Report on Proceedings of the Workshop on Alternative Business Models for Pesticide Reduction

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2024

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EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC136924

Seville: European Commission, 2024

How to cite this report: European Commission, Joint Research Centre, Rennick, G., Berling, A., Chappell, T.M., Vicent, A., Wolf, M., De Toffol, M., Hloben, P., Mack, G., Le Mouël, C., Sebastian, F., Dubois, B., Lely, D., Coutu, S., Mohring, N., Lefebvre, M., Raineau, Y., Rogna, M., Rodriguez Cerezo, E., Barreiro Hurle, J. and Gomez Barbero, M., *Proceedings of the Workshop on Alternative Business Models for Pesticide Reduction*, European Commission, Seville, 2024, JRC136924.

Contents

Abstract

Plant pests and diseases can cause considerable impacts on crop yields, and in turn food and feed security. Pesticides are one of the most frequent tools used to control or eliminate these pests and diseases playing a crucial role to assure food security. However, pesticide use also leads to undesired environmental and health impacts. The European Commission´s Joint Research Centre organized a workshop in November 2023 to explore innovative alternative business models that are emerging to facilitate reductions in pesticide use and risk while minimizing impacts in food security. This report summarizes the contributions presented at the workshop covering the legislative framework for pesticide reduction, theoretical considerations on pesticide reduction behaviour, examples of new technologies and business models being developed and insights from research on their potential to facilitate the transition to a low-pesticide use agriculture. The overall message stemming from the workshop is that outcome-based services and insurance policies can be key tool to enable farmers to achieve this reduction. However, the existing empirical evidence of the performance of these tools is still very scarce and these new business models still have to show their potential when upscaling from pre-commercial stage.

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1 Introduction

Plant pests and diseases can cause considerable impacts on crop yields, and in turn food and feed security. Pesticides are used to control or eliminate these pests and diseases. Therefore, they play a crucial role in agriculture but can also have environmental and health impacts.

The EU's Farm to Fork Strategy[1] and Biodiversity Strategy[2] state that the European Commission "will take additional action to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030. When considering the need to reduce pesticide use, the full spectrum of the Efficiency-Substitution-Redesign framework (Pretty, 2018) needs to be considered, leading to a new holistic and simple policy framework that engages all actors in the food value chain (Möhring et al. 2020). In particular, new ways of combining classic changes in agricultural practices and adoption of precision farming techniques (Anastasiou et al. 2023) with other interventions need to be considered. This calls for the development of what we call "Alternative Business Models" for crop protection based on the provision of services rather than the sale of pesticide products (Chappell et al. 2019). In particular, the potential of linking pesticide reduction targets with crop insurance had been identified as a promising avenue to overcome the reluctance of farmers to reduce pesticide us due to risk and loss aversion (Dalhaus et al. 2020).

This report puts together summaries of the interventions at the Workshop on Alternative Business Models for pesticide reduction held in Seville on 22nd and 23rd of November 2023. Overall, the workshop aimed to bring together experts and European Commission staff to exchange knowledge and explore new and potential approaches to develop alternative business models for pesticide reduction.

The workshop also intended to achieve the following specific objectives:

- Showcase examples of innovative business models undertaken by farmers and agricultural companies to reduce pesticide use.
- Explore emerging trends and future prospects in innovative business models.
- Provide a discussion platform for sharing information on technical questions.
- Promote collaboration and networking among JRC and the invited experts.

The rest of the proceedings are structured as follows: First, we present summaries of eleven out of the thirteen contributions drafted by the invited experts, following the structure of the workshop. Next, we provide a summary of the main conclusions from the discussions, conclusions that have been endorsed by all speakers. The report includes as annex the agenda of the event, the speakers' bios and presentations. .

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[1] European Commission. A Farm to Fork Strategy for a Fair, Healthy and Environmentally-friendly. Brussels, COM (2020) 381final.

[2] European Commission. EU Biodiversity Strategy for 2030. Bringing nature back into our lives. Brussels, COM (2020) 380 final.

2 Opening Session

2.1 EU regulatory framework: past and present

Gordon Rennick[3]

The inception and development of a legal framework to regulate pesticides has historically been a reactive process. To understand the timeframes concerned we must first examine the progression of pesticide discovery and identify the key drivers pushing this process forward. Importantly we must then pin-point when and why it was considered necessary to regulate these chemicals. For background and perspective, world population dynamics are ultimately responsible for driving the increases in production of food crops, animal feed crops and energy crops. World population estimates for the year 1AD lie somewhere between 170 million and 300 million, with periods of rapid growth experienced in the last 2,000 years resulting in a current population of circa. 8 billion people and various predictions for the world population to reach 10 billion people by 2050 are generally accepted. Consequently, considering the generally accepted population forecasts, considerable increases in agricultural productivity will be required over the next 25 years. Therefore, commensurate, ecologically sensitive and economically sustainable agronomic developments need to be advanced rapidly. While recent history shows us that we possess the ability through public and private, research and innovation, this has largely been chemically and seed trait driven, both of which present challenges for the agriculture sector in the current EU political and legal landscape.

2.1.1 A history of pesticide discovery

Below is an approximation of when certain active substances were discovered and is only meant as an illustration of what periods of our recent past saw the most chemical development but also when the awareness of integrated pest management became more important and also discovery and use of microorganisms for the control of crop pests.

Early pesticides primarily included the use of elements or simple compounds and botanicals. The ancient Sumerians utilised sulphur and the early Romans used “amurea” (crushed olive pits) to kill insect pests. Necessity, curiosity and scientific and cultural development led to the subsequent discovery of other chemical compounds and molecules but also biological organisms for crop protection. It is also important to stress that these new discoveries merely augmented the cultural, biological and mechanical control methods already used by the farmers and producers many of which are still used today.

1st generation

- 2500 B.C. Ancient Sumerians used sulphur compounds to kill insects.
- 300 B.C. Chinese recognize phenology (connection between climate and periodic biological phenomena).
- 1101 A.D. The Chinese discover soap as a pesticide (Fatty Acids).

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- 1600's Tobacco infusions (Nicotine), herbs and arsenic used for insect pest control.
- 1880-1900 Bordeaux Mixture, Mercuric chloride, Paris green (mix arsenic and copper sulphate).

2nd generation (Synthetic Pesticide Era--1939 to today)

- 1930's Trend toward synthesizing new compounds.
- 1936 Metaldehyde.
- 1940's During WWII both sides work on organophosphates as nerve gases and coincidentally discover the insecticidal properties of these chemicals.
- 1942-1950 Gamma HCH, Thiram, DDT, MCPA & 2,4-D.
- 1950-1960 Dimethoate, CIPC, Folpet, Demeton S Methyl, Dodine, Mecoprop, Atrazine, Simazine.
- 1960-1965 Organotins, Chlormequat, Mancozeb, DiQuat, Paraquat, Methiocarb, Chlorothalonil.
- 1965-1969 Carbofuran, Chlorpyrifos, Benomyl, Phenmedipham, Tridemorph, Desmedipham, Ethofumesate, Chlorotoluron, Propyzamide.
- 1970's Serious beginning of research on IPM approaches to pest control.
- 1970 IPU.
- 1971 Glyphosate.
- 1973 -1980 Triadimefon, Carbendazim, Difenzoquat, Deltamethrin, Guazatine, Pendimethalin, Cypermethrin, Diclofop methyl, Triclopyr, Cymoxanil, Flamprop-M, Metalaxyl, Prochloraz, Clopyralid, Triadimenol, Propammocarb, Propiconazole, Fenpropimorph, Esfenvalerate.
- 1980's Increase in IPM research & genetic engineering applications in agriculture.
- Fluazifop P, Mepiquat chloride, Kresoxim methyl, Fluroxypyr, Metsulfuron methyl, Flusilazole, DFF, Tribenuron, Thifensulfuron, Cyproconazole, Fenpropidin, Tebuconazole, Cyazofamid, Prosulfocarb, Propaquizafop, Fenoxaprop, Difenoconazole, Trinexapac.
- 1990s Fluazinam, Imidacloprid, Thiamethoxam, Triflusulfuron-methyl, Azoxystrobin, acetamiprid, Epoxiconazole, Ampelomyces quisqualis, Quinoxyfen, Ferric phosphate.
- 1994 Bacillus subtilis, also 1st Round Up ready soy bean variety developed.
- 2000s Pyraclostrobin, Picoxystrobin, Thiacloprid, Prothioconazole, Clothianidin, Fluopyram, Proquinazid, Boscalid, Pinoxaden, Chlorantraniliprole.
- 2010s Isopyrazam, Bixafen, Oxathiapiprolin, Sulfoxaflor, Mefentrifluconazole, fenpicoxamid.
- 2020s[4] Cinmethylin, Bixlozone, Benzobicyclon, Fenquinotrione, Dimpropyridaz, Isoflucypram.

[4] Not yet approved.

2.1.2 A history of pesticide regulation

The Step 1. 1960-1990

The Dangerous Substances Directive

Directive 67/548/EEC also known as "the dangerous substances directive" was one of the earliest pieces of chemical legislation. It applied to both pure chemicals and mixtures of chemical found in preparations and listed substances and classes of substances considered to be "dangerous". It was famously the legal basis from which it was illegal to market products classified as "very toxic" or "toxic" to the general public.

The "Limitations" and "Prohibitions" Directives

There was really no EU harmonised pesticide regulation until the adoption of Council Directive 91/414/EEC and its application in 1994. However, there were some early EU initiatives, among them were Council Directive 76/769/EEC (commonly referred to as the imitations directive) which limited the amount of certain active substances which could be placed in pesticide products. Then, in 1979 Council Directive 79/117/EEC (commonly referred to as the prohibitions directive) was adopted and was famously responsible for the banning of mercuric and organo-chlorine compounds.

The early pesticide residues directives

The first of the pesticide residue directives was agreed in 1976 in the form of Council Directive 76/895/EEC relating to the fixing of maximum permissible levels for pesticide residues in and on fruit and vegetables. This was followed some ten years later with the agreement of Council Directive 86/362/EEC fixing of maximum levels for pesticide residues permitted in and on cereals and Council Directive 86/363/EEC fixing of maximum levels for pesticide residues allowed in and on foodstuffs of animal origin.

Step 2. 1991- 2000

Council Directive 91/414/EEC

While some Member States (MSs) had active substance evaluation and product authorisation programmes, not all had both. Some MSs had basic systems in place, while others relied on safety assessments conducted by other MSs. However, in view of the increase in discovery of new active substances in the 1970s and 1980s, it was clear that a harmonised evaluation system was needed. Consequently, Council Directive 91/414/EEC or "91/414" as it was commonly known as, was the first real broad scoping attempt at harmonised pesticide regulation in the EU. It legislated for both active substance approval at EU level incorporating a programme of review of active substances already on the EU market and a process for evaluation of new active substances. Importantly, this legislation also built a product authorisation process into the framework allowing for risk based assessments to be the basis of whether a plant protection product (PPP) could be placed on the market or not. The directive also allowed for authorisation of Plant Protection Products (PPPs) in the MSs for a provisional period if the PPP contained new active substances not yet approved in the EU and allowed MSs authorise PPPs for a very limited period for emergency use to solve unforeseen plant health and plant pest issues. The directive also prescribed comprehensive data requirements for the production of data packages to support both active substance approval at EU level and PPP authorisation at MS level (the two-pronged safety approach). It also incorporated the "uniform principles" which outlined how evaluations and risk assessments should be conducted. Active substance reviews and evaluations were carried out by Rapporteur Member States (RMSs) resulting in a "monograph", with the evaluations being "peer reviewed" by experts form the other MSs. All in all, quite a leap forward for both evaluation standards and EU harmonisation.

The Dangerous Preparations Directive

After the groundbreaking adoption and implementation of Directive 91/414/EEC, further harmonisation of the classification, packaging and labelling of preparations and products was the next logical step. Directive 1999/45/ EC of the European Parliament and of the Council also known as the "dangerous preparations directive" provided harmonised criteria for evaluation of hazardous preparations, enabling harmonised classification, packaging and labelling of such of dangerous substances and preparations. The scope of the Directive included plant protection products and biocides and introduced the classification of "dangerous for the environment".

<u>Step 3. 2001-2009</u>

Water Framework Directive

Aside from the legislative instruments directly relating to pesticides and focusing on particular aspects of pesticide approval, use or marketing, there are a number of other legislative strands contributing to the regulation of pesticides. In addition, there are other initiatives planned and at various levels of progress such as the nature restoration targets, a pollinators initiative to address the decline of pollinators, the listing of pollutants and derivation of Environmental Quality Standards within Directive 2000/60/EC, also known as "the water framework directive" (WFD). Within the ambit of the WFD, groundwater and surface water bodies are monitored for possible contamination by pesticides.

General Food Law

The European Food Safety Authority (EFSA) was established under Regulation (EC) No 178/2002 of the European Parliament and of the Council. Since then, EFSA provides technical and scientific support for testing and evaluation of food and feed and importantly gives independent scientific advice to risk managers based on risk assessments conducted on pesticides. The European Commission and MSs take risk management decisions on regulatory issues, including approval of active substances and setting of legal limits for pesticide residues in food and feed (maximum residue levels, or MRLs). The regulation also established general principles and requirements of food law and set out detailed procedures in matters of food safety.

Commission Regulation (EC) No 2076/2002

A mass extinction event in crop protection occurred with the agreement and adoption of Commission Directive (EC) No 2076/2002, which detailed hundreds of active substances that could no longer be marketed in the EU. Among the many fold reasons behind the demise of so many molecules was the lack of data supporting them in the context of the new data intense review programme, while some molecules were just becoming outclassed, some were withdrawn for commercial reasons while others were just not toxicologically sound or environmentally acceptable.

Residues Regulation

The early pesticide residue directives formed a solid foundation on which to build the existing robust system regulating and establishing "Maximum Residue Levels" of pesticides in food and feed commodities which in turn underpins consumer confidence in the food we eat today. Regulation (EC) No 396/2005 of the European Parliament and of the Council on maximum residue levels of pesticides in or on food and feed of plant and animal origin, essentially brought all previous separate pieces of legislation together under one banner and remains to this day one of the corner stones of food safety and off course the pesticide monitoring programmes carried out annually by the MSs serves to confirm the proper application of PPPs in accordance with the authorisation issued within the MSs.

REACH

After some thirty years of regulating pesticide active substances, Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), established the European Chemicals Agency, and established a system for regulation of "other" chemicals some of which did and do appear as constituent parts of PPPs, in the form of emulsifiers, carriers, adjuvants and others.

Step 4. 2009 to 2023

The Pesticide Package

Regulation (EC) No 1107/2009

Directive 91/414/EEC operated for a productive 15 years, resulting in removal of around 800 active ingredients from the EU marketplace and approving many new compounds but most importantly harmonising the way in which PPPs were placed on the market in the expanding borders of the EU. The increased politicisation of pesticides and a general move towards a more ecologically conscious agriculture meant that while the "directive" had embarked on, and largely completed the enormous review programme of old active substances, it was time to review and improve the system again. This resulted in a shift away from risk based regulation, instead moving toward a hazard based system, which to this day embodies a set of cut off criteria which are based on the intrinsic hazard properties of the active substances evaluated. Thus, Regulation (EC) No 1107/2009 of the European Parliament and of the Council relating to the placing of plant protection products on the market was agreed as part of "the pesticides package", repealing Council Directives 79/117/EEC and 91/414/EEC.

Among the changes from Directive 91/414/EEC, were

- A shift to hazard based approval criteria both for human and environmental health.
- Introduction of the concept of candidates for substitution & comparative assessment.
- Introduction of "basic" substances and "Low risk" substances.
- Zonal authorisation of PPPs.
- Regulation of "parallel trade".
- Provisions on "safeners and synergists", adjuvants and unacceptable co-formulants.
- Data protection rules.
- Avoidance of vertebrate testing.
- Record keeping and information availability to the public.
- EFSA manages the peer review of Draft Assessment Reports (formerly known as "monographs").

But the basic principle remains unaltered, an active substance can be only be approved if it is demonstrated that the substance and its residues, do not have any immediate or delayed harmful effects on human or animal health either directly or through drinking water, food, feed or air, or through exposure in the workplace, as a bystander or as a resident or any unacceptable effects on the environment.

Sustainable Use Directive

While pesticide residues and the placing on the market of PPPs had been regulated for 30 years, broadly speaking the use phase of pesticides had not been regulated in a harmonised fashion. It is true to say that the pesticide residue monitoring programme is a tool for determining whether PPPs have been used in accordance with the requirements prescribed in the authorisation process and to that end at least some harmonised measures existed. However, individual MSs were left responsible for regular testing of pesticide application equipment, training of professional users, advisors and distributors, aerial application, handling and storage requirements, restrictions in sensitive areas, aquatic areas and areas used by the general public etc. Therefore, while some MSs had quite developed systems in place, others had very little. Directive 2009/128/EC of the European Parliament and of the Council established a harmonised framework for Community action to achieve the sustainable use of pesticides (commonly referred to as the sustainable use directive or "the SUD"). In addition to the above mentioned subjects, the requirement on MSs to construct a national action plan, incorporating quantifiable objectives, goals and timetables and indicators to measure success and the requirement to incentivise and ensure the application of the principles of Integrated Pest Management (IPM), were two of the more pivotal elements included in the directive. The SUD remains in force today.

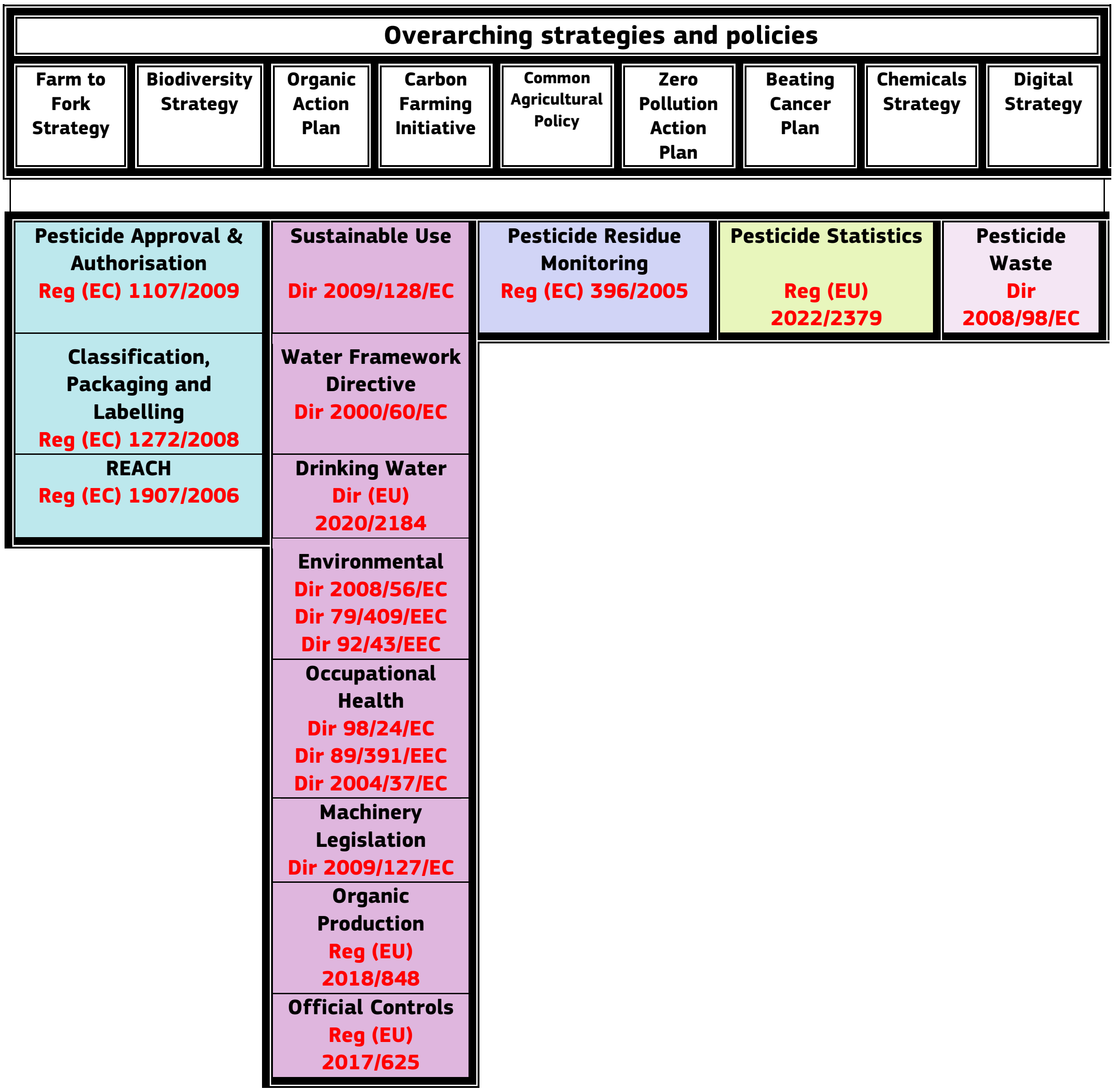
Machinery Directive

Directive 2006/42/EC also known as the machinery directive was a revised version of the Machinery Directive, which was first adopted in 1989. The revised Directive clarified and consolidated the provisions of the Directive with the aim of improving its practical application. The Directive aimed to harmonise the health and safety requirements applicable to and ensure the free circulation of machinery on the EU market. To this end, Directive 2009/127/EC of the European Parliament and of the Council, amended Directive 2006/42/EC with regard to machinery for pesticide application, establishing minimum requirements for placing on the market. These directives have been subsequently superseded by Regulation (EU) 2023/1230 which will enter into force in 2027

Statistics Regulation

Regulation (EC) No 1185/2009 of the European Parliament and of the Council set out a common framework for the systematic production and collection of statistics on the sales of pesticides and use of pesticides which are used in PPPs. This regulation was adopted as part of "the pesticides package" in 2009, however, it has subsequently been superseded by a new regulation on statistics on agricultural input and output, Regulation (EU) 2022/2379, now commonly referred to as "SAIO". The regulation allows for annual collection of sales data as was the case with the old statistics regulation and has much enhanced requirements for the collection of pesticide use data, with coverage exceeding 95% of pesticides used, from 2026, covering in excess of 75% of utilised agricultural area.

