical standards and met the requirements of the General Data Protection regulation (GDPR). Work Package 7 was the coordination and management component of the project. It included general project management such as monitoring the progress towards deliverables and milestones, arranging project meetings, delivering progress reports and facilitating internal and external communication.

The Project Management Executive (PME) consisted of the Project coordinator, all work package leaders, and the northern, central and southern zone leaders. The Project Steering Group (PSG) consisted of all other project partners, together the PME and PSG formed the General Assembly.

3.1.1 Main outputs from WP1 and WP7

- IPM Decisions monitored and complied with ethical standards throughout the project.
- IPM Decisions participated in the Open research Data pilot.
- The IPM Decisions Project Management Executive met regularly to coordinate project activities and delivery.
- The project consortium met at least annually and ensured a multi-actor approach to all aspects of the IPM Decisions Platform development.
- An IPM Decisions Initiative has been established to coordinate activities beyond the project period.

3.1.2 WP1 and WP7 Tasks and activities

WP1 incorporated an Ethics Committee and an Independent Ethics Advisor (IEA). The Ethics Committee was formed at the beginning of the project to oversee, discuss, and report on ethical compliance. The IEA was selected to assist the project in ensuring ethics compliance and provide guidance on how to best address the ethics challenges stemming from the project methodologies. The IEA was external to project delivery and was chaired by an external, independent industry expert free from conflict of interest.

Task 1.1 – Participant procedures and informed consent

(Lead partner: ADAS; Participants: Ethics committee).

IPM Decisions included the recruitment of research participants for workshops as part of WP5 and WP6. Before the collection of any personal data, the lawful basis for the data collection was defined and recorded. This included, for example, the draft questionnaires for the workshops, which were provided to the Ethics Committee via the IPM Decisions ethical

clearance application form. These forms were reviewed the Ethics Committee and given final consent and approval from the IEA. Participants completed informed consent forms as part of registration to the workshops activities.

Task 1.2 – Data protection

(Lead partner: ADAS; Participants: Ethics committee).

A full data management plan conforming to the principles of FAIR (findable, accessible, interoperable, and reusable) data management in H2020 (as published July 2016), and the General Data Protection Regulation (GDPR), was submitted as a public deliverable under D7.2. This deliverable detailed all data intended to be processed in the project and how it is relevant and limited to the purposes of the research, and was updated throughout the project.

Task 1.3 / 7.4 – Gender equality monitoring

(Lead partner: ADAS; Participants: Ethics committee and all project participants).

Appropriate actions were taken to demonstrate gender equality throughout the project. Gender balance was monitored within the consortium throughout the project, reporting an average 45% female to 55% male gender split across participants.

The gender balance and consideration of gender issues at transdisciplinary and multi-actor workshops was monitored to ensure adequate representation participants within each of the country specific workshops. In total, 705 participants attended the three rounds of workshops, 241 participants attended the first round, 334 in the second round, and 130 in the third round. Across all three rounds of workshops, there was a higher proportion of males (64%), with 35% female and 1% that did not specify. Efforts were made to pro-actively engage with a representative gender split throughout the project, and gender ratios varied between countries and years.

Task 7.1 – Administrative and Strategic Management

(Lead partner: ADAS; Participants: NIBIO, Aarhus University, Burgundy School of Business, Delphy, SLU, AUA)

IPM Decisions participated in the Open Research Data Pilot, the Data Management Plan was published in M06 as planned, detailing how data will be managed within the project. Both the Project Management Guide and Data Management Plan were created as 'living documents', under constant review. The Project Management Guide laid out the processes for tracking project progress, i) monitoring and managing the implementing the project work, ii) implementing any required corrective actions and contingency plans, and iii) acting on decisions of the PSG and PME. Six-monthly internal financial audits with all partners followed similar reporting protocols to that required on the H2020 financial reporting. This ensured i) all partners are familiar with the expectations and requirements of financial reporting, and ii) any financial issues are identified and corrected at the earliest opportunity. A Risk Management Plan was developed, maintained and reviewed as necessary, and in its entirety on an annual basis.

Task 7.2 - Project meetings and communication

(Lead partner: ADAS; Participants: All project participants)

The PME meet regularly (every 4-6 weeks) through online meetings, and face-to-face where possible, and were responsible for maintaining internal coordination and activity management. The PSG and PME met at the start of the project (Figure 3.2) annually (online or in person), and additional mid-year online update meetings with the whole consortia ensured all partners are up to date with project requirements and progress.

Figure 3.2 Consortium photo during the IPM Decisions kick-off meeting at SLU, Uppsala, June 2019.

The project website [https://www.ipmdecisions.net/] was set up soon after the project started, as a separate site to the IPM Decision Platform. The website contains details about the project aims, activities, and highlights.

Task 7.3 - Liaising between the EC and the consortium

(Lead partner: RSK Environment)

RSK Environment were the single point of contact for the Commission; all lines of communication have been between the Coordinator and Project Officer. On request from the Project Officer in April 2023, a summary report was provided on the project outputs relevant to reduction in pesticide use. IPM Decisions also contributed to a joint Policy recommendation for the Sustainable Use of Pesticides Regulation (SUR) with IPMWORKS[2].

[2] IPMWORKS - Policy recommendation for the Sustainable Use of Pesticides Regulation (SUR)

Task 7.5. Project longevity

(Lead partner: RSK Environment; Participants: All project participants)

This project funded the development and launch on an online platform for IPM DSS, along with research and resources for improving access to and uptake of IPM DSS. After the project, further funding is necessary to maintain and growth the platform, and to support development, integration, and validation of adapted and novel systems. Conditions of use of open access services restricts opportunities for the IPM Decisions to become a commercial pay-per-use service. The potential use of commercial advertising on the platform was ruled out by the consortium, as evidence from analysis of data collected in WP5 suggests that advertising is not well received by stakeholders and could erode trust in the platform content. The option to set up a new entity (either a new commercial business or charity) with responsibility for the Platform was explored, and while there are advantages associated with creating a new organization post-project, the primary route to funding needs to be agreed before specific entities can be considered. A three-step plan for securing longevity was created: (i) secure the Platform management structure, (ii) secure essential funding to 'keep the lights on', and (iii) grow the Platform and Network. In addition, core components of the platform are being made open access to enable wider exploitation of resources developed as part of the project. As such, the platform function and associated components can be adapted to future initiatives beyond the scope of the IPM Decisions specific platform.

Securing the IPM Decisions management structure from 1 June 2024

- A new IPM Decisions Initiative has formed, coordinated by ADAS, coming into effect from 1 June 2024.
- All members of the current consortium were invited to sign a Letter of Intent, detailing the management structure, commitments to share and discuss opportunities, and detailing Foreground Intellectual property.

Securing core funding from 1 June 2024

- National public funding bodies have been approached to secure essential funding for the platform, covering security and software upgrades necessary to keep the platform accessible.

Building on the IPM Decisions project – identifying suitable calls that could build on project outputs.

- Project partners identify national/international funding opportunities to exploit project results.
- The IPM Decisions Initiative remains open to approaches for following projects.

3.2 Integration and sharing of data, models and tools (WP2)

Project partners

NIBIO (Lead), ADAS, APCA, ENG, LUKE, MET Norway, and CIRAD

Project objectives addressed by this work package

This work package is delivering to the following project objectives:

1(ii) Increase farmer and farm adviser access to DSS through a pan-European Platform.

1(iv) Expand the range of DSS and weather data that can be used, by integrating European agro-meteorological networks on the Platform.

3(ii) Develop and publish open data formats and source code for web services and Dashboards for development by the DSS community.

Many Decision Support Systems require access to weather data and additional metadata (such as crop information) in order to calculate pest risk. In WP2, suitable sources of weather and/or metadata were identified and software necessary to enable DSS within the platform to access them was created. Application programming interfaces (API) enable DSS to communicate with sources of weather data. A catalogue of DSS created in WP4 enabled selection of weather data sources that meet the needs of the majority of DSS, and where essential data is not widely available proxy values will be estimated from available weather data using bespoke models developed in WP2.

3.2.1 Main outputs from WP2

- A dedicated Weather Service API has been created, providing sufficient information for a client to be able to connect to and get information from a range of weather data sources, to run IPM DSS integrated into the IPM Decisions Platform.
- Weather service source code: *https://github.com/H2020-IPM-Decisions/DSSService*
- A dedicated DSS Service API has also been created, enabling external exploitation of select DSS integrated with the IPM Decisions Platform.
- DSS Service source code: *https://github.com/H2020-IPM-Decisions/WeatherService*
- An online tool, IPM DSS Metadata file editor, has been developed to support integration of IPM DSS with the IPM Decisions Platform.

3.2.2 WP2 Tasks and activities

Available datasets required to support IPM DSS integrated into the IPM Decisions Platform must meet the input requirements of a wide range of models, be locally relevant, quality controlled and easy to find for the user. These requirements are met in the establishment of two APIs, the weather service (task 2.1) and the DSS service (task 2.2).

The IPM Decisions Weather Service

The weather service provides the system with sufficient information for a client to be able to connect to and get information from a range of weather data sources.

There are three main components of the weather service:

1. The platform's standard weather data format
2. A catalogue of weather data sources available to the platform
3. Adapters for weather data sources to get weather data in the standard format

A list of weather sources of which the Weather API can recognize data includes:

- The Norwegian AgroMet service
- The Finnish Meteorological service
- Metos (Pessl Instruments) weather stations
- Fruitweb agromet network (Davis, Pessl + own brand of stations)
- Deutscher Wetterdienst (DWD)
- Meteobot weather stations
- A-lab
- MeteoConcept

Other weather data providers will be included in this list as part of planned activities, such as, NetAtmo, A-lab and MeteoConcept.

The IPM Decisions DSS Service

The DSS service provides the system with sufficient information for a client to be able to connect to and get information from a DSS.

There are three main components of the service:

1. A catalogue of DSS and their models available to the platform
2. A standard for result data returned from DSS models
3. A standard for field observations sent as input data to DSS models

Source code for these APIs are available at:

https://github.com/H2020-IPM-Decisions/DSSService

https://github.com/H2020-IPM-Decisions/WeatherService

Task 2.1 – Weather data

(Lead partner: MET Norway; Participants: NIBIO, LUKE, APCA).

This task addressed the data needed for development of the weather service. As part of the Weather API, specific microservices have been developed:

- The Weather Data Source Service's main content is the catalogue of weather data sources, which is a searchable list of weather data providers available to the platform.
- The Meta Data Service describes the standard format that the platform is using for exchange of weather data, both internally inside the platform and for provision of weather data to the DSS models.
- A Weather Adapter Service is established to make data from various weather data sources available to the IPM Decisions Platform.

- The Amalgamation Service acts as a weather data broker, picking data from the best available data sources, given the request, and performing QC of the data delivered from the data source(s). If data are missing or fail QC tests, the service attempts to provide usable and "correct enough" data using fallback weather data sources such as weather stations close by or sets of gridded "historical" data from ECMWF, and simple interpolations and inference of values from existing parameters.

The contents of the weather service are generated as part of three activities described below.

Survey of available weather data sources in Europe

A summary of weather and climate data availability was delivered, dividing each country into different categories regarding open data policy. Backup solutions both for missing observations and missing fine scale numerical prognostic data are considered. Advices are given in accordance with dialogue and signals from DG level within the European Meteorological Community, to be sure IPM Decisions APIs will be designed for future meteorological possibilities and solutions. The list of available weather data sources (as of May 2024) including a number of weather data services from:

- Governmental data sources such as services from National Hydrological and Meteorological Services (NHMS).
- The platform's own weather data sources building on governmental data.
- Weather station networks from universities and agricultural advisory services.
- Private weather stations made available to the public.

Virtual weather data

A number of best practice methods to replace missing observations have been evaluated. Numerical Weather Prediction Analysis (NWP_ANA) is continuously improved by the Meteorological Society and are automatically on track with state of art within numerical weather forecasting. When data is lacking from observation in near part time, IPM Decisions uses models and reanalysed data. The European Centre for Medium-Range Weather Forecasts(ECMWF) Mars Archive, which covers all of Europe, can be used. Based on our evaluation, best practice methods are:

- Observations provided by IPM users, i.e. private weather stations
- Observations delivered directly from a national MET Institute
- NWP-ANA, post processed and fetched from MET API's
- ECMWF Mars Archive / Coperinus Climate Change Service (C3S)

Based on analysis of described DSS, Air temperature (T), relative humidity (RH), precipitation (RR) and leaf wetness (LW) are the four most used parameters and thereby key variables in agricultural meteorology. T, RH and RR are commonly available, but leaf wetness or leaf wetness duration (LWD) are more rarely provided. For calculation of LWD, five available models have been selected for evaluation, three models with different levels of complexity and need of input parameters have been verified and are recommended for implementation in the Weather API. The first model, Constant-RH, has been verified and handed over to WP3

to be added to the library of data manipulation algorithms, while a more advanced LSTM model has been described and submitted for peer review. This model for is also implemented for use in the Weather API.

To ensure access to data at any geographic location, a service called EuroWeather has been established. This is made available through a tailored service as part of IPM Decisions. Gridded seasonal and forecast weather data are stored and made available as an alternative to seasonal data where observations are missing, and is embedded into the WeatherService API. In the final year of the project, we have discovered a new and openly available weather data service: Open-Meteo.com. This service utilizes most openly available weather data sources in Europe (and many others around the globe) to offer a uniform location-based source of past, present and forecast weather data. We have substituted our own "Euroweather" fallback service with Open-Meteo.com, as it improves the sustainability of the IPM Decisions platform.

Basic quality control of data

A set of quality control routines have been chosen and implemented in the Weather Data Service, based on parts of MET Norway's quality control system. The routines are simple sanity tests to be used on private weather stations for which no routine quality control is performed. NHMS's all over Europe have complex quality systems providing quality-controlled observations to the user. These data will not be fed through the quality control rules in the Weather Data Service. The framework and the basic routines are implemented, additional routines may be implemented if needed. The thresholds set as default are general and will be to be tuned to be area dependent during beta testing.

The control routines can be split in two:

- Real time quality control, routines performed hour by hour.
- Non-real time quality control, routines performed on a set of data (time series).

When receiving a string of hourly data from a weather station, the real time quality control will run an interval test. The interval test will check whether the temperature, humidity or soil temperature lies between an upper and lower threshold. For temperature, the default range is -40°C to 50 °C. A logical test will then be performed, for weather parameters where we have min, mean and max values. The logical test also verifies that the minimum value is lower than the mean value, which is lower than the maximum value measured for the given hour.

There are several possible quality control results for each parameter given as input. There will be one quality indicator for each input parameter when handed over to be used in the IPM Decisions platform. The quality indicator will tell if the parameter is qualified by an external source, by IPM Decisions or if it failed qualification and why.

Task 2.2 – Model categorization and input data

(Lead partner: NIBIO; Participants: MET Norway, LUKE, CIRAD, APCA)

Pest prediction models are highly diverse in their design, complexity, and demand for input data. We focus on priority models identified as part of multi-actor engagement activities. The domain of decision tools was investigated to categorize the models and define standards and protocols that enable the annotation and integration of a wide range of models in the platform.

The VIPS DSS (Norwegian DSS platform) and its models were used as the starting point for the development of DSS Service APIs. These models differ in their input requirements and have provided a varied mix of models to categorize and to find ways of expressing their properties. Two specific microservices have been developed:

- The DSS Service contains a searchable catalogue of DSS models available to the platform.
- The Meta Data Service provides descriptions of the structure of a model output.

The DSS API delivering the DSS Model database contains 59 models covering a range of crops and pests, where 30 models are fully integrated and available in the IPM Decisions platform dashboard, and 19 DSS models are available as external links (up to May 2024). The list of DSS models available in the platform is dynamic, as new DSS and their models can be added to the catalogue without changing the DSS API. The current models are listed in Table 3.1, with the models that are fully integrated (but not necessarily available on the platform at this time, indicated). The list of DSS models available in the platform is dynamic, as new DSS and their models can be added to the catalogue without changing the DSS API.

Streamlining of the translation process for DSS Metadata

DSS metadata are such elements as model descriptions, result parameter names, charts headings etc. These all need translation, and this is a complicated process, involving several partners working in parallel on many different DSS/models and parts of the metadata simultaneously. We have created a system for tracking changes between releases of the platform, and enabling translators access to the translation files as Excel files on Teams, to avoid email attachment spaghetti. New DSS and changed elements are highlighted to minimize the effort for the translators. After all translations are completed, the Excel files are transformed into system files that perform the translations to the platform users.

Table 3.1: List of models/DSS available through the platform by end of May 2024.

