Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

SPRINT
SUSTAINABLE PLANT PROTECTION TRANSITION

Protocol of consistent regional innovation scenarios

Author: Claudia Meier, Antonia Riedel, Jennifer Mark, Kevin De Luca, Adrian Muller, Ana Frelih-Larsen, Farshad Soheilifard, Lucius Tamm

Deliverable number: 6.4
Due date: Month 48 – 31 August 2024
Dissemination level: Public
Lead beneficiary: FiBL
Deliverable type: Report
Version: 1

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

PROJECT INFORMATION	
Project Title	Sustainable Plant Protection Transition; A global health approach
Project Acronym	SPRINT
Call Identifier	H2020-SFS-2019-2; Sustainable Food Security
Grant Agreement no.	862568
Starting Date	01-09-2020
End Date	31-08-2025
Project duration	60 months
Website address	www.sprint-h2020.eu
Project coordinator	Wageningen University
Overall Project coordinator	Prof. Dr. V. Geissen +31317485144 (violette.geissen@wur.nl)
Scientific Project Manager	V. Felix da Garca Silva, MSc (vera.felixdagracasilva@wur.nl)
REPORT INFORMATION	
Report Title	Protocol of consistent regional innovation scenarios
Principle Author(s)	Claudia Meier, Kevin de Luca, Adrian Muller
Principle Author e-mail	claudia.meier@fibl.org
Deliverable Number	6.4
Work Package	WP6
WP Leader	Jennifer Mark, Claudia Meier
Other partners involved	Ecologic
Nature	Report
Dissemination	Public
Editor(s)	Anke Huss, UU
E--Mail(s)	A.Huss@uu.nl
Report Due Date	Month 48 – 31 August 2024
Report publish date	Month 48 – 26 August 2024

Table of Contents

Tables

Figures

Abbreviations

AOC	Protected designation of origin (french : Appellation d'Origine Contrôlée)
BAU	Business as usual scenario
BBCH	Growing stage
DTU	Technical University of Denmark
FiBL	Research Institute of Organic Agriculture
IPM	Integrated Pest Management
KOPOP	National program for the protection of ground water in Slovenia
PPPs	Plant Protection Products

Terminology

In this work, we will use the following terminologies to characterize farming systems:

- Organic farming system: Farm practicing certified organic production. If use of plant protection products (PPPs), selection restricted to PPP authorized in organic farming.
- Integrated Pest Management (IPM): Farms thoroughly implementing the principles of integrated pest management (IPM) by exploiting preventive strategies (e.g. crop rotations and resistant varieties) and by choosing and applying PPPs based on necessity supported by decision tools (i.e. no routine

treatments). Those farms can use the full range of authorized PPPs (including synthetic PPPs) with a preference for non-chemical solutions.

- Conventional farming system: Mainstream farming practice within the current legal framework without special efforts beyond standard practices. Farms use mainly synthetic PPPs based on standard plant protection strategies.
- Synthetic pesticide: Chemical pesticide not allowed in organic farming systems.
- Plant protection products (PPPs): Include both synthetic pesticides as well as PPPs authorized in organic farming.
- Agroecology measures: Measures which go beyond IPM and are not implemented as part of organic conversion. They can be implemented by an IPM farm or by an organic farm.

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

1. Introduction

This study proposes a set of consistent, regional innovation scenarios aimed at reducing the reliance on synthetic pesticides in Europe (including pesticide substitution and non-use scenarios). Scenarios, as we propose them in this study, are a combination of 'what if'-questions. For instance: 'What if 20, 40, 60, 80 or 100% of Slovenia's silage maize production area was managed following organic production standards? How would variables like silage maize yield, quantity of milk produced, pesticide usage be affected (if keeping land-use constant)? And what if at the same time the climate changes? How would these variables be affected then?'. By consistent we mean following a systematic approach or a consistent design rationale (see chapter 3). By regional we either mean at country or European level.

Importantly, 'what if'-questions should be relevant at country or European level. If they are too specific, a regional scenario is not meaningful. By too specific we mean involving only a single agronomic measure and/ or addressing a crop whose area share is too small.

The regional scenarios proposed here were developed on the basis of 'farm management strategies', which were identified in stakeholder workshops held as part of Task 7.2 (Frelih-Larsen & Riedel, 2024) and selected for an economic farm-level assessment in Task 6.3 (Meier et al., 2024). Building on output from Task 6.3, we focus at country level on Slovenia (focus crop: fodder crops), Bordeaux (France) (focus crop: grapes), and the Netherlands (focus crop: seed potatoes) – three out of four regions, which were also assessed in Task 6.3. Switzerland with focus crop apples is excluded here, as the area share of apples in Switzerland is too small for a country wide scenario to be meaningful.

The current deliverable is an important basis for Task 6.5, where the here proposed scenarios will be modelled using the biophysical mass-flow model SOLm to assess their environmental, and to some extent also health as well as some gross economic impacts, as far as available data allows. As this deliverable is an important working document for the task leaders of Task 6.5, we also describe the data which is available from the Sprint project which can potentially be used for modelling in SOLm in chapter 4.

2. Methodology

A set of consistent, regional innovation scenarios to reduce the reliance of synthetic pesticides was developed on the basis of agronomic management strategies identified in D7.2 (Frelih-Larsen & Riedel, 2024) and assessed in D6.3 (Meier et al., 2024). The following subsection 2.1 provides an overview of all agronomic management strategies identified in the aforementioned work (D7.2), following a classification framework proposed in D7.2 (Frelih-Larsen & Riedel, 2024) – distinguishing strategies by two different visions and three different strategy types. Agronomic management strategies assessed in D6.3 are highlighted in blue font.

The set of consistent, regional innovation scenarios, which are presented in chapter 3 of the current study, was drafted by the authors of D6.3 and refined as part of an internal workshop, with the active participation of the task leaders of Task 6.1 and 6.2 (Farshad Soheilifard from DTU), Task 6.3 (Claudia Meier, Jennifer Mark, Lucius Tamm from FiBL), Task 6.5 (Adrian Muller and Kevin de Luca from FiBL), and Task 7.2 (Antonia Riedel from Ecologic). The aim was to upscale the agronomic management strategies assessed in D6.3 to the regional (country or European) level.