Figure 1. Non-exhaustive schematic of current legislation directly and indirectly impacting plant protection products.



Source: own elaboration.

2.2 Sustainable use of pesticide and the Common Agricultural Policy

Aymeric Berling[5]

With its Farm to Fork Strategy[6], the Commission has set very ambitious EU targets for the reduction of the risk and use of chemical pesticides. The Commission's proposal for a new Regulation (SUR)[7,8] replacing the current Directive on the sustainable use of pesticides[9] provides that the EU targets on pesticides are set at EU level and will be translated into national targets. The SUR further proposes that the reduction targets are primarily met by generalising the implementation of the Integrated Pest Management (IPM) approach.

IPM is basically about emphasizing the growth of healthy crops with the least possible disruption to agro-ecosystems and encouraging natural pest control mechanisms[10]. Under IPM chemical pesticides are to be used only in the last resort after having exhausted various approaches, including agronomical practices, monitoring of pests and diseases, use of reduction techniques, use of resistant varieties, etc.

The Common Agricultural Policy (CAP) has a long history of environmental instruments targeting farming practices. The first agri-environmental measures were introduced as early as in 1992. The subsequent CAP reforms have not only strengthened the existing measures but added new policy instruments and increased the budget on which they are set, gradually building what is now known as the "green architecture of the CAP". In the current CAP, having started in 2023, this architecture includes a number of very different instruments and many of these instruments are relevant to promote the use of IPM by farmers or other beneficiaries of the CAP.

As a foundation of the CAP green architecture, a large proportion of CAP payments[11] are subject to conditionality rules, which links these payments to the respect of certain rules originating in the EU legislation. There are two types of requirements in this respect. The first one is the so-called Statutory Management Requirements (SMRs), which are a list of relevant provisions (legal obligations) of EU Directives and Regulations. This includes the Regulation on authorisation of pesticides and as from 2023 the SUD. The relevant provisions are about the compliance with the conditions of pesticide use specified on the label, the certification for the proper application of pesticides or for the equipment, the restrictions on pesticides use in protected areas and the handling and storage of the products and

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[6] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

[7] https://food.ec.europa.eu/system/files/2022-06/pesticides_sud_eval_2022_reg_2022-305_en.pdf

[8] By the time of drafting this text the SUR was still was still standing. The SUR proposal has been withdrawn by the Commission due to the position of co-legislators. However the objective of reducing pesticide use and risk remain.

[9] https://eur-lex.europa.eu/eli/dir/2009/128/2009-11-25

[10] See full EU definition in Article 3(6) of Directive No 2009/128/EC ("the SUD")

[11] They will apply to about 89% of the EU total agricultural area

their remnants. The other types of requirements are defined in the CAP itself in the form of a list of standards of Good Agricultural and Environmental Conditions (GAECs). The GAECs are essentially minimum standards for farming practices considering objectives related to the environment and the climate to be respected by farmers applying for support. A number of the standards are part of the IPM principles listed in the SUD. This is the case in particular of the need for farmers to undertake crop rotation or to maintain certain areas for biodiversity purpose, obligations which were strengthened in the last CAP reform. Under the system of conditionality, failing to respect the legal provisions under SMRs or the minimum standards defined under the GAECs may entail a reduction of the CAP payments received by the beneficiary, according to a percentage depending on the severity of the infringement.

Building on the foundation of conditionality (the SMRs and the GAECs forming the baseline of the green architecture) the CAP includes a number of support schemes helping farmers and other beneficiaries to adopt more environmentally-friendly practices such as IPM. A number of these schemes compensate or reward these farmers for practices more ambitious than the mere legal baseline forming the scope of conditionality (the baseline is also complemented by national requirements).

This is the case in the so-called "first pillar" of the CAP[12] with a new instrument of direct support, the eco-schemes. Eco-schemes must be made available to farmers by Member States and a determined share (25% as a general rule) of the significant budget of direct payments[13] must be devoted to these schemes. Member States have a wide leeway to define the conditions for benefiting from eco-schemes, a number of which being relevant to IPM such as ambitious crop rotations or higher share of the land managed for biodiversity. Farmers annually commit to eco-schemes on a voluntary basis and in return receive annual payments for applying beneficial practices.

The "second pillar" of the CAP (the Rural Development tier)[14] also includes schemes relevant for IPM. This is the case of agri-environmental and climate management commitments. These schemes operates similarly and with the same objectives as the eco-schemes but, since they are part of the Rural Development policy, they reward multiannual commitments. This allows to a certain extent more targeted objectives and ambitious practices. For instance, a number of Member States have chosen to finance the transition to organic farming with second Pillar management commitments while the maintenance of the organic farming practices are supported by first Pillar eco-schemes.

The CAP "second pillar" also includes schemes supporting the additional constraints for farmers entailed by the implementation of the Water Framework Directive or the Nature Directives (Habitat and Birds). These constraints may include certain restrictions for the use of pesticides if the Member States have decided so. The "second pillar" may also support investments aiming at reducing the use

[12] The "first pillar" of the CAP is the set of measures financed by the European Agricultural Guarantee Fund (EAGF) on an annual basis. It includes income support in the form of payments made directly to farmers (direct payments) and other annual direct payments.

[13] 190 billions euros for the period 2023-2027.

[14] The "second pillar" of the CAP is the set of measures financed by the European Agricultural Fund for Rural Development (EAFRD) on a multi-annual basis. It includes all rural development measures among which agri-environmental and climate commitments.

and risks of pesticides, such as precision spraying equipment or pests and diseases monitoring devices.

Under the markets component of the CAP (part of the "first pillar"), operational programmes for the fruits and vegetables sector must include environmental expenditure, in particular promoting the uptake of IPM in this sector, which is a key user of pesticides. As regards vineyards, the change of grapevine varieties to more disease-resistant ones may also for instance be supported by the market measure for restructuring and conversion.

The CAP also requires national authorities to make available to all farmers and other CAP beneficiaries Farm Advisory Services (FAS) on a number of issues, including the sustainable use of pesticides and IPM. The CAP further requires that the FAS is interlinked with research, final users and all actors of the knowledge chain[15]. The setting up or the use of these advisory services may further be financed by the knowledge transfer and information actions measures of the CAP "second pillar". The cooperation between farmers, researchers and advisory services, promoted through the European Innovation Partnership (EIP AGRI), is also important and may cover innovative ways to reduce the use of pesticides and a number of these initiatives promote IPM. Sharing the knowledge on IPM is at the same time a key component of its development and a challenge because of the numerous and varied approaches developed. A number of studies and initiatives aim at addressing this challenge[16]

The CAP has contributed to significant growth in organic farming, so that in 2020, 9.1% of Utilisable Agricultural Area was farmed under organic production systems, compared to 2% in 2000, with further financial support possible by the CAP Strategic Plans (eco-schemes and/or rural development) for both conversion to and maintenance of organic farming practices and methods. This financial support is based on the principle that the supported production methods go beyond the baseline legal requirements, including those of IPM. Organic production among others requires crop rotation and severe restriction on which pesticides maybe used.

Finally, and complementing the CAP, research is also very important for the development of IPM. Following on from Horizon 2020, the next research and innovation framework programme Horizon Europe continues to support IPM related activities.

The new CAP and in particular its 'green architecture' gives significant additional flexibilities for Member States in using and designing the policy instruments to address the needs identified by national authorities, including the need to contribute to the sustainable use of pesticides and to promote the use of IPM. Member States had to describe in their CAP Strategic Plans how the way they have adapted the green architecture to their context can contribute to addressing their needs and reaching the Farm to Fork targets and the objectives of the EU legislations. The CAP Plans are ultimately approved by the Commission. Besides, a set of common impact and result indicators are used for evaluating the performance, with a system of performance review allowing the Commission to take remedial actions if needed.

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[15] The concept is defined as the Agricultural Knowledge and Innovation System (AKIS)

[16] In this respect, a database hosted by the Commission (Joint Research Center) makes publicly available a number of these IPM approaches, including the IPM "crop-specific guidelines" developed by national authorities of Member States in implementation of the SUD: https://datam.jrc.ec.europa.eu/datam/mashup/IPM/index.html

3 Existing and future business models for crop protection (I)

3.1 Service-based business models to incentivize the efficient use of pesticide in crop protection

Thomas M Chappell[17]

The scale of activities involved in agricultural production varies dependent especially on logistical and operational constraints. The geographic size of property, the speed and mobility of machinery, and the economics of transport and storage all affect the spatial scale of agricultural operations. Challenging agricultural operations is the requirement to align the spatial scale of pest management with that of other activities, especially when biological processes governing pest dynamics and evolution do not unfold at the scale of human-administered actions. Pest management is most often conducted at the field scale: a field owner or lessee ultimately decides whether and how to engage in potential pest management activities, and the decision is made at the level of the field. Agricultural producers and researchers have explored management at smaller or larger scales than the field, through zoned management at the sub-field scale enabled by precision agricultural technology, or through area-wide management at the super-field scale enabled by cooperative agreements or delegated management. However, incentives encouraging efficiencies at scales greater than the field are not as obvious as those affecting field-scale management, and the potential consequences to producers with financial interest in their fields encourage risk aversion in localized decision making. Whereas the balance of local-scale risk against larger-scale environmental impacts may be seen as an optimization problem, there are arguably few if any entities with incentives to optimize a system so conceived. As a result, local productivity and crop protection are incentivized at the local level by agricultural producers, while distributed environmental impacts such as those resulting from pesticide use are engaged by researchers and regulators with the goal of impact reduction. Enforced regulatory limits can result in reduced impacts, and producers can innovate to meet potentially competing demands of productivity and regulatory constraint on use of pesticides; however, incentives for dynamically optimizing pesticide use efficiency do not primarily drive agricultural operations on either the production or the impact reduction side.

Insurance, and the transfer of risk from the individual to a pool, is an important tool for managing systems characterized by probabilistic hazards and commensurate losses that can be locally expensive. The agricultural producer faces costly threat of crop loss due to local pest occurrence, and may manage this risk through the prophylactic use of pesticides. Widespread use of pesticides results in widespread environmental and other impacts, in addition to the costs incurred through the logistics of pesticide production and use. Importantly, widespread use also results in selection for evolution of pest resistance to given pesticides. Absent other means to be protected from local crop loss, producers have incentive to protect crops through use of pesticides even if most use can be deemed unnecessary post facto. Insurance thus provides a potential mechanism to support balancing the competing spatial scales and the probability of pest-caused crop loss, by creating an entity with financial interest in managing risk at the relatively larger scale of the pool (many fields), while still supporting maximal productivity at the smaller scale of the field.

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We explore a business model framework that begins by hypothetically changing agricultural pest management slightly to be more like urban pest management, in that the provision of a hypothetical pest-managing entity is the absence of pest-caused loss, rather than the tools to be used by a purchaser for crop protection. This exploration is not novel in identifying insurance as a potential mechanism for reaching such an objective, but does provide justification for defining risk pools, management objectives, and timelines on the basis of pest ecology, evolution, and monitoring. A utility of the exploration is its illustration of incentives affecting parties traditionally involved in agricultural pest management. For example, if in one potential scenario an agrochemical company agrees with several spatially contiguous producers to provide protection from a given pest group (under a defined management plan), then the provider may be able to afford exposure to crop loss commensurate to the long-run probability of loss. If enough pesticide is being wasted at the spatial scale engaged by such a provider, then there is opportunity to increase profit at the distributed scale while decreasing pesticide inputs. Expected challenges to this otherwise simplistic application of an insurance framework to pest management are those of monitoring and rapid response to incipient pest threats, especially incipient resistance evolution. For a low-pesticide operation to contain incipient invasion (be it typical or an aberration) or incipient resistance evolution will require coordinated monitoring/surveillance, conducted by an entity with incentive to optimize its operation. Here, the business model framework is extended to combine elements of insurance with elements of public health, in which risk is pooled in order to maximize efficiency (and minimize waste), and manifestations of hazard are monitored at the pool level in order to contain transmissible occurrences of loss to the smallest scale possible.

3.2 Reducing fungicide use in agriculture with decision support systems

Elena Lázaro[18], David Makowski[19], Antonio Vicent[20]

Annual sales of pesticides in the European Union (EU) amounted to almost 360,000 tonnes, with a 46% share of fungicides as the most sold group (Eurostat, 2021). Even with the deployment of resistant cultivars and integrated control strategies, fungicides still contribute heavily to plant disease control in conventional farming (Oliver and Hewitt, 2014). Even organic systems, although promoted for their environmental benefits, also depend on fungicides. In these systems, the amounts applied are sometimes high to compensate for lower efficacy (Tam and Holb, 2015). Recently, new fungal plant diseases have emerged worldwide associated with the globalization of trade and environmental change (Fisher, 2012), thus further increasing farmers' dependency on fungicides. Nevertheless, their use in agriculture has been associated with growing environmental (Ballabio et al., 2018) and public health (Perlin et al., 2017) concerns.

To promote more sustainable agricultural systems, EU Directive 2009/128/EC established several key principles to reduce pesticide use, fostering the adoption of prevention measures, non-chemical control methods, and chemical compounds with lower environmental impacts. Importantly, according

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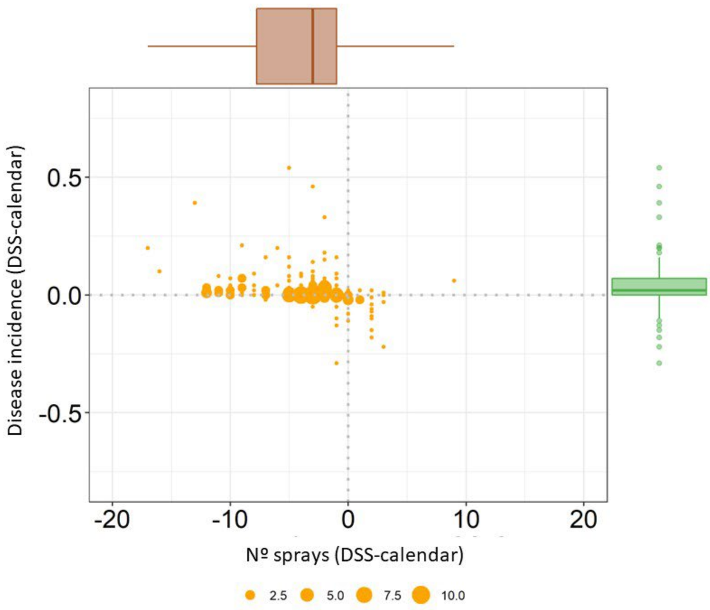
to this Directive, any control intervention should in principle be based on field monitoring and trigger thresholds in order to reduce doses and treatment frequencies, thus limiting the risk of the development of pathogen resistance. The willingness to reduce the use of pesticides and especially fungicides was again highlighted in the 'from farm to fork' strategy of the European Green Deal, which targets a reduction in the use of chemical pesticides by half by 2030 (European Commission, 2021). Nevertheless, despite this regulatory framework, the amount of fungicides sold annually in the EU increased by up to 11% in the period 2011–2018.

Fungicide use in agriculture can be slightly reduced with improved spray application methods (Garcerá et al. 2020), but to achieve a more substantial reduction a drastic decrease in the number of applications is essential. Decision support systems (DSSs) have been put forward as tools to substantially lower pesticide application frequency. In contrast to calendar-based fungicide programs, DSSs allow farmers to schedule fungicide applications based on an observed or a predicted risk of disease and thus spray only when necessary (Gent et al., 2013). Numerous field experimental studies have been carried out to assess the performances of DSSs for different crops, diseases, and regions. However, to date, the whole set of data obtained in these experiments has not been compiled and subjected to rigorous statistical analysis to quantify the benefits resulting from the use of DSSs.

Our meta-analysis of 80 independent experiments conducted worldwide indicated that, for a given fixed number of fungicide sprays, DSSs were as effective as calendar-based programs (or more so) in reducing disease incidence for a wide range of crop species, fungal pathogens, types of fungicide and regions (Lázaro et al., 2021). When the number of sprays was halved, the resulting increase in disease incidence was greatly mitigated with a strategy based on DSSs rather than on calendars (Fig. 1).

Our analysis thus shows that DSSs are essential tools for reducing fungicide use while limiting plant health risk and may help achieve the goals of the European Green Deal[7]. In addition to reducing the economic cost and environmental impact of disease control, the reduction in the number of sprays resulting from the use of DSSs also decreases the risk of developing resistance, thereby prolonging the effective life of the fungicides (Lázaro et al., 2021). Ensuring the credibility of DSSs is essential to overcome producers' aversion to perceived risks and thus make their application more widespread (Rossi et al, 2019) (Möhring et al., 2020).

Figure 2. Reduction in the number of fungicide sprays and difference in disease incidence between decision support systems (DSS) and calendar strategies (Source: Lázaro et al., 2021).



Source: own elaboration.

3.3 Outcome-based business models for CP reduction

Marius Wolf[21] and Marco De Toffol[22]

3.3.1 Bayer Crop Science strategy: Outcome-based models

Over the past few years, Bayer Crop Science has pioneered outcome-based business models to drive the shift from selling inputs to selling outcomes. This has led to the development of several new digitally-enabled business models that are currently in development or shortly before commercial launch. Focusing on outcomes represents a significant shift for Bayer, its partners and customers: Outcomes would be something that farmers, distributors or food chain partners value directly. Typical examples would be yield, maximum residue levels for crop protection products or mycotoxins, or disease damage levels on a crop. In these models, Bayer does not simply sell seeds or crop protection products but rather a guaranteed performance. If the result is not achieved (i.e. the outcome falls below the agreed result), Bayer compensates farmers, thus effectively sharing or even removing input risks for farmers. For this presentation, we are focusing on cereal crops (wheat and barley) and maximum acceptable disease damage as an outcome.

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3.3.2 Key challenges for cereal farmers

With a production of 150 million tons per year, wheat and barley are among the most important crops in the EU. However, crops are constantly under thread from various fungal diseases with septoria tritici, fusarium, stripe rust and leaf rust being some of the most common and critical ones. Untreated, those diseases can cause up to 50% of yield loss. With an average yield of 7.9 t/ha and a wheat price of ~290€/ton, any loss of yield due to fungal diseases has significant economic impacts for a grower. Fungicide treatments are a well-established way to mitigate these risks. With typical treatment costs ranging between 30-50€/ha (including fungicide products, labor and energy), the economic incentive will lead growers more towards applying fungicides rather than skipping or reducing a treatment.

Especially in situations where the disease risk is somewhat unclear, growers are likely going to err on the side of caution and rather apply than skip a treatment. However, due to societal and regulatory pressure on reducing the use of crop protection products, growers are looking for better solutions that will allow them to meet these expectations and comply with existing and future regulations, while also ensuring good yields and farm profitability.

3.3.3 Bayer's PreDiMa offer

In order to help growers balance agronomy, farm profitability and sustainability in a better way, Bayer is currently developing an offer under the working title "PreDiMa" (Predictive Disease Management). This offer includes three key elements:

1. Field specific recommendations: Growers will get a science-based recommendation for each field whether or not they should apply a fungicide. This includes disease risks for each disease, growth stage and weather information.
2. Fungicide delivery: Appropriate fungicides will be delivered as needed for each spray application.
3. Financial guarantee: The package will be offered at a fixed price per ha with no additional charges even for high-disease years. Performance of the program will also be guaranteed, with growers receiving a payment if disease levels are above defined thresholds.

The offer is designed to help growers achieve stable and predictable yields while improving sustainability and farm profitability. The solution will be delivered using custom-made digital tools (accessible via web and mobile phone), Bayer's FieldView ecosystem and selected technology and commercial partners. It is currently in a pre-commercial testing phase.

3.3.4 Benefits

Bayer has been testing the new offer through market research, customer tests, field trials and simulations with generally favourable results. Some key benefits have been emerging as a result of these initiatives which could help align interests between growers, regulators and value chain partners:

1. Fixed price per ha for an effective disease management (outcome) eliminates economic incentive for higher volumes of crop protection. In this model, there is an aligned interest to use minimal amounts of crop protection necessary to secure yield.
2. Performance guarantee ensures grower confidence in the solution's performance. It ensures risk coverage and economic incentive that disease is sufficiently controlled.

3. Digital ecosystem enabled by FieldView supports growers to fulfil legal obligations regarding electronic record keeping of crop protection application, while minimizing their administrative burden. Automated documentation of fungicide applications and justification of interventions can be ensured. Sharing this documentation is straightforward upon growers' request.

3.3.5 Enabling policy framework

Outcome-based models can contribute to strengthening the sustainability of agriculture in the EU (across the three pillars: economic, social, environmental) in line with the Green Deal and Farm to Fork objectives. An enabling policy framework can be crucial to untap their full potential and promote their adoption. While testing these solutions and getting feedbacks from partners, we have identified certain levers and open questions which policymakers may explore or take into consideration when designing relevant policy initiatives and legislation.

Public incentives: Will there be any form of incentive for farmers to change their practices and shift towards models like the one proposed? (e.g., via financial mechanisms rewarding farmers for their sustainability performance or via inclusion in products' sustainability schemes/labeling).

EU-wide independent certification: Some countries (e.g., France) have already established certification for (crop protection) recommendation services. However, there is currently no standardization for certification processes across EU countries and unclear regulations. A harmonized EU-wide certification scheme would reduce costs and complexity of certifying these models in different member states, while allowing to prove their sustainability credentials.

FVC specifications: Marketing standards required by certain food value chain actors often include extralegal requirements which restrict what plant protection products farmers can apply to their crops. This poses more and more challenges to farmers who are already facing an erosion of active ingredients available and need to manage pest resistance. What initiatives can be put in place to favor a shift towards the adoption of outcome-based programs instead?