Source name	DSS Model name	ID	Fully integrated	External link
VIPS	Carrot fly flight model	PSILARTEMP	x	
VIPS	Cabbage fly flight model (Scandinavia)	DELIARADIC	x	
VIPS	Cabbage moth model	MAMESTRABR	x	
VIPS	Nærstad model	NAERSTADMO	x	
VIPS	Alternaria TOMCAST	ALTERNARIA	x	
VIPS	Negative prognosis	NEGPROGMOD	x	
VIPS	Onion downy mildew DOWNCAST	DOWNCASTMO	x	
SEGES	Septoria Humidity Model	SEPTORIAHU	x	
SEGES	CPO model for Mildew in Barley	CPO_HORVX_ERYSGR	x	
SEGES	CPO model for Brown rust in Barley	CPO_HORVX_PUCCHD	x	
SEGES	CPO model for Barley net blotch	CPO_HORVX_PYRNTE	x	
SEGES	CPO model for mildew in wheat	CPO_TRZAX_ERYSGR	x	
SEGES	CPO model for yellow rust in wheat	CPO_TRZAX_PUCCST	x	
SEGES	CPO model for Septoria in wheat	CPO_TRZAX_SEPTTR	x	
SEGES	CPO model for brown rust in wheat	CPO_TRZAX_PUCCRE	x	
SEGES	CPO model for tan spot in wheat	CPO_TRZAX_PYRNTR	x	
Horta-srl	Horta Tomato DSS	it_horta_dss_tomato		x
Horta-srl	Horta Wheat DSS	it_horta_dss_wheat		x
Aarhus University RustWatch	Yellow Rust early warning	YellowRustEarlyWarning		x
Aarhus University RustWatch	Stem Rust genetic frequency distribution	StemRustGeneticFrequency		x
Aarhus University RustWatch	Leaf Rust genetic group frequency distribution	LeafRustGenetic GroupFrequency		x
Aarhus University RustWatch	Yellow Rust genetic group frequency distribution	YellowRustGenetic GroupFrequency		x
eDWIN	eDWIN Platform (Poland only)	eDWIN_LINK		x
gaiasense	Downy mildew of grapevine (North East Region of Peloponnese, Greece only)	PLASVI	x	
Best4Soil DSS for nematodes and soil borne diseases	Best4Soil Support Tool nematodes	nematodes		x
Best4Soil DSS for nematodes and soil borne diseases	Best4Soil Tool pathogens	pathogens		x

Source name	DSS Model name	ID	Fully integrated	External link
BlightApp	DSS Potato Late Blight	BlightApp		x
ISIP	ISIP (Germany only)	siggetreide		x
IPM Decisions	Cutworm Model	DASGPA	x	
IPM Decisions	Orange Wheat Blossom Midge Emergence Model	SITDMO	x	
IPM Decisions	Pollen Beetle Migration Model (simplified)	MELIAE	x	
IPM Decisions	Saddle Gall Midge Model	HAPDMA	x	
IPM Decisions	Codling moth flight model	CARPPO	x	
IPM Decisions	BYDV TSUM model	RHOPPA	x	
IPM Decisions	Hutton Criteria Late Blight Model	PHYTIN	x	
IPM Decisions	Grey Field Slug (Cereals)	DEROAG_Cereals	x	
IPM Decisions	Grey Field Slug (Oilseed rape)	DEROAG_OSR	x	
University of Warwick	Large Narcissus Fly Model	LAMTEQ_WarwickHRI	x	
University of Warwick	Pollen Beetle	MELIAE_WarwickHRI	x	
University of Warwick	Cabbage Root Fly	HYLERA_WarwickHRI	x	
University of Warwick	Carrot Fly	PSILRO_WarwickHRI	x	
AHDB	Sclerotinia forecast	SLESC		x
AHDB	Phoma leaf spot forecast	LEPTMA		x
IPMConsult	IPMwise Denmark	ipmwiseDK		x
IPMConsult	IPMwise Spain	ipmwiseES		x
IPMConsult	VIPS-ugras Norway	ipmwiseNO		x
IPMConsult	IPMwise demo version	ipmwiseDEMO		x
IWMPRAISE	IWMPRAISE Weed Management Tool	IWMPRAISE_Tool		x
Farming online Ltd	Slugwatch	SlugWatch2023		x

Task 2.3 – Standards and data formats

(Lead partner: NIBIO; Participants: MET Norway, CIRAD, APCA, ADAS, LUKE, Engineering)

Pest prediction models are highly diverse in their design, complexity and demand for input data. Data formats have been established and expressed as Json Schemas in the DSS and Weather APIs. The weather data format is based on experiences with weather data in VIPS and the Norwegian Met office. It provides flexibility, readability and is compact. The model input formats use a combination of predefined schemas (for Weather data and Field pest observations) and dynamic schemas for expressing a model's specific and unique inputs.

A format for DSS model outputs (D2.7) and for exchange of weather data and description of DSS model requirements (D2.8) were established (D2.7). These allow for flexibility and predictability for users when results from running a DSS model are presented in the platform dashboards, and enable flexibility and consistency in data exchange.

Our conclusion from surveying the potential for integration with other systems in the IPM Decisions platform, such as Farm management information systems (FMIs), suggest the best approach will be to encourage FMIs to adapt to the standards of the platform, not the other way around.

3.3 Development of dashboard and platform (WP3)

Project partners

ADAS (Lead), ENG, INRAE, NBIO, CIRAD

Project objectives addressed by this work package

1(ii) Increase farmer and farm adviser access to DSS through a pan-European Platform.

2(iv) Enable comparisons between DSS for their benefits.

3(iii) Develop a toolkit for researchers and DSS providers to combine multiple DSS, to enable users to address multiple pest threats to their crop with a single system.

3(ii) Develop and publish open data formats and source code for web services and Dashboards for development by the DSS community.

Work package 3 led the development of the IPM Decisions Platform and associated dashboards.

3.3.1 Main outputs from WP3

The IPM Decisions Platform (https://www.platform.ipmdecisions.net/) was launched in September 2022, containing:

- Farm Management area – for adding Farm locations and selecting DSS
- DSS Use Dashboard – for consulting selected DSS
- External Link DSS Dashboard – for selecting and linking to 3rd party DSS sites
- DSS Comparison Dashboard – for comparing outputs from up to 5 DSS, or comparing a DSS with previous year outputs
- DSS Adaptation Dashboard – for adapting some parameters of existing DSS.
- Dynamic open access IPM Decisions Risk Maps

The IPM Decision platform is available in twelve major European languages (English, Italian, Greek, Swedish, French, German, Dutch, Slovenian, Finnish, Norwegian, Lithuanian, and Danish), arranged through interactions with partners across Europe to translate web page content and error messages. A further 'Integration Dashboard' was also developed, providing a route for advanced DSS development and integration into the Platform based on existing and complimentary resources. A repository of central source codes is available on GitHub at https://github.com/H2020-IPM-Decisions. This repository provides anyone with the ability to retrieve the latest version of the code and see all of the development history for the code.

3.3.2 WP3 Tasks and activities

A development version of the IPM Decisions Platform on an internal test server facilitates the development and updates of the microservices (small self-contained web-enabled functions or processes that communicate with each other via web messaging to provide the back end functionality for a web page or a set of web pages). This is used to test these microservices and ensure that they integrate with each other as expected. A set of initial data manipulation

algorithms have been produced and made accessible through a web-based API (Deliverable 3.9). Algorithms to calculate hourly temperature and relative humidity have been included along with the first version of a leaf wetness index, provided by work package 2. Alongside these data, some simple threshold-based DSS models have been included, which will be used in the platform to allow "on-the-fly" checking of observation data entered by users. When a user enters a pest observation, the observation will be compared with the relevant action threshold in the background, and if the observation exceeded the action threshold an instant response is provided to the user that action needs to be taken.

Task 3.1 – Design of DSS Use, DSS Evaluation and DSS Adaptation Dashboards

(Lead partner: Engineering; Participants: NIBIO, ADAS)

This task specified and developed the three user dashboards:

- DSS Use Dashboard which enables selection and running of the DSS tools by farmers and advisors;
- DSS Comparison Dashboard which allows users (targeting advisors and researchers) to compare different DSS tools and their outputs;
- DSS Adaptation Dashboard which enables developers and researchers to modify the parameters within a DSS to facilitate adaptation of the DSS to specific countries.

Work focused on defining the user workflows for each of the dashboards. As part of this process, presentations were given during the second round of multi-actor workshops that provide potential users with the opportunity to influence the design of the dashboards and the way in which data is entered into the platform (including the use of shortcuts and common practice to minimise user data entry where possible) to ensure that the dashboards are simple and easy to use and fulfil the needs of users. The usability of the platform was enhanced on mobile devices through the implementation of a responsive template which ensures that all functions offered by the IPM platform to be accessed.

Informative Disclaimers:

To provide users with information regarding the DSS within the platform, informative disclaimers were strategically placed on various web pages within the IPM Platform. These disclaimers or web contents serve the purpose of effectively informing users about the functionality offered and usage guidelines of the DSS features, ensuring that users are well-informed and can utilise the system optimally.

Design of Dashboards

This sub-task was carried out with the aim of designing the user dashboards. The first steps provided a draft design of the three dashboards (DSS Use, Comparison, and Adaptation) and the characteristics of popular DSS tools. Based on this, initial mock-ups that were used in the first round of stakeholders' workshops, organized by work package 6. A user-centered design approach was followed, with involvement of end-users (farmers, advisors, researchers) and relevant stakeholders in the definition of user stories. In order to ensure the dashboards were

easy to use and fulfilled the needs of the end users, the design process began by identifying and incorporating the needs and preferences of key user groups. To this end, a set of Excel forms were used to collect user stories systematically and consistently across different users in different geographical locations, organizations and across different user groups / working roles. The form provided the users with a pre-defined set of user stories that outlined key functionality, which they were asked to assign an importance level to and provided an opportunity for the user to provide their own user stories. This offered a balance between a structured approach and an opportunity for participants to give their own subjective opinions. Two core user groups were identified: Farmers and advisors, Researcher and developers. During the workshops, participants were asked to fill in the user stories forms and to give their feedback on mock-ups of some dashboards that were presented.

User stories were collected from Greece, Netherlands, Italy, UK, Finland, Sweden. In total, 211 responses were received, with 161 responses from farmers and advisors and 53 responses from researchers and developers. The farmers and advisors identified the ability to add the farm location to get closest weather data; the ability to have multiple crops and the ability to access DSS for multiple pests, diseases and weeds as the three most important requirements. The researchers and developers thought that having the ability to compare different DSS; change DSS parameters and the export of DSS outputs were the three most important requirements for them. Based on the rankings provided by these groups, the initial requirements related to the design of the three dashboards and the first mock-ups were identified and incorporated into the written specification for the dashboards. Text within the platform has been kept to a minimum (which will reduce the amount of translation required) and the interfaces made intuitive to use. Mockups of the dashboards were then used in the presentations for the second round of user workshops (organized by work package 6) in January 2021 to obtain feedback on the design from potential users. Development of the dashboards has been based on the requirements collected from interactions with stakeholders, and on the definition of the IPM web platform Reference Architecture (RA), defining the modules constituting the platform and the interactions between them. Sub-task 3.3.1 “Development of platform portal” provided inputs to this Sub-task in terms of the graphical design to be used within the dashboards.

Once the business and user requirements were identified, appropriate front-end technologies (e.g. development frameworks, software libraries) suitable for the development of the dashboards were selected. At the same time, a series of technical meetings were started to better define the different modules of the architecture and the interactions with other modules, such as the back-end APIs. After a first review on the technical modules and improvements, the end-user interfaces (UI) was designed, along with the definition of client module services APIs, the data service model improvements and all the interactions with the others involved module. The development repositories on GitHub were structured to host the IPM dashboards front-end source code (https://github.com/H2020-IPM-Decisions/IPM-Decisions-Platform) and the deployment model of the components was defined using docker technology.

Task 3.2 – DSS Integration Dashboard Development

(Lead partner: INRA, CIRAD; Participants: NIBIO, ADAS)

The DSS Integration Dashboard was built on the specification extending existing scientific workflows framework for integration of DSS tools, data manipulation algorithms, and data sources, and is hosted on the scientific workflow framework OpenAlea[3]. A new service, the IPM-Decisions Factory has been implemented. It allows transforming any OpenAlea node into an IPM-Decision DSS, ready to be deployed on the platform. The created DSS consists of an auto-generated docker file hosting a web service fully compatible with IPM-Decisions requirements, and an auto-generated *json* file that allows registering the new model in the IPM-Decisions DSS catalogue (Figure 3.3). A demonstration example of the DSS integration use has been released on GitHub, in the form of a jupyter notebook (Figure 3.4).

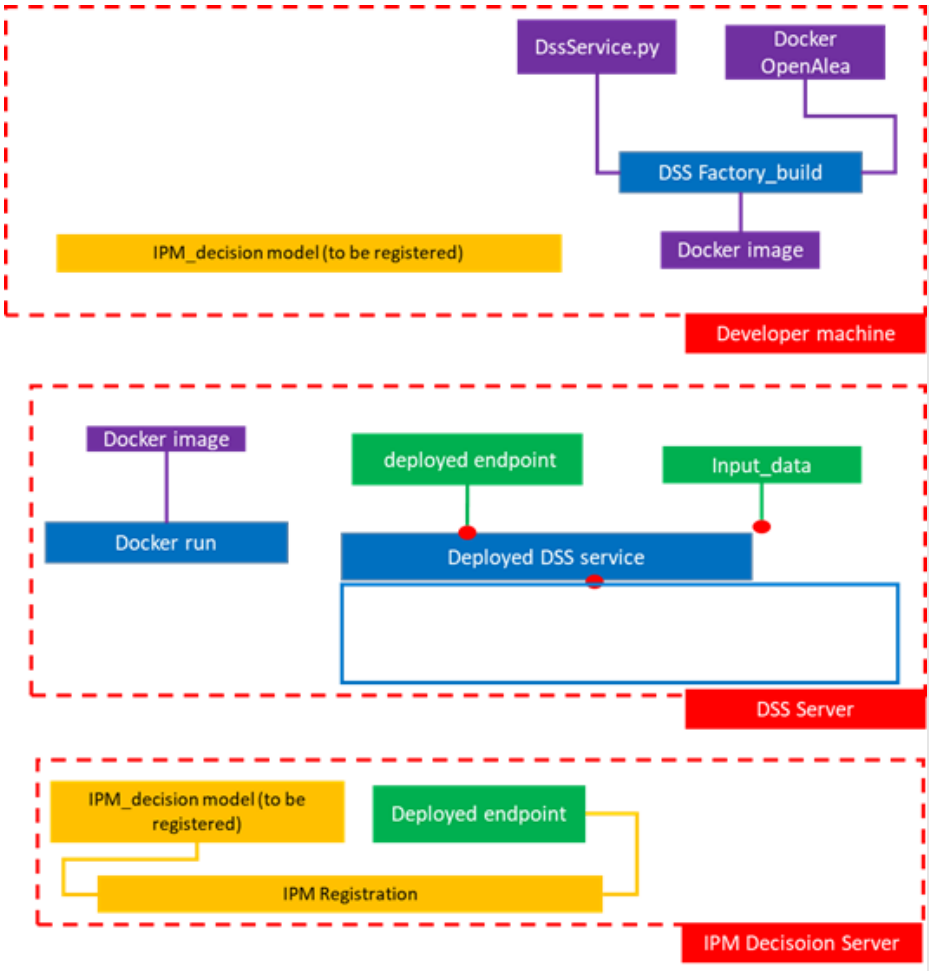
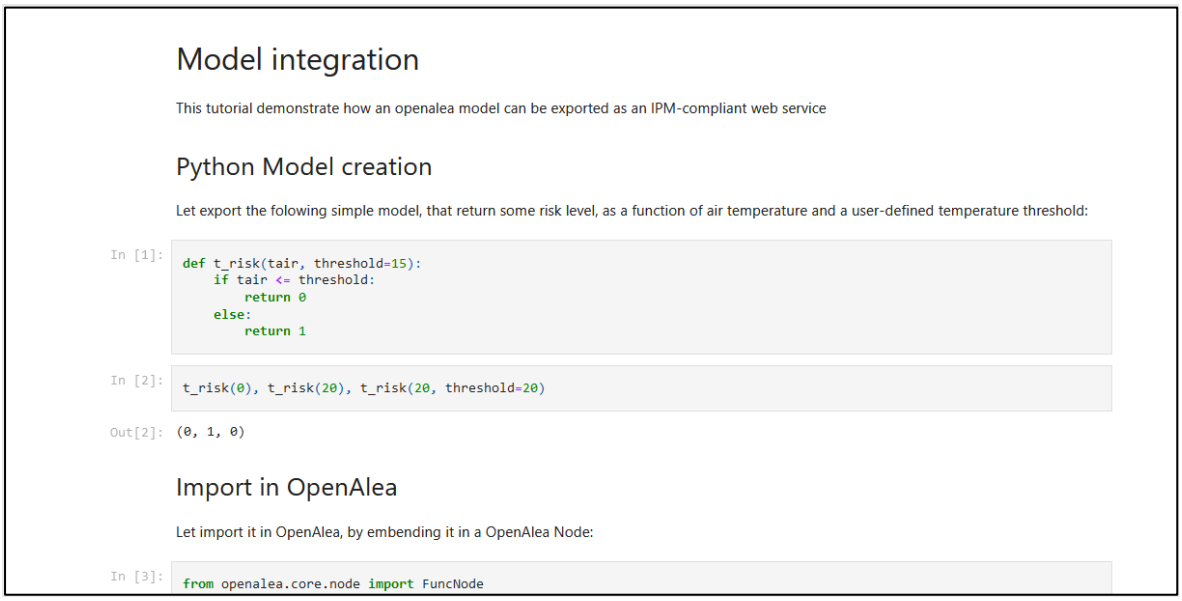


Figure 3.3: Deploying a new model from Integration Dashboard generated objects. First (top), the developer can embed their model in a Docker image, using a generic script (DSSFactory_build), publish it on DockerHub or deploy it on a server (middle panel). The model definition, updated with the deployed endpoint, can then be submitted to IPM-Decisions to be registered on the platform.