Step-wise approach followed:

1. List of agronomic management strategies for all Sprint case study sites (D7.2)
2. Selection of (farm-level) agronomic management strategies relevant for the case study sites Slovenia, France, Switzerland, and the Netherlands for farm economic assessment (D6.3)

3. Upscaling of (farm-level) agronomic management strategies to consistent, regional scenarios using an internal workshop (D6.4 – current deliverable)
4. Modelling of six consistent, regional scenarios using SOLm (D6.5)

2.1 Classification of agronomic management strategies

Table 1 shows the classification of agronomic management strategies to reduce the reliance of synthetic pesticides as proposed in D7.2 (Frelih-Larsen & Riedel, 2024).

Table 1: Classification rationale for agronomic management strategies (Frelih-Larsen & Riedel, 2024)

	At least 50% reduction of the use of plant protection products	**Agriculture without chemicals using non-chemical alternatives to pesticides**
Efficiency: Increase efficiency and reduce use of pesticides	Quadrant A: Strategy 1 Strategy 2 …	X (not relevant)
Substitution: Substitute conventional practices and inputs with agroecological alternatives	Quadrant B: Strategy 1 Strategy2 …	X (not relevant)
System re-design	X (not relevant)	Quadrant C: Strategy 1 Strategy 2 …

Table 2 first shows the agronomic interventions identified for quadrant A (efficiency) and B (substitution) to reach a reduction of at least 50% of the use of plant protection products in Europe. Table 3 then shows the agronomic interventions identified for quadrant C (system re-design) to reach an agriculture in Europe without chemicals, using non-chemical alternatives to pesticides. This list was provided by the authors of D7.2. A more detailed list can be found in the corresponding report (Frelih-Larsen & Riedel, 2024). Agronomic interventions which were selected for the economic farm-level assessment in D6.3 (Meier et al., 2024) and formed the basis for scenario development are highlighted in light blue font.

Table 2: Agronomic management strategies to reach a at least 50% reduction of the use of plant protection products through an increase in efficiency or substitution.

	At least 50% reduction of the use of plant protection products

Efficiency: Increase efficiency and reduce use of pesticides	• **Improved Pest Monitoring**: pheromone traps and other advanced techniques (NL).
	• **Targeted PPP Application**: strips, outbreaks (CZ) or trunk injections (CH).
	• **Use Less Toxic Products**: Select products with improved ecotoxicological profiles (PT, FR, SL).
	  ○ Slovenia (focus crop: silage maize): Substituting a synthetic herbicide containing the active substances s_metolachlor and terbuthylazine by a less toxic synthetic herbicide containing the active substances isoxaflutole and thiencarbazone_methyl (both broad spectrum activity herbicides).
	• Employ **advanced equipment** for plant protection.
	  ○ France (focus crop: grapes) & Switzerland (focus crop: apples): Foil coverage (rain protection)
	• **Enhanced Computer Models**: use improved computer models for application determination (e.g., AI and GPS) (all).

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

Substitution: Substitute conventional practices and inputs with agroecological alternatives	• **Habitat Diversification**: Strengthen beneficial enemies and prevent damaging organisms (all).
	• **Tolerant or Vigorous Varieties**: Cultivate tolerant or more vigorous crop varieties (CZ, PT, CH, HR).
	  ○ France (focus crop: grapes) & Switzerland (focus crop: apples) & Netherlands (focus crop: potatoes): Robust varieties (against fungus diseases)
	• **Use of Biological Control Agents** (all).
	  ○ France (focus crop: grapes) & Switzerland (focus crop: apples): Low residue strategy (no synthetic fungicides after flowering, only PPPs authorized in organic farming)
	• **Weeding:** Mechanical, mulching, burning (NL, HR), False Seed Beds (NL).
	  ○ Slovenia (focus crop: silage maize): Mechanical weeding only (no herbicides)
	• **Increase Soil Health**: Implement practices to enhance soil health (FR, HR).
	• **Relay Intercropping and Companion Planting** (CH).
	• **Use of Microorganisms:** Apply beneficial microorganisms like *Bacillus, Trichoderma*, and *mycorrhiza* (ES, DK).
	• **Reduction in Soil-Borne Pathogen Inoculum:** Alternate with non-host crops (IT, NL).
	• **Pheromone-Mediated Mating Disruption:** (IT, DK).
	• **Raising Vine Height**: Increase the height of vines to improve health and yield (PT).

Table 3: Agronomic interventions to reach an agriculture in Europe without chemicals, using non-chemical alternatives to pesticides, through system re-design

	Agriculture in Europe without chemicals, using non-chemical alternatives to pesticides

System re-design	**Diversity**
	• **Crop Diversity:** Mix of annual and perennial varieties, genetic variability within crop cultivations, and avoidance of monoculture.
	• **Wide Range of Crops available:** Inclusion of traditional and new varieties for resilience. Key Traits: Resistance to diseases and pests, flavour, and not just maximum yields.
	• **Advanced Seed and Genetic Development:** Availability of diverse seeds and genetic varieties.
	• **Temporal and Spatial Diversity:** Crop rotation and different varieties on one plot to reduce pest and disease damage.
	  ○ Slovenia (focus crop: silage maize) & Netherlands (focus crop: potatoes): Wider/ more diverse crop rotation
	• **Economic Activities:** Expanding the number of marketed crops or economic activities (e.g., adding new crops like wheat, producing tea or extracts, selling byproduct, e.g. olive wood).
	
	Farming systems
	• **Mixed Agricultural Systems:** Combining livestock and crops.
	• **Agroforestry:** Combining fruit and nut trees with crops.
	• **Inter-Farm Diversity:** Effective pest protection through diversity between farms.
	• **Organic agriculture**
	  ○ France (focus crop: grapes) & Switzerland (focus crop: apples) & Netherlands (focus crop: potatoes): Changing to organic production system
	• **Biodynamic agriculture**
	
	Machinery

	• **Local Adaptation:** Machinery is adapted to local conditions, lighter and smaller, remote-controlled or electrically powered. **Soil Health & Nature** • **Biodiversity:** Agriculture working with nature, including biodiversity-relevant plants in rotation, agro-ecological infrastructures, or border planting. • **Space for Nature:** Incorporation of fruit and other trees for environmental functions, windbreak hedges, flowering, and greening belts. • **Specific Biodiversity Share:** Specific shares devoted to biodiversity (e.g., 10%, rule of thirds). **Biological Control Methods** • **Standard Elements:** Replacing synthetic pesticides with natural products, using beneficial insects and other organisms. • **Research:** Ongoing research into microorganisms and plant defence mechanisms for plant protection. **Other Themes:** • **Reduced Size:** Smaller vineyards or fields. • **Combination of Discoveries:** Blending traditional and new discoveries. • **Decision-Support Tools:** Availability and use. • **Research Integration:** Access to research and its practical integration to benefit farmers.