Digitalization of EU agriculture: Digital solutions are the foundation for outcome-based and sustainability-focused business models. Public actors have a key role to play in ensuring that the technical foundations and basic infrastructure are developed and incentivized (e.g., broadband access in rural areas, farm machine connectivity).

4 Existing and future business models for crop protection (II)

4.1 Innovations in application technology for crop protection

Peter Hloben[23]

The presentation provided by Deere & Co which is one of the leading members of the European Agricultural Machinery Industry (CEMA) during JRC workshop dealt the machinery industry alignment with EU Farm-to-Fork Strategy objectives related to plant protection products (PPP) use reduction, current key-challenges in crop protection, overview of the state-of-the-art of application technologies, detailed explanation of the See&SprayTM system which allows site-specific application of herbicides, future needs for data sharing used for documentation of the application tasks and with the industry proposal for future incentive programs for the support and early adoption of modern spray technology.

4.1.1 Farm-to-Fork and Key-challenges in crop protection

The agricultural industry has already several times stated that is aligned with the Farm-to-Fork objectives related to reduction of PPP use and risk by 50% by 2030 and committed to supply modern technologies that will allow reaching this goal without sacrificing the demanded production of food commodities. Beside meeting the EU objective we have identified other challenges which the growers must deal with in the current agricultural practice and for which the spraying technologies must be developed, among these belongs: growing problems with resistances against herbicides and fungicides, reduced portfolio availability of approved PPPs, more and tighter application restrictions, biological effectiveness while meeting up to 95% (in some sensitive areas up 99%) drift reduction, narrower operating windows to spray at optimum timing and higher complexity and more expertise required for spraying.

4.1.2 State-of-the-art of application technologies

In the future, the crop protection will be much more automated, precise, need based and selective to address major agronomical, economic, and ecological challenges. The recent developments within the sensor technology, Artificial Intelligence (AI) and deep learning offer completely new possibilities for recording field variability and identifying everything from diseases, insects, weeds, to individual plants. It is just desired and obvious to combine the sensors with the application technology. Such systems already nowadays presented in the agricultural practice, e.g. the high productive spot sprayer See&SprayTM which can analyze area of to 196 m2 within 200 ms by cameras mounted on the spray boom and treat it at speed of 19 km/h. Beside these high-end technologies there are other key technologies which can significantly contribute to the higher precision of application of the PPP application hence to their overall reduction, and which can acquired by the smaller farms. These technologies are e.g.: GNSS based boom section or individual nozzle control, task controller (ISOBUS), GNSS receiver, targeted row or band spraying, automatic boom height and tilt adjustment, PWM controlled nozzles, etc.

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4.1.3 Data & connectivity

To ensure connectivity and seamless data exchange between the machines and grower's farm management system is essential for more targeted and selective manner application as well as for the general acceptance of these novel technologies. The new communication standards incl. incorporation of legal requirements for data privacy and ownership is currently being developed by the Agricultural Industry Electronic Foundation which has in the past successfully introduced the ISOBUS standard. The main content of the information transferred will be related to pest infestation, target and as- applied maps for each individual field, decision advice from specialized applications and decision support systems e.g. weather data, plant production product data. This information flow will require an access to a 5G telecommunication networks especially in the rural areas. The cost for the communication equipment and the connectivity fees will be certainly not negligible part of the operational costs of the production system and could be in scope of the incentives programs.

4.1.4 Scope of future incentives programs

In general, the agriculture industry supports the free market based on fair business conditions and healthy competition between producers. Only the offered product features and quality and grower needs shall be the driver for acquisition decisions. Nevertheless, we also recognize the current situation of most of the growers e.g. low redemption prices of commodities, increase cost of all input materials which blocks the quicker update of the machinery fleets and acquisition of new equipment and services which will contribute to reduction of PPP usage. The targeted incentives programs may help here. The financial amount shall be linked to the number of hectares managed / treated in a site-specific way rather than to support the growers by covering of the acquisition costs for the new equipment or field kits upgrades directly. Such incentives could cover the contractor's service costs, the software upgrades (note please that e.g. the weeds/diseases recognition AI models and decision tools will have to be regularly updated), fees for mobile internet network coverage with 5G bandwidth, license fees for GNSS, FMIS and other service apps e.g. Weather forecast, scouting, field registers.

The new incentives programs could be based also on a conditional principle where the receiver of the financial support will have to commit to share data e.g. as-applied maps with the authoritative bodies which will check that the plan protection products were applied in a way which is compliant with the valid regulations.

Regarding the financial support of the insurance programs, there can be offered special insurance conditions, or interest rates for those growers who are using targeted application technology to cover the potential risks arising from e.g. modelling of pest prediction, weather, and seasonal pest effects. Such programs will certainly gain an interest by the growers, will reduce the level of uncertainty, and will help to un-lock the rapid uptake of the novel technologies that contributes to the reduction of PPP use.

5 Modelling policies towards pesticide-free agricultural production systems

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Published in:

Mack, G., Finger, R., Ammann, J., El Benni. N., (2023). Modelling policies towards pesticide-free agricultural production systems. Agricultural systems. Volume 207 (2023), 103642. https://doi.org/10.1016/j.agsy.2023.103642

The use of pesticides implies negative effects on human health and the environment and is therefore under big political debate. In 2021, the people of Switzerland voted on two popular initiatives that intended to ban all chemical synthetic pesticides resp. to restrict all direct payments to pesticide-free production (Schmidt et al., 2019; Finger, 2021). Although both initiatives were rejected, the reduction in pesticide risks without harming food security and farmers' income is a key policy goal in Switzerland. Switzerland aims to reduce pesticide risks by 50% until 2027 compared to the average of the years 2012–2015 (BLW, 2021). After the initiation of private schemes to support pesticide free production (e.g. Möhring and Finger 2022), a national scale agri-environmental scheme for pesticide-free, non-organic production systems on arable land in Switzerland was launched 2023.

The aim of this study was to ex-ante investigate the adoption potential and impacts of this policy. Our study is the first national-scale study on the implications of adopting a pesticide-free, non-organic crop production system by using Swiss crop production as an illustrative example. We also provide methodological innovation, e.g. regarding the assessment of so far non-existing pesticide-free production systems coherently in bio-economic models.

Therefore, an ex-ante impact assessment at the national scale was conducted. The assessment combined qualitative and quantitative methods and linked databases from different sources. First, a Delphi study was conducted to assess expected crop-specific yield losses when farmers switch from currently intensive (all types of pesticides are applied) resp. extenso (insecticide and fungicide free cropping systems) to pesticide-free (but non-organic) systems. Second, based on national data repositories, a database on changes in crop-specific machinery costs and labour requirements resulting from the adoption of pesticide-free cropping systems was built for typical Swiss arable cropping systems. Third, farmers' decisions to adopt voluntary pesticide-free direct payment programmes were determined using 1,907 bio-economic single-farm optimisation models. These models reflect the heterogeneous farm sample of the Swiss FADN farms. Data records on expected yield losses and changes in machinery costs, as well as labour requirements, were implemented in the 1,907 farm optimisation models. All optimisation models were part of the agent-based

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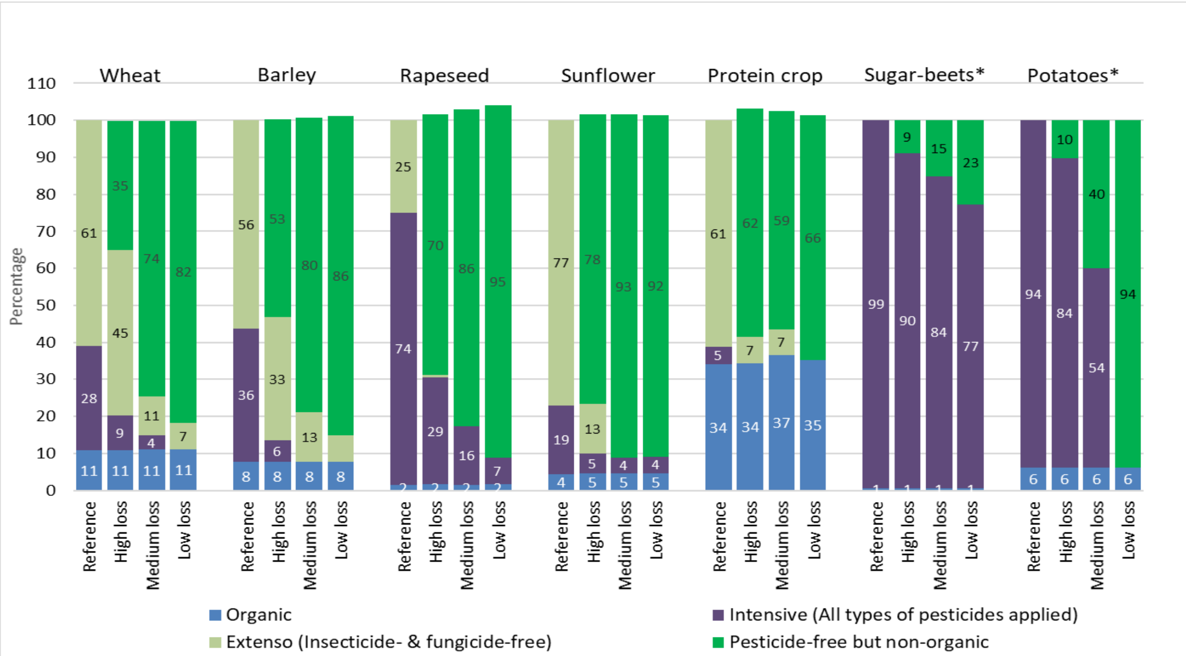
agricultural sector model SWISSland (Möhring et al., 2016), which allowed us to upscale model results to the national scale.

The modelling results show that the extent of crop-specific yield losses has an especially significant effect on the adoption rate of pesticide-free cropping systems (Fig 1). The impacts of introducing voluntary direct payments for pesticide-free production at the national scale imply reduced food (volume) and calorie production but only minimal reductions in the production value, especially due to expected higher prices for pesticide-free products. The effects on farmers' income are small, as participation in pesticide-free production is compensated with direct payments and higher prices and often implies cost reduction in labour and machinery due to non-use of pesticides. To establish large-scale production systems between conventional and organic cropping systems and, thereby, reduce trade-offs resulting from both extremes, policy schemes need to be flexible, allowing the adoption of a pesticide-free paradigm for some parts of the crop rotation but not necessarily entire crop rotations.

Figure 3. Adoption of pesticide-free direct payment programmes for single crops. Percentage of pesticide-free (but non-organic) area in Switzerland under the different scenarios (year 2027)



Note: * For sugar beets and potatoes, the direct payment programme for pesticide-free crop systems allows specific herbicide and fungicide treatments.

High-loss scenario: 10% highest
Medium-loss scenario: Average
Low-loss scenario: 10% lowest

} yield losses due to pesticide-free were assumed based on the Delphi study.

Source: own elaboration.

5.1 European pesticide-free agriculture in 2050

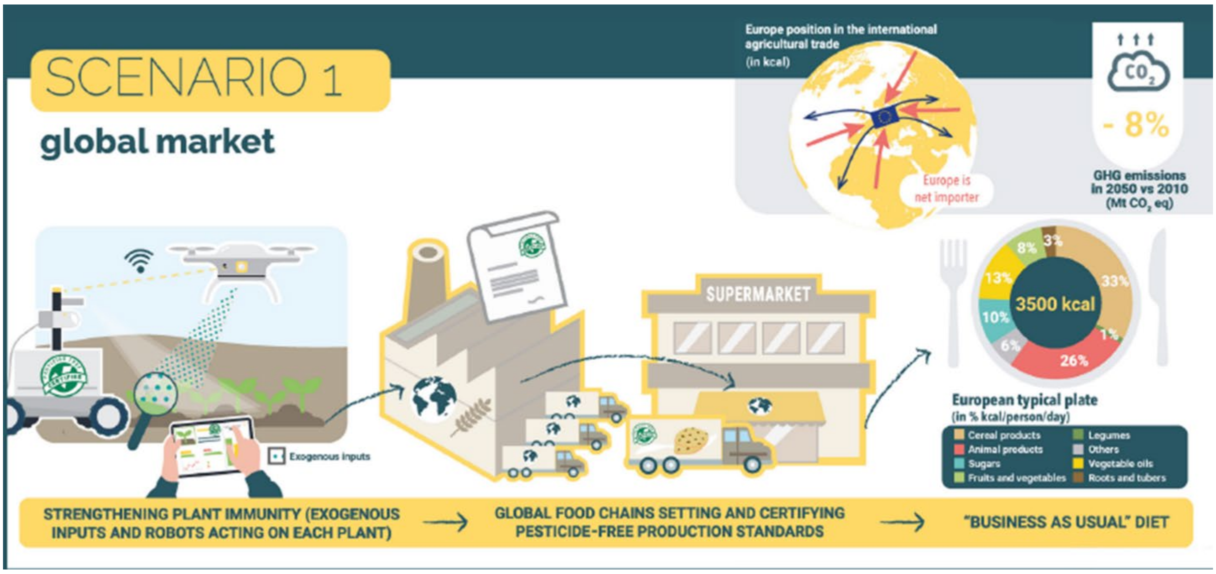
Chantal Le Mouël[27]

Given their negative impacts on the environment, biodiversity and human health, the use of pesticides is a major issue for the sustainability of agriculture and food systems. Launched by INRAE at the request of the priority research program "Growing and protecting crops differently" (PPR-CPA), the aim of the "European chemical pesticide-free agriculture in 2050" foresight study is to open up a research, policy and public debate on the possibility of building a chemical pesticide-free agriculture in the future, considering that it could be a major lever for improving the sustainability of European food systems.

The "European chemical pesticide-free agriculture in 2050" foresight study (Mora et al. 2023) combines a scenario planning approach to imagine scenarios of European chemical pesticide-free food and agriculture, a backcasting approach at European level and in four European regions, and a simulation approach based on a biomass balance model to assess the impacts of these scenarios on production, trade, land use and GHG emissions.

The foresight study proposes three scenarios, which include three future of crop protection without chemical pesticides, based on plant immunity, plant holobiont and microbiomes, and the role of landscape in regulating pests (Fig. 1). The first scenario explores the development of robotics and bio-inputs and the related changes in global food chains. The second scenario explores the mobilization of holobionts and microbiomes at all stages of European food chains. The third scenario explores landscape management and the relocation of food chains. Model simulations of the scenarios suggest that it is possible to develop such agriculture in Europe while maintaining, or even improving, the European trade balance in calories, and reducing GHG emissions from European agriculture.

Figure 4. The three scenarios of European pesticide-free agriculture in 2050



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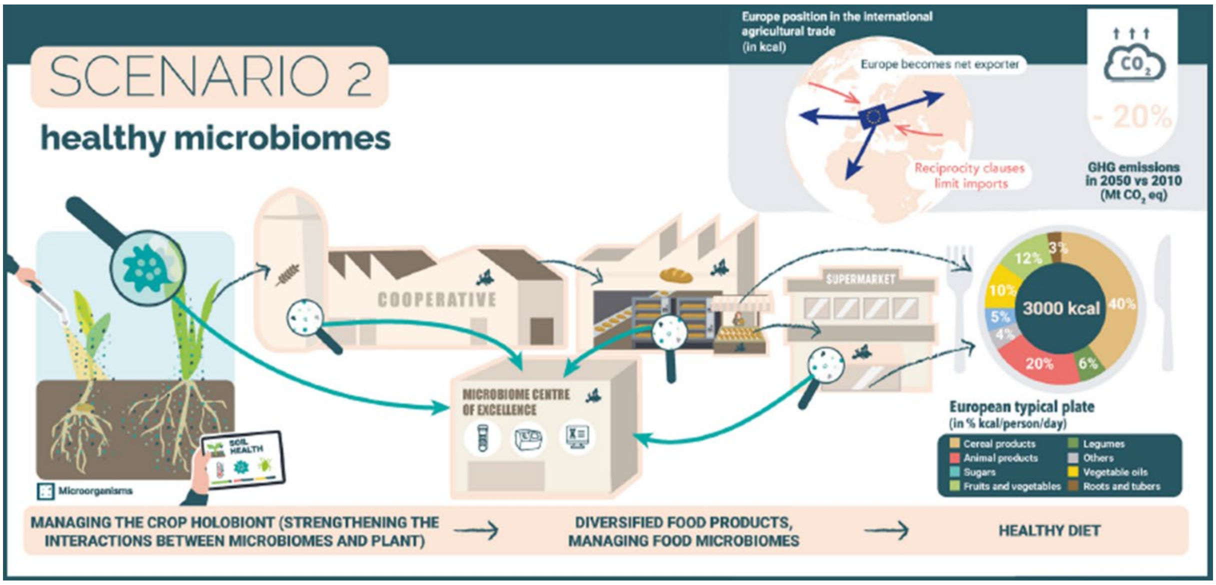

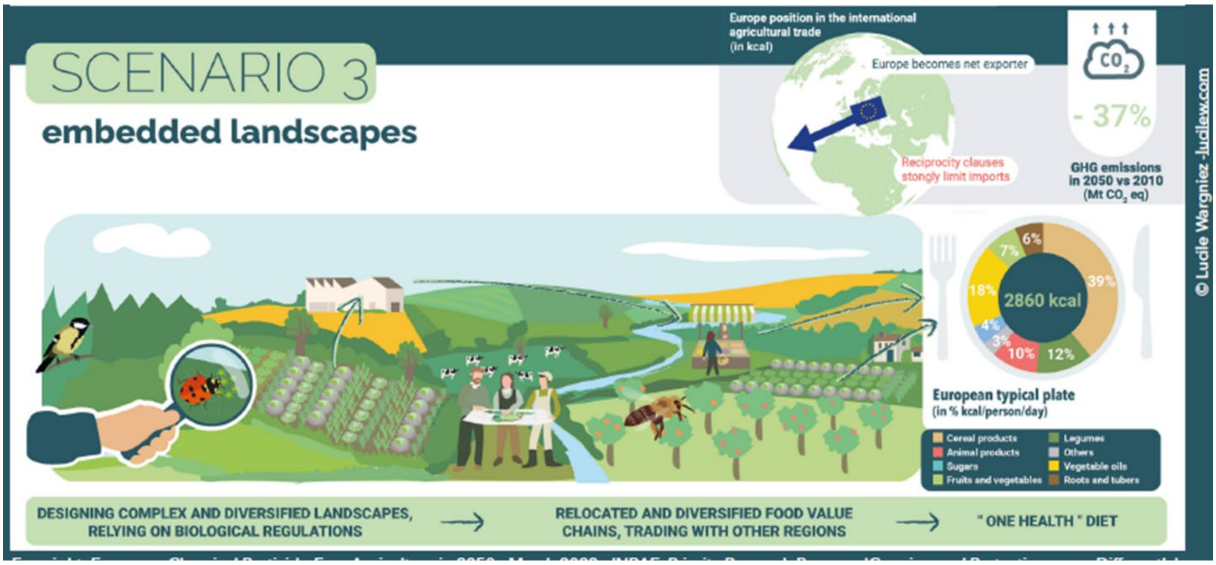

Source: Lucile Wargniez.

Our scenarios and simulation results show that a European transition towards chemical pesticide-free agriculture is possible and achievable. It will require strong involvement from all the actors of the food chain, beyond cropping systems, changes all along the food supply chains and food markets, and a coherent set of European public policies on agriculture, food, health, environment and trade to support the transition. Such scenarios are not just a sectoral issue but also a societal choice and a global environmental choice.

More information and access to all deliverables: https://www.inrae.fr/en/news/european-pesticide-free-agriculture-2050

6 Linking pesticide reduction and insurance products: theory, institutions and experiences

6.1 Implications of PPP reduction on insurance: some basic concepts

Francisco Sebastián[28]

6.1.1 Introduction: Understanding the mechanisms of insurance

Insurance, at its core, operates as a mechanism to mitigate risk and provide financial protection against unforeseen events. Insurers assess risks and pool resources by collecting premiums from policyholders. In return, they offer coverage against potential future losses, thus spreading the financial impact across a collective pool of insured individuals or entities.

Insurance pricing is not arbitrary; it is a meticulously calculated process. Actuaries and underwriters analyse factors such as historical data, risk probabilities, and statistical models to determine appropriate premiums that accurately reflect the risk exposure.

6.1.2 Non-life insurance pricing dynamics

Here we aim to delve deeper into the mechanisms behind non-life insurance pricing. We will explore the rationale behind these methods and investigate the impact of various changes, be it in the frequency or severity of events, while also highlighting the significant influence of ruin risk on pricing strategies.

By understanding the underlying principles and dynamics of insurance, we pave the way to comprehend the nuances of non-life insurance pricing and its intricate relationship with risk, frequency, severity, and financial stability.

1. Rationale and Methods in Non-Life Insurance Pricing

We will commence by exploring the rationale behind the methods employed in non-life insurance pricing. This section will highlight the fundamental principles and methodologies used in determining the premiums and structures in this sector.

2. Impact of Changes in Frequency: Independent vs. Non-Independent Events

A critical factor in non-life insurance pricing understands the impact of changes in frequency. We will take a closer look at how independent and non-independent events influence this, shedding light on the dynamics when such events occur and their implications for pricing structures.

3. Impact of Changes in Severity: Focus on Catastrophic Events

Another significant facet of our discussion will revolve around changes in severity, specifically focusing on catastrophic events. We will analyse how these events can dramatically affect the insurance landscape, exploring the implications for pricing structures and risk management.

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4. Ruin Risk and its Influence on Pricing

Ruin risk is a substantial concern in the insurance realm. This section will elucidate how the possibility of financial ruin influences pricing strategies and risk assessment within the non-life insurance sector.

6.2 Helping wine and spirits producers deliver on regenerative agriculture goals and pesticide reduction with adaptation consulting and transition insurance

Sylvain Coutu[29]

6.2.1 Introduction

Axa Climate is committed to helping to de risk the transition to regenerative agriculture, helping to reduce the 23% of GHG emissions from agriculture and protecting biodiversity. As part of these efforts, we have developed transition insurance products, working with spirits producers, cooperatives, input providers and individual farmers to provide coverage for practice change. This helps to de risk cost intensive efforts including reducing pesticide use or introducing bio control, which can initially reduce yield and impact revenues for the grower.