[3] *Pradal C., Dufour-Kowalski S., Boudon F., Fournier C., and Godin C. (2008) OpenAlea: a visual programming and component-based software platform for plant modelling. Functional Plant Biology 35(10) 751-760* https://doi.org/10.1071/FP08084



Model integration

This tutorial demonstrate how an openalea model can be exported as an IPM-compliant web service

Python Model creation

Let export the folowing simple model, that return some risk level, as a function of air temperature and a user-defined temperature threshold:

In [1]:
```
def t_risk(tair, threshold=15):
    if tair <= threshold:
        return 0
    else:
        return 1
```

In [2]:
```
t_risk(0), t_risk(20), t_risk(20, threshold=20)
```

Out[2]: (0, 1, 0)

Import in OpenAlea

Let import it in OpenAlea, by embending it in a OpenAlea Node:

In [3]:
```
from openalea.core.node import FuncNode
```

Figure 3.4: Demonstrating the use of Integration Dashboard

(https://github.com/H2020-IPM-openalea/DSS/blob/dss_integration_tutorial/example/model_integration.ipynb)

For open access data:

- EpyMix model : https://github.com/openalea/EpyMix (https://zenodo.org/record/7139051)
- WeatherData Package : https://github.com/H2020-IPM-openalea/weatherdata (doc : https://weatherdata.rtfd.io)
- OpenAlea DSS Library : https://github.com/H2020-IPM-openalea/DSS (doc : https://ipmdss.rtfd.io)
- AgroServices Library : https://github.com/openalea/agroservices (doc: https://agroservices.rtfd.io)

Development of a scientific workflow framework for integration of DSS tools, data manipulation algorithms and data sources.

The OpenAlea framework (http://openalea.gforge.inria.fr/dokuwiki/doku.php) was used to create the Integration Dashboard. This consists of a set of libraries in tools written in the Python programming language. These are then integrated with a graphical user interface that allows the user to create models through a visual interface by designing the model in the form of a flow chart (describing the flow of different bits of information between different components of the overall model). As part of the process of creating the dashboard, there was a need to replicate the core functionality of the APIs within the IPM Decisions platform in Python, so that the dashboard could access the DSS and the weather data from the IPM Decisions platform. Two Python packages were developed to make the link between the DSS and Data on the IPM Decisions Platform and OpenAlea, described below.

A common ontology for models and DSS has been designed with NIBIOS, CIRAD, and INRAe to define a shared API. A common API on weather data has also been defined. Then, the open-source Python library agroservices have been developed to access the web services programmatically. Based on this library, weather data and DSS libraries have been developed to implement respectively new data manipulation algorithms and visualisation tools on weather data as well as a full integration layer in OpenAlea. Finally, a complex model is currently developed in OpenAlea as a demonstrator, to simulate complex patho-systems by reusing both research models and weather data.

The code for the software are all available on GitHub:

- AgroServices: https://github.com/openalea/agroservices
- WeatherData : https://github.com/H2020-IPM-openalea/weatherdata
- DSS : https://github.com/H2020-IPM-openalea/DSS.

We extended the integration of IPM in VisuAlea, to form the integration dashboard. The extensions consist of an automated import of weather datasource and DSS in OpenAlea package manager, so that individual WeatherDataSource and DSS models become nodes that can be dragged and dropped in Visualea workspace, and used to create new models (Figure 3.5)

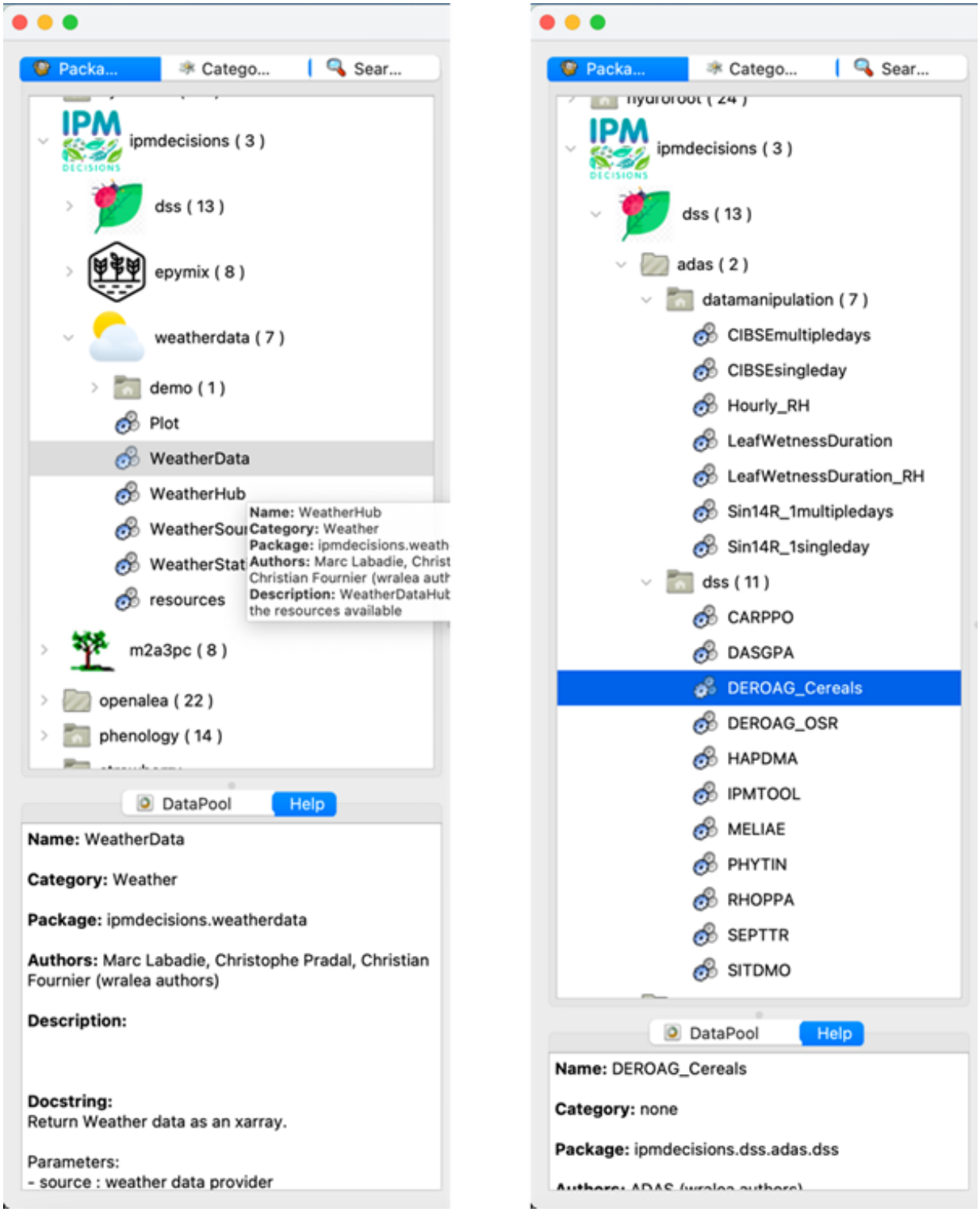


Figure 3.5: The Package Manager stores all the OpenAlea Packages.

Each Package contains a set of Models that are organized hierarchically. In the left of the Figure, we show the IPM Decision meta-package that contains three package : DSS, EpyMix and WeatherData. In the right, the DSS package store recursively all the DSS with their associated models.

AgroService Python Package
(https://github.com/H2020-IPM-openalea/agroservice)
This provides access to the DSS on the IPM Decisions Platform using a set of Web Services wrappers that effectively translate the Java language used for the API on the IPM Decisions Platform into the Python language used by OpenAlea. This then allows OpenAlea to query and access data services, the DSS catalogue and to use DSS models (through the IPM Decisions platform.

WeatherData Python Package
(https://github.com/H2020-IPM-openalea/weatherdata)
This does a similar thing to the agroservice, described above, but for the weather data. It allows OpenAlea to retrieve data from the IPM Decisions Platform and stores it in a format accessible to OpenAlea. It also includes a number of functions that allow the weather data to be manipulated (e.g. calculation of day degrees, leaf wetness indices, etc.).

Development of default data manipulation algorithms
A set of algorithms have been developed for estimating hourly temperature, hourly relative humidity and hourly leaf wetness duration. All algorithms have been developed in C#.NET and made accessible via an API hosted on a web server. The algorithms have been designed to allow a user to use them for either a single point in time, where the inputs consist of individual values or for multiple time points, where the inputs are provided as a list with a value for each time point. A brief description of each algorithm is given below.

Weather Data Manipulation Algorithms
Hourly Temperature: Two algorithms to estimate hourly temperatures from daily values have been developed using the methodologies described in Chow and Levermore (2007). The first algorithm uses the CIBSE method (1982) which strategically allocates times of maximum and minimum temperature using the CIBSE Guide A2, before fitting two sinusoidal curves to generate hourly temperature for a single day. The second algorithm, known as Sin (14R-1) was adapted from CIBSE, however uses standard formulae for calculating sunrise and sunset times for each location based on latitude.

Hourly Relative Humidity: An algorithm to calculate hourly relative humidity from hourly temperature was also developed using the methodology of Eccel (2012), whereby relative humidity is expressed as a ratio between actual water vapour and saturation vapour. This algorithm relies on the assumption that minimum temperature is a first guess estimate of dew temperature.

Hourly Leaf Wetness Duration: A threshold-based algorithm was developed to estimate leaf wetness, using the methodology described by Kruit *et al.* (2008).

DSS models
Example DSS have been made available through APIs. These DSS will be useful for users and are acting as test cases for functioning of the platform and Use dashboard. There are many

simple DSS based on pest thresholds. Two types of threshold model have been implemented, the first is a simple single value threshold which sends back an appropriate message if the pest observation provided by a user is greater than the threshold. The second type of threshold model allows the comparison of observation data against multiple thresholds, with the recommended action dependent upon the threshold exceeded. The metadata for all the weather data manipulation algorithms has been created, and checked by work package 2, so that they can be included within the DSS database for the Platform and accessed via the API developed in work package 2. This has acted as a test of the process for the integration of DSS into the Platform and has identified a need to produce a set of step-by-step instructions on how to complete the metadata.

Following the development of the original algorithms for manipulating weather data, we have developed DSS for key pests to integrate into the IPM Decisions platform. Several DSS have been made available for integration on the platform through APIs developed specifically for the IPM Decisions Platform, as opposed to including DSS that already have existing APIs, such as those on the Norwegian VIPS system. All of the algorithms for these DSS have been developed from either scientific papers or third-party research, with interpretation to allow the DSS to provide an indication of risk posed by the pest, categorised as low, medium or high. Appropriate guidance on what to do for each risk level has also been identified and is included in the meta data for the DSS to be displayed in the information pages for the DSS on the IPM Decisions Platform. Optional parameters, specific to each DSS, have been made available to the user. These optional parameters allow modification of key parameters used by the DSS for the calculation of risk, such as the start and end date, the addition of spray application and risk thresholds. These can be used to adapt the DSS to either the specific management of the crop on the farm of interest, or to adapt the DSS for use in a new country.

Task 3.3. Development of platform and associated web services

(Lead partner: Engineering; Participants: ADAS, NIBIO, INRA, CIRAD)

The IPM Decisions Platform acts as the single point of access to the dashboards and information about IPM, and hosts a repository for all the source code for the web components, web services, Dashboards and data manipulation functions. This repository is available on GitHub at https://github.com/H2020-IPM-Decisions, and contains all the code developed for the IPM Decisions Platform. This repository provides anyone with the ability to retrieve the latest version of the code and see all of the development history for the code.

Development of platform portal

Integrating multiple DSS and data sources within a single framework is a challenge, as DSS differ in the input data required and in the types of outputs produced from the DSS (treatment guidance, pest risk levels, disease incidence, etc.). The architecture for the IPM Decisions Platform can handle this variety whilst ensuring that the DSS are presented to the users in a consistent easy-to-use format.

The IPM Decisions Platform consists of the following components:

1. A framework for linking decisions support tools and data together based on an API gateway and/or a set of micro-services and data standards.
2. A set of dashboards that provide a user interface for the framework.
3. A set of web pages that provide information about the platform, the decision support tools, weather data, etc. For the DSS and weather data, these web pages will use metadata included with the DSS and weather data.
4. A set of (extensible) data standards (JSON schema) defining:
    a. modifiable variables within DSS systems,
    b. data inputs required by DSS systems,
    c. output data from DSS systems (categorised by key types),
    d. weather data from a range of sources:
        i. National weather archives
        ii. National weather forecasts
        iii. Data loggers & weather stations

The main functions provided by the micro-services include:

- User registration/authentication and authorisation,
- Content management system,
- Farm management system,
- Access to metadata on decision support tools and weather data sources,
- DSS selection in defined standard formats.

In order to improve the stability of the platform, additional configurations have been incorporated to prevent overloading the platform. These settings allow the person responsible for the platform to specify the commencement time of the daily schedule. They enable the platform to make a limited number of attempts to execute a DSS (Decision Support System) in the event of an error caused by incorrect user input. There is also a setting that permits the execution of DSS that produced erroneous results earlier in the day.

Development of web services for management of the interaction of the Dashboards with the DSS and data sources

Optimization of resources is important to ensure a great user experience in the platform, so the process has been carefully integrated in the platform. An underpinning data model has been developed for storing the users' farm and DSS information that allows for the identification of users that are running DSS for the same pest on the same crop with the same weather data or requesting the same weather data. Where this occurs, the User Provision (UPR) microservice (the microservice that manages user data) will only make one call to the DSS and then share the results to all users with the same combinations of crop, pest and weather data location. This acts to minimise the load within the platform, reduce data storage, and minimise the number of calls to external DSS. In addition, the results can be cached (temporarily stored) to allow them to be shared with future requests. An initial version of the UPR is up and running and currently being tested on the test server as part of the

integration of the microservices. The web services interact with the weather and DSS information services, allowing the collection and interpretation of the results. The web services have been prepared to run with default parameters without the need for user inputs, increasing the speed of setting up the system. Once the results have been returned and saved, depending on the dashboard selected the web services will get, transform, and interpret the data to display useful information to the user. To work correctly with the DSS and data sources, a queuing and scheduling web service has been developed to allow time for a third-party system to process the request of the IPM Decisions platform.

Open access risk maps

Risk maps have been designed to provide an immediate summary of potential risks for pests, and allow visualisation of the change in risk across Europe over time. Risk maps covering Europe and countries surrounding the Mediterranean ocean have been created for selected pests and diseases. The maps are presented at the platform's front page and do not require a login. The models are calculated for each point in a 7x7 km grid covering the area. The weather data come(s) from Euroweather (see WP2), designed based on input from WP6 activities, and implemented through infrastructure developed in WP3. The risk maps are calculated on a daily basis, and the user can view all maps from the start of the warning period and as far as the weather forecast allows (up to two days). The measure of risk reflects the same levels as are used within the platform, indicated in simplified form as "No risk" (green colour), "Possible risk" (yellow colour) and "High risk" (red colour). As the models used are weather based only, users are encouraged to check either by logging into the platform and running the corresponding model for the user's farm with specific farm data or by other means. The models available in 2024 are:

- The Septoria Reference Humidity Model / Wheat / Aarhus University & SEGES
- The Pollen Beetle Migration Model / Oilseed rape / ADAS
- Codling Moth Model / Apple /

Example: Septoria Humidity Model (restricted)

The Septoria Humidity Model (restricted) risk map (Figure 3.6) is based on a restricted version of the Septoria Humidity Model, using only the weather dependent aspects of this Decision Support System. The full Septoria Humidity Model is available in the IPM Decisions platform. Risks displayed in the map may be higher or lower when crop specific parameters are provided. Consultation of the full version is required to support IPM decisions. This map indicates the risk of splash-borne foliar diseases of wheat (septoria leaf blotch, glume blotch and tan spot) based only on the number of 'wet hours' in a 72 hour period (yesterday, today and tomorrow). The risk criteria were developed in Denmark as the Septoria Humidity Model (Restricted). The risk map can be used to assist (not replace) decisions by experienced crop managers, taking into account all relevant local risk factors. If a risk is indicated in your area, please login and set up the complete Septoria Humidity Model for your farm, and check its outputs for a more in-depth assessment.