3. Scenarios

Scenarios presented here are intended to be modelled in SOLm as part of task 6.5 of the SPRINT project. SOLm is a biophysical mass-flow model. Any biophysical indicators can be modelled (as dependent variables) if corresponding data is available. Economic indicators can be computed alongside if corresponding data is available. However, as market dynamics are not represented in SOLm, the computation of economic indicators is done under the assumption that prices remain constant (i.e. all prices for physical inputs, labour and products sold).

SOLm takes a food system perspective. It typically uses two or more dimensions (independent variables) to open an option space of different future scenarios and computes indicators (dependant variables) for these scenarios. An example can be found in Müller et al. (2017).

In its default version, SOLm runs with data from FAOSTAT (https://www.fao.org/faostat), Eurostat (https://ec.europa.eu/eurostat), and IPCC (https://www.ipcc.ch/).

In what follows we present the scenario design rationale used as well as a proposal for scenarios building up on the output of SPRINT deliverables D7.2 and D6.3.

3.1 Scenario design rationale

As described above, SOLm uses two or more dimensions with multiple levels each (independent variables) to open an option space of different future scenarios and computes indicators (dependant variables) for these scenarios. An example can be found in Muller et al. (2017), illustrating an option space for different shares of organic agriculture, different levels of reduction in food-competing feed and different levels in waste reduction, resulting in an option space of several dozens of combinations of these dimensions. The combination of the dimensions' lowest levels (e.g. 0%) typically represents the 'business as usual (BAU)' scenario. For each scenario potential drivers and barriers are identified based on SPRINT deliverables 6.3 and 7.1. Depending on the dimensions used, a scenario consists of one or several options in the option space. Generally, SOLm is particularly adequate to assess trade-offs and synergies between larger changes along different scenario dimension and for scenarios that are of a more systemic character (i.e. assessing the change from 0 to 25 to 50% organic agriculture, with all its production and commodity availability changes, rather than assessing the increase of an area where a certain practice is applied by few percentages, all else being equal). Such smaller change can also be modelled and deliver important insights, though.

Table 4 shows the SOLm output in a stylized fashion for two dimensions with four and three levels each, leading to an option space with 4 x 3 = 12 options.

Table 4: SOLm output in stylized fashion for two dimensions with four and three levels each and 4 x 3 = 12 options.

		Dimension 1			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Dimension 2	**Level 1**	BAU (L1-L1)	L2/L1	L3/L1	L4/L1
	Level 2	L1/L2	L2/L2	L3/L2	L4/L2
	Level 3	L1/L3	L2/L3	L3/L3	L4/L3

In the following subsection we present a number of different option spaces with corresponding scenarios based on the output of SPRINT deliverables D7.2 and D6.3. Each option space represents a proposal of scenarios – based on the selected dimensions and levels. Dimensions can be removed or added in a flexible manner to build more simple or complex option spaces, respectively.

Example: Dimension 1 could represent the organic share in a specific country with levels 0, 25, 50, 75 and 100%. Dimension 2 could represent food waste reduction with levels 0, 25, 50, 75 and 100%. The option space then represents all the combinations of these two dimensions (i.e. 5x5 = 25 options). For each option some indicators are computed, e.g. land use. The model output then shows to what extent land use is affected by each combination, e.g. how land use changes if the organic share is increased to 50% and food waste at the same time reduced by 50%.

3.2 Proposal of scenarios

In what follows we present the option space (dimensions and levels) together with the focus country/ region, focus crop, business as usual scenario (BAU), indicators, data sources, and drivers and barriers. We also provide a justification and related narratives for each option space. The description of the BAU is based on the data collected in the SPRINT farm survey. Drivers, barriers, justification, and narratives are based on the expert interviews conducted as part of Task 6.3. More detailed information can be found in D6.3 (Meier et al., 2024).

Region: Slovenia

Table 5 outlines option space 1.1 for the region Slovenia and focus crop silage maize:

Table 5: Option space 1.1 – region: Slovenia – focus crop: silage maize

Country (=region):	Slovenia
Focus crop:	Silage maize (arable)

Business as usual scenario (BAU):	IPM production of silage maize for cattle (almost 100% of farms conventional); use of synthetic herbicides for weeds (mainly 1 treatment/ year with a more or less toxic synthetic herbicide to control annual weeds – a lot of emphasis is put on the timing of application – and 1 treatment in 5 years with Glyphosate, to control perennial weeds); minimal mechanical weeding (e.g. once before seeding); minimal crop rotation with grass-clover mixture once in five years – but at least 3 crops (silage maize 3 times, grass-clover mixture once, cereal once); cover crops in winter.
Dimension 1:	Increase in the share of farms implementing agroecology measures (e.g. wider/ more diverse crop rotation (including legumes); increase in mechanical weeding) leading to a reduction in pesticide use of at least 50% (mainly herbicides)
Levels:	0% (BAU), 25%, 50%, 75% and 100%. With each step the crop rotations become more diverse (including higher shares of clover) and pesticide applications are replaced by mechanical weeding
Dimension 2:	Rainfall intensity
Levels:	Low, medium, high (either linked to reduced yields or increase in PPP)
Indicators:	Land use (based on 'plant protection-based yield gap'), environmental and health damage costs from synthetic pesticide use (based on D6.1 and D6.2), quantity of dairy cows and milk produced (if holding land use constant), food/ feed imports and exports, quantity of nutrients produced (protein, fat, etc.) (holding land use constant), labour productivity, investment (machinery, fuel, …)
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	Farm to Fork Strategy (Green Deal); KOPOP national program for the protection of ground water (demands at least three crops and at least once grass in five years; does not allow the use of the synthetic herbicide containing terbuthylazine).
Barrier(s):	No IPM label/ communication; low milk prices; allowed number of animals per hectare relatively high (small farms 'economically forced' to use a very simple crop rotation); no incentive to reduce the number of animals allowed; machinery equipment used for mechanical weeding not optimal; farmers' habits.