6.2.2 The challenge

New business models are needed to deliver more sustainable use of pesticides regulation as outlined in proposals that aims to slash pesticide use in half by 2030 in the EU due to increasing concern from consumers and the need for GHG emissions reduction. Wine and spirit producers are committed to introducing more sustainable agricultural practices, working to certify winegrowers for higher environmental standards. Incentives are needed to engage cooperative winegrowers to invest in more environmental practices to make the cognac sector more sustainable and deliver on halving carbon emissions per bottle by 2030 and reaching Net Zero carbon emissions by 2050. Convincing farmers to introduce bio control given the risk of disease outbreak and potential revenue loss is challenging. Increased exposure to drought and floods makes changing practices even more difficult but necessary to improve carbon sequestration and reduce pesticide usage. Due to the more volatile weather conditions, growers tend to be conservative and overprotect their vineyard by applying pesticide more frequently and in larger amount than necessary. Existing insurance schemes do not incentivize wine growers to reduce input use.

6.2.3 The solution

Climate Risk Exposure Assessment

The client's sustainability, risk and agronomy teams work closing with Axa Climate's agriculture consulting, insurance, science, and data science teams to quantify risks. This involved better understanding exposure to climate risk in their supply chain and how to help their suppliers to adapt. This process examines how changing temperatures will require them to adapt their crops in the

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coming years using climate models to assess the impact on yield up to 2030. Increases in drought, fire, flood, frost, wind, and pests make it increasingly important for grape growers to understand these risks and how to proactively manage them.

Transition insurance

Their risk team invested in transition insurance covering potential yield loss for winegrowers provided by Axa Climate. The insurance premium covering reduction in yield due to disease following introduction of bio control is a policy renewed on a yearly basis.

Co Creation

Co Creation of the solution with the client is an important part of developing the right business model. This involved a series of workshops to better understand the risk related with a change of the frequency and type of treatment. The impact of changing practice on the occurrence of downy mildew, powdery mildew and black rot was assessed working closely with their agronomy team.

Premium Calculation

The premium is based on size and value of land covered, with the value of wine growing regions in France is quite high. The yield loss for specialty crops and vineyards might reached very high levels (up to 60%) in years with challenging weather conditions. It is important to use historical data to quantify the impact that the reduction of fungicide usage could have on disease development and related yield losses. Historical yield data is analysed looking at the client own experimental data and combining it with publicly available data. A premium to be paid per hectare can then be calculated.

Payment and Claims Process

The premium is paid by the spirit producer to cover their growers. A ceiling is placed on the amount of the payout and a deductible defined. Claims are paid to the spirit producer directly to distribute to individual growers. On-site inspection is used to measure field disease occurrence to efficiently trigger claims. Payout of claims is expected to increase adoption by more winegrowers. This process could potentially be further optimized and digitized with the use of satellite imagery, sensors or MRV solutions with further research.

Decision Support Tool

The introduction of a decision support tool to verify the grower use a well-planned biocontrol strategy is a critical success factor. This process around the decision support tool is defined by the company's agronomy team in collaboration with the national institute for viticulture. Wine growers receive recommendation on the usage of biocontrol depending on the local weather condition and the forecast. They are able to report the different treatments applied (biocontrol) and can check if this complies with the guidelines provided. This decision support tool and the insurance solution helps to reduce the amount of conventional chemical treatment of up to 90%.

Key Benefits

The expectation is that more farmers engage in the transition from using conventional to biocontrol treatment. Greater acceptance of transition to bio control following claims payment is also expected. Optimization of best practice sharing on sustainable practices and quality control between growers is another benefit. Potential decrease in the cost of inputs is another potential benefit. More grape growers are expected to be certified in the national standardization scheme for pesticide reduction in part due to the insurance incentive. Combined with additional fertilizer and soil management practices, emissions reduction that can be reported on to meet scope three emissions and Science Based Targets is also possible though this needs to be carefully quantified.

Who Can Benefit

Transition insurance can be beneficial to row crops and specialty crops for individual farmers or cooperatives of a certain scale. Around 5000 hectares (for row crops) or more is ideal given the underwriting work involved. Commodity buyers can pay the premium for their suppliers as an incentive to help them to deliver on GHG emission reduction or regenerative agriculture goals.

6.2.4 Transition insurance case studies overview

Table 1. Transition Insurance Case Studies Overview

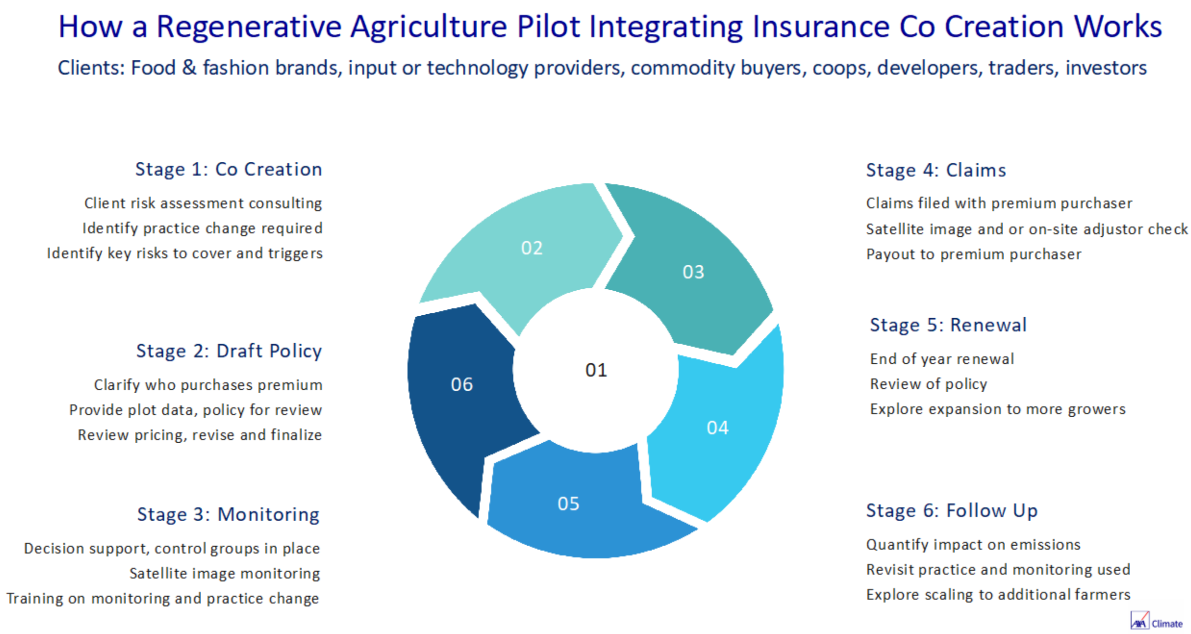
Clients	**Transition Insurance Projects**
Wine producer increasing growers introducing bio control with disease outbreak coverage.	Challenge: Risk of disease outbreak when switching to bio control inputs Solution: Covering disease outbreak for grape producers supplying the wine industry Benefit: Greater acceptance of transition to bio control following claims payment Methodology: In field disease occurrence measurement, Introduction of decision support tool to verify biocontrol use
Cooperative scaling transition program introducing more eco-friendly agriculture practices.	Challenge: Convincing growers to change practices and participate in transition program Solution: Yield reduction coverage following implementation of cover cropping, nitrogen reduction, residue management Benefit: Maintaining grower participation and trust in cooperative Methodology: Yield comparison between transition and reference groups
Input provider helping farmers receive "No Pesticide Residue Label" with revenue loss insurance.	Challenge: Encouraging farmers to change pesticide practices Solution: Commercial guarantee to cover potential revenue loss for farmers using new pesticide protocol for soft wheat Benefit: Incentivize farmers to adapt pesticide use and increase revenue Methodology: Definition of clear agronomic guidelines and verification of the absence of pesticide residue

Source: own source

6.2.5 Recommendations

1. Clearer pan European standards are needed to define requirements for labels such as no pesticide use. Similar harmonization of organic, regenerative, or emissions reduction labels or standards are also needed to make it easier for growers and consumers to understand.
2. Education and Training support for the food industry, farmers, and consumers to help them to understand how to reduce pesticide use and to introduce more regenerative practices would help to scale these initiatives.
3. Insurance subsidies condition to sustainable agriculture practice and/or subsidies to agriculture insurance products supporting the agriculture transition. EU farm subsidies scheme could help to encourage more farmers to adopt these practices by helping to de risk the process.
4. Funding to help to support pesticide reduction pilots to reduce the use of inputs could help to de risk the process for farmers who are reluctant to change practices. This could include a guarantee to make sure there is a buyer for these commodities on the market or grants.
5. Support for scientific research is also needed to help to further digitize the monitoring of pesticide use and modelling to show how this affects biodiversity and soil health.

Figure 5. How Regenerative Agriculture Pilot Integrating Insurance Co Creation Works



Source: own source

7 What have agricultural economists found out about linking insurance and PPP reduction?

7.1 Crop insurance and pesticide use in European Agriculture.

Niklas Möhring[30]

Reducing the harmful effects of agricultural pesticide use on the environment and human health, as well as reducing income risks for farmers, are both top priorities for agricultural policy.

The From-Farm-to-Fork strategy of the European Union, for example, envisions ambitious pesticide use and risk reduction targets. At the same time, we have seen a rise in publicly funded agricultural insurances (Dalhaus et al., 2023) after changes in the regulation of premium subsidies in the Common Agricultural Policy (Regulation (EU) 2021/2115).

In my talk, I will explore the link between (subsidized) crop insurance and pesticide use. Given the recent policy developments, this is key in order to align agricultural policy objectives, and additionally provide insights in the role of risks for farmer's uptake of (service-based) plant protection solutions.

In an article in Agricultural Systems (Möhring et al., 20202), we analysed the relationship between crop insurance and pesticide use in European agriculture, using France and Switzerland as examples. We found that crop insurance is associated with an increase in pesticide expenditure of between 6% and 11%. The magnitude of the effect and the underlying mechanisms were specific to each country.

At the time, in both France and Switzerland, hail and multi-risk insurance made up the bulk of crop insurance used. However, these countries differed in terms of insurance system, agricultural systems and agricultural policy. In Switzerland, insurance mostly comprises of hail and multi-peril insurances. In addition, insurance covering extreme weather conditions such as drought and heavy rain is becoming increasingly popular. Crop insurance is not currently subsidized in Switzerland. French insurance, on the other hand, receives substantial support from the EU's Common Agricultural Policy, up to 65% of the premium in 2020. Contracts cover a range of weather-related risks, and most crops are insured, including grassland. In 2018, more than 70,000 French farms took out crop insurance policies, representing over 4 million hectares and 30.5% of usable agricultural land.

Agriculture in both countries is diverse in terms of production systems, farm types and sizes. On average, however, Swiss agriculture is characterized by a greater number of smallholders, more mountainous regions and greater importance of grassland than in France. Although agricultural policies differ in Switzerland and France, farmers in both countries are subject to public policies aimed at reducing the risks associated with pesticide use.

In the analysis, we consider the two main channels of interaction in the way crop insurance and pesticides are applied. Firstly, insurance may induce farmers to modify pesticide use per hectare for a given crop/production system ("intensive margin effect"). Secondly, insurance can induce farmers to modify their land-use decisions, which are closely linked to pesticide use ("extensive margin effect"). It is important to take both these effects into account in the analysis, as pesticide use levels vary

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greatly from one crop to another (average pesticide use on fruit, for example, can be ten times higher than on some field crops). Induced changes in land use decisions can therefore have a significant effect on pesticide use levels.

At the extensive margin, insurance may lead to a switch to crops that are economically riskier, or a switch from grassland to cropland - these riskier crops are generally also associated with higher (chemical) input use. At the intensive margin, decisions on crop insurance and pesticide use are primarily linked to their relationship with economic risk. If pesticides reduce these risks, pesticide use and crop insurance can substitute each other, meaning that taking out insurance would reduce pesticide use. On the other hand, if pesticides increase these risks, pesticide use and crop insurance may be complementary, meaning that taking out insurance would increase pesticide use. The literature on this subject is ambiguous, making the direction of the intensive margin effect an empirical question (see, for example, Möhring et al. 2020b).

In our empirical analysis, we study farmers' decisions regarding insurance purchase, land use and pesticide use - and their interdependencies. We use panel data series at farm level in France and Switzerland. We take into account potential intensive and extensive margin effects (focusing on land use in grassland and crops), as well as a large set of control variables, including farm and farmer characteristics, weather conditions and exposure to climatic risks, such as hail.

Our results show that without insurance, pesticide expenditure would be 6% lower in France and 11% lower in Switzerland. The mechanisms differ: while the extensive margin effect (changes in land use) dominates in Switzerland, the intensive margin effect (pesticide use per hectare) dominates in France. We attribute the differences in mechanisms to the higher share of temporary grassland in Switzerland and the higher insurance subsidy in France.

Our results show that providing crop insurance can lead to increased pesticide use. However, this does not mean that crop insurance is an inappropriate risk management tool for agriculture. On the contrary, it is an essential tool for farmers' risk management and is gaining in importance. However, we point out that there may be unintended side-effects that need to be taken into account. From a governmental point of view, our results reveal the risks associated with subsidizing crop insurance, as it can thwart other environmental objectives. Thus, if insurance is subsidized, even greater financial resources may be needed to achieve environmental objectives. Our findings thus underline the need for careful evaluation of crop insurance support policies. We therefore need to develop sustainable insurance solutions that are good for both farmers and the environment. Finally, our results clearly highlight the need for a holistic vision of agricultural policy, in order to propose tools and instruments adapted to the different objectives and actors of agricultural policy.

7.2 Green insurance for pesticide reduction: acceptability and for French viticulture.

Marianne Lefebvre[31], Yann Raineau[32], C ´ecile Aubert[33], Niklas Möhring[34], Pauline Pedehouraand Marc Raynal[35]

The authors thank Max-R ´egis Ogounchi and Adrianne Moreau for their help in programming the survey, the REECAP network for providing initial feed-back during the "check before you collect" webinar, as well as participants to the FRIES webinar organized by ETH. They acknowledge funding by R ´egion Pays de Loire (project BEHAVE) and the support of the Grand Plan d'Investissements d'Avenir through the program Territoires d'Innovation (PIA VitiREV) as well as support of the French National Research Agency (ANR) under the grant 20-PCPA-0010 (VITAE). Access to some confidential data, on which is based this work, has been made possible within a secure environment offered by CASD – Centre d'acc`es s ´ecuris ´e aux donn ´ees (Ref. 10.34724/CASD).

Green insurance is an innovative tool to help producers manage (perceived) risks of transitioning to more environmentally-friendly crop management strategies. It is not yet part of the agricultural policy toolbox nor is it marketed privately on a large scale. We here investigated the best design, uptake determinants and potential pesticide reduction from green insurance for a decision support system (DSS) for pesticide reduction in grapevine production. This is an important example, as pesticide use reduction is high on the agricultural policy agenda and grapevine production is a major contributor to global pesticide use. For our analysis, we conducted a Discrete Choice Experiment with 412 French vine growers. We find that 45% to 58% of growers are likely to subscribe to green insurance, with differences across contract types and prices. Producers transitioning to organic production are the most interested in the contract. All types of producers exhibit on average lower interest for group contracts and index-based insurance than for the traditional individual loss-based contract. Using data from field experiments on DSS performance in reducing fungicide use, we estimate that adopters could reduce their fungicide use by 35% on average and a quarter of the producers by more than 55%. Our results suggest that green insurance could be a cost-effective tool to advance ambitious pesticide policy goals, and more broadly, support the transformation to more environmentally-friendly farming practices.

Decision support systems (DSS) for farmers to optimally time applications according to actual local disease pressure have the potential to reduce pesticide use while maintaining yield levels (Pertot et al. 2017; Chen et al. 2020; Anastasiou et al. 2023). However, their uptake is often low. One important

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reason is that expected risks of yield losses are perceived as higher when adapting management strategies (Shtienberg 2013; M¨ohring, Wuepper, et al. 2020).

Green insurance, which insures potential yield losses when switching practices, is not currently included in policy toolboxes, despite its potential to increase farmers' uptake of DSS-based crop protection strategies. With green insurance, the insured producer receives financial compensation in case of yield losses caused by the failure of best management practices (here the inability of the DSS to contain diseases). If producers have biased perceptions regarding the effects of new practices on the level and variability of yields or profits (Feather and Amacher 1994), green insurance could help them revise these perceptions by allowing them to try these practices risk-free (Mitchell and Hennessy 2003; Aubert et al. 2020). In other risk areas, it has been shown that sub-optimal insurance levels are observed when agents face an explicit or implicit cost to discovering the true probability of losses, but public subsidy can trigger optimal insurance decisions (Kunreuther and Pauly 2004). It suggests that subsidy to green insurance could be needed. Compared to agri-environmental schemes (AES), subsidizing green insurance can be more cost-effective since public support is triggered only for actual losses (Baerenklau 2005), and the level of support required to induce participation by risk-averse producers does not need to include a risk premium.

A few green insurance contracts have been experimented with in the US and in Europe. But these experiments have only been conducted on a small scale, with no proper measure of cost-efficiency nor evaluation of the levers to increase acceptability. A fundamental challenge is to design insurance products that will be adopted by a large range of farmers, will actually lead to best management practices' adoption and are more cost-efficient than other instruments (Hazell and Varangis 2020). Ex-ante evaluation is thus important for industry and policy to develop products and supporting programs that are attractive to producers. Such (subsidized) risk management tools for pesticide use reduction may have a high global relevance - in the EU as well as beyond (Möhring, Kanter, et al. 2023).

Here we assess the effect of different insurance designs on acceptability, as well as the potential impact of a subsidized green insurance, targeting fungicide use in French viticulture[36]. We conducted a large discrete choice experiment with 412 French grapevine growers on the uptake and design of the insurance and combine it with field experimental data on the pesticide use reduction potential. We evaluate acceptability of both loss-based and index-based insurance, since the latter is perceived as having a large potential, also in developed countries, to contribute to better farm-level risk management and more efficient use of natural resource (Dalhaus, Musshoff, and Finger 2018).

We find that between 45% and 58% of the vine growers are likely to subscribe to the green insurance, depending on contract design and prices. Producers transitioning to organic certification are more interested in the contract. This result suggests that green insurance could – in addition to intensive margin effects on pesticide intensity – also have extensive-margin effects: it could help reduce pesticide use by supporting transitions to organic farming. Clear preferences emerge for contract design: all producers exhibit less interest for group and index-based contracts. Using data from field experiments on the DSS impact on fungicide use, we estimate that adopters could reduce their

[36] Grapevine production is globally among the most pesticide-intensive and economically relevant crops, and therefore represents a key entry point to reduce pesticide use in agriculture. In France, the iconic wine production covers only 3.3% of the agricultural area, but is responsible for 14.4% of total agricultural pesticide use (Butault et al. 2010). Fungicides represent more than 80% of pesticides used on vines in France (French agricultural ministry 2022).

fungicide treatments by 35% on average. A quarter of them can reduce their fungicide treatments by more than 55%. The chosen set-up would entail higher potential subsidy costs, compared to existing policy tools in France, but also a higher pesticide reduction potential.

7.3 Choosing between Insurance and Protecting Devices: The Case of Apple Farmers in South Tyrol.

Marco Rogna[37] European Commission's Joint Research Centre

The dependence of agricultural output from weather conditions is one of the main sources of revenues volatility in agriculture (Moss and Shonkwiler, 1993; Ray et al., 2015), differentiating it from other economic sectors. The strategic importance of agriculture, accompanied by a structural weakness of this sector – the income of agricultural entrepreneurs is sensitively lower than the income of entrepreneurs in other productive sectors (European Commission, 2015) – have encouraged efforts in order to stabilize or, at least, sensibly smooth, agricultural incomes.

Insurance has been one of the first proposed method to reach this goal. Although theoretically effective, given that systemic weather effects induce a high-correlation among individual farms' risk exposure, private insurance markets are generally unsustainable (Miranda and Glauber, 1997). This has lead to a strong state interventionism in such markets, usually characterized by a variable subsidization of insurance premia. The contrast between the need of supporting such instrument and the risk of distorting the market has attracted the attention of academic researchers. Interest that has been further fostered by the puzzling scarce adoption rate of agricultural insurance despite the high level of subsidization, this last reaching even 70% of premia in either the United States and the European Union (Coble et al., 1996). In particular, the elasticity to premium and the determinants of farmers' demand for insurance have been the main object of empirical investigations. First in the US, i.e. Goodwin and Kastens (1993); Just and Calvin (1994); Coble et al. (1996); Smith and Baquet (1996), and, subsequently, in the EU: Finger and Lehmann (2012); Falco et al. (2014) and Santeramo et al. (2016).

If the determinants of agricultural insurance adoption have been largely investigated both theoretically and empirically, the effect of alternative hedging strategies has been generally overlooked. At best, they have been included in the mentioned empirical investigation on insurance adoption. Crop diversification, for example, generally regarded as an alternative risk management practice, has been found to significantly decrease the demand for insurance: e.g. Nieuwoudt et al. (1985); Barnett et al. (1990) and Finger and Lehmann (2012). The effect of disaster relieve programs, also supposed to have a competing effect with insurance, has been tested by Smith and Baquet (1996) and Finger and Lehmann (2012), with the former finding a complementary role whereas the latter confirming the theoretical expectation.

The role of alternative hedging strategies is, in our humble opinion, much more relevant than the attention it has received until now. Understanding if an alternative hedging strategy is likely to be preferred by high risk rather than low risk bearing farmers is of crucial importance since, in the former case, it could play in favour of insurance actuarial soundness whereas, in the second case, the

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opposite would hold. Moreover, this is of clear interest for the allocation of public contribution. It could be more cost-effective to divert part of the premium subsidy towards alternative hedging strategies if these are preferred by high risk bearing farmers whereas discouraging instruments could be introduced for alternative strategies potentially undermining actuarial soundness.