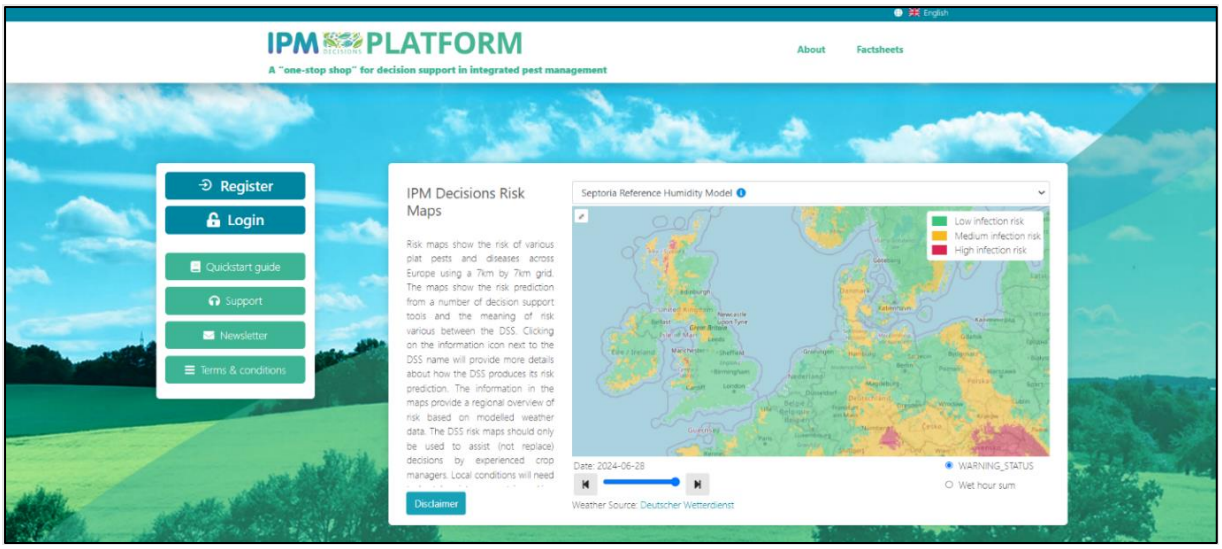


Figure 3.6 Screenshot of a regional risk map on the IPM Decisions Platform homepage

Sharing farm Locations

Advisors work closely with their clients to provide effective guidance on crop protection strategies. To support this process, a Farm sharing function has been built into the IPM Decisions platform that enables users to share Farm DSS outputs between accounts. An advisor (or any users) can make a 'Farm share request' through the Account Manager settings (Figure 3.7), using the third parties account email address to make the request. The third party (for example, a farmer working with the advisor), receives an email alerting them to the request, which they then accept or reject in their account. If accepted, the advisor is then able to view the DSS outputs in their DSS Use Dashboard, and so are kept up to date on potential risks on their client's farm. The advisor cannot edit or amend the shared farm details but can use the 'Adaptation Dashboard' to create a copy of the shared farm, which can then be updated, and shared back with their contact. In this way, multiple users can track changing risks, compare effects of parameter updates, and ensure timely action is taken.

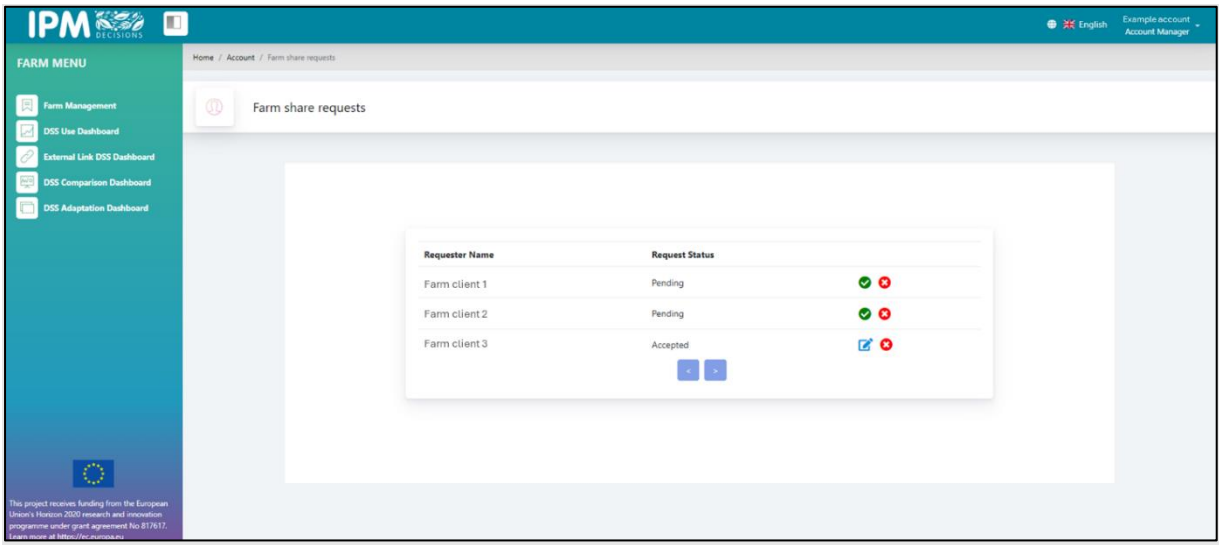


Figure 3.7 Screenshot of the Farm share request function in account settings

3.4 DSS Validation and evaluation (WP4)

Project partners

AU (Lead), ADAS, AUA, LfL, APCA, DELPHY, LAMMC, LUKE, IPM Consult, NIBIO, RRES, SLU, SEGES, GAIA

Project objectives addressed by this work package

2(i) Provide a toolkit of methods to test and quantify the benefits (economic, environmental and societal) from decision support use.

2(ii) Create and deliver large open access sets of observational data on key pests.

2(iii) Test a range of DSS in different biogeographical regions for accuracy and value.

2(iv) Enable comparisons between DSS for their benefits.

IPM DSS are more likely to be used if there is evidence for economic returns. The testing of DSS usually involves comparing predictions of pest risk against observational data of pest prevalence. However, predictive value does not necessarily translate into economic benefits. Work package 4 has developed methods for economic analysis of DSS and is applying those methods to a set of contrasting pest/crop systems. To enable this analysis, data sets of pest observations across many sites and seasons have been obtained and, along with the evaluation methods, made available through the platform and by open access publication.

3.4.1 Main outputs from WP4

- Methods have been developed for evaluating the value and impact of IPM DSS.
- Seven pest and climate observation data sets have been made freely available for reuse.
- Several open access publications demonstrating the validity of IPM DSS have been supported.
- A key conclusion was that while DSS provide reliable guidance, consultation must always be complimented with field observations.
- Assessment of the impact of increased uptake of DSS in Europe show significant potential for reducing pesticide inputs while maintaining profit margins.

3.4.2 WP4 tasks and activities

To facilitate a rigorous investigation of DSS performance, we developed a statistical tool to evaluate the quality of risk guidance given by a particular DSS. Specifically, we investigated those DSS that give advice on pesticide dose, pesticide spraying frequency and the timing of pesticide spraying. For the DSS that were evaluated (septoria in wheat, potato late blight, sclerotinia in oilseed rape), we found that the DSS were all on average providing economical and environmental benefits. However, the average positive outcomes came with an uncertainty and probability of a negative outcome that could be large. Thus, DSS should be consulted in combination with field monitoring.

We assessed the impact that could be achieved by a more widespread usage of DSS in European agriculture. The analysis concluded that DSS could provide significant economical gains for European farmers as well as benefits for the environment in terms of reduced pesticide use. The analysis was focused on three crops (wheat, potatoes and grapes), which are economically important and representative of diverse growing systems (southern *vs.* northern regions, annual *vs.* perennial crops, different plant taxa). Thus, increased implementation of DSS could assist growers achieving the EU sustainability targets relating to reducing the use of pesticides. One caveat, however, is that the DSS included in the analysis were all targeted at the proper use of fungicides against plant diseases. For other pests and for weeds, the use of DSS was not yet widespread enough to allow an analysis across the EU.

Task 4.1 – The accuracy of DSS prediction

(Lead partner: Niels Holst, AU; Participants: RRES, ADAS, APCA, Luke, NIBIO, LAMMC, IPM Consult, SLU, BASF, FMC, Corteva, LfL, GAIA, AUA, SEGES)

The algorithms behind models and DSS were evaluated using a series of historical datasets provided by project partners. Local, historical weather data has been provided in WP2 and used as model input to assess DSS. It is believed that these data sets will be useful, especially for teaching IPM. Data sets on plant diseases and insect pests, obtained from BASF, Corteva and SEGES, were uploaded to the public domain:

- Data from 56 fungicide trials in wheat fields across Europe 2017-2019 (zenodo.org/record/6521175)
- Data from 36 fungicide trials on grape downy mildew across Europe 2012-2019 (zenodo.org/record/6520937)
- Data from 89 fungicide trials on apple scab across Europe 2008-2018 zenodo.org/record/6520484
- Data from 168 fungicide trials in wheat fields across Europe 2014-2018 (zenodo.org/record/6390211)
- Data from 18 fungicide trials on potato late blight in UK and Ireland 2013-2017 (zenodo.org/record/6352735)
- Cereal aphids monitored in 2,110 fields in Denmark 2002-2019 (zenodo.org/record/6352394)
- Trap catches of carrot fly (*Psila rosae*) and cutworm (*Agrotis ipsilon*) from 142 fields in Denmark and Southern Sweden 1997-2019 (zenodo.org/record/6351794)

We developed a statistical tool that can evaluate the quality of risk guidance given by a particular DSS. It was found that, in general, data from pesticide field trials are not ideal for the validation of DSS. Literature studies revealed that field trials purposely designed to test DSS resulted in better evidence for DSS validity. Examples include field trials testing DSS for septoria, grape downy mildew and apple scab. We developed tools to analyse the benefits of DSS, both economically and environmentally (in terms of reduced pesticide use) and found that use of DSS offers benefits on both accounts compared to fixed spraying schedules.

Task 4.2 – DSS description and verification

(Lead partner: Lise Nistrup Jørgensen, AU: Participants: NIBIO, RRES, ADAS, Luke, SLU, Gaia, Coldiretti, Delphy, IPM Consult, SEGES, FERA, BASF, FMC, CORTEVA.)

A catalogue of DSS relevant to the IPM Decisions Platform was created, and all DSS tools included in Task 4.1 were reviewed to verify the extent to which they have been validated. The review described the input and output interface of each DSS and the underlying mathematics/logic. DSS that are not evaluated in WP4.1, which are intended for integration with the Platform (through WPs 2 and 3) were described in brief, together with the evidence on which they are based. This task utilized and updated information from the ENDURE project, which produced a review of DSS (authored by some of the participants in this project). The information was collated in a report and made generally accessible. The catalogue was used in WP2 and WP3 to provide case models for the design and implementation of generic DSS modelling tools and, by WP5 for a systematic user perspective analysis.

Catalogue of DSS collated with details on inputs, outputs and functionality (D4.9)

To design the IPM Decisions Platform and Dashboards, we need to know what IPM decision support systems (DSS) are available and their characteristics. Important characteristics include, for example, the types of input data the Platform needs to provide for a user to be able to run the DSS, and the types of maps, charts or tables which the Dashboards need to be able to provide for users to see the DSS output.

In total, information has been collected for initially 73 DSS, which has been collated in the IPM Decisions DSS catalogue. This currently includes40 DSS covering diseases, 26 covering insects, 6 covering weeds, 2 covering slugs and 1 on potato haulm killing. Most of the systems are web based, but a few are installed and run on the user's computer, some of which are excel based. Most of the systems require weather data input; temperature and rainfall data are the most common requirements. This deliverable provides an overview of prioritized DSS; the full catalogue is available to all project partners. Development of this catalogue has taken place in parallel with contacting DSS owners (through Work Package 6). The catalogue ensures that the project group is well informed about the DSS which are available and their characteristics. The discussions with DSS owners aim to find out which systems from the list will ultimately be fully or partially integrated with the Platform or make use of resources from the Platform.

Task 4.3 – The usefulness of DSS predictions

(Lead partner: Alice Milne, RRES; Participants: AU, ADAS, IPM Consult)

In task 4.1 we are evaluating the performance of a DSS or model by assessing how accurately it predicts a disease, pest or weed infestation, although importantly this does not adequately evaluate its usefulness for farmers and advisers. Crop protection DSS usually aim to adjust crop management practice such that yield loss and/or inputs of plant protection products are reduced, and economic gain increased. Therefore, the evaluation of the performance of such forecasting systems should be done at the level of economic return or the amount of pesticide reduction of the pesticide application program. This task aims to develop a systematic and generic method to evaluate disease, pest and weed DSS tools in terms of the value of prediction (VP) and use the method to evaluate the DSS identified in catalogue. The potato late blight data were used to develop a generic method for the assessment of the economic and environmental benefits of DSS, and extended to cover septoria, which is quite different

in terms of disease dynamics and control strategies. We developed methods for DSS validation that will be made available to researchers and engineers as open-source R scripts and a scientific publication.

Description of the general outline methods for DSS evaluation of the value of a prediction (D4.10)
The expected value of a DSS is defined as the economic or environmental benefit derived from using a DSS over a standard practice. We present a framework describing how these two types of benefit can be calculated for various types of DSS and for various formats of validation data. Specifically, we consider the situations where predictions inform (i) the number of sprays (ii) total dose of pesticides (iii) onset of spraying, and (iv) spray timings. We explain that to be meaningful, estimates of the expected value of DSS should be accompanied by a quantification of the likely variation in value, hence allowing the user to make a risk-based assessment.

Task 4.4 – Environmental and economic impact assessment

(Lead partner: ADAS; Participants: RRES)

The socioeconomic impacts associated with the use of IPM DSS in wheat, potato, and grape production were evaluated. Our analysis shows that using IPM DSS can provide economic benefits for farmers by reducing the treatment frequency index, thus lowering overall cost of production and total pesticide usage. This work was based on broad assumptions and extrapolations from limited datasets, provides an overview of the potential impacts of scaling up consultation of IPM DSS. The work[4] outlines the methods used, which should be applied to regionally specific scenarios using appropriate data to reflect current and potential future adoption more accurately. The approach used makes substantial, but necessary, assumptions required to assess complex disease management programmes.

The analysis combined the results from the meta-analysis with European and country level data on pesticide usage, crop areas and cost of pesticide applications at the per hectare level, to calculate a partial budget for the impact of implementing DSS within each of the three crops. Scenarios of different levels of DSS uptake (current practice - estimated at about 5% DSS use, and an additional 25% and 50% of crop area under DSS) were then used to scale up the hectare level impact to national level (for Belgium, Denmark, France, Germany, Ireland, Lithuania, Slovenia, and the United Kingdom) and European level to determine the potential impact on overall pesticide usage, and the potential cost savings for farmers.

[4] IPM Decisions Deliverable 4.17 – DSS environmental and economic impact assessment for Europe

3.5 Incentives and barriers to DSS uptake (WP5)

Project partners

BSB (Lead), MPS

Project objectives addressed by this work package

1(i) Understand constraints with current routes of access to DSS, by engagement of the end users

1(iii) Guide users of the DSS Platform towards DSS that suites their needs the most.

In this work package, information on user characteristics and DSS features was combined to assess how a specific user type is prone to accept and use a DSS, according to the DSS features desired by the end-user and those offered by the DSS. It was assumed that there is not a globally superior DSS for all users, but a specific DSS could optimally fit the needs of each user type. From the DSS providers' point of view, we described the set of available DSS, in terms of their structural and performance features. Regarding the demand side, current and potential users of DSS were interviewed and surveyed to evaluate the overall performance of DSS. In that aspect, the users' perception of desirability for each DSS feature was assessed as well. Additionally, the study of users' profiles identified linkages between user characteristics and reasons for their acceptance/no acceptance of various types of DSS.

3.5.1 Main outputs from WP5

- The main identified barriers to the adoption of DSS for all farmers in Europe were the lack of trust in DSS and the feeling that they lack the knowledge to use such systems.
- The main barrier identified among farm advisors across Europe was poor access to marketing information about DSS.
- A typology for user-specific selection of DSS for IPM in Europe has been created, and used to develop freely accessible online tool called IPM Adviser (https://ipmadviser.ijs.si/) was launched in 2024, supporting users in finding appropriate IPM DSS.

3.5.2 WP5 Tasks and activities

As part of the workshops organised in WP6, questionnaires designed in WP5 provided insight into the constraints on DSS uptake, as perceived by potential users of the IPM Decisions platform. The results confirmed our initial identification of constraints across Europe, as well as identifying some key differences between potential users. Differences between users were addressed by designing specific 'dashboards' for each user type in WP3, through which users will interact with the platform to obtain the services they need. Findings from stakeholder questionnaires fed back into software design of the platform.

Task 5.1. Description of the DSS as vectors of characteristics

(Lead partner: MPS; Participants: BSB, ADAS)

The results of engagement with stakeholders during the three rounds of workshops showed that access to information is one of the major barriers to DSS adoption. We developed a typology for user-specific selection of DSS for IPM in Europe, with which we systematically described 80 DSS and created a catalogue with structural and performance characteristics. The systematic approach to describing DSS is designed to be used by end users, and so help overcome this barrier to DSS adoption. The catalogue of structural and performance characteristics of the 80 DSS describes the following four aspects of the assessed DSS:

1. information about **who the target user of the assessed DSS is** and what the spatial, temporal and technical constraints are for the problem in question.
2. information about the **decision problems** that could be solved by the assessed DSS and what kind of decision alternatives this DSS can provide.
3. information on the **decision analysis** method on which the assessed DSS is based and the required input data.
4. information on the **required knowledge** of the end-user for the daily use of the assessed DSS.

The data from this was integrated in freely accessible online tool called IPM Adviser (https://ipmadviser.ijs.si/, Figure 3.8), which facilitates access to information about developed IPM DSS for Europe. The description of the development of the typology for IPM DSS in Europe and the development of the web tool is published in open access journal (Marinko et al., 2024).