Table 6 outlines option space 1.2 for the region Slovenia and focus crop silage maize:

Table 6: Option space 1.2 – region: Slovenia – focus crop: silage maize

Country (=region):	Slovenia
Focus crop:	Silage maize (arable)
Business as usual scenario (BAU):	IPM production of silage maize for cattle (almost 100% of farms conventional); use of synthetic herbicides for weeds (mainly 1 treatment/ year with a more or less toxic synthetic herbicide to control annual weeds – a lot of emphasis is put on the timing of application – and 1 treatment in 5 years with Glyphosate, to control perennial weeds); minimal mechanical weeding (e.g. once before seeding); minimal crop rotation with grass-clover mixture once in five years – but at least 3 crops (silage maize 3 times, grass-clover mixture once, cereal once); cover crops in winter.
Dimension 1:	Organic share

Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 2:	Reduce the amount of silage maize (and other feed) produced on cropland and only use permanent pastures available for milk production (reduction in animals!)
Levels:	0%, 50%, 100%
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Land use (based on 'plant protection-based yield gap' and 'mineral fertilizer yield gap), environmental and health damage costs from synthetic pesticide use (based on D6.1 and D6.2), quantity of milk produced (if holding land use constant), food/ feed imports/ exports; quantity of nutrients produced (protein, fat, etc.) holding land use constant, labour productivity.
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	Organic label
Barrier(s):	Low demand for organic; low organic milk prices

The dimension 'Increase in the share of farms implementing agroecology measures' (option space 1.1) represents an increase in the adoption of efficiency and/or substitution measures to achieve a reduction in pesticide use – mainly herbicides – of at least 50%. Specifically, in option space 1.1 an increasing number of farms replaces synthetic herbicides by implementing a wider/ more diverse crop rotation and/or by increasing mechanical weeding (and/or other efficiency and substitution measures listed in Table 2 in chapter 2.1 Classification of agronomic management strategies). The agronomic and economic impacts of implementing a wider/ more diverse crop rotation (including legumes) or increasing the use of mechanical weeding in silage maize production in Slovenia were assessed in D6.3 (Meier et al., 2024). A summary of corresponding insights is provided below. Regarding the agronomic and economic impacts of crop rotations and the use of legumes there is a substantial amount of literature from which data could be obtained (Lazali & Drevon, 2023).

The dimension 'organic share' (option space 1.2) represents an increase in the adoption of a system re-design measure to achieve a synthetic-free agriculture. Specifically, in option space 1.2 an increasing number of farms converts to organic production where no more synthetic pesticides are used. Insights from D6.3 regarding this dimension are provided below.

The dimension 'reduce the amount of silage maize (and other feed) produced on cropland' represents a gradual reduction of the food-competing-feed production and a consequent reduction in the number of animals to a final number that can still be fed with the permanent pastures available (no assumption of expansion of permanent pastures). The effect of food-competing-feed production was for example assessed in Müller et al. (2017).

The dimension 'rainfall intensity' represents a concern raised by experts in interviews conducted as part of task 6.3. They pointed out that a reduction of synthetic pesticides makes farms more weather dependant and less flexible in their response to weeds: "Factors such as increased weather dependency, mainly in excessively wet conditions, contribute to a potentially serious yield loss. Particularly in very wet years, the critical days before weeds overtake the maize can be missed, as it takes at least a few days without rain to hoe. In contrast, herbicide application remains a viable option even if it rains 5 hours after application" (Meier et al., 2024). The effect is captured either by reduced yields under constant use of PPP or increased PPP use under constant yields.

Related findings and narratives from D6.3 (Meier et al., 2024):

Please note: the following insights are based on a multicriteria assessment with experts. Thus, they represent expert opinions.

Related to crop rotation/ cultivation of legumes:

- Crop rotation can be improved by incorporating silage maize into the cycle only every 2-3 years and growing a variety of crops such as cereals, potatoes, grass-clover mixtures, lucerne mixtures or legumes such as forage peas.
- Including grass in the crop rotation was highlighted by the experts as a strong measure to better control perennial weeds, as grass is mowed several times a year.
- A combination of mechanical weeding with more grass in the crop rotation to control perennial weeds could be an effective strategy to fight both annual and perennial weeds.
- One expert indicated that organic farms usually grow grass in two consecutive years and with that succeed to improve the control of perennial weeds.
- Generally: The low price for milk and the high number of animals allowed per hectare pushes farms to grow a lot of silage maize.
- Depending on the area for cultivation each farm has, the extension of the crop rotation can be a serious challenge.
- The current share of farms with two times grass in their crop rotation is about 30 to 40%, according to experts. A further increase is not expected by the experts, however, due to the restriction of cultivation area in the case of smaller farms and the current political environment.

Related to mechanical weeding:

- The current share of silage maize growing farms relying on mechanical weeding is very low (as is the current share of organic silage maize growing farms).
- According to experts, the elimination of synthetic herbicides (except for using glyphosate every 5 years) and the use of mechanical weeding only, leads to a slight, moderate, or strong decrease in yield due to an increase in weed pressure.
- According to experts, harrowing would have to be done once or twice, hoeing two to three times per season.
- One strategy to reduce the reliance on synthetic pesticides is blind seeding, a method of preparing the field and allowing weeds to germinate, followed by mechanical destruction with a harrow and simultaneous fertilizer amendment. This approach allows a single application of herbicide during one growing season and provides better control of weed growth. According to experts, this approach is followed by a lot of farms.
- The experts emphasize that a combination of mechanical and chemical treatments can be used to control weeds. Using mechanical weeding alone is seen as a big challenge. According to experts, it is not possible to maintain the same level of yield with mechanical treatment alone.
- Factors such as increased weather dependency, mainly in excessively wet conditions, contribute to a potentially serious yield loss. Particularly in very wet years, the critical days before weeds overtake the maize can be missed, as it takes at least a few days without rain to hoe. In contrast, herbicide application remains a viable option even if it rains 5 hours after application.
- Apparently, according to the experts, mechanical weeding is also limited in its effectiveness against perennial weeds and more effective against annual weeds. A combination of mechanical weeding with more grass in the crop rotation to control perennial weeds could be an effective strategy.

- Another challenge is the financial aspect, as, according to experts, more labour and fuel are needed for the increased number of passes with the tractor. In particular, experts indicated that farms would have to purchase new machinery for effective weeding. Current machinery is not effective enough to fully rely on mechanical weeding.