Although interesting, this result is plagued by several simplifying assumptions required to keep the model tractable. In order to obviate to this problem, a simulation using real data is performed. In particular, data related to apple growers in the region of South Tyrol, where the risk of hail is relatively high, have been collected from the FADN-RICA (Farm Accountancy Data Network) database and from the South Tyrolian association for the protection against weather shocks ("Hagelschutzkonsortium" or HSK). A representative agent-based simulation has been performed. This has substantially confirmed the results of the theoretical model, except for risk aversion whose role in shifting preferences between insurance and anti-hail nets is reversed. The simulation further serves to quantify the certainty equivalent expected utility for the different hedging strategies, and their differences, for various parameter values.

From our analysis it results that anti-hail nets, being preferred by high risk farmers, are potentially beneficial for the actuarial soundness of the hail insurance market. It could then be wise to rethink the EU subsidy policy that, at the moment, only focuses on insurance premia and completely disregards anti-hail nets. However, the negative externalities of anti-hail nets, that have a strong impact on the landscape, must be taken into consideration when considering the possibility to incentivize this hedging instrument.

8 Conclusions

There seems to be a widespread consensus that reducing pesticide use is a desirable objective irrespective of the fate of the different legislative initiatives taken at EU level. Even in the absence of a Sustainable Use Regulation, the Convention on Biological Diversity maintains an internationally recognised aspirational target. In particular its target #7 "Reduce Pollution to Levels That Are Not Harmful to Biodiversity". As part of the monitoring framework for the Kunming-Montreal Global Biodiversity Framework, a headline indicator on "*pesticide environmental concentration*" (indicator 7.2) has been proposed. The specific details of how this indicator will be measured are being designed by an expert group lead by the Food and Agricultural Organization of the United Nations.

The feasibility and magnitude of the reduction remains a contentious issue (Schneider et al. 2023). However, what becomes evident of the discussions during the workshop is that for whatever reduction innovative solutions will be needed. These are already being developed by the classic agents in the agricultural eco-system (machinery and input suppliers) but also by some that would not come to mind when thinking about pesticides (insurance companies, data analytics companies).

However, if these new business models are to deliver on their promise there are several key aspects that need to clarified or better understood. Building on the closing statements by Chantal Le Mouël and Emilio Rodriguez-Cerezo the following main messages can be put forward.

1. Data on pesticides are scarce and its availability key to design better policies. Without data we cannot design or evaluate pesticide reduction strategies.

    (a) We need a more comprehensive understanding of the relationship between pesticide use and yields. In this sense, improved data availability on pesticide use and the linking of accounting data and biophysical and climatic characteristics becomes key.

    (b) We also need to better understand pesticide use risk both for farmers and society.

    (c) We need an agreement on common metrics for analysis, in particular for the measurement of pesticide use. In particular, the societal objective is to reduce risk, with use being an actionable proxy in absence of robust risk measurement.

    (d) The data needs to be accessible by all actors involved, when thinking about data availability data sharing, ownership and confidentiality needs to be included in the equation to design an optimal pesticide data environment.

    (e) Without this data most of the alternative business models presented in the workshop will not work.

2. While much focus has been given to the costs of the transition to a low pesticide agricultural sector, we still lack quantitative estimations of the benefits of the change. Benefits that need to be better quantified include increased biodiversity and how the ecosystem services provided by enhanced biodiversity can partly offset pest pressure.

3. Combining the first two issues, pesticide reduction research should aim to develop a marginal abatement curve (MAC) for pesticides. Similar to greenhouse gas mitigation, such a MAC would allow comparing and ranking different pesticide reduction strategies.

4. The different business models discussed in the workshop have focused mostly on famers and upstream actors in the value chain. Downstream agents such as processors and retailers also have a role to play in the transition to a lower pesticide use food system. Examples of such initiatives include low-pesticide systems developed by retailers and processors (Finger and Möhring, 2024).
5. Crop protection provided by pesticide use can be partly substituted by other management practices. Pesticide reduction must be accompanied by other changes in agricultural management that mitigates yield loss, in particular a more strict application of Integrated Pest Management guidelines.
6. New business models should not exclude more traditional economic tools such as taxation based on internalization of external costs. The Danish example shows that such traditional economic instruments deliver significant pesticide use reductions (Nielsen et al. 2023).
7. Most of the new business models rely in the use of digital support systems (DSS) that enhance the efficiency in pesticide use. The data of DSS needs strong validation so trust in them increases. Moreover, accountability for errors in DSS needs to be embedded into contracts for both type I and II errors. Under type I errors farmers will be applying pesticides when they are not needed, thus hampering the objective of pesticide use reduction. Under type II errors farmers will fail to control the pest thus incurring into additional yield losses.
8. New business models generate new relationships between and across agents, which up to now have worked on a bilateral basis. A farmer would purchase insurance from a company, pesticides from another one and machinery from a third one. We need to understand how this multilateral relationship is going to work.
9. Business models such as those presented in the workshop could also be applied for natural pest control. The incentives for such an extension needs to be considered.

The renewed interest in developing pesticide reduction strategies and business models in the last five years has been driven by the legislative process in the EU. While international commitments begin to be a driving force (see above) it is not clear that this thriving environment will remain. Most of the participants believe that this will be the case, which is also the wish of the editors of these proceeding. However only time will allow assessing whether this is the case.

Overall, this workshop has shown that the different agents in the food system (farmers, cooperatives input suppliers, financial institutions) have the possibility of setting up alternative business models for pesticide reduction. Outcome-based services and insurance policies can help farmers, with an accompanying adequate policy (e.g. subsidies), to achieve this reduction. However, the existing empirical evidence of the performance of these tools continue at a pre-commercial stage and/or it is based on field experiments. Further research is needed combining case studies with experimental data.

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Annex 1: Bios

Day 1

Opening Session

Aymeric Berling is an agricultural engineer, specialised in plant protection. He started in the French Plant Protection Service in various positions in laboratories, diagnosis, trials and international affairs. He then joined the European Commission in the Plant Health Inspectorate, carrying out audit missions in Member States on quarantine inspections. In 1999, he joined DG Agriculture where he carried out audits of the CAP expenditure for the newly established agri-environmental measures then later broadened as the Rural Development policy of the CAP. Aymeric then moved to work on the newly established cross-compliance system making the link between CAP payments and other policies in the field of environment, public, plant and animal health as well as animal welfare. He then worked on the more general greening of the CAP during several years. He works since 2022 on the new system of social conditionality and on the link between the CAP and the pesticides policy.

Session 1 (Part I)

Dr. Thomas Chappell is Assistant Prof. in the Dept. of Plant Pathology and Microbiology at Texas A&M University. He received his Ph.D. from Duke University, postdoctoral training from North Carolina State University, and he studies epidemiology and pest phenology in agriculture.

Antonio Vicent has a PhD in Plant Pathology. He is a plant disease epidemiologist. He is the Head of the Centre Plant Protection and Biotechnology, Valencian Institute for Agricultural Research (IVIA). Member Plant Health Panel European Food Safety Authority (EFSA).

Marius Wolf – Venture Lead EMEA – Digital Farming Solutions (Bayer). Marius Wolf is currently Venture Lead EMEA and leading a team developing new business models in the space of cereal crop production in Europe. He holds a M.Sc. in computer science from RWTH Aachen University with a specialization in human-computer-interaction.

Marco De Toffol – Public Affairs Manager EMEA at Bayer. Marco De Toffol currently holds the position of Public Affairs Manager at Bayer (CropScience division) where he focuses on legislation related to the sustainable use of plant protection products as well as digital farming. Marco holds a bachelor's degree in politics and international relations and a master's degree in EU studies.

Day 2

Session 1 (Part II)

Peter Hloben is Product Safety & Compliance Engineer - Crop Care Platform, John Deere Mannheim Regional Centre, Mannheim, Germany. He is also Chairman of Application Technology project team at CEMA which deals with EU AT related regulations (Machinery regulation and SUR). (Dr. Agr.) Institute für Landtechnik, University of Bonn, Bonn.

Gabriele Mack is the head of the research group "Economic Modelling and Policy Analysis" at Agroscope in Tänikon, Switzerland. She is an agricultural economist with a PhD from the University of Hohenheim. Since 25 years, she has been working for Agroscope. Her main research focus is agricultural policy evaluation and impact analysis.

Chantal Le Mouël is an economist and senior researcher at INRAE. She initially focused her research on international agricultural trade and WTO negotiations, before turning her attention to farmers' production decisions in connection with CAP reforms. More recently, she has focused on global food security and land-use change. For the foresight “European Pesticide-Free Agriculture in 2050”, she was in charge of the quantitative work.

Session 2

Francisco Sebastian has two decades of experience in insurance and pensions. His expertise covers fundamental and quantitative research, which he has cultivated during his tenure at PIMCO, Wellington Management, the European Commission and Spain´s Ministry of Finance. He is also a Fellow of the Institute of Actuaries, a Chartered Insurance and Pensions Regulator in Spain (on leave) and author of multiple publications in the field of investment management, insurance and pensions, and accounting.

Dimitri Lely works for Groupama Centre Atlantique in Niort where he is Director of Agriculture and Expertise. He oversees the agricultural part, products, tariffs, the management of agricultural claims and the management of climatic risks on crops. He is graduated with a master's degree in agro-resource management in 2004 from the University of Reims.

Baptiste Dubois was graduated in 2012 of AgroParisTech, the French first agronomic school.

He first worked for the French Institute of cereals and forages (Arvalis) as an economic project manager. Since 2018, he has worked at Groupama Assurance Mutuelles and he is currently in charge of the climate insurance for crops.

Session 3

Niklas Möhring is an Agricultural Economist working on human decision-making in agricultural and food systems, taking an inherently interdisciplinary approach. His research aims to support food-value chain actors in the transformation to more sustainable and resilient agricultural and food systems, with a specific focus on sustainable plant protection. Niklas is head of the Production Economics Group at the Agricultural Faculty of the University of Bonn, Germany.

Marianne Lefebvre is associate professor at Angers University, France. She earned her PhD in 2011 from Montpellier University and has then worked 3 years for the JRC in Seville. Her main fields of research are agricultural and environmental economics, relying mostly on behavioural and experimental methods. She recently worked on evaluating ex-ante programs targeting transition towards more environmentally-friendly agricultural practices (including reducing pesticides and water withdrawals for irrigation). She is a founding and current board member of REECAP (Research Network on Economic Experiment for the Common Agricultural Policy), and active in the scientific committee of the natural park of her area.

Yann Raineau works at INRAE (ETTIS/BSE), where he conducts research in agricultural and environmental economics, with a focus on experimentation and the vine/wine sector in cooperation with ISVV. He also leads a scientific mission for INRAE on the developing topic of agroecosystem Living Labs, and has previously worked for public institutions (FR Ministry of Agriculture, Nouvelle-Aquitaine Region/VitiREV). Yann holds a PhD in Economics from the University of Bordeaux and a Master's degree in Agricultural sciences from AgroParisTech.

Marco Rogna is an agricultural and environmental economist working in the Micro-Africa team at the Joint Research Centre in Seville, in the unit D4: Economics of the Food System. Before, he has worked as Post-Doc at the Hochschule Bochum and at the Free University of Bolzano/Bozen, where he has conducted research on environmental coalitions and on hail insurance. He has obtained his PhD from the University of Trento with a thesis on cooperative game theory applied to climate negotiations.

Annex 2: Slides

Pesticides
EU Regulatory Framework
an overview

22nd November 2023

- DG Health and Food Safety
- Gordon Rennick

European Union

What we will look at ....

- Drivers of agricultural production..... Pesticide use
- What are pesticides
- A few facts
- A brief history of pesticide discovery
- A brief history of pesticide regulation
- Statistics

Drivers of production

2%

40%

- Energy crops
  - Biodiesel, Ethanol, Biomass, CC&S
- World population dynamics
- Wealth
- Diets

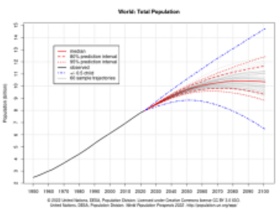
- Land availability
  Deforestation
  Wetlands drainage
  Irrigation

Drivers of production

Trends in world cereal production & land availability

	1961	1970	1980	1990	2000	2006
			(million tonnes)			
Wheat	222	311	440	592	585	606
Total Cereals	877	1,198	1,550	1,953	2,051	2,221
Cereals/ capita (kg)	286	325	348	371	338	336
Arable land (million ha)	1,268	1,302	1,331	1,383	1,380	
Irrigated land (million ha)	139	168	210	244	271	

•Source: FAOStat



What are PESTICIDES ??

- **Plant Protection Products**

Definition–

Fungicides

Herbicides

Insecticides

Molluscicides

Etc......

- **Biocidal Products**

Definition–

Disinfectants / Detergents / soaps

Preservatives for wood etc..

Fungicides, rodenticides etc.. Not used for agricultural purposes.

Any product not covered by PPP, Veterinary, Cosmetic or REACH legislation

What are PESTICIDES ??

Plant Protection Product is comprised of:

Active Ingredient

Co-formulants

Carriers

Anti foaming agents

Adjuvants

Safeners

Solvents etc....

A few facts.........

- EU review removed 800+ "old" pesticides..
- Currently about 445 actives approved.
  - 71 are micro-organisms
  - 24 are basic substances
  - 71 are considered "low risk" (27 M/O)
  - 50 are considered "candidates for substitution"(more hazardous)
  - 69 are pending not being used
- Currently commercialising <5 new actives p.a.
- New active substances have generally a more positive profile...
- EU process ultra precautionary

NOT APPROVED

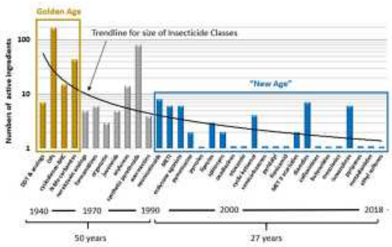
APPROVED

Just the Facts

What is there to regulate?

- Registration of the pesticide
  Registration and Marketing Regulation (EC) No 1107/2009
- How the product is used
  Sustainable Use Directive 2009/128/EC
- Consumer exposure
  Maximum Residue Level Regulation (EC) No 396/2005
- Collection of statistics
  Regulation (EU) 2022/2379 on statistics on agricultural input and output (Repealing Regulation (EC) No 1185/2009)
- Pesticide application equipment
  Directive 2009/127/EC (amending Directive 2006/42/EC with regard to machinery for pesticide application)
- Classification, Packaging and Labelling
  Directive 2009/127/EC (amending Directive 2006/42/EC with regard to machinery for pesticide application)

A history of discovery



HISTORY

A brief history (1st generation)

- 2500 B.C.
  Ancient Sumerians used **sulfur** compounds to kill insects
- 300 B.C.
  Chinese recognize phenology (connection between climate and periodic biological phenomena)
- 1101 A.D.
  The Chinese discover **soap** as a pesticide (**Fatty Acids**)
- 1600's
  Tobacco infusions (**Nicotine**), **herbs** and **arsenic** become the major materials used for insect pest control
- 1746 **Nicotine**
- 1828 **Pyrethrum**
- 1848 **Rotenone, Sulfur...lime sulfur**
- 1880s **Bordeaux Mixture**
- 1890 **Mercuric chloride**
- 1900 Paris green (mixture of arsenic and **copper sulfate**)used for the control of Colorado potato beetle

A brief history (2nd Generation)

Synthetic Pesticide Era--1939 to today

- 1920's Bacillus thuringiensis
- 1930's trend toward synthesizing new compounds
- 1936 Metaldehyde
- 1940's During WWII both sides work on organophosphates as nerve gases and coincidentally discover the insecticidal properties of these chemicals
- 1942 Gamma HCH, Thiram
- 1944 DDT
- 1945-47 MCPA & 2,4-D
- 1950's early 60's "The Green Revolution"
- 1951 Dimethoate, CIPC
- 1952 Folpet
- 1954 Demeton S Methyl
- 1956 Dodine, Mecoprop, Atrazine, Simazine
- 1959 Organotins
- 1960-61 Chlormequat & Mancozeb
- 1962 DiQuat & Paraquat, Methiocarb Silent Spring
- 1964 Chlorothalonil
- 1965-66 Carbofuran & Chlorpyrifos, Bacillus sphaericus (not EU approved)

A brief history (Modern times)

- 1968 Benomyl, Phenmedipham
- 1969 Tridemorph, Desmedipham, Ethofumesate, Chlorotoluron, Propyzamide
- 1970's Serious beginning of research on IPM approaches to pest control
- 1970 IPU
- 1971 Glyphosate
- 1973 -1980 Triadimefon, Carbendazim, Deltamethrin, Guazatine, Pendimethalin, Cypermethrin, Diclofop methyl, Triclopyr, Cymoxanil, Flamprop-M, Metalaxyl, Prochloraz, Clopyralid, Triadimenol, P ropammocarb, Propiconazole, Fenpropimorph, Esfenvalerate
- 1980's Increase in IPM research & genetic engineering applications in agriculture
- 1981 Fluazifop P, Mepiquat chloride
- 1983 Kresoxim methyl, Fluroxypyr, Metsulfuron methyl
- 1984 Flusilazole
- 1985 DFF, Tribenuron, Thifensulfuron
- 1986 Cyproconazole, Fenpropidin, Tebuconazole
- 1987 Cyazofamid, Prosulfocarb, Propaquizafop
- 1988 Fenoxaprop, Difenoconazole
- 1989 Trinexapac
- 1990 Fluazinam

A brief history (Modern times)

- 1990 Imidacloprid, Thiamethoxam
- 1991 Triflusulfuron-methyl,
- 1992 Azoxystrobin, acetamiprid
- 1993 Epoxiconazole
- 1994 Bacillus subtilis
- 1995 Ampelomyces quisqualis, Flufenacet
- 1996-1998 Quinoxyfen, Ferric phosphate, Indoxacarb, Trifloxystrobin
- 1999 Picolinafen
- 2000 Pyraclostrobin, Picoxystrobin, Thiacloprid
- 2002 Prothioconazole, Clothianidin, Spirotetramate
- 2004-2005 Fluopyram, Proquinazid, Flonicamid
- 2006 Boscalid, Pinoxaden, Chlorantraniliprole,
- 2010 Isopyrazam
- 2011 Bixafen
- 2013 Sulfoxaflor
- 2016 Oxathiapiprolin, Sulfoxaflor
- 2016-to date Mefentrifluconazole, Fenpicoxamid, Flupyrimin, Bixlozone, Cinmethylin

A step back in time

Approved

Beer
Clayed charcoal
Diammonium phosphate
Equisetum arvense L.
Fructose
Sucrose
Hydrogen peroxide
Lecithins
Onion oil
Mustard seeds powder
Salix spp. cortex
Sodium chloride (Salt)
Sodium hydrogen carbonate (baking powder)
Sunflower oil
Urtica spp.(nettle juice)
Vinegar
Whey

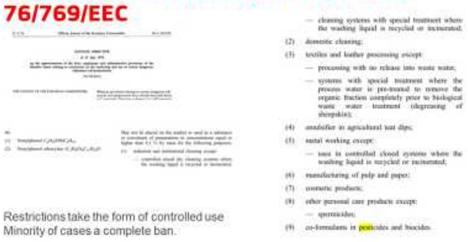
A history of regulation

This is only half the story…….

1967 "Dangerous Substances Directive" Directive 67/548/EEC

Listed substances and classes of substances considered to be "dangerous".
It was famously the legal basis from which it was illegal to market products classified as "very toxic" or "toxic" to the general public.

1976 "Limitations directive" Directive 76/769/EEC



Restrictions take the form of controlled use
Minority of cases a complete ban.

1978 "Prohibitions directive" Directive 79/117/EEC

The early pesticide residue directives 76/895/EEC, 86/362/EEC & 86/363/EEC

COMMISSION REGULATION (EC) No 2076/2002

91/414
Council Directive 91/414/EEC

New active substances discovery

- Active substance evaluation for new active substances
- Review programme for existing actives substances
- Product authorisation risk based assessments
- Data requirements both AS and
- "uniform principles" which outlined how evaluations and risk assessments should be conducted.
- Active substance reviews and evaluations were carried out by Rapporteur Member States (RMSs) resulting in a "monograph".
- Evaluations being "peer reviewed" by experts from the other Member States.

The Pesticide Package

- ***Regulation (EC) No 1107/2009*** *Authorisation, Marketing and Use (91/414/EEC)*
- **Directive 2009/128/EC** *Sustainable use*
- **Regulation (EC) No 1185/2009** *Statistics*
- **Directive 2009/127/EC** *pesticide machinery*

General Food Law

Regulation (EC) No 178/2002

Establishment of EFSA....

Technical and scientific support

Independent scientific advice to risk managers

Approval of active substances

Setting of legal limits for pesticide residues in food and feed (MRLs).

efsa European Food Safety Authority

Regulation (EC) No 1107/2009

concerning the placing of PPPs on the market and repealing Council Directives 79/117/EEC and 91/414/EEC

- A shift to hazard based approval criteria both for human and environmental health
- Introduction "candidates for substitution"
- Introduction of "basic" substances and "Low risk" substances
- Zonal authorisation of PPPs and Mutual Recognition
- Regulation of "parallel trade"
- Provisions on "safeners and synergists", adjuvants and unacceptable co-formulants
- Data protection rules
- Avoidance of vertebrate testing
- Record keeping and information availability to the public
- EFSA manages the peer review of Draft Assessment Reports (formerly known as "monographs")

REACH

Regulation (EC) No 1907/2006

Establishment of ECHA....

Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

Regulation of "other" chemicals some of which did and do appear as constituent parts of PPPs, in the form of emulsifiers, carriers, adjuvants etc....