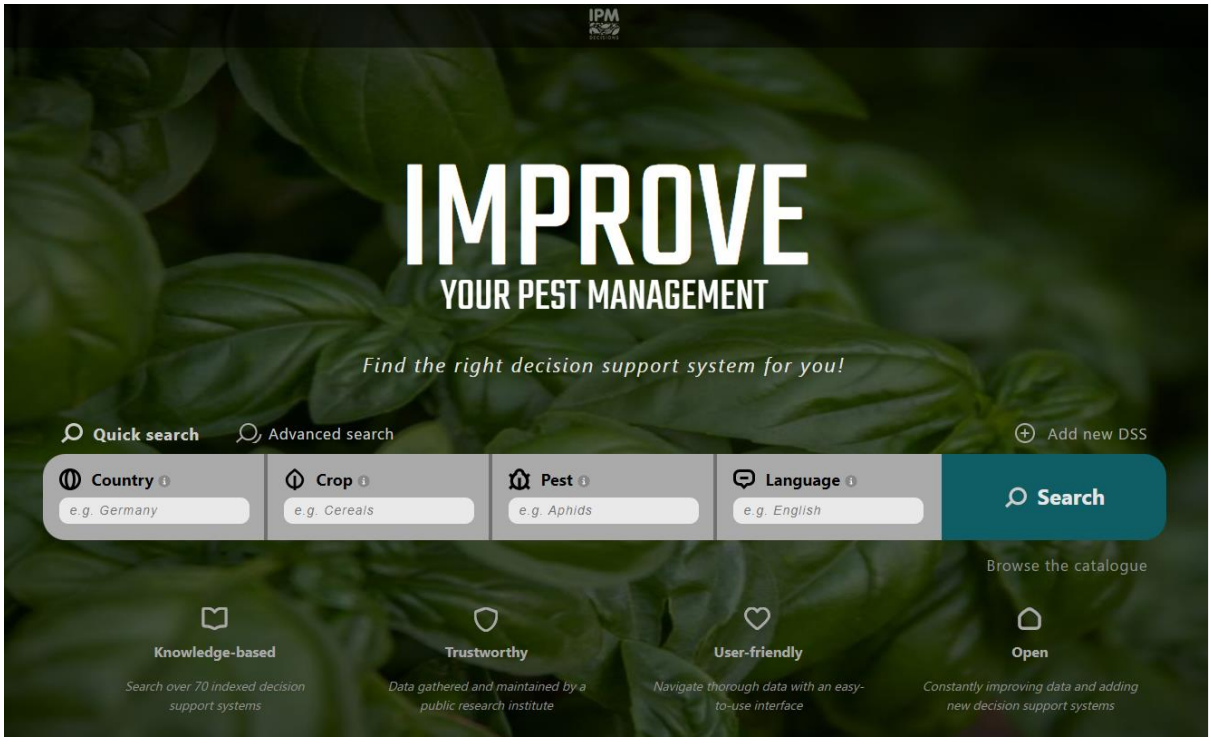


Figure 3.8 Screenshot of the IPM Advisor online tool (31 May 2024)

Task 5.2. Elicit potential users' attitudes

(Lead partner: Burgundy School of Business (BSB); Participants: MPS, Delphy)

During this task, the research team developed a survey questionnaire in order to collect information about current and potential users of the DSS. The questionnaire was partially differentiated into three versions by user type (farmers, DSS developers and farm consultants), and distributed among the participants in the first round of workshops under the supervision of local workshop organizers. A high number of responses was collected (N=380, 145 farmers, 150 consultants and 85 developers) with a small number of wrong or incomplete answers (10, from the total population of participants, N=390). This dataset was organized in a unified database which is stored respecting the appropriate data-management protocols. A second survey aimed to validate the findings of the first survey during the second round of project workshops.

The analysis of the combined dataset[5] reveal that the main barriers to the adoption of DSS for all farmers in Europe were the lack of trust in DSS and the feeling that they lack the knowledge to use such systems. The main barrier identified among farm advisors across Europe was poor access to marketing information about DSS. Region-specific barriers to DSS adoption was also identified for farmers and farm advisors. Farm size is the unique significant farm-related factor which increases a farmer's likelihood to adopt a DSS. Regarding trust in DSS, exposure to demonstration sessions increases a potential adopter´s trust in DSS, advertising sessions have the contrary effect.

Task 5.3. Model the adoption of a DSS by potential users according to their profile and the type of IPM problems. (Lead partner: Burgundy School of Business BSB; Participants: MPS)

Analysis of the information obtained in Tasks 5.1 and 5.2 and modelling of adoption decisions by combination of users' characteristics (T5.2) and profiles of DSS features (T5.1). In total, eight approaches to overcoming barriers and utilising incentives for DSS adoption were proposed and linked to descriptions of DSS (Table 4.4). All proposed approaches correspond to DSS characteristics from three thematic sections of DSS descriptions: (i) Decision problem, (ii) Decision analysis, and (iii) Final output. For each DSS descriptor (attribute), we have highlighted the value that has the greatest positive impact on IPM DSS adoption. Thus, the interactive table provides a region- and user-specific overview of barriers and incentives for IPM DSS adoption.

[5] Akaka, J. J., García-Gallego, A., Georgantzis, N., Tisserand, J.-C., Vasileiou, E., & Ramsden, M. (2024). Curated dataset for analysis for the paper "Decision Support Systems Adoption in Pesticide Management" [Data set]. Zenodo. https://doi.org/10.5281/zenodo.10888114

Table 3.2 Key broad approaches to overcome identified barriers or exploit identified incentives to IPM DSS uptake among farmers and farm advisors.

Key approaches
- Develop/include additional DSS for vegetables, vineyards and ornamentals.
- Reduce dependence of DSS use from speed of and/or access to internet.
- Raise users' awareness of the benefits of DSS, - Stimulate the sharing of positive experiences among farmers, - Stimulate developers to provide evidence of efficiency of their DSS, - Increase trust.
- Minimise login requirements.
- The necessity of the national language is well addressed in our project (translation of the platform)
- Minimise manual input of weather data to support user friendliness of the DSS
- Increase the effectiveness of communicating DSS results to end users
- Grants/subsidies for development/use of advanced (payable) DSS, - Developers should offer free trial versions.

Task 5.4. Synthesis and recommendations. *(Lead partner: Burgundy School of Business (BSB; Participants: MPS)*

Specifically the determinants identified are:

Farm size (and satisfaction with current production for WTP)

- Farm size is a significant determinant factor of both DSS adoption and a farmer's willingness to pay for a DSS. Furthermore, regarding the effect of farm size on WTP, we found that such an effect is stronger for farmers who are satisfied with their current level of production.
- Potential users associated with larger farms are more likely to adopt DSS, and more willing pay for DSS, than those associated with relatively smaller farms.
- When engaging with larger farms, promotion activities should focus on the benefits to avoiding unnecessary applications while maintaining levels of production.
- When engaging with smaller farms, promotion activities should focus on the free access, and opportunities to reduce input costs/increase production through lower input/targeted inputs according to need.

Arable Crops

- Like farm size, it is a significant driver of a farmer's willingness to pay for a DSS, while it interacts positively with farm size (arable crops related to larger farms) to enhance DSS adoption.
- Farmers growing arable crops are more likely to be willing to pay for DSS, especially when adopted on larger farms.
- When engaging with large arable farms, promotion activities should focus on facilitating engagement between farmers to help i) promote farmers advocating DSS use already, and ii) improve support in interpretation and confidence in outputs.
- When engaging with non-arable farms, promotion activities should focus on the benefits of free access, and how DSS can be developed, evaluated, and demonstrated – ideally using existing examples, or connecting users and developers.

Unique crop

- It is positively related with DSS adoption, although the effect is weaker for male farmers.
- Farmers focusing on unique crops are more likely to use DSS, more so if the user is female.
- When engaging with farmers growing unique crops, promotion activities should focus on identifying the specific crop/pests of interest and connecting them directly with appropriate systems and/or developers to create them.
- Already used DSS
- It increases the probability that a farmer is willing to pay for a DSS and its effect is stronger under the perception of a DSS as efficient and when farmers use the same DSS as their advisors.
- When engaging with farmers already using DSS, promotion activities should focus on presenting up to date evidence of benefits and encouraging farmers to discuss each DSS with their advisor.

Income

- Income is positively associated with both DSS adoption and WTP for a DSS, but the effect is related to that of farm size.
- As it is not appropriate to confirm income levels of farmers during engagement, this is effectively covered through approaches for engaging with larger farms.

Gender

- Gender has a discrete role in the adoption model alone. Being male implies a weaker "unique crop effect."
- Thus, the impact of gender on DSS adoption and WTP is not sufficiently influential to justify approaching engagement of farmers of different genders differently.

Age

- Younger farmers are more likely to adopt DSS because they enjoy using new technologies.
- When engaging with younger farmers, promotion activities should focus on the technical aspects of using the systems through the platform; ability to adjust parameters, compare models, review data etc.
- When engaging with older farmers, promotion should focus on ease of use to get a quick risk assessment.
- When engaging with a mixed group, focus should be on the ease of use, and the ability to only look at more detail if needed.

Individual attitudes towards risk and trust

- Trust has a weak positive effect on the willingness to pay for a DSS. However, the factors leading a farmer to trust a DSS relate mostly to underlying psychological processes like risk attitudes, a farmer's generic willingness to try new products and a farmer's tendency to trust in friends' and colleagues' advice. Trust can be weakly (and negatively) affected by DSS advertising.
- Risk attitudes matter for willingness to pay, but the mechanism is more complex than through the usual risk aversion channel. Both risk aversion and sensitivity to risk-return variations are needed to describe risk attitudes, which then determine trust in DSS.
- When engaging with farmers, the concept of risk needs to be made clear at the start of the presentation, outlining what risk forecasts are and how they need to be interpreted within the context of each individual farm, even field. It should also be made clear how DSS outputs can be reviewed during/after a season and provide opportunity for discussion and review. Examples of DSS results, and routes to look at historic data should be made available. Each farmer should be able to i) understand the risks and how they consider them in making decisions, and ii) understand how they should first start using DSS on their farm to minimize risk in any one year.

Willingness to use new products

- It is a major factor in both DSS adoption and WTP for DSS. In the adoption model, it becomes the explanation why younger farmers are more likely to use a DSS.
- When engaging with farmers, this could be a starting question to the audience, 'How willing to adopt new products are you?', and this can be asked again at the end 'How willing are you now to adopting a new DSS?'

Perceived DSS productivity

- It has a direct and significant impact on DSS adoption, while it impacts willingness to pay by moderating the effect of already having used a DSS. In that case, the perception that a DSS is productive is higher when the farmers use the same DSS as their advisors.
- When engaging with farmers not already using DSS, promotion activities should focus on presenting evidence of DSS benefits to productivity
- When engaging with farmers already using DSS, promotion activities should still present benefits of DSS on productivity, but also the benefits of facilitating discussion with advisors to fine tune management decisions.

DSS perceived as "easy to use"

- It has a strong direct effect on the DSS adoption decision.
- When engaging with farmers, the simplicity of the platform should be emphasized.

Importance of low price

- It has a strong negative effect on a farmer's WTP for a DSS.
- Thus, farmers willing to pay for DSS are not influenced by a low value attributed to the DSS. They are looking to pay for a system that works, not a cheap system.

Legislative requirements

- It does not seem to significantly affect adoption decision or the farmer's WTP for a DSS.
- At present, there is no legislative requirement for DSS adoption in Europe. Where this changes, the influence of this may be relevant.
- When engaging with farmers, reference to legislative requirements should be minimize unless there are highly relevant national/international requirements.

DSS Demonstrations

- Demonstrations influence positively DSS adoption, but not a farmer's willingness to pay for a DSS.
- When engaging with farmers, this should either be done within the context of a demonstration visit, or a relevant case study should be presented either using existing case studies or using the platforms 'comparison' dashboard.

Marketing

- Exposure to DSS marketing has a weakly negative effect on trust in DSS.
- When engaging with farmers, generic messages must be avoided, and impacts should be tailored to the region and group. Where resources are shared, these should be explicit in messages to avoid being seen as marketing.

3.6 Multi-actor activities, networking and dissemination (WP6)

Project partners

DELPHY (Lead), ADAS, AU, AHDB, AUA, LfL, APCA, COLDIRETTI, ENG, MPS, LAMMC, LUKE, INRAE, IPM Consult, NIBIO, SLU, SEGES, GAIA, CIRAD

Project objectives addressed by this work package

1(i) Understand constraints with current routes of access to DSS, by engagement with end users

1(ii) Increase farmer and farm adviser access to DSS through a pan-European Platform.

1(iii) Guide users of the Platform towards DSS most suited to their needs.

3(i) Accelerate adoption of DSS and innovation in DSS by creating an effective marketplace for IPM DSS.

The work package used a multi-actor approach for interactions with users and stakeholders. Interactions were coordinated across three bio-geographical zones (Figure 1.1), with each zone coordinated by a 'Zone leader'. Multi-actor engagement was managed in two phases. The first phase focused on gathering information into the project ('information in') from representative groups of users and stakeholders from contrasting sectors of agriculture and geographic zones. This phase (i) promoted benefits of the Platform and identify DSS developers with an interest to cooperate with the project, and (ii) ensure that WP 2-5 received the key inputs they need to understand the constraints with current routes of access to DSS, and user input to the design and content of the Platform and Dashboards. In the second phase, the IPM Decisions Network was expanded to full scale for dissemination to wide user and stakeholder communities ("information out"), to foster uptake of the Platform and IPM DSS.

3.6.1 Main outputs from WP6

- Three rounds of multi-actor workshops were completed between Dec 2019 and March 2022. These took place across 12 countries, engaging with over 700 participants.
- Stakeholder engagement across Europe helped prioritise key crop:pest combinations where decision support would be valuable (Table 3.3).
- IPM Decisions jointly coordinated two international Conferences in Brussels; the FarmDemo Conference in 2022 and the IPM Conference in 2024.

Table 3.3 DSS with highest and second highest priority from potential platform users

Priority 1		
Wheat	*Zymoseptoria tritici*	Septoria leaf tritici blotch
	Puccinia striiformis	Yellow rust
	Fusarium spp	Fusarium head blight
	BYDV	Barley Yellow Dwarf Virus
Barley	*Pyrenophora teres f. teres*	Net blotch
Potato	*Phtypthora infestans*	Potato late blight
	Alternaria solani/alternata	Potato early blight
Oilseed rape	*Sclerotinia sclerotiorum*	Sclerotinia stem rot
Apple	*Venturia inaequalis*	Apple scab
	Cydia pomonella	Codling moth
Priority 2		
Wheat	*Pyrenophora tritici-repentis*	Tan spot
	Sitonbion avenae (plus)	Summer aphids
Onion	*Peronospora destructor*	Downy mildew
	Botrytis aclada	Grey mould
Oilseed rape	*Meligethes auneus*	Pollen beetle
Weeds	Major weed species	
Nematodes	Several species (cyst/free living nematodes)	

3.6.2 WP6 Tasks and activities

Task 6.1. Identify user needs: Information in

(Lead partner: Zone leaders (SLU, AUA, Delphy); Participants: Gaia, AHDB, ADAS, APCA, INRA, CIRAD, Coldiretti, Engineering, SEGES, IPMC, Aarhus, LAMMC, LfL, Luke, NIBIO, MPS)

This task covers all the activities with the users and stakeholders of the Platform, to ensure input and feedback for the development stage of the project. A stakeholder map for each country (list of key users and stakeholders) was created, and key groups in each zone were identified. In the first phase of the project special attention was given to the DSS owners/developers. We then identified national policy makers dealing with crop protection, advisors and research people and in the next task tailored dissemination to the specific needs of each group.

Identify DSS owners/developers with an interest to cooperate

During the early stages of the project, an initial stakeholder list per country was created, with representatives of the most important stakeholder groups. The list was maintained throughout the project, and included farmers, advisors, DSS developers, policy people, education, value chain partners and other stakeholders.

Organise initial and follow up workshops

The objective of the stakeholder meetings was to get feedback on the IPM decisions dashboard “mock-ups”, in order to i) identify the needs and ambitions of interested DSS owners/developers, and ii) engage with potential end users to foster co-ownership of

results and facilitate acceptance and dissemination of new ideas. The meetings also aimed to identify and define the constraints in end user access to existing decision support systems (DSS). Meetings were held in twelve countries with potential end users, developers and other stakeholder groups to understand requirements in the different countries. These national groups form the core for expansion of stakeholder engagement (building from existing regional, national and EU initiatives) forming the multi-actor IPM Decisions network. The first round of workshops was organised from December 2019 to February 2020, in United Kingdom, Norway, Sweden, Finland, Denmark, Latvia, Germany, The Netherlands, France, Slovenia, Italy and Greece. In most countries two workshops took place, in 'smaller' countries just one; in total 20 workshops were held. Based on feedback during these workshops, summary reports were produced per country, which identified the needs and ambitions of interested stakeholders are detailed (farmers, advisors, and DSS owners/developers). The results from each meeting is combined and categorised in; key messages and feedback, farmer results, advisors result and developer results. Any country specific results are summarised, the overall preference of interaction from the platform is shown and the next steps are laid out.

In the second reporting period two rounds of workshops were conducted, during November 2020 – January 2021 and April 2022 – May 2022. The last series of workshops initially was planned in January-February 2022. General conclusions from the workshops were that the platform offers interesting functionality for farmers, advisors and researchers. Participants like the way the platform works and the type of output it generates. The registration process and farm set-up need good instruction but are quick and easy. In order to make the platform a success across Europe, a wider range of DSS are needed, and this must include DSS that are trustworthy in countries other than where they are already available. Trust in the DSS outputs is a crucial factor. Additional validation work might be needed to reach this stage for a range of DSS.