Related to organic production:

- Conventional silage maize production is very widely spread in Slovenia, whereas organic silage maize production is still relatively modest, with a maximum of 1% of farms following organic production practices.
- Organic livestock farms are especially prevalent in the hilly areas, rearing livestock mainly on pasture and focusing on small livestock, with farm sizes ranging from 5 to 10 hectares.
- It was said that farms on higher slopes would not use mechanical weeding. Mechanical weeding can do a lot of damage to the crop and the soil in hilly areas.
- According to the experts, organic farms do rather not choose to grow silage maize due to the difficulty of growing silage maize without synthetic herbicides. As weed control in silage maize production is a significant challenge for organic farms, they favor grass silage over maize silage, as grass cultivation allows for easier weed control through regular ploughing and mowing (two consecutive years with grass to fight perennial weeds).
- According to the experts, conventional farms also use grass silage, but rely on maize silage for its energy content, whereas organic farms use wheat and barley as energy-rich alternatives.
- Overall, the demand for organic milk as well as organic milk prices are low in Slovenia.

Region: Bordeaux (France)

Table 7 outlines option space 2.1 for the region Bordeaux (France) and focus crop vineyards:

Table 7: Option space 2.1 – region: Bordeaux – focus crop: vineyards

Country (=region):	France – La Gironde (Bordelais region)/ Bordeaux
Focus crop:	Vineyards – for red wine (e.g. Merlot, Cabernet Franc, Cabernet Sauvignon)
Business as usual scenario (BAU):	IPM production (88%), planting density: 1.50 to 2 metres between rows (narrow), first fungicide treatment in BBCH15, total of 13 chemical treatments with fungicides (powdery and downy mildew) – 8 treatments with synthetic fungicides and 9 with PPPs authorized in organic farming, total of 10 synthetic fungicide products and 5 PPPs authorized in organic farming.
Dimension 1:	Share of farms growing robust varieties representing 20% of the total area at farm-level (resistance to mildew)
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 2:	Share of farms using the 'low residue strategy'
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Yield/ land use, number of chemical treatments or amount applied, labour productivity, environmental and health damage costs

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	'Low residue strategy': There are many positive examples farmers can profit from. Robust varieties: Subsidies for replacing old vines.
Barrier(s):	Low residue strategy: No subsidies; growers' distrust in the effectiveness of copper. Robust varieties: AOC production standards too strict; consumer preferences/ acceptance; resistance breakdown risk; no subsidies (except for the replacement of old vines).

Table 8 outlines option space 2.2 for the region Bordeaux (France) and focus crop vineyards:

Table 8: Option space 2.2 – region: Bordeaux (France) – focus crop: vineyards

Country (=region):	France – La Gironde (Bordelais region)/ Bordeaux
Focus crop:	Vineyards – for red wine (e.g. Merlot, Cabernet Franc, Cabernet Sauvignon)
Business as usual scenario (BAU):	IPM production (88%), planting density: 1.50 to 2 metres between rows (narrow), first fungicide treatment in BBCH15, total of 13 chemical treatments with fungicides (powdery and downy mildew) – 8 treatments with synthetic fungicides and 9 with PPPs authorized in organic farming, total of 10 synthetic fungicide products and 5 PPPs authorized in organic farming.
Dimension 1:	Share of farms growing robust varieties representing 20% of the total area at farm-level (resistance to mildew)
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 2:	Organic share
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Yield/ land use, number of chemical treatments or amount applied, labour productivity, environmental and health damage costs
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	Robust varieties: Subsidies for replacing old vines. Organic share: Organic label (subsidies for organic production).
Barrier(s):	Robust varieties: AOC production standards too strict; consumer preferences/ acceptance; resistance breakdown risk; no subsidies (except for the replacement of old vines). Organic share: Additional equipment/ machinery and workforce needed (organic is stricter on 'green work'); additional knowledge and skills (timing and 'positioning' of non-synthetic treatments); stronger weather dependency.

The dimension 'Share of farms growing robust varieties representing 20% of the total area' represents a substitution measure to reach the 50% reduction goal. The area share is set at 20%, as one expert interviewed as part of Task 6.3 stated, that no more than 20% of the total vineyard should be used for resistant varieties to prevent a resistance breakdown. The agronomic and economic impacts of growing robust varieties in vineyards in France were assessed in D6.3 (Meier et al., 2024). A summary of insights is provided below.

The dimension 'Share of farms using the 'low residue strategy'' also represents a substitution measure to reach the 50% reduction goal. The 'low residue strategy' proposed here, consists of omitting synthetic pesticides after the flowering period, replacing them with biological alternatives. The agronomic and economic impacts of implementing the 'low residue strategy' in vineyards in France were also assessed in D6.3 (Meier et al., 2024). A summary of insights is provided below.

The dimension 'organic share' represents a measure for system re-design to reach an agriculture in Europe without chemicals, using non-chemical alternatives to pesticides (same dimension as in region Slovenia). The economic and agronomic impacts of organic conversion in vineyards in France were also assessed in D6.3 (Meier et al., 2024). A summary of insights is provided below.

The dimension 'rainfall intensity' is considered relevant, as overly wet conditions render the implementation of the 'low residue strategy' as well as organic conversion more difficult.

An additional scenario for wine production in France is outlined in 'Foresight: European Chemical Pesticide-Free Agriculture in 2050 (INRAE, 2023). The scenario consists of 'mosaics of crops' – mixing vineyards, fruit trees, hazelnut trees, cereals, and pastures – and of semi-natural habitats, including hedgerows, copses, flowering strips, and wetlands. Together these create "complex and resilient landscapes, where pests are regulated" (INRAE, 2023, p. 7).

Generally, some further inspiration for systemic scenarios will be taken from this report INRAE (2023) for the other cases as well to complement the more specific practice-related assessments. This is particularly adequate for the food-system level focus of SOLm and some emphasis thus may be put on such systemic scenarios, in particular if specific data is difficult to source in due detail for the more practice-related scenarios.

Related findings and narratives from D6.3 (Meier et al., 2024):

Please note: the following insights are based on a multicriteria assessment with experts. Thus, they represent expert opinions.