ECHA EUROPEAN CHEMICALS AGENCY

Re Ac H
Registration
Evaluation
Authorisation and
Restriction of
Chemicals

How a new PPP comes to market in the EU

Pesticide Residues Regulation

Regulation (EC) No 396/2005

Built on early pesticide residue directives

Establishment of MRLs

Underpins consumer confidence

Residue monitoring programme

2021 Results

[illegible] were taken for the [illegible]

Risk based in 91/414/EEC to hazard based......in Reg 1107

- Hazard based "cut-off" criteria
  - human and environmental
  - Derogation?
- Actives classified as Carcinogenic, Mutagenic or Reprotoxic Cat 1 or 2
- Endocrine disruptors
- Actives classified as Carcinogenic Cat 3 and Reprotoxic Cat 3
- Actives classified a POP or a PBT or a vPvB

The raw numbers (EU)

1970s 1500+ actives

1978 "Prohibitions directive" Council Directive 79/117/EEC

1990s 1000+ actives identified for review.

1st EU Review Programme (4 stages) 1992........~ 800 non approvals

2nd EU Review Programme "AIR" 2007 ~40 non approvals

~40 approvals + New

Currently ~ 445 approvals

Directive 2009/128/EC

establishing a framework for Community action to achieve the sustainable use of pesticides

- National Action Plans – to reduce risks
  - USE REDUCTION TARGETS – 1% or 50%
- Training & Certification – advisors, distributors, users
- Inspection & certification of application equipment – now 3 years
- Aerial Application – prohibition / restriction
- Restrictions to protect – aquatic env; sensitive areas, schools
- Handling & storage of pesticides, packaging & remnants
- IPM – compulsory since 2014

National Action Plan

- Culmination of all measures in the directive
- Clear quatifiable goals and objectives

Training

- Spray operatives (professional users)
- Distributors (storekeepers)
- Advisors

Each group have distinctly different requirements

Inspection of application equipment

- Harmonised standards
- Inspected at least 1 year in 3 since 2020

Aerial Spraying

- General prohibition
- Derogation in certain circumstances where no viable alternatives exist

Specific measures to protect Aquatic Env. And DW

- Product choice
- Application technique
- Mitigation measures
- Elimination / reduction in areas e.g., road verges, railway lines, hard surfaces

Reduction of pesticide use or risks in specified areas

Indicators (Article 15)

National indicators and Harmonised Risk Indicators

Member States shall

- calculate HRIs using statistical data collected under EU legislation.
- Identify trends in use of certain active substances
- Identify priorities such as certain crops, actives, practices or regions etc...

Integrated Pest Management

"means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment.

'Integrated pest management' emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms"

Definition from Directive 2009/128/EC (Very similar to the definition from FAO UN)

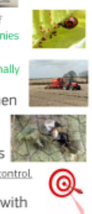
IPM Cultural / Mechanical

IPM Biological / Chemcial

Integrated Pest Management

General Principles (Annex III Dir 2009/128/EC)

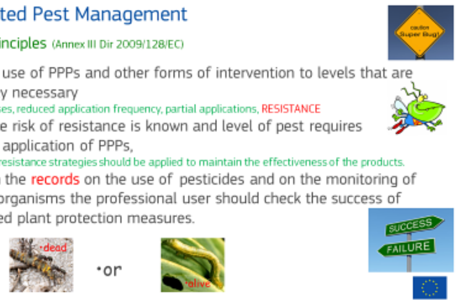
- Prevention/suppression of key pests, diseases and weeds choice of Cultivars, cultivation techniques, nutrition and irrigation practices, protection of natural enemies
- Harmful organisms must be monitored
  Field observations, forecasting and early diagnosis/warning systems, advice from professionally qualified advisors.
- Based on the monitoring the user has to decide whether and when to apply plant protection measures.
  Threshold levels specific to area, crops and climatic conditions
- Sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.
- Pesticides applied shall be as specific as possible for the target with least side effects on human health, NTOs and the environment.



Integrated Pest Management

General Principles (Annex III Dir 2009/128/EC)

- Keep the use of PPPs and other forms of intervention to levels that are absolutely necessary
  by reduced doses, reduced application frequency, partial applications, RESISTANCE
- Where the risk of resistance is known and level of pest requires repeated application of PPPs,
  available anti-resistance strategies should be applied to maintain the effectiveness of the products.
- Based on the records on the use of pesticides and on the monitoring of harmful organisms the professional user should check the success of the applied plant protection measures.



Pesticide Statistics

Statistics on Agricultural Input and Output (SAIO)

Regulation (EU) 2022/2379 on statistics on agricultural input and output (Repealing Regulation (EC) No 1185/2009)

Sales data	-	Member State annual reporting at active substance level (100% coverage)
Use data	-	Member State ANNUAL reporting at active substance level (85% coverage, 95% from 2026), 75% UAA

Pesticide Sales Statistics

Data provided by the MSs in aggregated form.

National sales data is transmitted at active substance level but also grouped using agreed groupings, to DG ESTAT, by each Member State.

This data is then analysed

Pesticide Use Statistics

Data provided by the MSs in aggregated form.

National use data is transmitted at active substance level but also grouped using agreed geographical levels, to DG ESTAT, by each Member State.

This data is then analysed.

Pesticide Use RECORDS

Commission Implementing Regulation 2023/564

- Prescribes format and content of PPP use records for all professional users.
- Competent Authorities may request submission of records in electronic format

Other....

- WFD (Directive 2000/60/EC) , listing of pollutants, EQS,
  GW and SW monitoring.....
- Future...other initiatives planned and at various levels of progress
  Nature restoration targets,
  Pollinator initiative,
  SUR, sensitive areas and use reduction targets...

Future

- Sustainable Use Regulation
- Indicators
- Resource efficiency (water, fertiliser, plant protection)
- Investment – return
- Innovation –
- Development
- Leadership

Thank you

European Union

The sustainable use of pesticides and the Common Agricultural Policy (CAP)

Aymeric BERLING
DG Agriculture

JRC Workshop on alternative business models for pesticides reduction – Sevilla – 2-23 November 2023

Background

- The **Farm to Fork Strategy** proposes targets for the reduction by 50% by 2030 of the use and risk of pesticides
- The **Commission proposal for a Regulation (SUR)** replacing the Directive on sustainable use of pesticides (SUD) provides that these targets are set at EU level and that national targets are set for that purpose
- In the SUR, the approach of **Integrated Pest Management (IPM)** is at the core of the strategy to reach the targets

Integrated Pest Management (IPM)

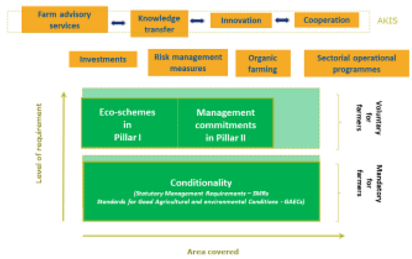
IPM is about emphasizing the growth of a healthy crop with the least possible disruption to agro-ecosystems and encouraging natural pest control mechanisms (chemical pesticides are the last resort)

The definition is translated in the Directive on sustainable use of pesticides (SUD) by applying 8 general principles:

1. Prevention and supression
2. Monitoring
3. Decision-making
4. Non-chemical methods
5. Pesticides selection
6. Pesticides use reduction
7. Resistance prevention
8. Evaluation

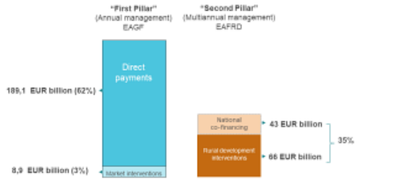
The « green architecture » of the CAP and the sustainable use of pesticides

The "green architecture" architecture of the CAP 2023-2027



CAP budget

(CAP total financing 2021-2027 *(% of total public expenditure (EU + nat.))*



Conditionality

- A **link** between CAP payments and Directives & Regulation (Statutory Management Requirements-SMRs) and standards of Good Agricultural and Environmental Conditions (GAECs)
- **Reduction of CAP payments** in case of non-compliances
- Applies to **89% of farmers and agricultural area**
- Includes the **pesticides Regulation**
- **New requirements** added in the scope, in particular **the Directive on sustainable use of pesticides (SUD)**

Conditionality

- The **SUD provisions** include
  - Certification of equipment
  - Certification of users
  - Restrictions in protected areas
  - Handling, storage and disposal of remnants
- The conditionality framework also allows Member States covering by conditionality the **general Integrated Pest Management (IPM) principles** which are fit for this mechanism, depending on how the principles are implemented at national level on the basis of the SUD:
  - General IPM principle 1: GAEC standards on crop rotation, ecological infrastructure, cultivation techniques, adequate plant protection techniques, ...
  - General IPM principles 5, 6 and 7: SMR on relevant conditions for proper use

Eco-schemes

- **Voluntary** support to be offered by Member States to farmers
- **25% of direct payments budget**
- Basically **annual** commitments
- Practices **beyond the baseline** of legal requirements
- **Level of support** to be decided by Member States, which may take the form of :
  - **Remuneration of public good** provided (top-up of income support), and/or
  - **Compensation** of cost incurred/income foregone

Eco-schemes

- Support many types of **voluntary actions** going beyond conditionality and other relevant obligations, such as for instance :
  - *Establishment of non-productive areas on agricultural land*
  - *Diversified crops on the rotation*
  - *Conservation agriculture without pesticides: rotation, no ploughing, soil cover*
  - *Maintenance of organic farming*
  - *etc…*

Support for rural development

- **Voluntary** support to be offered by Member States to farmers or other beneficiaries
- Rural development support
  - must cover **environment- and climate-friendly land management**, and
  - may also cover animal welfare, compensation for disadvantages, **investments**, **risk management**, **knowledge-building**, **innovation** and **co-operation**.
- Basically **multi-annual** commitments (5-7 years for management commitments)
- Practices **beyond the baseline** of legal requirements
- **Level of support** takes the form of **compensation** of cost incurred/income foregone
- Minimum mandatory expenditure for **environment and climate: 35%** of the EAFRD

Support for rural development

- Support many types of **voluntary actions** going beyond conditionality and other relevant obligations, such as for instance :
  - *Reduced or ban of use of pesticides*
  - *Use of Integrated Pest Management beyond the obligations under the SUD*
  - *Longer multiannual rotation and diversified crops*
  - *Payments for investments for pesticides management and localized spraying*
  - *Payments for training and advice*
  - *Conversion to organic farming, etc…*

  But also
  - *Investments for precision spraying equipment*
  - *Financing risk management*
  - *Contributing to advice, cooperation and monitoring systems, etc …*

Sectoral interventions

- **Sectoral programmes (wine, fruit & vegetables, olive oil, hops**…) integrated in strategic plan regulation
- A **higher profile for the environment and climate**
- **At least 15% of funding** for operational programmes in the **fruit and vegetables sector** must be spent on actions for environment and climate (10% in the past period), such as IPM
- Possibility for **dedicated actions in other sectors**

Knowledge, research & innovation

- Advancing research, knowledge-sharing, and innovation is essential for a smart and sustainable agricultural sector
- EUR 9 billion under **Horizon Europe (2021-2027)** dedicated to food, environment, agriculture, bioeconomy
- Knowledge and innovation are a **cross-cutting objective** of all CAP strategic plans
- **European Innovation Partnership** (EIP-AGRI) key to stronger agricultural knowledge and innovation systems
- The **Farm Advisory Services are** key tool in sharing new knowledge and ideas, to be included in the AKIS

The CAP and the transition

Supporting compulsory practices during the transition

- Normally the CAP does not support farming practices which are required in the **baseline** (including in particular minimum requirements established by union law and GAEC standards). The principle is that no public money is provided to just respect the legal baseline.
- Due to the ambitious and close Farm to Fork targets for pesticides reduction, a **derogation to this principle of baseline is foreseen in the proposed SUR (Art. 43)**. This would help farmers to meet new raising standards.
- **During 5 years MSs will be able to support with CAP money compulsory practices** that they will develop in their "crop-specific rules".
- The support will be possible with **eco-schemes (CAP "Pillar I money")**, **management commitments** and **investments (CAP "Pillar II money")**.

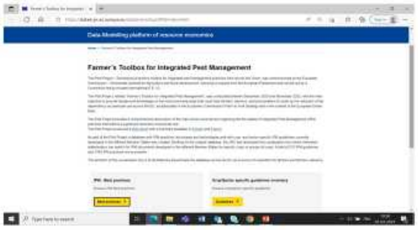
Supporting compulsory practices during the transition

- The support will however remain **within the CAP national envelopes** and will need to be **set in CAP Strategic Plans**. There is no additional money for that purpose.
- Compulsory practices will be **developed by MSs (NAP of the SUR)** and it will be **up to them to finance them** or not with the CAP. At these 2 levels MSs will remain free of their choices.
- The compulsory practices will **remain in the CAP conditionality.** That means that in case of infringement of a compulsory rule, there will be a penalty under conditionality on top of the penalty for non eligibility.

The database « IPM Toolbox fo farmers »

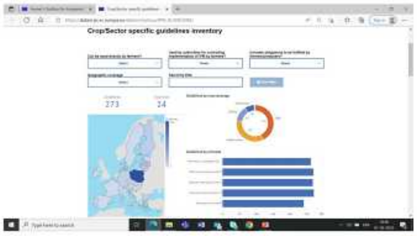
« IPM Toolbox » Database

https://datam.jrc.ec.europa.eu/datam/mashup/IPM/index.html



European Commission

European Commission



European Commission

Thank you

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European Commission

Service-based business models to incentivize the efficient use of pesticide in crop protection

Check for updates

Perspective SCI

Received: 8 March 2019 Revised: 17 May 2019 Accepted article published: 18 June 2019 Published online in Wiley Online Library: 29 July 2019

(wileyonlinelibrary.com) DOI 10.1002/ps.5523

Perspective: service-based business models to incentivize the efficient use of pesticides in crop protection

Thomas M Chappell,[a*] Roger D Magarey,[b] Ryan W Kurtz,[c] Christina M Trexler,[b] Godshen R Pallipparambil[b] and Ernie F Hain[b]

Pest Manag Sci 2019; 75: 2865–2872 www.soci.org

❖ Definitions and ➢assumptions

❖ "Pesticide-use waste" (hereafter "waste") is use in excess of what is **required for crop protection.**

- ➢ Waste is nonzero

❖ "Crop protection" is a **condition** in which the **cost of realized crop loss** to a pest is **less than** the **expenditure** made to prevent that loss.

- ➢ Excess crop protection results in waste

❖ A common goal is to eliminate **waste.**

❖ This is necessarily distinct from optimizing anything else.

Overview

1. Questions leading us to this topic

   How to achieve goals of IPM / IDM?

2. Rationale for our work

   What incentivizes pesticide use efficiency?
   How may models be used in support of efficiency?

3. Operational considerations, possible opportunities

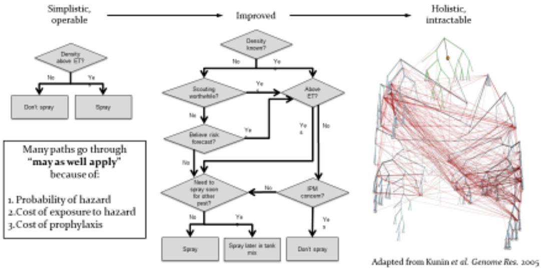
Goals

We are biologists, modelers of agricultural pests and disease.

- Enhance risk pool definition
- Identify functional assets to insure
- **Monetize pesticide non-use**
- Enable competition for *efficiency*

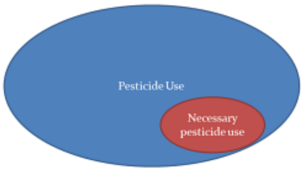
Beginning with questions about decisions and incentives underlying pesticide use:

Research: Models of pesticide application decision-making



Why waste?

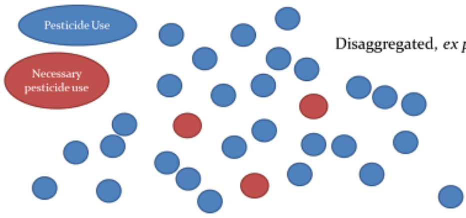
- Waste is use in excess of what is **required for crop protection.**
- Requirement is not completely known before harvest.



Waste is known *ex post*, in aggregate

Why waste?

Even if pest process is constant at scale, it varies at farm level.

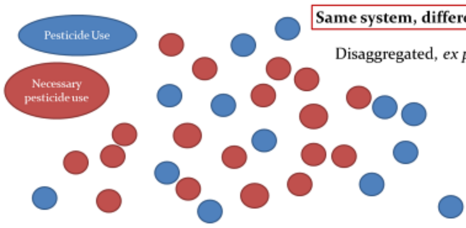


Disaggregated, *ex post*

Why waste?

Pest process variation at scale increases uncertainty further.

Same system, different year

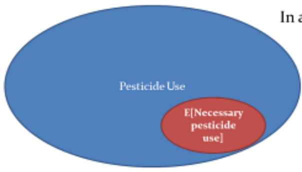


Disaggregated, *ex post*

Why waste?

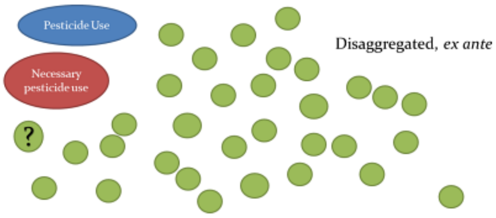
Appearance of waste varies depending on spatial and temporal scale.

In aggregate, *ex ante*



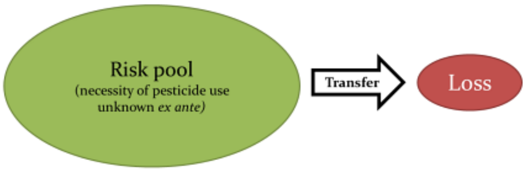
Why waste?

At individual farm scale, low aggregate risk still motivates use because
cost(exposure|hazard) >> cost(application|no hazard)



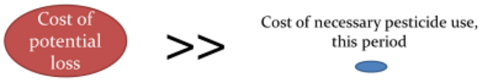
And so we arrived at insurance

Can it address individual vs. aggregate risk?



Insurance

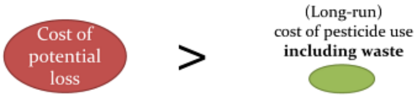
- "Crop protection" is a **condition** in which the **cost of realized crop loss** to a pest is **less than** the **expenditure** made to prevent that loss.



Ex post,
if loss **was going to** occur, pesticide use was worth the cost.

Insurance

- "Crop protection" is a **condition** in which the **cost of realized crop loss** to a pest is **less than** the **expenditure** made to prevent that loss.



***Ex ante*, when future hazard is unknown,**
pesticide use is worth the cost in the long run, even including waste.

Insurance – not the obvious solution to us

Health insurers work to reduce premiums by encouraging **prevention.**

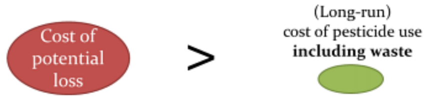
This reduces costs borne by the risk pool,
or in some models, those borne by the public.

Pest management scenario supports prevention, economically.
E.g., insurers don't want to cover measles infections.

Insurance... and questions

If economics and logistics encourage **prevention**,
what can incentivize exposure?

If not crops, what may be insured?



Rationale: **How** can waste be reduced?

Most answers to this question involve technology.

- Decision support
- Forecasting
- Monitoring
- Alternatives to pesticide

These are our primary research topics.

They may **reduce** unnecessary pesticide use,
but they do not necessarily **incentivize non-use**.

Problem: reduction tech. competes with provision tech. in sales models.

~~How can waste be reduced?~~

Who benefits from reducing waste?

Farmers

Stakeholders

Near residents

Consumers

More...

~~How can waste be reduced?~~

Who benefits (**monetarily**) from reducing waste?
(if waste is associated with prevention)

Farmers? Not in the long run.
Though it is often farmers who are told to reduce waste.

Stakeholders in agriculture? No.

Near residents? No.

Consumers? Trivially if at all.

~~How can waste be reduced?~~

Who benefits (**monetarily**) from reducing waste?
(if waste is associated with prevention)

A **service provider,**
operating at the scale at which waste occurs consistently.

We considered a hypothetical agrochemical company.

Service provision is not a new idea:
"We have discussed selling yield"
"Urban pest management is service-based"

Service provision addresses operational constraints

1) Mechanistically connected, sometimes opposed optima:
- Yield
- Profit
- Crop protection (of which pesticide use can be one part)
- Resistance evolution

2) Spatial and temporal scales, variously determined:

Object/process	Scaling process(es)
Crop (to protect)	Logistics, economics
Yield value	Crop/commodity quantity, demand
Crop protection	Crop, economics
Resistance evolution	Pest biology, crop protection

Competition functions in service provision

3) Economically and ecologically connected actors, with sometimes competing incentives:

Actor	Incentive(s)
Farmer	Meet revenue goals, sustain means
Agrochemical company	Maximize profit, sustain means
Pest management advisor*	Sustain means
Stakeholder	Receive ag output; minimize deleterious exposure
Near resident	Sustain ag; minimize deleterious exposure
Environmental regulator	Minimize (prevent) deleterious exposure

A service provider does not compete with these actors,
and would instead compete with other service providers.

How can waste be reduced?

By a **service provider,**

operating at the scale at which waste now occurs consistently.

This provider can afford some crop loss (similar to insurance),
if offset by gains arising from scale of provision.

A major caveat is that the **client** in this formulation
is not currently organized. Organization is needed.