Task 6.2 Foster uptake: Information out.

Lead partner: Zone leaders (SLU, UA, Delphy); Participants: Gaia, AHDB, ADAS, APCA, INRA CIRAD, Coldiretti, Engineering, SEGES, IPMC, Aarhus, LAMMC, LfL, Luke, NIBIO, MPS)

Task 6.2 covers all activities to: (1) create the multi-actor IPM Decisions Network, to (2) promote the Platform facilities and (3) to foster end user acceptance and uptake of the Platform facilities. A multi-media and multi action strategy was used to disseminate the Platform possibilities to the target group.

Preparation for platform promotion and demonstration

The platform is available in twelve languages, before starting platform promotion activities it was necessary to translate the following information:

- The general information on the platform, the information about the four platform dashboards and the registration page. For this goal the file 'Button and menu translation file' was created, it contains more than 250 lines. Other clusters were Common labels, Information messages, Countries, Language selector, Home, Register,

Terms and conditions, Forgot password, User header, User menu, User menu footer, User account, Edit user account, Farm share, Farm request, Farm list, Add Edit farm, DSS information table, DSS use dashboard, DSS details, DSS model selection and DSS model parametrisation.

- Meta data information about all the DSS integrated in the platform.
- Explanation information for all the DSS, the 30 DSS integrated in the platform and the 19 DSS with a link on the platform. The information contains the DSS name, the purpose of the DSS, a description of the DSS and information about the authors of the model, the source and source organization.

The IPM Decisions platform was ready for public demonstration from September 2022, at the end of the growing season. Experience showed that the best way to demonstrate DSS is under real circumstances, i.e., during the growing season. From March 2023 the focus of project dissemination was on platform demonstration, with the aim of increasing the numbers of registered users. Feedback from users shows that the platform is an interesting tool for farmers and advisers to advise on integrated pest management in several crops. By the end of May 2023, 616 users had registered accounts on the platform. The platform underwent a further series of updates and DSS integrations between the 2022/23 and 2023/24 production seasons, and an updated version of the platform was released in early 2024. Platform promotion and demonstration activities were ongoing, but increase during the key pest risk periods to enable demonstration under real circumstances. By the end of May 2024, 1,319 users had registered accounts on the platform.

Demonstration of the Platform and dissemination through national networks and learned societies

In excess of 88 platform demonstrations were conducted across Europe following its launch in 2022 (Figure 3.9). There were two topics related to platform promotion: 1) promotion of the platform itself and 2) promotion of the DSS information. A general conclusion from engagement with stakeholders across all countries was that the functionality of the platform is nice, interesting and good. For the DSS information provided, the conclusions were country specific, and feedback gather as part of the third round of works is detailed in D6.5. The availability of validated DSS for the county, and trust in the DSS outputs is a crucial aspect for advisors to promote the DSS and for farmers to incorporate the outcome into management decisions. There are significant differences between the partner countries in the availability of validated DSS. A few aspects are mentioned in most countries: (i) trust in the weather data used to run models, (ii) desire for the option to use data from own/local weather stations, (iii) make it possible to scroll back in the growing season or use historical data.

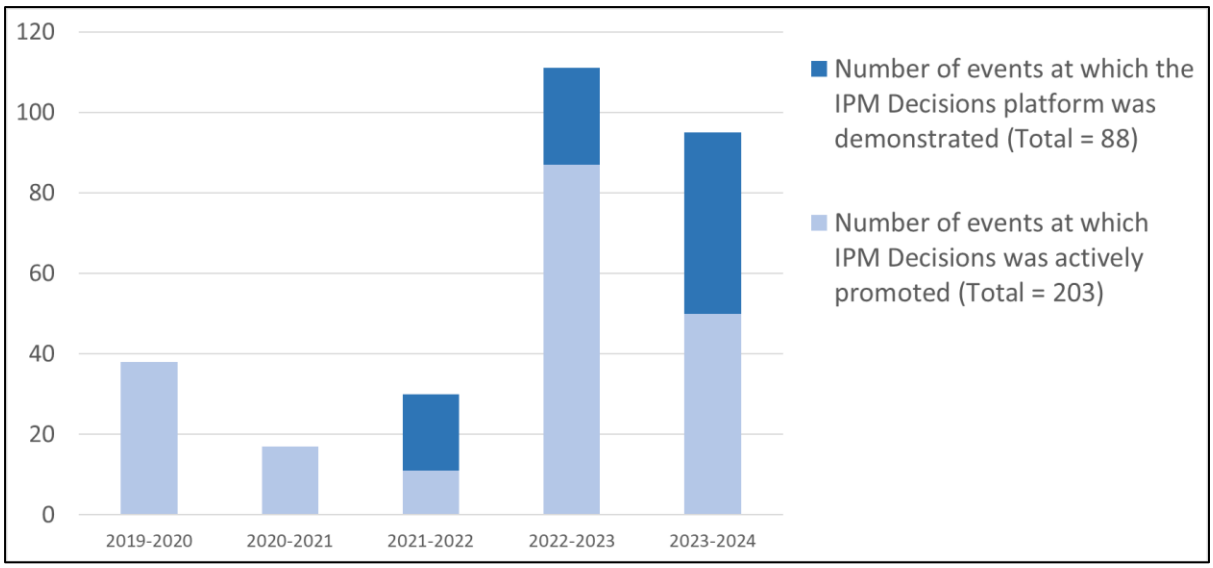


Figure 3.9 The number of events at which the IPM Decisions project and platform were promoted/demonstrated during the five years of the IPM Decisions project (years run June-May)

In some countries national IPM DSS platforms or other information systems were already available (Norway, Denmark, Germany, France, Italy, Sweden), in other countries there is little experience with use of DSS (Finland, Lithuania, Slovenia, Greece), and in other countries commercial DSS for some pests are on the market (The Netherlands, United Kingdom). For a number of countries there are few validated DSS available on the platform, as indicated by the country flags. Summaries of the approach, focus and plans for platform promotion for the final reporting period, per country, are provided in Deliverable 6.8.

In addition to demonstration of the platform at events, demonstration videos were created and shared on the project YouTube Channel. The two main videos created in support of the platform were the IPM Decisions Platform demonstration 2022 [October 2022: 598 views up to May 2024, Figure 3.10), and a short instructional video on How to register on the IPM Decisions Platform (September 2022: 266 views up to may 2024). Other demonstrations of the project have been shared on YouTube where they were recorded as part of network webinar series, including:

- Warwick Crop Centre webinar: Demonstrating the IPM Decisions and IPMWORKS projects for the reduction of pesticide inputs
- AHDB Cereals and Oilseeds Agronomists' Conference 2022 and 2023
- Annual meeting in LAMMC on plant protection issues
- Promotion video about the platform and demonstrating how to set up and account and use the platform
- Video on pollen beetles and how to use IPM decisions and pollen beetle model

Figure 3.10 Screen capture of the IPM Decisions Platform Demonstration video 2022

The IPMWORKS e-learning modules have been prepared based on successful experiences within the project network, including technical aspects of IPM strategies, farm performance or co-innovation and method for farm hub coaching, targeting both farmers and advisers. Modules on agroecosystem approach, on holistic pest management examples and on the key topic of policies are also included to frame the technical ones. The role of DSS was including in several chapters, and explicitly covered in Module 5: Integrated Invertebrate Pest Management, chapter 5.4: Decision Support Systems and monitoring as part of Invertebrate IPM. All training modules can be found on the IPMWORKS Resource Toolbox, and the specific chapter on DSS can be found within the Toolbox: [Chapter 5.4], including a video recording and a pdf of the presentation.

Dissemination through social media

Social media was used by IPM Decisions to inform a wide public about the IPM Decisions project and to share project result with all target groups. IPM Decisions created three central social media channels for communication: Facebook, Twitter/X and LinkedIn. Public Deliverable 6.9 provides an overview of activities and outreach across social media channel.

IPM Decisions website:	https://www.ipmdecisions.net/
IPM Decisions platform:	https://www.platform.ipmdecisions.net/
IPM Decisions Twitter:	https://twitter.com/IpmDecisions @IpmDecisions
IPM Decisions Facebook:	https://www.facebook.com/profile.php?id=100063972940071
IPM Decisions LinkedIn:	https://www.linkedin.com/company/ipm-decisions/
IPM Decisions YouTube:	https://www.youtube.com/@ipmdecisions1717
	IPM Decisions on the EU FarmBook

Social media channels were used during the IPM Decisions project, both centrally and by some of the project partners, to compliment targeted engagement activities. Social media facilitates rapid sharing of information about the project and project results with large numbers of people. The widespread use of LinkedIn, Facebook and X/Twitter also enables wider sharing of outputs across partner projects; increasing the potential reach of any individual initiative. Public engagement with projects via social media is highly variable between groups and across different parts of Europe, especially for farmers and advisors. The number of followers of the IPM Decisions social media accounts is similar to numbers following other EU projects, but relatively low compared to the number of followers of the individual partner accounts. Partner accounts are established and maintain over longer periods and offer a greater diversity and continuity that individual projects can. It was a deliberate choice to focus on 'other' type of activity to increase the number of platform users. The statistics collected on the pathway of visitors to the platform show that more than 80% of the platform users came in 'direct' or through the project website. Project and platform web address and/or QR codes were included in promotion material and invitations for meetings and events.

IPM Decisions QR code linking to the platform registration page

Partners responsible for communication and dissemination in each country represented in IPM Decisions were provided with resources and templates, and selected appropriate media pathways according to their experience and networks. A series of external newsletters were created to be translated and shared across the project networks, complimenting central social media campaigns. Many partners prefer alternative routes to stakeholder engagement, as while high profile social media platforms offer an immediately quantifiable measure of impact, often this does not translate into lasting impact where it is needed. This is partly driven by the high turnover nature of social media content, prioritize high volumes of low detail content. IPM Decisions invested resource into engaging with national and international collaborations, such as EUFRAS and the EU-FarmBook; favoring the long-term impact through dedicated agricultural platforms over shorter-term exposure through more generic social media platforms.

Dissemination through the EIP network

Factsheets have been produced for all the DSS available on the platform. These factsheets have provided the basis for Practice Abstracts (PA) for dissemination through the EIP network, and on the EU FarmBook. As a start of the collaboration with the EIP network, the platform was demonstrated in a meeting organized by 'Netwerk Platteland', the Dutch CAP coordinator

(September 2022). The conclusion of the participants was that the platform has interesting functionality. After the demonstration of the platform a discussion followed about best ways to promote and increase the number of users of DSS in The Netherlands. Trust in the outcome and ease of use were considered important, but other incentives were recognised as important since DSS have been promoted in the Netherlands for many years already and the number of users is still rather low.

IPM Decisions was present in the CAP network workshop about innovative arable crop protection, organised by the EIP in Amsterdam from 19—21 April 2023. The workshop focussed on exchanging knowledge and sharing innovative, inspirational practices that support farmers, advisors and other stakeholders to ensure greater uptake of non-chemical plant protection methods in arable crops by using economically and ecologically sustainable approaches and to reduce pesticide use by 50% by 2030 at European Union level. Participants were selected through an open call for expression of interest. IPM Decisions was accepted as participant and presented a poster in the meeting. Approximately 65 people from across Europe joined the meeting.

Dissemination through internation crop protection project partners

The activities from the IPM Decisions international crop protection partners are listed in D6.13, further details about target groups and number of people reached are included in Deliverable 6.8. BASF and Corteva AgriSciences had no formal role in project communication, but they did contribute to communication work in their networks during the project.

Dissemination through project partner networks

IPM Decisions established collaborations with a number of EU initiatives (Table 3.4). The most significant partnership was with our sister project, IPMWORKS (detailed in Section 1.2: Interactions between IPM Decisions and IPMWORKS). In addition, links with other EU projects enable wider dissemination of project outputs, as well as opportunities for integration of DSS and resource sharing. As well as links with EU projects, IPM Decisions also established links with national initiatives, such as VIPS (Norway), CPO (Denmark), ISIP (Germany), and eDWIN (Poland), to promotion integration of national platforms with the IPM Decisions pan-European platform. Partner networks were kept informed about IPM Decisions and progress made via the external newsletter and through the workshops. Several IPM Decisions project partners maintain direct contacts to potential platform users and exchanged information through their regular activities and national networks. Each partner utilised the most appropriate AKIS channels for their region and targeted stakeholders, such as social media channels, website, articles, newsletters, participation in all kinds of events and meetings. List of activities are provided in Deliverable 6.8.

Table 3.4 Collaborations between relevant European initiatives and IPM Decisions

European Initiative	Nature of collaboration agree with IPM Decisions
VIPS	VIPS is an online forecast and information service for decision support in integrated management of pests, diseases and weeds, run by NIBIO in Norway. Many of the DSS on VIPS have been integrated into the IPM Decisions platform, and VIPS is also using resources from IPM Decisions.
ISIP	ISIP - the Information System Integrated Plant production - is a common Internet portal of the Agriculture Advisory Boards and Federal States for crop protection and plant cultivation in Germany. The focus is on decision-making tools for determining treatment dates, needs and strategies to combat plant pests and diseases. Several DSS from ISIP are integrated into the IPM Decisions platform.
eDWIN	EDWIN is a national IT system for plant protection in Poland. Developers are working towards both integration of DSS and utilisation of IPM Decisions resources.
Crop Protection Online	Crop Protection Online (CPO) is a 'decision support system' which has been developed to reduce the use of pesticides as much as possible on a field level, without neglecting other considerations in the production system. Crop Protection Online is published by Department of Agroecology, Aarhus University and SEGES Innovation. Several models from CPO have been integrated into the IPM Decisions platform.
EU FarmBook	EU-FarmBook is a Horizon Europe project that is working at regional, national, and European (EU) levels to build an Online Platform. Gathering and sharing agriculture and forestry knowledge. IPM Decisions are working with EU FarmBook developers to enable integration of dynamic knowledge objects, such as risk maps, into the FarmBook. IPM Decisions Factsheets and other outputs, are available in the EU FarmBook.
IPMWORKS	IPMWORKS has established an EU-wide farm network demonstration and promoting cost-effective IPM strategies. As sister projects IPM Decisions works closely with IPMWORKS, collaboratively promoting outputs and co-hosting events. Several demonstrations of IPM DSS have been made through IPMWORKS.
PestNu	Digital Platform for Agro-advisory and Business services, IPM decisions and PestNu have collaborated to co-share outputs.
Farmtopia	IPM Decisions and Farmtopia are promoting outputs, and the Farmtopia platform developers are working to utilise resource available in the IPM Decisions platform.
EUFRAS	Platform promotion and demonstration in EUFRAS meetings, information about IPM Decisions and a link to the IPM Decisions platform on the EUFRAS website

AdvisoryNetPEST	AdvisoryNetPEST Project – Enhancing Agricultural Advisory Services in Europe to reduce the use and risk of pesticides. The IPM decisions platform will be promoted through this new advisory network, including through demonstrations were appropriate.
SmartProtect	SmartProtect is a thematic network focusing on cross regional knowledge sharing of SMART Integrated Pest Management (IPM) solutions for farmers and advisors. The IPM Decisions coordinator was a member of the SmartProtect Advisory Board, and outputs were shared between the projects.
RUSTWATCH	RustWatch established a stakeholder driven early-warning system to improve preparedness and resilience to emerging rust diseases on wheat, which is Europe's largest agricultural crop. RustWatch has been integrated into the IPM Decisions platform as a 'Linked' DSS.

Making communication and dissemination materials

From the start of the project a series of communication materials & templates have been developed and shared with the project partners for use in their communication activities. All materials are developed in English. For relevant materials a translation template was made that partners could use for translation into their own languages. After sending back the translations, Delphy took care of the production of the translated materials in the correct IPM Decisions formats. The complete list with communication materials, templates and products is summarized in D 6.15. Technical details about the various IPM Decisions branded resources, files, and templates for use in exploiting and promoting the IPM Decisions platform are available in a file in the EU Open Research Repository https://zenodo.org/records/11473304[6]. All resources are licensed under Creative Commons Attribution Share Alike 4.0 International[7].

Dissemination through the EU expert group on Sustainable Use Directive

Policy actors were an important target group for IPM Decisions. The Danish Environmental Agency (DEA) and UK Health and Safety Executive (HSE) were partners within IPM Decisions consortium. The foreseen role of DEA and HSE was to provide insight in the role of DSS in regulation, and to inform regulatory colleagues in other EU member states about the platform, e.g. at the regular meetings organized by the EU Commission. Discussion regarding a proposed Sustainable Use Regulation meant EU-Commission stopped organizing meetings for member states regulatory authorities to discuss the Sustainable Use Directive, including IPM activities. Country specific engagement with national policy actors was maintained by partners throughout the project.

[6] Ramsden, M. (2024). IPM Decisions branding and templates (1.01.01). Zenodo. https://doi.org/10.5281/zenodo.11473304

[7] Attribution-sharealike 4.0 Internation: Deed https://creativecommons.org/licenses/by-sa/4.0/

In May 2022, three projects worked together to organise a Farm Demo Conference in Brussels. Nefertiti, IPMWORKS and IPM Decisions co-organized the policy dialogue event and farm demo conference from 10-11 May 2022. The policy dialogue event on farm demonstration networks started with a field visit and afterwards a round table discussion about the need/options for support from public authorities for the future of farm demonstration networks in Europe to promote sustainable agriculture. The Farm Demo conference on 11 May was open for policy makers (national and EU level), advisory services, farmers, researchers and actors in the agricultural value chains. On the agenda in the morning session was the introduction of the three organising projects, testimonies from demonstration farmers and advisors, the role of demonstration farms in innovation adoption and how new policies can support farmers to achieve the Green Deal targets. In the afternoon there were a series of parallel workshops from the three projects.