Related to robust varieties:

- The cost of removing old vines, coupled with a three-year waiting period before returning to production, is a financial constraint. Growers would need financial support and technical assistance.
- Another challenge to introduce robust varieties into viticulture are according to the experts the restrictions coming from the AOC production standards (AOC: controlled designation of origin; French: appellation d'origine controlée), limiting the cultivation of robust varieties to 5% of the vineyard. If farmers currently want to cultivate more than 5%, they have to step out of the standard and will in turn be declassified.
- Another challenge is that a new variety means a new product with a new taste and therefore involves significant marketing efforts to gain consumer acceptance.
- In addition, the industry is afraid of resistance breakdowns. To deal with the risk of resistance breakdowns a disease monitoring tool is currently being developed (OSCAR[1]). An expert stated, that no more than 20% of the total vineyard should be used for resistant varieties to prevent a resistance breakdown.

[1] National 'Observatory for the Deployment of Resistant Cultivars' (OSCAR; https://observatoire-cepages-resistants.fr/en/).

- Experts also pointed out that robust varieties are 'only' resistant against mildew and oïdium, but not against black rot.
- According to experts, growing robust varieties leads to a slight, moderate, or strong increase in yield as well as an increase in yield stability.
- According to experts, growing robust varieties does not lead to an increase in the full cost of bulk wine, overall.
- According to experts, growing robust varieties leads to a strong decrease both in the number of different synthetic and non-synthetic fungicides applied as well as in the number of treatments.
- According to experts, costs both for mechanisation as well as labour would rather decrease.
- According to experts, there are no subsidies for growing robust varieties.
- According to experts, robust varieties are currently grown on a very low share of land. Experts expect the area to increase in the near future to 10, 20 or even 40%.

Related to 'low residue strategy':

- According to experts, no subsidies are provided if a farm follows the 'low residue strategy'.
- According to experts, farms distrust copper, which may hinder the adoption of the 'low residue strategy'.
- According to experts, the low residue strategy leads to no change or only a slight decrease in yield. Yield stability may decrease.
- According to experts, the product quality stays unchanged.
- According to experts, the full cost of bulk wine remains unchanged or slightly increases.
- According to experts, there is a decrease in the number of different synthetic fungicides used as well as in the number of treatments with synthetic fungicides. If the total number of fungicides (synthetic and non-synthetic) would increase, decrease or stay unchanged is not clear.
- Regarding the current share of vinyard surface where the low residue strategy is implemented, experts' opinions differed quite substantially from up to 20 or up to 50%.

Related to organic production:

- Changing to organic may lead to a slight decrease in yield.
- Product quality remains unchanged.
- The full cost of bulk wine will moderately increase.
- The number of treatments will moderately increase by up to 40%.
- Overall, costs for fungicide products will decrease.
- Total costs for mechanisation as well as for labour will moderately increase. There is a requirement for additional agricultural equipment.
- The current share of organic vinyards is 20% (in terms of surface) and is expected to increase to 25 or even 60%.

Region: The Netherlands

Table 9 outlines option space 4.1 for the region 'North Holland (Groningen, Friesland)' and focus crop seed potatoes:

Table 9: Option space 4.1 – region: The Netherlands – focus crop: potatoes

Country (=region):	North Holland (Groningen, Friesland)
Focus crop:	Seed potatoes

Business as usual scenario (BAU):	Conventional production; crop rotation width: 1:3; other crops in the crop rotation: barley, wheat, sugar beet, onions; about 8 to 10 treatments with 3 to 5 synthetic fungicide products (no non-synthetic fungicides used); buyer: large traders (also for export); yield: 30 to 40 tons/ha; generally seed potato farms are growing in size – the largest farms ranging between 400 and 500 ha (Small farms usually lease their land to larger farms in the year when seed potatoes are grown); which varieties and for how long a variety is grown very much depends on the offer and demand on the side of seed potato traders with whom seed potato growers have contracts; generally a farm grows 8 to 10 varieties or more and each variety for 3 to 8 years.
Dimension 1:	Share of farms growing robust varieties representing 20% of the total area at farm-level.
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 2:	Increase in the share of farms implementing agroecology measures (e.g. wider/ more diverse crop rotation – 1:4 or 1:5 instead of 1:3 (including legumes)) leading to a reduction in pesticide use of at least 50%
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Yield/ land use, number of chemical treatments, labour productivity, environmental and health damage costs
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	Robust varieties: Breeding stations are working hard to develop more resistant potato varieties. Wider/ more diverse crop rotation: effective against fungus disease in the soil.
Barrier(s):	Robust varieties: market forces (influential trading companies); strong dependence of varietal choice on influential trading and industrial companies; concerns about resistance breakdown; no governmental subsidies Wider/ more diverse crop rotation: growing seed potatoes is extremely profitable; no governmental subsidies/ regulations for wider crop rotation; effective against fungus disease in the soil, but not against late blight of potato, which is the greatest risk of poor harvests in seed potato cultivation.

Table 10 outlines option space 4.2 for the region 'North Holland (Groningen, Friesland)' and focus crop seed potatoes:

Table 10: Option space 4.2 – region: The Netherlands – focus crop: potatoes

Country (=region):	North Holland (Groningen, Friesland)
Focus crop:	Seed potatoes
Business as usual scenario (BAU):	Conventional production; crop rotation width: 1:3; other crops in the crop rotation: barley, wheat, sugar beet, onions; about 8 to 10 treatments with 3 to 5 synthetic fungicide products (no non-synthetic fungicides used); buyer: large traders (also for export); yield: 30 to 40 tons/ha; generally seed potato farms are growing in size – the largest farms ranging between 400 and 500 ha (Small farms usually lease their land to larger farms in the year when seed potatoes are grown);

	which varieties and for how long a variety is grown very much depends on the offer and demand on the side of seed potato traders with whom seed potato growers have contracts; generally a farm grows 8 to 10 varieties or more and each variety for 3 to 8 years.
Dimension 1:	Share of farms growing robust varieties representing 20% of the total area at farm-level.
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 2:	Organic share
Levels:	0%, 20%, 40%, 60%, 80%, 100%
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Yield/ land use, number of chemical treatments, labour productivity, environmental and health damage costs
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs)
Driver(s):	Robust varieties: Breeding stations are working hard to develop more resistant potato varieties. Organic conversion: subsidies; higher farm gate price.
Barrier(s):	Robust varieties: market forces (influential trading companies); strong dependence of varietal choice on influential trading and industrial companies; concerns about resistance breakdown; no governmental subsidies Organic conversion: no subsidies during conversion; low demand for organic seed potatoes; derogation possibility for the use of organic seeds.