A **service provider can respond differently**

Event	Farmer response	Service provider response
Overwhelming pests at one farm	Write off; inform neighbors out of virtue	Manage at area scale (inform self out of self interest)
Resistance evolution	Detect by crop impact	Detect by monitoring; react intensively
Resistance detected	React alternatively *if economical at farm scale*	React alternatively to preserve efficacy/revenue
Resistance not detected where expected	Continue management program	Expand area under program

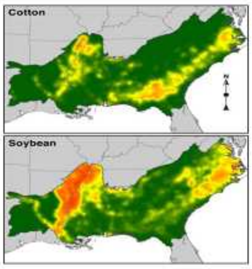
A **service provider can behave differently**

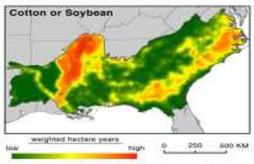
Some pesticides could in theory never go to market
- Service providers could use or prescribe them
- Provider use, delayed public release
  → **delayed competition with generics**

Providers could use monitoring/forecasting/AI to compete
- Higher performing DSS → reduced waste (and price)
- Better coordination → larger clients (areas)

Pesticides used in services may also be sold at higher price
- Provider has other revenue streams, is not limited to sales
- Pesticides can be used where client size limits coordination,
  → but with incentive to **reduce waste,** potentially use provider info.

Large-scale pest resistance evolution forecasting

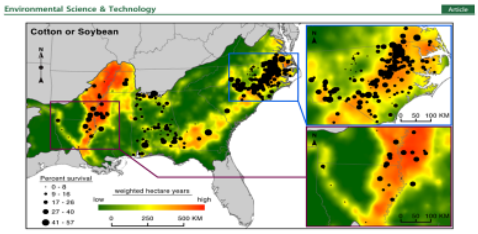




$$WHY = \sum_{i=1}^{8}\sum_{d=1}^{8}\left[CotSoy_{i,d}(e^{-di})\frac{1}{(5d)^{a}}\right]$$

Resistance evolution impacts are at areawide or larger scale.

Can be used to identify efficient programs



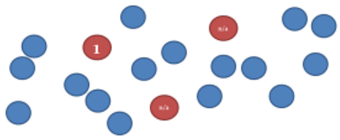
Success arising from unknown cause is only visible at scale.

How can insurance be involved?

If it doesn't make sense to insure against raw crop loss due to elective exposure, then what can be insured?

Can "elective exposure" be made more strict, *e.g.* "exposure *to first loss*?"

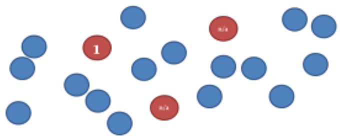
Can the coordinator who prevents *secondary loss* be **insured**?



How can insurance be involved?

If improved practices reduce overall frequency of **costly loss**
(because of cost savings due to waste reduction),

will insurance not compete as much with affordable prevention?



Conclusions

The business model is
- Monetization of pesticide non-use
- Provision of pest management,
  coupled with insurance against crop loss

Critical to success of such a model is
- **Increased efficiency of pesticide use**
- Coordination across scales:
  - Pest phenology
  - Resistance evolution
  - Crop phenology

These are ecological processes; research is needed.

Frontiers in Insect Science, Frontiers in Agronomy

Conclusions

Current incentives do not encourage waste reduction

Insurance formulations compete with affordable prevention

Sellers should not be expected to reduce sales-based revenue streams

Technology can reduce waste but does not necessarily monetize non-use

Service provision addresses several of these concerns

Technology may be better suited to service provision

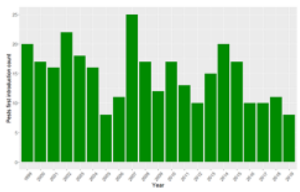
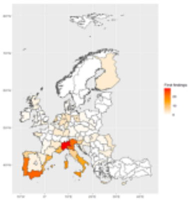
GENERALITAT VALENCIANA
ivia Institut Valencià d'Investigacions Agràries

Reducing fungicide use in agriculture with decision support systems

Antonio Vicent
Centro de Protección vegetal y Biotecnología
Instituto Valenciano de Investigaciones Agrarias (IVIA)

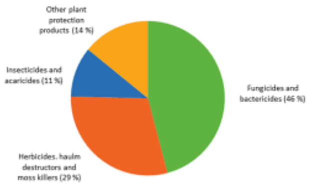
Fungicide use in EU agriculture

- New pest introductions in the EU

Rosace et al. (2023) Scientific Data 10:731

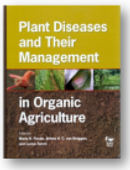
Fungicide use in EU agriculture



ec.europa.eu/eurostat

Fungicide use in EU agriculture

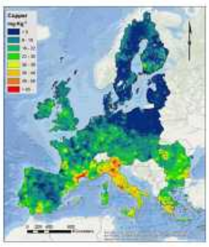
- Towards low-pesticide-input disease management
  - Organic agriculture (Regulation EU 2018/848)



*"Control of **airborne diseases** by means of direct plant protection is **clearly more demanding in organic farming** systems because the plant protection products allowed are often less effective"*

Fungicide use in EU agriculture

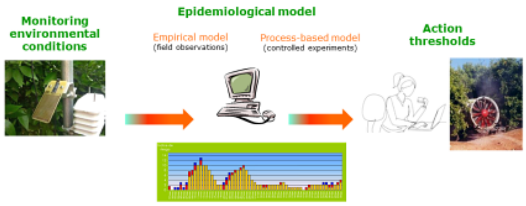
- Towards low-pesticide-input disease management

Fungicide use in EU agriculture

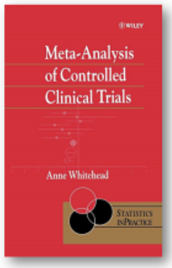
- Fungicide resistance, also a public health concern

Decision support systems



Decision support systems (meta-análisis)

Decision support systems (meta-análisis)



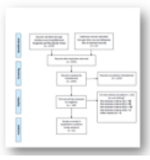
- Meta-analysis:

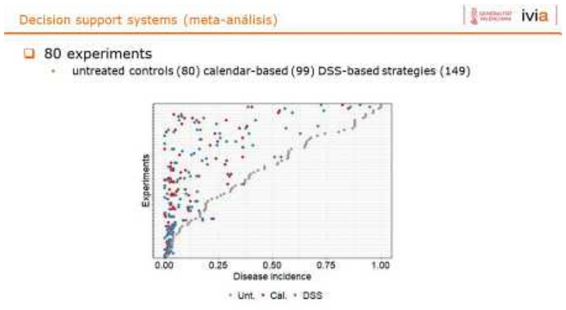
statistical analysis of the data from independent experiments focused on the same question

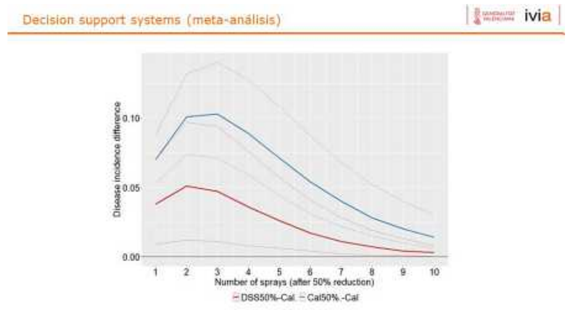
Decision support systems (meta-análisis)

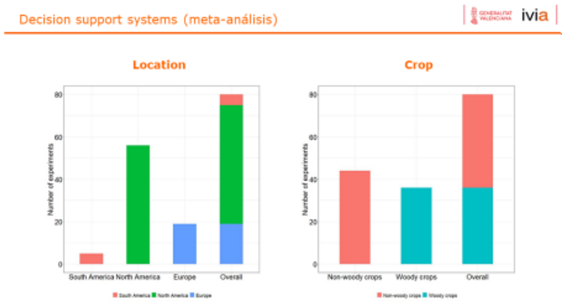
The published experiments had to satisfy the following criteria:

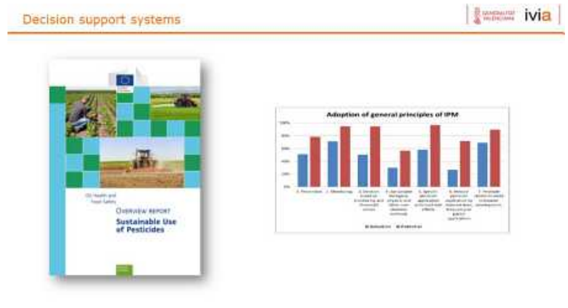
1. At least one untreated control (**Unt**), one calendar-based strategy (**Cal**) and a DSS-based strategy (**DSS**) were tested
2. Disease incidence (i.e., the proportion of diseased organs)
3. Sample size (i.e., the total number of organs evaluated)
4. Number of fungicide sprays in each strategy




Decision support systems (meta-análisis)
ivia
80 experiments
untreated controls (80) calendar-based (99) DSS-based strategies (149)
Experiments
0.00 0.25 0.50 0.75 1.00
Disease incidence
Unt. Cal. DSS


Decision support systems (meta-análisis)
ivia
Disease incidence difference
0.10
0.05
0.00
1 2 3 4 5 6 7 8 9 10
Number of sprays (after 50% reduction)
DSS50%-Cal Cal50%-Cal


Decision support systems (meta-análisis)
ivia
Location
Crop
Number of experiments
South America North America Europe Overall
Non-woody crops Woody crops Overall


Decision support systems
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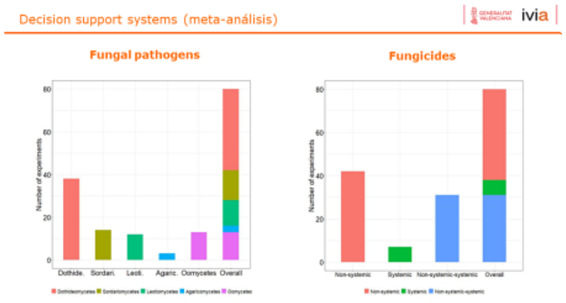
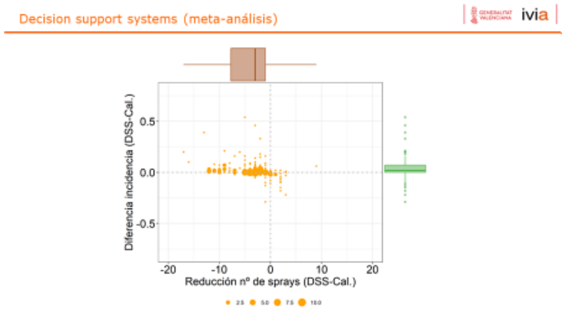
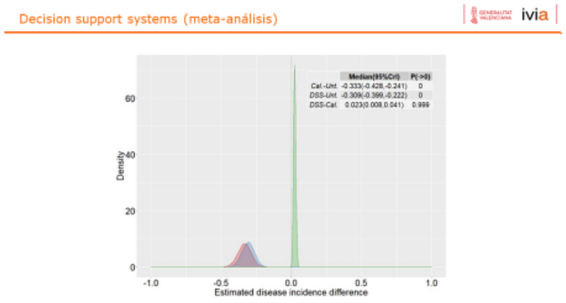
Overview report
Sustainable Use of Pesticides
Adoption of general principles of IPM


Decision support systems (meta-análisis)
ivia
Fungal pathogens
Fungicides
Number of experiments
Dothide. Sordari. Leoti. Agaric. Oomycetes Overall
Non-systemic Systemic Non-systemic-systemic Overall


Decision support systems
ivia
In Conversation With Nobel Laureate Frances Arnold
"Everybody says, 'Oh, my technology is useful.' But if nobody uses it, it's not useful."


Decision support systems (meta-análisis)
ivia
Diferencia incidencia (DSS-Cal.)
0.5
0.0
-0.5
-20 -10 0 10 20
Reducción nº de sprays (DSS-Cal.)

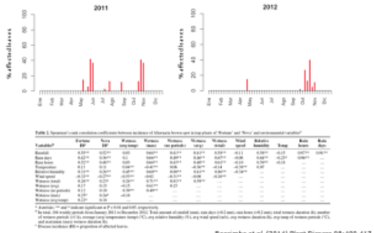

Decision support systems
ivia
Phytopathology
SYMPOSIUM
Perceptions of Risk, Risk Aversion, and Barriers to Adoption of Decision Support Systems and Integrated Pest Management: An Introduction
Growers feel safer with calendar-based schedules


Decision support systems (meta-análisis)
ivia
Median(95%CrI) P(>0)
Cal.-Unt. -0.333(-0.428,-0.241) 0
DSS-Unt. -0.309(-0.399,-0.222) 0
DSS-Cal. 0.023(0.008,0.041) 0.999
Density
60
40
20
0
-1.0 -0.5 0.0 0.5 1.0
Estimated disease incidence difference


Alternaria brown spot of mandarins (Alternaria alternata)
ivia

Alternaria brown spot of mandarins (*Alternaria alternata*)

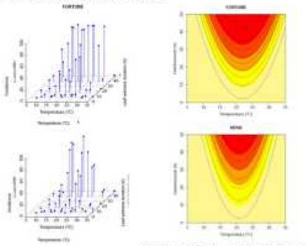
- Empirical models (infections under field conditions)



Bassimba *et al.* (2014) Plant Disease 98:409-417

Alternaria brown spot of mandarins (*Alternaria alternata*)

- Process-based models (infections under controlled conditions)

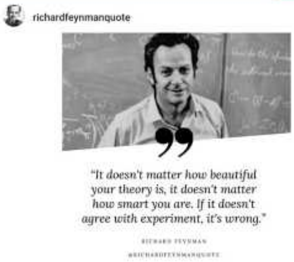


Bassimba *et al.* (2017) Phytopathology 107:721-731

Alternaria brown spot of mandarins (*Alternaria alternata*)

- A suite of models:

1. Alter-Rater
   - Scores assigned daily and accumulated for each week
2. Simple Rule System (**SRS**)
   - Average weekly temp (T_{week}) ≥12ºC and accumulated weekly rainfall (R_{week}) ≥2mm
   - Then T_{week} + R_{week} or zero otherwise
3. Generalized Additive Model (**GAM**)
   - All leaf wetness periods in each week, outputs accumulated weekly
4. Generalized Additive Model / rain (**GAM$_{rain}$**)
   - Outputs of GAM x2 in weeks where R_{week} >2mm
5. Generic infection model (**GIM**)
   - All leaf wetness periods in each week, outputs accumulated weekly
6. Generic infection model / rain (**GIM$_{rain}$**)
   - Outputs of GIM x2 in weeks where R_{week} >2mm



Alternaria brown spot of mandarins (*Alternaria alternata*)

- Model validation

Alternaria brown spot of mandarins (*Alternaria alternata*)

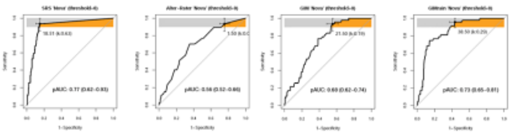
- Model validation

- **False positive** (specificity)
  - Unnecessary fungicide spray
- **False negative** (sensitivity)
  - The entire harvest may be lost

In our conditions, models for ABS control should operate in a **high-sensitivity range** to avoid false negatives

Alternaria brown spot of mandarins (*Alternaria alternata*)

- Model validation
  - Receiver Operating Characteristic (ROC) curve analysis



Bassimba *et al.* (2017) Phytopathology 107:721-731

Alternaria brown spot of mandarins (*Alternaria alternata*)

- Model validation
  - Receiver Operating Characteristic (ROC) curve analysis

Models	Specificity		Sensitivity	
	'Fortune'	'Nova'	'Fortune'	'Nova'
Alter-Rater	0.253	0.24	0.923	0.936
SRS	-	**0.849**	-	**0.936**
GAM	0.400	0.470	0.969	0.914
GAM$_{rain}$	0.517	0.552	0.938	0.936
GIM	0.422	0.438	0.953	0.936
GIM$_{rain}$	0.590	0.602	0.907	0.914

Bassimba *et al.* (2017) Phytopathology 107:721-731

Alternaria brown spot of mandarins (*Alternaria alternata*)

- DSS implementation

Growers feel safer with calendar-based schedules

Model performance is critical for adoption by growers

The future of crop pest advisors?

The future of crop pest advisors?

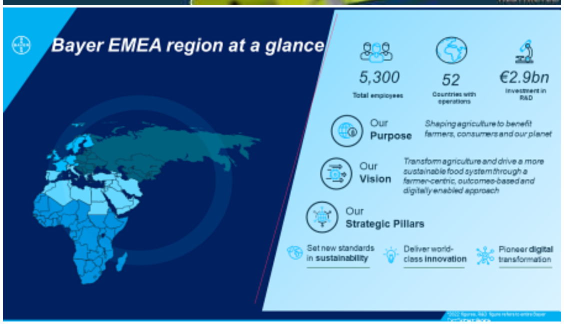
The MIT Press

The Myth of Objective Data

The idea that machines allow us to see true has long been outmoded.

- Subtantial **reducción** in the number of fungicide sprays
- Crucial to fully understand:
  - the **epidemiology** of the disease
  - the **needs** of the **end user**
  - the **means available** for **implementation**
- Robust **validation**
- Can never replace **crop pest advisors**

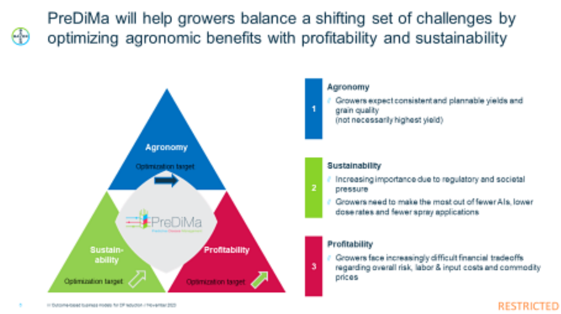

BAYER
Outcome-based business models for CP reduction
RESTRICTED


Bayer EMEA region at a glance
5,300
Total employees
52
Countries with operations
€2.9bn
Investment in R&D
Our Purpose
Shaping agriculture to benefit farmers, consumers and our planet
Our Vision
Transform agriculture and drive a more sustainable food system through a farmer-centric, outcomes-based and digitally enabled approach
Our Strategic Pillars
Set new standards in sustainability
Deliver world-class innovation
Pioneer digital transformation


We will transform our offerings from products to solutions, systems and outcomes
This shift will help our customers switch to practices that produce more with less, while restoring more
From selling inputs
Risk sharing
Digitally enabled systems
To selling outcomes and tailored solutions
Tailored solutions & Outcome based models
PRECEON
PreDiMa
ResiYou
Ambition to reach
30% sales generated
from these offerings
100%
100%
2020
2030


Cereal farmers' challenge
Balancing agronomy, economics and regulatory aspects
Cost of a spray application ca. 30-50€/ha (incl. CP, fuel, labor)
Pressure to reduce CP through Green Deal
Limited mitigation through variety choice, rotation, planting
Potential yield loss of ~50% if untreated
Septoria can only be prevented, not cured
Typical yield 3.4-11.5 tonnes/ha (7.9 EU average)
Current wheat price ~230 €/ton
Farmers can't afford yield loss from common cereal diseases.
Fungicides as key tools are under pressure from regulations.
Better solutions are needed.
RESTRICTED


PreDiMa: a modern system for cereal disease management
Predictive Disease Management
A sustainable system for disease management across the season invoiced per HA
FIELD-SPECIFIC RECOMMENDATIONS
Growth stage, disease risks, if and when to spray
PRODUCT SUPPLY
Delivery of required products based on disease pressure
FINANCIAL SECURITY
Grower peace of mind through fixed price and guarantee (compensation if disease above threshold)
RESTRICTED


PreDiMa will help growers balance a shifting set of challenges by optimizing agronomic benefits with profitability and sustainability
Agronomy
Optimization target
Sustain-ability
Profitability
PreDiMa
Agronomy
Growers expect consistent and plannable yields and grain quality (not necessarily highest yield)
Sustainability
Increasing importance due to regulatory and societal pressure
Growers need to make the most out of fewer AIs, lower dose rates and fewer spray applications
Profitability
Growers face increasingly difficult financial tradeoffs regarding overall risk, labor & input costs and commodity prices
RESTRICTED


Three digital products currently support our offer
Enrollment & Commercial offer
Multi-account agronomy
In-Season / Agronomy
Field data management
Distributor Tool (web-based application)
PreDiMa App (iPhone / Android)
Climate FieldView
CLIMATE FIELD VIEW
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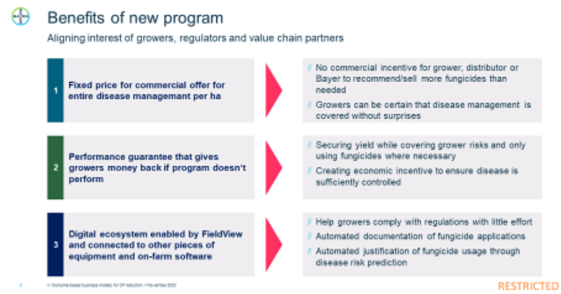
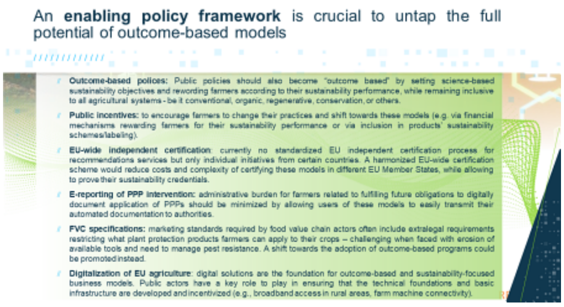

Benefits of new program
Aligning interest of growers, regulators and value chain partners
Fixed price for commercial offer for entire disease managemant per ha
No commercial incentive for grower, distributor or Bayer to recommend/sell more fungicides than needed
Growers can be certain that disease management is covered without surprises
Performance guarantee that gives growers money back if program doesn't perform
Securing yield while covering grower risks and only using fungicides where necessary
Creating economic incentive to ensure disease is sufficiently controlled
Digital ecosystem enabled by FieldView and connected to other pieces of equipment and on-farm software
Help growers comply with regulations with little effort
Automated documentation of fungicide applications
Automated justification of fungicide usage through disease risk prediction
RESTRICTED


An enabling policy framework is crucial to untap the full potential of outcome-based models
Outcome-based polices: Public policies should also become "outcome based" by setting science-based sustainability objectives and rewarding farmers according to their sustainability performance, while remaining inclusive to all agricultural systems - be it conventional, organic, regenerative, conservation, or others.
Public incentives: to encourage farmers to change their practices and shift towards these models (e.g. via financial mechanisms rewarding farmers for their sustainability performance or via inclusion in products' sustainability schemes/labeling).
EU-wide independent certification: currently no standardized EU independent certification process for recommendations services but only individual initiatives from certain countries. A harmonized EU-wide certification scheme would reduce costs and complexity of certifying these models in different EU Member States, while allowing to prove their sustainability credentials.
E-reporting of PPP intervention: administrative burden for farmers related to fulfiling future obligations to digitally document application of PPPs should be minimized by allowing users of these models to easily transmit their automated documentation to authorities.
FVC specifications: marketing standards required by food value chain actors often include extralegal requirements restricting what plant protection products farmers can apply to their crops – challenging when faced with erosion of available tools and need to manage pest resistance. A shift towards the adoption of outcome-based programs could be promoted instead.
Digitalization of EU agriculture: digital solutions are the foundation for outcome-based and sustainability-focused business models. Public actors have a key role to play in ensuring that the technical foundations and basic infrastructure are developed and incentivized (e.g., broadband access in rural areas, farm machine connectivity).