Project results were presented to over 40 MEPs from a range of countries and political groups, including commissioner Janusz Wojciechowski and EP rapporteurs on the new SUR Regulation. A clear outcome of the conference was that we need to accompany farmers in the transition towards a significant reduction in pesticide use, and this would need significant support from the CAP.

Full report available on the IPMWORKS Toolbox: Farm Demo Conference 2022

The European Union set ambitious targets to reduce pesticide use and impact in European agriculture. IPMWORKS and IPM Decisions contribute to these challenging objectives by promoting a holistic approach for Integrated Pest Management (IPM) and jointly organising the IPM Conference 2024 in Brussels, 14th May 2024. The IPM Conference 2024 provided a forum for stakeholders involved in the development of IPM, including: farmers, advisory services, retailers, agro-industries, researchers, decision support developers and policy makers. The Conference presented results and tools produced by the two projects, with testimonies of farmers and advisers highlighting success stories in IPM implementation and practical solutions to reduce the reliance on pesticides. Over 140 participants joined the Conference from across Europe, including advisors, researchers, developers and policy actors.

Full report available on the IPMWORKS Toolbox: IPM Conference 2024

IPMWORKS and IPM Decisions demonstrated the impact of IPM on pest control in the European Parliament in February 2023

Together with IPMWORKS, IPM Decisions co-organised an event in the European Parliament in Strasbourg on 14 and 15 February 2023. Posters about the work in the projects were presented, alongside meetings with MEP's and demonstrations of the IPM Decisions platform.

Further details are available here

IPM Decisions – Project public update May 2023

With one year left of the project, IPM Decisions published a Public Report on resources developed in support of increasing access to and uptake of decision support systems for integrated pest management across Europe. The report includes summary evidence for the benefits of IPM DSS in Europe, and on incentives and barriers to the uptake of IPM DSS.

Full report available here.

IPM Decisions contributes to the IPMWORKS Policy recommendation for the Sustainable Use of Pesticides Regulation (SUR)

This document was produced by the IPMWORKS consortium, with contributions from the IPM Decisions consortium. It elaborates recommendations for policies to support the wide adoption by European farmers of a holistic vision of Integrated Pest Management, in order to reduce the reliance of European agriculture on pesticides, in line with targets of the Farm-to-Fork strategy.

Full report available on the IPMWORKS Toolbox: Policy recommendation for the Sustainable Use of Pesticides Regulation (SUR)

Platform users

Accounts were registered from all over Europe, extending beyond countries represented in the project consortium. The majority of accounts (approximately 60%) were registered in the United Kingdom, The Netherlands and Denmark. In these countries, DSS have been on the market and being used for a longer time by farmers, and they generally recognise the added value DSS bring in crop protection decision making. In Germany and Norway, long established DSS platforms with a range of DSS for relevant pests and diseases are embedded into advisory networks (ISIP and VIPS respectively). In these countries, IPM Decisions has focused on developing collaborations and resource sharing the improve uptake and access to IPM DSS, rather than competing for users, and so the number of direct users creating accounts in these countries is relatively low. In Denmark the 'Crop Protection Online' (CPO) platform is running for more than 10 years, many of the CPO models are since April 2024 also integrated in the IPM Decisions platform. For South Europe very few validated DSS are available, and in South and East Europe there is little experience with the consultation of DSS in crop protection decision making. The real number of farmers that benefit indirectly from DSS outputs will be much higher than the number of farmers with an account. The largest category of users are the advisors, around 35% of all accounts. Experience from Denmark (CPO) and Norway (VIPS) has been that many advisors include/integrate the DSS information in their advisory work for integrated pest management. Although it is not possible to quantify indirect use of the platform, we estimate that half of the advisors with an account use DSS information for their clients, and that each serve 20-40 farmers with this information, a total of 5-10 thousand farmers received indirect DSS information across Europe. A clearer indication of the use of the platform is the distribution of farm locations created across user accounts. Individual users proactively using the platform to assess risk during the season are able to create multiple locations representing different parts of a farm, different farms, or gauge regional differences in pest risk during the season. Across the 970 accounts created in Europe, 1,282 farm locations were created (Figure 3.11).

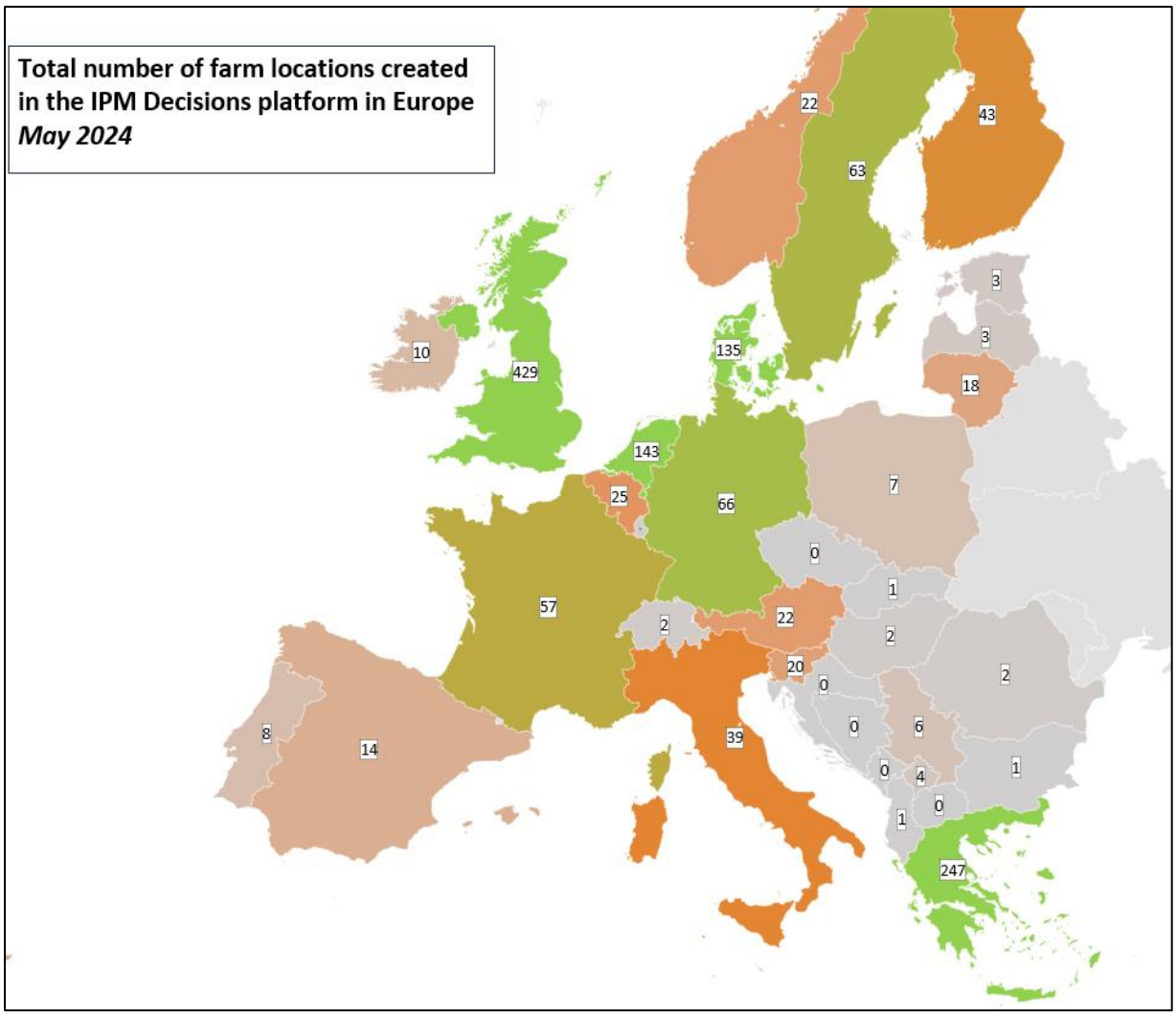


Figure 3.11 Farm locations created in IPM Decisions accounts across Europe.

4 IPM Decisions – Results and Impact

4.1 IPM Decisions Public Deliverables

WP No	Del No	Title	Description	Lead Beneficiary
WP2	D2.3	Weather data repository and management API - production version	The Weather API provides forecast and historical data (point data measured by weather stations and calculated gridded data) used as input for Decision Support Systems in the IPM Decisions platform. The Weather API delivers data from National hydrological/ meteorological institutes and public and private agricultural weather stations.	MET Norway
WP2	D2.6	API for interaction with repository of model metadata - final version	The DSS API delivering the DSS Model database contains 20 models covering a range of crops and diseases, available for implementation in IPM Decisions platform. Seven of these are at the time of delivery fully integrated and available in the IPM Decisions platform dashboard. In addition, four DSS models are available as external links.	NIBIO
WP2	D2.7	Standard formats for model result output	A format for DSS model outputs has been established. It allows for flexibility and predictability when results from running a DSS model will be presented in the platform dashboards.	NIBIO
WP2	D2.8	Standard formats for weather data and other model input data	Formats for exchange of weather data and description of DSS model requirements have been established. The formats enable flexibility and consistency in data exchange.	NIBIO
WP2	D2.9	Publications in peer reviewed journals	Outline of two papers to be submitted as output from the WP2 developments.	NIBIO
WP3	D3.2	Library of open-source widgets and snippets for dashboards	All of the source code for the IPM Decisions platform can be found in the project GitHub repository at https://github.com/H2020-IPM-Decisions. An overview description of the contents is provided in Deliverable 3.11.	ADAS
WP3	D3.3	DSS Use Dashboard for farmers and advisors	IPM Decisions has produced the first full-functional version of the IPM Decisions Platform and Decisions Support Systems Use Dashboard complete with services that automate the retrieval of weather data and running of DSS on a daily basis.	ENG
WP3	D3.4	DSS Comparison Dashboard for farmers, advisors and interest groups	The IPM Decisions Platform comparison dashboard provides users with the ability to select and compare outputs from multiple DSS.	ENG
WP3	D3.5	DSS Adaptation Dashboard for farmers, advisors and interest groups	The IPM Adaptation dashboard provides advisors and researchers with the ability to modify the parameters within a DSS to facilitate adaptation of the DSS to specific countries.	ENG
WP3	D3.6	DSS Integration dashboard for researchers and interest groups	The integration dashboard has been released and demonstrated with a use-case extending the platform to provide a crop mixture strategic decision support model. It allows researchers to developing and integrate new DSS with the IPM-Decisions platform, and expands its horizon to agroecological practices. The integration dashboard is hosted on the Openalea platform, and benefits from a visual programming environment to ease the development and integration process.	CIRAD
WP3	D3.7	Scientific workflows framework for integration of DSS tools, data manipulation algorithms and data sources	A scientific workflow environment has been created to allow researchers accessing IPM Decision resources and elaborate new models. The environment, hosted on OpenAlea platform, allows access to weather data and IPM decision support systems, enabling them to be combined with research models available in OpenAlea.	CIRAD
WP3	D3.8	Python-based libraries of tools and data sources	A set of Python-based libraries has been implemented to interact with IPM Decisions tools and data sources from within python. They offer a python API to access weather data and run DSS models. The library is public and available from GitHub and conda.	CIRAD
WP3	D3.9	Library of data manipulation algorithms	A library containing algorithms to calculate leaf wetness, hourly temperatures from daily maximum and minimum temperatures and relative humidity from temperature data has been created. Each algorithm has been coded using c#.NET and made available through a web-based Application Programming Interface (API).	ADAS

WP No	Del No	Title	Description	Lead Beneficiary
WP3	D3.10	A web-based portal for the platform with user authentication	This deliverable describes the development of the IPM Decisions project website (www.ipmdecisions.net) and the design and implementation of the IPM Decisions Platform web portal. The deliverable describes not only the software delivery, but also the specification for	ENG
WP3	D3.11	Web services providing access to dashboards source code and key information on DSS tools and data	All of the source code for the IPM Decisions platform can be found in the project GitHub repository at https://github.com/H2020-IPM-Decisions	ADAS
WP4	D4.1	Data set for DSS evaluation collected: apple scab and potato late blight	Apple scab and potato blight observation data were documented, describing the measurements carried out (meta data).	AU
WP4	D4.2	Data set for DSS validation collected: septoria and wine downy mildew	Data from fungicide trials in wheat and grapes were kindly provided by BASF and Corteva. The data will be used to assess decision support systems providing guidance on the control of the diseases Septoria tritici blotch in wheat and grape downy mildew in grapes.	AU
WP4	D4.3	DSS tested for validity: septoria and wine downy mildew	The strongest test of a DSS is to run field trials comparing outcomes from treatment decisions with and without access to the DSS. Here we assess whether disease/yield data from trials for other purposes can be used, and conclude that such data has considerable limitations.	AU
WP4	D4.4	Data set for DSS validation collected: aphids and vegetable pests	An extensive data set on trap catches of cutworm in Denmark/Sweden has been released.	AU
WP4	D4.5	DSS tested for validity: aphids and vegetable pests	The use of modelled pest phenology as decision support systems in Europe work best if used in conjunction with local pest monitoring (e.g., by trapping) and, ideally, web-based regional pest monitoring networks.	AU
WP4	D4.6	Data set for DSS validation collected: weeds	Weed data has been collated from Greece and the IWMPraise project, to be used to validate weed DSS outputs.	RRES
WP4	D4.7	DSS tested for validity: weeds	We present the parameterization of dose response curves for a weed management DSS (IPMwise) for wheat crops in Greek conditions, and a subsequent validation. Our analysis shows that using such a system should help to reduced pesticide use with negligible impact on yield.	RRES
WP4	D4.8	Selected data sets made available to end-users for DSS validation	Data sets with historical monitoring data of a selection of pests and associated pesticide trials have been published to assist the further development of DSS and the teaching of IPM.	AU
WP4	D4.9	Catalogue of DSS collated with details on inputs, outputs and functionality	This deliverable provides an overview of prioritized DSSs; the full catalogue is available to all project partners. Development of this catalogue has taken place in parallel with making contact with DSS owners (through Work Package 6). The catalogue ensures that the project group is well informed about the DSS which are available and their characteristics.	AU
WP4	D4.10	Description of the general outline methods for DSS evaluation of the value of a prediction	We present a generic framework for evaluating the value of decision support systems (DSS), and then describe how this can be applied in practice for various formulations of the DSS and under different data constraints.	RRES
WP4	D4.11	Paper: On the methods related to value of prediction	An outline of a paper to be submitted to the Journal of Theoretical Biology.	RRES
WP4	D4.12	DSS evaluated for economic and environmental benefits: apple scab and potato late blight	In this report we develop a method for calculating the value of a DSS, based on how often fungicide sprays target pathogen infection risk periods, as determined by a DSS. As examples of application of the analysis, we use this method to calculate the value of three DSSs, two that identify risk periods for potato late blight (caused by the oomycete *Phytophthora infestans*), and one that identifies risk periods for apple scab (caused by the fungus *Venturia inaequalis*).	RRES
WP4	D4.13	DSS evaluated for economic and environmental benefits: septoria and wine downy mildew	Growers need information about a DSS' performance so that they can weigh up the relative benefits of using it to make decisions about crop protection. We develop a novel method for evaluating DSS using existing trials data about septoria in wheat and downy mildew in vines.	RRES