The dimension 'share of farms growing robust varieties representing 20% of the total area at farm-level' represents a substitution measure to reach the 50% reduction goal (same dimension as in the region Bordeaux and Switzerland). As seed potato farms grow 8 to 10 varieties or more, the assumption that 20% of the total area cultivated at farm level would be used for robust varieties seems reasonable – particularly also due to concerns raised by experts about resistance breakdown risk. The agronomic and economic impacts of growing robust varieties in seed potato production in North Holland were assessed in D6.3 (Meier et al., 2024). A summary of corresponding insights is provided below.

The dimension 'increase in the share of farms implementing agroecology measures' represents an increase in the adoption of efficiency and/or substitution measures to achieve a reduction in pesticide use – mainly fungicides – of at least 50%. Specifically, an increasing number of farms replaces synthetic fungicides by implementing a wider/ more diverse crop rotation (and or other efficiency and substitution measures listed in Table 2 chapter 2.1 Classification of agronomic management strategies). The agronomic and economic impacts of implementing a wider/ more diverse crop rotation (1:4 or 1:5 instead of 1:3) in seed production in North Holland were assessed in D6.3 (Meier et al., 2024). A summary of corresponding insights is provided below.

The dimension 'organic share' represents an increase in the adoption of a system re-design measure to achieve a synthetic-free agriculture (same dimension as in region Slovenia, Bordeaux and Switzerland). The economic and agronomic impacts of organic conversion in seed potato production in North Holland were assessed in D6.3 (Meier et al., 2024). A summary of insights is provided below.

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

The dimension 'rainfall intensity' is considered relevant, as overly wet conditions render the implementation of agroecology measures as well as organic conversion more difficult.

Related findings and narratives from D6.3 (Meier et al., 2024):

Please note: the following insights are based on a multicriteria assessment with experts. Thus, they represent expert opinions.

Related to robust varieties:

- Market forces, particularly influential trading companies such as HZPC, AGRICO and AVERIS, have substantial control over the choice of potato varieties grown.
- According to the experts, about 80% of the seed potatoes produced in the Netherlands get exported to international markets, underlining the enormous influence of export markets in determining the range of potato varieties grown. The majority of these potatoes are intended for industrial production, which means that the industry must be persuaded to adopt new potato varieties.
- Experts also stated the concern about resistance breakdown.
- According to experts' assessment, the adoption of robust seed potato varieties will not affect the yield.
- Other characteristics, such as peel quality and internal quality, play a greater role than disease resistance.
- There are no governmental subsidies for growing robust varieties.
- Currently, about 2 to 5% of the area cultivated with seed potatoes can be attributed to the growth of robust varieties. One expert expects this share to increase.
- Apparently, breeding stations are working hard to develop more resistant potato varieties, but this will take years.

Related to wider crop rotation:

- According to the experts, expanding crop rotation is a challenge without an economically competitive crop, as seed potatoes are extremely profitable in comparison. One expert highlights that seed potatoes make up to 75% to 80% of a farm's income. The other highlights that the income from seed potatoes is at least 4 to 6 times higher than the income from wheat. The expert specifies that a 1:5 crop rotation would be best, but the economic impact would be dramatic.
- Currently, there are no governmental subsidies for a wider crop rotation.
- According to the experts, a wider crop rotation can be effective against fungus desease in the soil (Rizoptonia) but not necessarily against late blight of potato (phytophtera infestans), which is the greatest risk of poor harvests in seed potato cultivation
- Experts only see a potential for a wider crop rotation in the case of organic farms or if regulations from the government demand a wider crop rotation. In the latter case, however, farms would have to be compensated for the economic loss incurred.
- The adoption of a wider crop rotation may have a positive impact on yield (within one season), as the soil can rest and therefore has the potential to produce a higher yield.
- One expert emphasizes that there is too little objective experience with the effect of increasing crop rotation on fungal diseases.

Related to organic share:

- According to the experts, a conversion to organic production faces challenges such as increased weeding, increased labour requirements, and decrease in yield (by 15 to 20 tons/ha).
- According to experts, the yield stability is lower under organic conditions and can go down to 25 tons/ha in a wet season.
- Subsidies for organic farming are provided from the state, but not during conversion.

- According to experts, the incentive for conventional seed potato farms to convert to organic is low, as the business of conventional seed potatoes is so profitable, the demand for organic seed potatoes low (small market and possibility for organic potato producers to use conventional seed potatoes), and the conversion costs borne by the farm itself. Hence, to motivate farmers to convert, experts suggest the following measures: financial support for conversion; higher market price for organic seed potatoes; no tax on organic crops; and phasing out the derogation for the use of organic seeds.
- The share of good quality seed potatoes will slightly or moderately decrease, from 90% to about 60 to 70%.
- The farm gate price for organic seed potatoes is moderately higher (premium of 0.10 to 0.20 EUR/kg).
- The current share of organic seed potato farms – in terms of area cultivated – is small, lower than 2%. One expert expects this share to increase, is not entirely sure though how fast the share will increase, due to ongoing discussions about the Green Deal. The expert emphasizes that political decisions have a lot of influence.

Region: Europe

Given the focus of SOLm on food system strategies as well as the need for thorough transformation of our agrifood systems, we suggest to also model a scenario for the whole of Europe, inspired by the 'Foresight: European Chemical Pesticide-Free Agriculture in 2050 (INRAE, 2023) report already mentioned above (cf. Table 11 below).

Table 11: Option space 5.1 – region: Europe, focus: food system level scenarios

Country (=region):	Europe
Focus crop:	Agricultural and food system (focus on food and feed production)
Business as usual scenario (BAU):	From the report (INRAE, 2023)
Dimension 1:	Organic share
Levels:	0%, 25%, 50%, 75%, 100%
Dimension 2:	From the three scenarios detailed in INRAE 2023.
Levels:	tbd
Dimension 3:	Rainfall intensity
Levels:	Low, medium, high
Indicators:	Calories / yields, amount of chemical pesticides used, environmental and health impacts
Data sources:	SPRINT agronomic farm-level data; modelling output of D6.1 and D6.2 (impacts and damage costs), INRAE 2023
Driver(s):	Organic share

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

Barrier(s):	Yield productivity, transformation costs, ???

The transformation to organic farming is examined in the scenarios for all regions. With regard to INRA 2023, a systemic approach will be pursued by examining the goal of chemical-pesticide-free agriculture via organic farming across the entire agricultural system. The previous scenarios refer to regional case studies with a focus on one crop. The final systemic European scenario attempts to transfer the findings to the European agricultural system.

4. Data available from the Sprint project

Datasets from the SPRINT project which can potentially be used for modelling in SOLm are listed below. All data is stored in the sprint-data.eu platform: https://sprint-data.eu/f/114106

4.1 SPRINT agronomic farm-level data

Person responsible: Mark Jennifer jennifer.mark@fibl.org (FiBL)

Repository: sprint-data.eu platform:

https://sprint-data.eu/apps/files/?dir=/Shares/WP6/Final%20database&fileid=114106

(Or manually: All files – Shares – WP6 – Final database)

The data will be published soon and be available as open source database in Zenodo.

Type of data: Quantitative; data was collected in the SPRINT project using a questionnaire.

Level: farm-level (around 10 farms per case study site, non-representative sample)

Time span: One year (2021), no time series

Variables: Mostly agronomic data for the focus crop (e.g. silage maize), including yield (tons/ha), price per unit sold, pesticide application (products applied and corresponding active substances, number of treatments, dosage of product and active substances applied), pesticide product prices (not complete), crops in crop rotation, production system (conventional, IPM, or organic), labour input (not complete), machinery used (not complete).

Related SPRINT deliverable: D6.3.

4.2 Farm-level environmental and health impacts and damage costs

Person responsible: Farshad Soheilifard farso@dtu.dk (DTU)

Repository: not on sprint-data.eu platform. Get in touch with person responsible.

Type of data: Quantitative; model output data (input: SPRINT agronomic farm-level data)

Level: farm-level (around 10 farms per case study site, non-representative sample)

Time span: One year (2021), no time series

Geographical coverage: Only SPRINT case study sites.

Variables: Human Health Impacts (μDALY/ha), Ecosystem Quality Impacts (PDF.m2.yr/ha), Resource Use Impacts (MJ/ha), Human Health Damage costs (EUR/ha), Ecosystem Quality Damage Costs (EUR/ha), Resource Use Damage Costs (EUR/ha).

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

Comments: Impacts and damage costs relate to whole supply chain (not only pesticide direct impacts).

Related SPRINT deliverable: D6.1.

4.3 Water catchment level environmental and health impacts and damage costs

Person responsible: Farshad Soheilifard farso@dtu.dk (DTU)

Repository: not on sprint-data.eu platform. Get in touch with person responsible.

Type of data: Quantitative; model output data (input: external data provider; input data is 'mass applied' in kg/year by active substance and crop; this data is not publicly available yet)

Level: water catchment level

Time span: One year

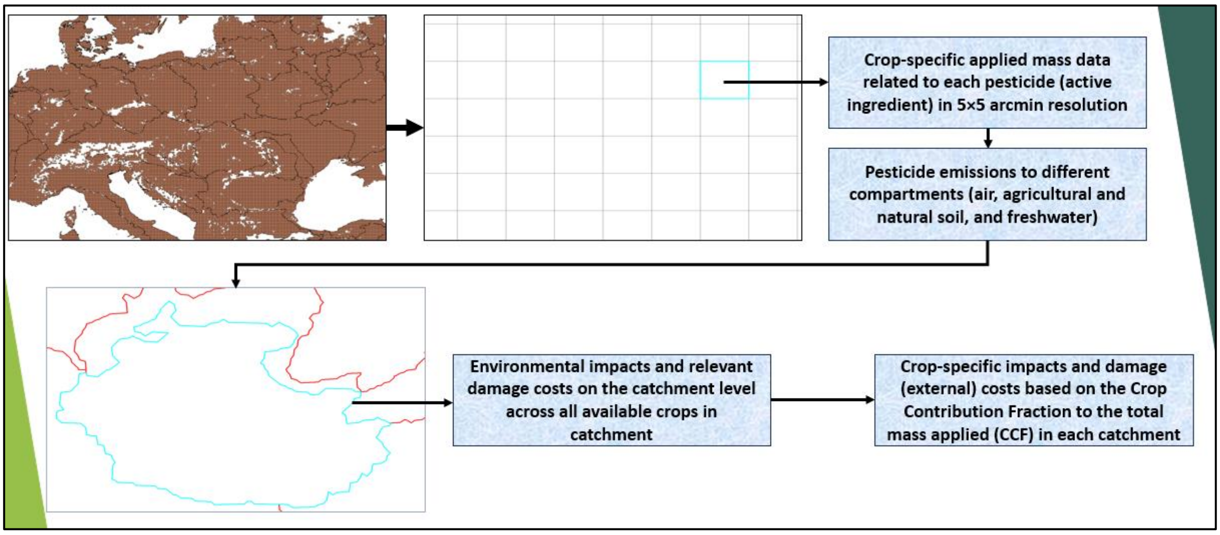
Geographical coverage: All water catchments in Europe.

Variables: Crop and active substance specific impact score (PDF.m2), crop and active substance specific damage costs (Euro)

Comments: Impacts and damage costs relate only to pesticide direct impacts. Other type of impacts have been computed elsewhere already (see for example Ecoinvent database).

Related SPRINT deliverable: D6.2

Figure 1: Illustration of how 'Water catchment level environmental and health impacts and damage costs' were calculated.



Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

References

Frelih-Larsen, A., & Riedel, A. (2024). *Transition to sustainable plant protection: Visions and building blocks.* (Project Deliverable 7.2).

INRAE. (2023). *Foresight: European Chemical Pesticide-Free Agriculture in 2050*.

Lazali, M., & Drevon, J. J. (2023). Legume ecosystemic services in agro-ecosystems: A review. *Communications in Plant Sciences*, *13*(2023). https://doi.org/10.26814/cps2023002

Meier, C., Mark, J., Blockeel, J., Ineichen, L., Grovermann, C., & Tamm, L. (2024). *Internal report on farm level impacts of different pesticide reduction strategies* [Project deliverable].

Muller, A., Schader, C., El-Hage Scialabba, N., Brüggemann, J., Isensee, A., Erb, K.-H., Smith, P., Klocke, P., Leiber, F., Stolze, M., & Niggli, U. (2017). Strategies for feeding the world more sustainably with organic agriculture. *Nature Communications*, *8*(1), 1290. https://doi.org/10.1038/s41467-017-01410-w