WP No	Del No	Title	Description	Lead Beneficiary
WP4	D4.14	DSS evaluated for economic and environmental benefits: aphids and vegetable pests	We present a model-based approach for assessing the value of decision support systems (DSS) that target insect pests. Compared to spraying insecticide based on a calendar date, DSS could save thousands of euros per hectare.	RRES
WP4	D4.15	DSS evaluated for economic and environmental benefits: weeds	Two DSS for weed management were evaluated. The first, IPMWise, takes a more tactical view and considers within season control. The second, Weed Manager, guides management over the rotation. Our analysis shows that these approaches can provide robust effective control.	RRES
WP4	D4.16	DSS validation method available to end-users	This deliverable provides a high-level outline of a method that can be used to estimate the value of decision support systems.	RRES
WP4	D4.17	Report: Impact of DDS on pest management and pesticide usage in EU	The socioeconomic impacts associated with the use of IPM DSS in wheat, potato, and grape production were evaluated. Our analysis shows that using IPM DSS can provide economic benefits for farmers by reducing the treatment frequency index, thus lowering overall cost of production and total pesticide usage.	ADAS
WP5	D5.3	Scientific paper on interactions between end-users characteristics and structural-performance features of assessed DSS	Incentives and barriers to adoption of IPM decision support systems (DSS) by farmers and farm advisors, identified through analysis of questionnaire data, were linked to structural and performance characteristics of IPM DSS. Approaches to overcome each identified barrier and to use incentives for DSS adoption were suggested.	BSB
WP5	D5.4	Report on the incentives and barriers to uptake DSS by different end-user types	The main drivers and barriers for the adoption of Decision Support Systems in pesticide management have been identified through analysis of potential user responses to a questionnaire administered during a series of workshops throughout Europe.	BSB
WP6	D6.1	Stakeholder map (stakeholder list with users) per country	This document is the IPM Decisions project Stakeholder's map (list of key DSS users and stakeholders). This is a public document, and as such all personal information has been removed from the stakeholders map.	Delphy
WP6	D6.7	First country list with demonstration activities, number of visitors reached	IPM Decisions project has created an online platform, allowing farmers and advisors across Europe to access Decision Support Systems (DSS) for integrated pest management. The platform uses a large range of DSS which can be adjusted for regional conditions, giving farmers and advisors indicators for risk. The first edition of www.ipmdecisions.net was launched in September 2023, which was also the starting point for platform promotion. In March 2023 the platform was updated and now has 26 DSS fully integrated in the platform and 19 more DSS linked to the platform. This document provides a summary of the promotion activities up to the end of April 2023.	Delphy
WP6	D6.8	Second country list with demonstration activities, number of visitors reached	The IPM Decisions online platform allows farmers and advisors across Europe to access Decision Support Systems (DSS) for integrated pest management. The final version of www.ipmdecisions.net was launched in March 2024 and now has 29 DSS integrated in the platform and 19 more DSS linked to the platform. The platform is promoted and demonstrated by the project partners, creating a multi-actor IPM Decisions Network.	Delphy
WP6	D6.9	Number of followers and friends on social media after 3, 4 and 5 years	Social media was used by IPM Decisions to inform a wide public about the IPM Decisions project and to share project result with all target groups. IPM Decisions created three central social media channels for communication: Facebook, Twitter/X and LinkedIn. This deliverable gives an overview of activities and outreach across social media channel.	Delphy
WP6	D6.10	Contributions to EIP Agri, mo48 and 60	IPM Decisions has produced 43 Practice Abstracts for the agricultural European Innovation Partnership, summarizing all decision support systems for integrated pest management fully integrated into the platform during the project. Additional practice abstracts were produced summarizing results in each of the participating countries.	Delphy
WP6	D6.11	List of contributions to EUFRAS activities, number of visitors reached	EUFRAS is the European Forum for Agricultural and Rural Advisory services. Members of EUFRAS were regularly updated about the progress made in IPM Decisions.	Delphy

WP No	Del No	Title	Description	Lead Beneficiary
WP6	D6.12	List of contributions to national network activities	Deliverable 6.12 provides a list of contributions through national networks and learned societies with an interest in IPM, and project partners are members of these networks. Meetings of these networks provide opportunities to promote the IPM Decisions platform and are part of the overall platform dissemination strategy.	Delphy
WP6	D6.13	List of contributions to dissemination through PAN European partners	Deliverable 6.13 is a list of contributions to dissemination through the IPM Decisions international crop protection project partners, BASF and Corteva AgriScience. BASF and Corteva AgriSciences communicate with farmers and advisors across Europe, by field demonstration events, technical literature and via agronomists, and as well as with other stakeholder groups.	Delphy
WP6	D6.14	List of promotion activities through regular activities by project partners	Deliverable 6.14 provides a list of promotion activities through regular activities from project partners. Most project partners have regular contacts to several of the project target groups. These activities offered opportunities to promote the platform to a wider audience with an interest in IPM and are part of the overall communication and promotion plans in the different countries. This deliverable provides a list of these activities.	Delphy
WP6	D6.15	List with communication material, including templates	From the start of the project a series of communication materials & templates have been developed and shared with the project partners for use in their communication activities. All materials are developed in English. For relevant materials a translation template was made that partners could use for translation into their own languages.	Delphy
WP6	D6.16	List with contributions to SUD	The European Sustainable Use Directive (SUD) represents the overall European policy towards crop protection. National and international policy organization belong to the target groups in IPM Decisions. This deliverable gives an overview of the activities conducted for policy organizations, and of activities with participation of national and international policy actors.	Delphy
WP7	D7.2	Data management plan agreement	The IPM Decisions Data Management Plan conforms to the principles of FAIR (findable, accessible, interoperable and reusable) data management in H2020 (as published July 2016), and the GDPR.	ADAS
WP7	D7.12	Scientific publications	Ten peer review scientific journal papers and four chapters were published during the project period June 2019 – May 2024, with a further five papers and one chapter in preparation.	ADAS
WP7	D7.13	Project reports in agreement with EC	With one year left of the project, IPM Decisions produced a summary report on resources developed in support of increasing access to and uptake of decision support systems for integrated pest management across Europe. This report provides a summary of project outputs up to May 2023.	ADAS
WP7	D7.14	Final report	The final report is a public overview of IPM Decisions project activities, results and outputs.	ADAS
WP7	D7.15	Biannual review of gender equality	This document reports the summary of the biannual review of gender equality throughout the IPM Decisions project.	ADAS
WP7	D7.17	Participate in the Open Research Data Pilot	During the IPM Decisions project, the consortium has participated in the Horizon 2020 Open Research Data Pilot. As part of our commitment to open data, all publications, datasets, and platform code has been made open access, either through Gold (open access publication) or Green (self-archiving) open access models.	ADAS

4.2 IPM Decisions Scientific and Data Publications

The papers and chapters listed below were published during the project period, additional pending publications are outlined in D7.12 – Scientific Publications. The data resources and further information about data management and availability are detailed in D7.17 – Participation in the Open research Data Pilot.

Andersson, B., et al. 2022. Comparison of models for leaf blotch disease management in wheat based on historical yield weather data in the Nordic-Baltic region. Agronomy for Sustainable Development 42-44 https://doi.org/10.1007/s13593-022-00767-7

Holst N. (2020) Mathematical models. In: Chantre G.R. & González-Andujar J.L. eds. Decision Support Systems for Weed Management. Berlin, Springer Verlag, 3-23 https://doi.org/10.1007/978-3-030-44402-0_1

Helps, J.C., van den Bosch, F., Paveley, N. et al. A framework for evaluating the value of agricultural pest management decision support systems. Eur J Plant Pathol (2024). https://doi.org/10.1007/s10658-024-02878-1

Jalli, M, et al. (2020) Yield increases due to fungicide control of leaf blotch diseases in wheat and barley as a basis for IPM decision-making in the Nordic-Baltic region. European Journal of Plant pathology, Eur. J. Plant Pathol (2020) https://doi.org/10.1007/s10658-020-02075-w

Jørgensen, L.N., et al. (2020) Validation of risk models for control of leaf blotch diseases in wheat in the Nordic and Baltic countries. European Journal of Plant Pathology, 157, 599-613 https://doi.org/10.1007/s10658-020-02025-6

Jørgensen, L. N. et al. 2021. Using risk models for control of leaf blotch diseases in barley minimises fungicide use – experiences from the Nordic and Baltic countries. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 71:247-260 https://doi.org/10.1080/09064710.2021.1884742

Levionnois S., Pradal C., Fournier C., Sanner J., and Robert C. (2023) Modelling the impact of proportion, sowing date, and architectural traits of a companion crop on foliar fungal pathogens of wheat in crop mixtures. Phytopathology. https://doi.org/10.1094/PHYTO-06-22-0197-R

Leybourne D., Ramsden M., White S., Wang R., Huang H., and Xie C. (2023). Online decision support systems, remote sensing and artificial intelligence applications for wheat pest management. In book: Advances in understanding insect pests affecting wheat and other cereals https://doi.org/10.19103%2FAS.2022.0114.21

Marinko J., Ivanovska, A., Marzidovsek, M., Ramsden M., and Debeljak M. (2023) Incentives and barriers to adoption of decision support systems in integrated pest management among farmers and farm advisors in Europe. International Journal of pest Management, https://doi.org/10.1080/09670874.2023.2244912

Marinko, J., Blazica, B., Jorgensen, L.N., Matzen, N., Ramsden, M.W., and Debeljak, M. (2024) Typology for Decision Support Systems in Integrated Pest Management and Its Implementation as a Web Application. Agronomy, https://doi.org/10.3390/agronomy14030485

Midingoyi C.A., et al. (2020) Reuse of process-based models: automatic transformation into many programming languages and simulation platforms. In silico Plants, 2(1) https://doi.org/10.1093/insilicoplants/diaa007

Midingoyi, C.A., Pradal, C., Enders, A., Fumagalli, D., Lecharpentier, P., Reynal, H., Donatelli, D., Fanchini,D., Athanasiadis, I.N., Porter C., Hoogenboom, G., Oliveira, F.A.A., Holzworth, D., and Martre, P. (2023), Crop modeling frameworks interoperability through bidirectional source code transformation. Environment Modelling & Software, https://doi.org/10.1016/j.envsoft.2023.105790

Ramsden, M. and O'Driscol A. (2022) Advances in decision support systems (DSS) for integrated pest management in horticultural crops. In book: Improving integrated pest management in horticulture. https://doi.org/10.19103/AS.2021.0095.07

Ramsden, M., Telling S., Leybourne, D., Alonso, N., and Georgantzis N. (2023) Advances in pest risk assessment techniques focusing on invertebrate pests of European outdoor crops. In book: Advances in monitoring of native and invasive insect pests of crops. https://doi.org/10.19103/AS.2021.0095.07

Reza Akbarinia, Christophe Botella, Alexis Joly, Florent Masseglia, Marta Mattoso, et al.. Life Science Workflow Services (LifeSWS): motivations and architecture. Transactions on Large-Scale Data- and Knowledge-Centered Systems, 2023, 14280, pp.1-24. https://dx.doi.org/10.1007/978-3-662-68100-8_1

4.3 IPM Decisions Impact

Expected Impacts (relevant EI are shown in the central column for each objective)		
Providing broader access to the existing knowledge on IPM throughout Europe, by: A. Creating a European platform to share and further develop IPM DSS, covering various bio-geographical areas. B. Establishing partnerships between stakeholders developing cost effective IPM DSS.		C. Increasing awareness of the available IPM toolbox. D. Increasing on-farm use of IPM techniques E. Supporting relevant plant health policies, in particular the implementation of the SUD.
Objective 1: increase access to, and uptake of, DSS	Impacts	IPM Decisions Impact
1(i) Understand constraints with current routes of access to DSS, by engagement with end users. • Consult DSS stakeholders across IPM Decisions Network zones through multi-actor workshops. • Map the links between user characteristics and their attitudes towards IPM and DSS. • Design four DSS Dashboards based on feedback from each type of user.	B CD AB	The first round of workshops were held in December 2019 – February 2020, facilitating consultation of DSS stakeholders across Europe. Survey data collected during these initial workshops enabled mapping of stakeholder characteristics and attitudes towards DSS, and lessons learnt have been used in designing platform and dashboard functionality. The second and third round of workshops were held in December 2020 – February 2021, and April – May 2022, respectively. The DSS Use dashboard, DSS Comparison dashboard and DSS Adoption dashboard have been designed to meet the needs of the target stakeholder groups. Results from stakeholder consultation survey data collected from project workshops have been analyses and published. This has identified the key characteristics and barriers to be overcome to improve uptake of IPM DSS. The DSS use dashboard, comparison, and adaptation dashboards have been demonstrated to stakeholders across Europe, along with the IPM DSS Factory (integration dashboard).
1(ii) Increase farmer and farm adviser access to DSS through a pan-European platform. • Create standardised data formats and web services for DSS, data and platform communications. • Develop programming interfaces to link DSS covering key pests of outdoor production systems into the Platform. • Develop programming interfaces to link input data sources to the Platform. • Develop DSS Dashboards to facilitate user access, incorporating user feedback on functionality.	ABDE ABDE ABDE ABDE	Data formats, web services, interfaces, and associated links have been created, and the IPM Decisions Platform has been launched and promoted in 12 countries across Europe. Feedback on the platform function and useability has been collated and used to improve further updates. Across all project zones, feedback has been gathered to target future engagement and enable bespoke promotion to improve access across Europe.

1(iii) Guide users of the Platform towards DSS most suited to their needs. • Create a DSS selection tool that identifies DSS relevant to particular user needs. • Produce and disseminate knowledge exchange resources to guide users.	CDE CDE	A QuickStart Guide supports new users in creating an account and setting up their farm(s). The Platform guides users to relevant DSS for their farm. Users select relevant crops from a drop-down menu. DSS for pests relevant to those crops are shown, with information to aid DSS selection. Once DSS have been selected, opening the Platform takes users directly to pest risk summaries from the selected DSS. Various publications disseminate the use, benefits, incentives and barriers to IPM DSS consultation. Demonstration videos, factsheets, and publications, have been released, and new DSS selection tool, IPM Advisor, has been created, helping guide users toward relevant DSS. The IPM Decisions platform has been linked to the IPMWORKS Resource Toolbox, improving visibility of DSS hosted on the platform.
Objective 2: Quantify the benefits of DSS use		
2(i) Provide a toolkit of methods to test and quantify the benefits (economic, environmental and societal) from decision support use. • Develop systematic methods to evaluate DSS. • Carry out test DSS evaluation cases. • Create and disseminate a protocol for DSS evaluation.	BD BCD BC	Methods for DSS evaluation have been developed and reported in a public deliverable. A peer review paper has been submitted for open access publication. This publication includes a protocol for DSS evaluation, as well as results of test evaluation cases.
2(ii) Create and deliver large open access sets of observational data on key pests. • Catalogue observational pest density data sources within consortium and in public domain. • Accumulate observational data sets for evaluating DSS on key pest/crop combinations.	AB AB	Data sets of observations of pest density and associated crop information have been made publicly available. Data has been evaluated and reported in deliverables for the following pests: apple scab, potato late blight, septoria (wheat), grape vine downy mildew, aphids and vegetable pests (various crops), and weeds (various crops).
2(iii) Test a range of DSS in different biogeographical regions for accuracy and value. 2(iv) Enable comparisons between DSS for their benefits. • Test accuracy of selected DSS against observational data sets. • Assess usefulness of DSS predictions. • Quantify environmental and economic impact of DSS uptake.	 BCD BCD BCDE	See 2(i) and 2(ii) above. The methods for evaluating DSS have been published in an open access paper, and shared within relevant networks (Helps et al. 2024; https://doi.org/10.1007/s10658-024-02878-1) Quantification of the environmental and economic impacts of DSS uptake are detailed in public Deliverable 4.17

Objective 3: Foster DSS innovation through the Platform to secure longevity of impact		
3(i) Accelerate adoption of DSS and innovation in DSS by creating a marketplace for IPM DSS. • Establish Europe-wide 'IPM Decisions Network' with national and European stakeholder groups. • Engage with other actors in IPM (e.g. manufacturers of biopesticides). • Engage with future H2020 SFS-6-2020 consortium 'Demonstration farm network'.	BCDE CDE BCDE	The IPM Decisions Network established through the first round of workshops has been developed through two further rounds of workshops across Europe. IPM actors have been engaged, including manufacturers or products and service providers. Links have been established with several national and international IPM initiatives. Close engagement continues with the 'IPM Works' consortium, implementing the demonstration farm network , including in the joint organisation of the Farm Demo Conference in Brussels, May 2022.
3(ii) Develop and publish open data formats and source code for web services and Dashboards for development by the DSS community. • Publish a set of formats for sharing of data developed from a typology of DSS and data defined in consultation with DSS users and developers. • Publish source code for DSS Dashboards and web services, with documentation, on the Platform.	AB AB	The code developed in 1(ii) has been made open source though GitHub. • A repository of central source codes is available on GitHub at https://github.com/H2020-IPM-Decisions • Weather service source code: https://github.com/H2020-IPM-Decisions/DSSService • DSS Service source code: https://github.com/H2020-IPM-Decisions/WeatherService
3(iii) Develop a toolkit for DSS developers to combine multiple DSS, to enable users to address multiple pest threats to their crop with a single system. • Adapt the OpenAlea system to provide a DSS development framework through an open-source Python library.	ABDE	A toolkit for DSS developers to combine multiple DSS is in development. A toolkit for DSS developers to combine multiple DSS is in development, scheduled for completion in the third reporting period.

5 Summary conclusion

It is to the benefit of agricultural workers, wider stakeholders, the general public and the environment to manage pests without any pesticide wasted, through optimal pest management and targeting of treatments as part of a holistic approach to IPM. Farmers and their advisors benefit from easy access to services, tools and resources that support and promote transition towards holistic IPM. The IPM Decisions platform is designed to facilitate access to IPM DSS and associated resources and be sufficiently robust and adaptable to grow with future innovations and policies. While securing funding for core platform maintenance and updates will always be a challenge, the platform design requires relatively modest resource for maintenance and updates compared with the costs of creating new interfaces for regional DSS platforms. By making the source code open access, the platform can be extended, replicated and adapted to future needs as required.

There are various limitations on the consultation of IPM DSS across Europe, which the IPM Decision platform been designed to address. The platform provides a single pan-European market place for IPM DSS, making it easier for people to review a suite of available systems. By providing a common, user centric dashboard interface for all DSS, designed in consultation with end users, the platform offers quick and easy DSS consultation in multiple languages. The design allows users to access more detailed information about each system, including how it works, any assumptions or limitations, and where further details have been published. The structure of the platform also enables additional supplementary resources, such as evidence on the benefits of a given DSS, to be added to the detailed information. The ability to integrate multiple DSS from different sources means the platform can grow over time and will increasingly provide information on multi-pest pressures and on wider areas of IPM decision making (e.g. prevention decisions, or wider landscape considerations). Perhaps most importantly, the platform provides a framework for international collaboration on IPM decision support, accelerating innovation and access to effective support for IPM decision making.