Innovations in Application Technology for Crop Protection

Dr. Peter Hloben, Deere & Co.

23. November 2023, JCR Alternative Business Models for Pesticide Reduction Workshop, Sevilla, Spain

JOHN DEERE

Agenda

1. Introduction
2. Innovations in Field Crops Sprayers
   - See & Spray™ Select
3. Data, Networks, Documentation
4. Proposal for Incentives Programs

Introduction

Key Challenges in Crop Protection

- Growing problems with **resistances** against herbicides, fungicides
- Reduced **portfolio availability** of plant protection products
- More and tighter (application) **restrictions**
- Biological effectiveness while meeting up to 95-99% **drift reduction**
- Narrower **operating windows** to spray at optimum timing
- Higher complexity and more **expertise** required for spraying
- **Public & legal pressure** to minimize use of chemicals

EU Targets

State-of-the-Art (for Professionals)

Basic technologies necessary for precision application:

- Application map ("off-line" application)
- Task controller (ISOBUS)
- GNSS based Section, or Individual Nozzle control
- Automatic boom height adjustment

IVA study* on technology adoption in Germany:
Use of Weed/Application map: **ca. 24 %**
Section control or INC: **ca. 56%**

Technological Innovations - Field Crops

Classification / Terminology for Different Spray Methods

– JKI Proposal (modified)

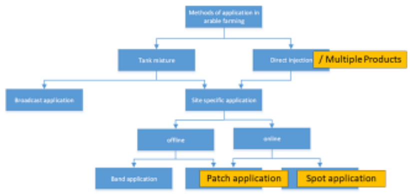


Figure 1: Classification of different spray methods for the application of Plant Protection Products.

Key Technologies for High Precision Application

Individual Nozzle Control with PWM

Technology Developments

- Individual nozzle control
- Pulse Width Modulation (PWM)
- Manual and automatic nozzle switch from the cab
- Curve compensation
- Volume flow adjustment of each individual nozzle position

Benefits and Customer Value

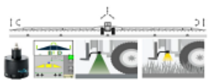
- Much wider speed range with constant rate and droplet size
- Variable application rate with constant spray quality
- Application rate control per individual nozzle possible
- Droplet size and flow rate can be set completely independently

Key Technologies for High Precision Application

High Precision 3D Boom Control

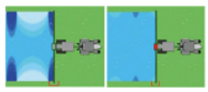
Technology Developments

- Automatic boom height and inclination control of spray nozzles and the angle of the individual boom arms
- Distance measurement to the ground, crop canopy or hybrid mode
- Advanced boom yaw control of horizontal movements
- High-strength, stable, lightweight construction (e.g. carbon fiber)



Benefits and Customer Value

- Better longitudinal and lateral distribution of spray liquid
- Reduction of over and underdosing
- Less spray drift and better crop penetration
- **Precondition** for precise and selective application



Key Technologies for Selective Application

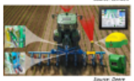
Band Spraying with Boom Sprayer

Technology Developments

- Targeted row or band spraying with field sprayers
- Nozzles with a narrow spray angle (30 or 40°) and rectangular distribution
- Adjustable nozzle spacing for adaptation to row widths
- Highly precise nozzle positioning, and boom row guidance required
- Implement guidance technology enabler

Benefits and Customer Value

- High-precision mechanical weeding combined with band spraying on row
- Targeted application of other PPPs in early growth stages in row crops
- Significant savings potential depending on row spacing and band width
- Low wind spraying conditions required



Key Technologies for Selective Application

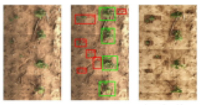
Selective Application of Herbicides with Weed Identification

Technology Development

- Online cameras to differentiate between weeds and crops
- AI and machine learning technology
- Algorithms developed per crop and weed species
- Selective application of herbicides in various stages of development
- Solution approaches with single tank mix or dual application systems

Benefits and Customer Value

- Highest potential for non residual herbicide savings (50-90%)
- Less crop stress and growth depression
- More effective weed control through optimized dosage
- Minimizing the environmental impact
- Single or double product application



John Deere Weed Detection Technologies:

Application of total herbicides with "green objects" detection

- See & Spray™ Select (green on brown)

Selective application of herbicides with weed detection in crops:

- **See & Spray™ Select Plus** (green on brown with rows extraction)
- See & Spray™ Ultimate (green on green)

See & Spray™ Select Plus

- System description

S&S™ Select Plus - System Description

- Originally developed for customers with fallow as part of the cropping rotation
- Further developed for rows extraction and used for spraying weeds within row plant production systems
- Single product application
- Hit-rate equal to broadcast spraying
- Saving up 2/3 of the normal use*

*The actual savings depend on weed density and row spacings. Higher savings are possible with low weed density.

S&S™ Select Plus - System Description

Camera Technology

- Captures field images on the go
- Identifies green objects on brown soil
- Camera spacing: 100 cm (nozzle spacing 50 cm)

Processing Controllers

- Analyze 196 m^2/s at 19 km/h (36 cameras)
- Determines if a green weed/plant is present
- Actuates the correct spray nozzle
- Herbicide hits the weed
- All within **200 milliseconds**

S&S™ Select Plus - System Description

Nozzle bodied & Spray modes

- Utilizes ON/OFF (INC) control for See&Spray
- 2 spray modes:
  - See & Spray from nozzle B
  - Broadcast sprays from nozzle A while using See & Spray from nozzle B.

Operation and Control

- Switch between See & Spray and broadcast from the cab.
- Multiple run page modules to enable on-the fly adjustments
- Ability to dial-in setting preferences
- Diagnostics

S&S™ Select Plus - System Description

Records:

- where chemical has been applied
- how much
- area covered, but not applied

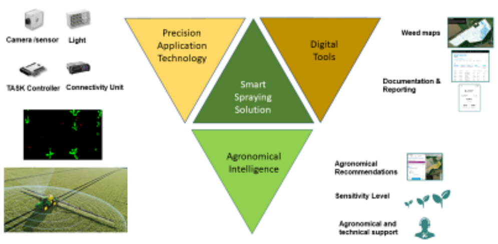
Technological Innovations – Data Networks

Data Collection - ISOBUS

ISOBUS is one-dimensional connection between **Terminal– Implement – Software**

The future is **multi-dimensional** => Diverse platforms will replace one software.

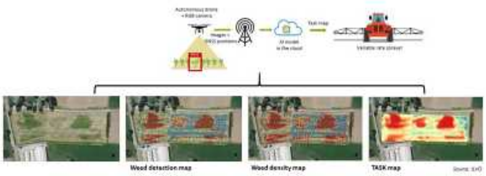
Multi-Dimensional Data Platform for Smart Spraying



Use Case: Creation of TASK map

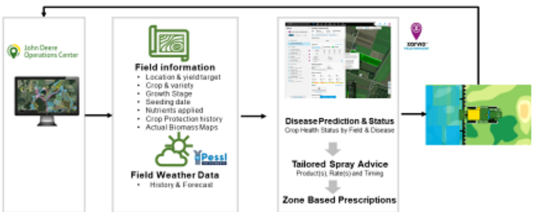
A case study (ILVO):

- Semi-real time TA in maize. TASK map was prepared within ca. 15 minutes (**5G network**):

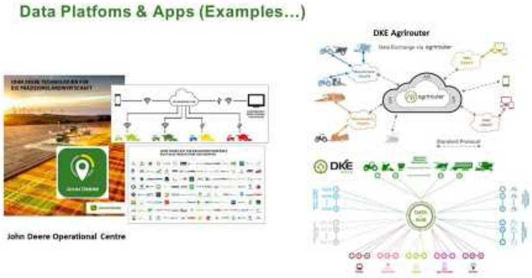


Data Enabled Disease Prediction & Zone Based Spray Advice

Integrated Digital Tools from Decision Support to Precise Spray Execution

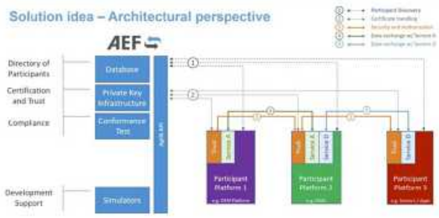


Data Platfoms & Apps (Examples…)



AgIN – Agricultural Interoperability Network

A CEMA/AEF project - a base for a „structural interoperability"



AgIN – Agricultural Interoperability Network

Summary & Discussion

Summary and Outlook

- In the future, crop protection will be much more automated, precise, need based and selective to address major agronomic, economic and ecologic challenges.
- Developments within sensor technology, AI and deep learning offer completely new possibilities for recording field variability and identifying everything from diseases, insects, weeds, to individual plants.
- The weeds/diseases recognition AI models and decision tools will have to be regularly updated.
- To ensure connectivity and seamless data exchange between stakeholders is essential for more targeted and selective manner application and for the general acceptance of these novel technologies.

For Disccussion … Areas of the future incentive programs

- Acquisition cost of machinery / field kits upgrades
- Contractor's service costs per hectare
- Software upgrades (additional crop production, diseases, etc..)
- Fees for mobile internet network – 5G coverage and bandwidth
- License fees for GNSS (RTK)
- License fees for FMIS, other service apps e.g. weather info, scouting, field registers
- Digital documentation – Incentivize data owner for sharing certain data e.g. "as-applied maps".
- Special insurance conditions, or interest rates for those who are using targeted application technology – sustainability goals - reduced volume of applied PPP

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Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Wirtschaft, Bildung und Forschung WBF
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Modelling policies towards pesticide-free agricultural production systems

Gabriele Mack, Robert Finger, Jeanine Ammann, Nadja El Benni

Gabriele.Mack@agroscope.admin.ch

23.11.2023

Political background

- In 2021, two popular initiatives focusing on the reduction of pesticides in Switzerland.
- The reduction in pesticide risks is a key policy goal.
- A national scale direct payment program for pesticide-free, non-organic production systems on arable land in Switzerland was launched 2023.
- Pesticide-free production is under political debate because it might reduce food production

Content

1. Assessment of the adoption potential of policies supporting pesticide-free (non-organic) cropping systems for Switzerland
2. Assessment of the implications of these policies for Switzerland:
   - Food production (volume and value)
   - Income

Public support for arable cropping systems in Switzerland

- Three main cropping systems supported by direct payments in the past:
  1. **Intensive cropping systems** have to meet the Swiss cross-compliance standards. All types of pesticides are allowed.
  2. **Extenso cropping systems**: Application of insecticides, fungicides and growth regulators are not allowed. Eligible crops were cereals, oilseeds, and protein crops.
  3. **Organic cropping systems**: Meeting standards of organic production including a ban on all synthetic pesticides and mineral fertilizers.

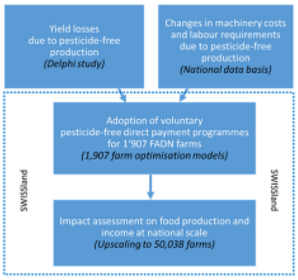
⇨ The environmental goals regarding biodiversity, water, air and soil quality were not achieved!

Public support for arable cropping systems in Switzerland

4. **Pesticide-free but non-organic cropping systems** are supported for cereals, oilseeds and protein crops, potatoes and sugar-beets from 2023 onwards.

Crop type	Pesticide-free cropping systems CHF/ha
Cereals (wheat, barley)	650
Rapeseed	1400
Sunflower	650
Protein crops	650
Sugar-beets	1400
Potatoes	1400

Mixed methods approach



Delphi study

- High-quality responses from a selected panel of experts
- Panel of crop protection consultants:

Organisation	Invited	Participated
Cantonal offices	12	7
Training, advisory and associations	8	5
Research	10	6
Total	30	18

- Questionnaire describing the specific requirements for pesticide-free cropping systems.
- The experts estimated the yield losses (in percentages). For each crop, the experts received a set of reference yields (in dt/ha).
- Average yield losses over a period of 5 years with different disease and pest pressures due to weather changes
- Two Delphi-rounds: Experts re-evaluated the questions, considering the feedback from the first round.

Changes in machinery costs and labour requirements

- Farmers adopt mechanical weeding.
- Additional fixed costs arise for weeders.

Modelling adoption decisions of farmers

- Farm level optimization models to forecast productions decisions (farmer is a profit-maximizer).
- Factors influencing adoption decisions:
  - Yield losses (from Delphi study)
  - Price premium
  - Cost savings (pesticide, hail insurance and cleaning & drying costs)
  - Changes in labour requirements
  - Changes in variable and fixed machinery costs.

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Modeling scenarios

	Reference scenario	Pesticide-free (but non-organic) scenarios		
Name of the scenario	Reference	High loss	Medium loss	Low loss
Expert rating of yield losses from the Delphi study		10% highest ratings	Average of all ratings	10% lowest ratings

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Modeling scenarios

	Reference scenario	Pesticide-free (but non-organic) scenarios		
Name of the scenario	Reference	High loss	Medium loss	Low loss
Expert rating of yield losses from the Delphi study		10% highest ratings	Average of all ratings	10% lowest ratings
Price premium for pesticide-free production		From extenso to pesticide-free: 10% From intensive to pesticide-free: 20%		

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Modeling scenarios

	Reference scenario	Pesticide-free (but non-organic) scenarios		
Name of the scenario	Reference	High loss	Medium loss	Low loss
Expert rating of yield losses from the Delphi study		10% highest ratings	Average of all ratings	10% lowest ratings
Price premium for pesticide-free production		From extenso to pesticide-free: 10% From intensive to pesticide-free: 20%		
National direct payment budget	2.8 bn CHF	2.8 bn CHF Reduction in transitional payments if the budget is exceeded due to the pesticide-free payments		

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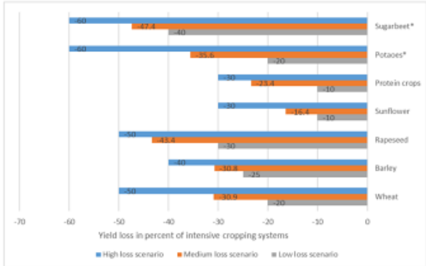
Delphi study: Expected yield losses of intensive cropping systems



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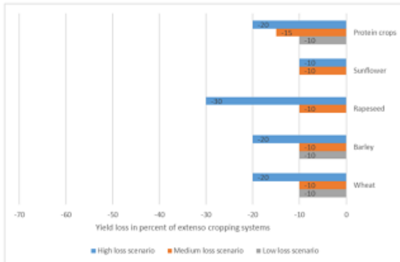
Delphi study: Expected yield losses of Extenso cropping systems



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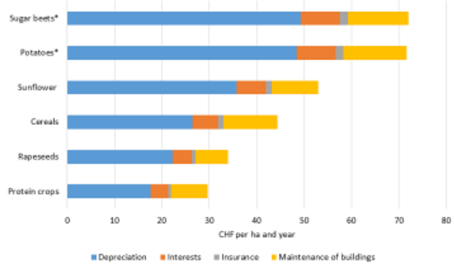
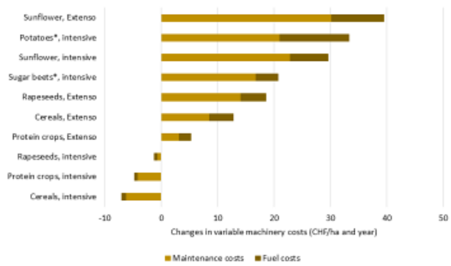
Additional annual fixed machinery costs



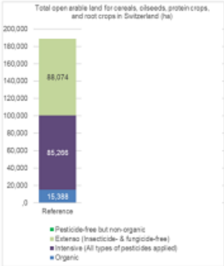
Agroscope

Additional variable costs



Agroscope

Adoption potential of pesticide-free cropping systems



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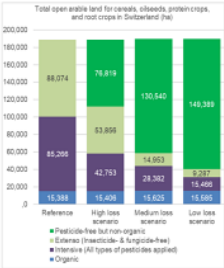
Adoption potential of pesticide-free cropping systems



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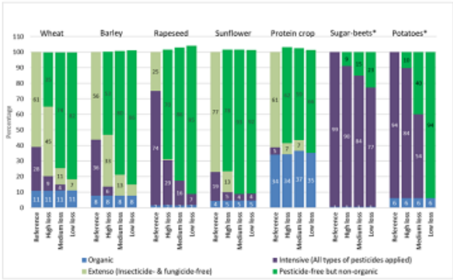
Adoption potential of pesticide-free cropping systems



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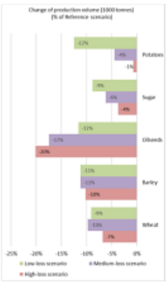
Change of production



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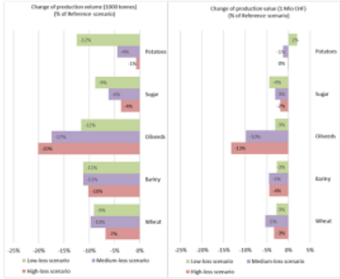
Change of production



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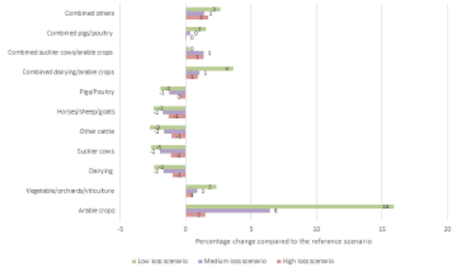
Impact on farmers' income



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Summary & conclusions

- We model the transition to pesticide-free production using a mixed method approach.
- Especially yield losses determine whether pesticide-free cropping systems are adopt-ed.
- Widespread voluntary adoption of pesticide-free systems is possible only if farmers are compensated for yield losses and cost increases
- Flexible, voluntary pesticide-free policy and incentive programmes reduce trade-offs in food production.
- Swiss policy programs will likely trigger large-scale adoption of pesticide-free but non-organic production systems

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Agricultural Systems 207 (2023) 103642

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

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Modelling policies towards pesticide-free agricultural production systems

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HIGHLIGHTS

- We model the transition to pesticide-free production using a mixed-method approach.
- Especially yield losses determine whether pesticide-free cropping systems are adopted.
- Widespread voluntary adoption of pesticide-free systems is possible only if farmers are compensated for yield losses.
- Flexible, voluntary pesticide-free policy and incentive programmes reduce trade-offs in food production.
- Swiss policy programs will likely trigger large-scale adoption of pesticide-free but non-organic production systems.

GRAPHICAL ABSTRACT

European Chemical Pesticide-Free Agriculture in 2050

Presentation: Chantal le Mouël (INRAE SMART)
Coordination: Olivier Mora (INRAE DEPE)
with the contribution of C. Meunier (INRAE DEPE), J-L. Drouet (INRAE ECOSYS/DEPE), J-A. Berne (INRAE DEPE), V. Kieffer (INRAE SMART), L. Paresys (INRAE DEPE), A. Forslund (INRAE SMART)

Workshop on alternative business models for pesticide reduction
22-23 November 2023, JRC, Seville

Why a foresight on European chemical pesticide-free agricuture in 2050?

- Targets of European public policies that are part of the Green Deal (F2F): **- 50% in the use and risk of chemical pesticides** and more hazardous pesticides by 2030
- Limited impacts of past policies in terms of pesticide use justify a change in the approach of innovation in cropping systems (Jacquet et al., 2021): A **paradigm shift** in research from an **incremental approach** aiming at reducing pesticide use to a **disruption approach** aiming at building cropping systems without chemical pesticides
- A foresight study to **explore the possibility of chemical pesticide-free agriculture in 2050 at EU level** and build transition pathways
- Supported by the French national priority research programme (PRP) 'Growing and Protecting crops Differently', and linked (through case studies) to the European Research Alliance 'Towards Chemical Pesticide-free Agriculture'. Presented during a one day conference the 21 March in Paris (https://www.inrae.fr/en/news/european-pesticide-free-agriculture-2050)
- *Chemical pesticides correspond to synthetic pesticides and mineral pesticides that have a negative impact on environment and human health.*

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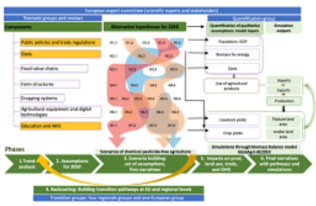
An original foresight method mixing scenario planning, modelling and backcasting



- 2 years project
- A dedicated project team
- 144 European experts mobilised in a European expert committee and thematic experts groups

Three results:

- **Three scenarios and their transition pathways**
- **A quantitative assessment of the impacts of the scenarios**
- **Four case studies in 4 EU regions (Finland, France, Italy, Romania)**

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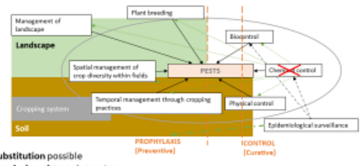
Building disruptive strategies of chemical pesticide-free crop protection in 2050

What strategies for chemical pesticide-free crop protection in 2050?



1. **No simple substitution** possible
2. A need for a **redesign** of cropping systems
3. A shift from a **curative** strategy against pests to a **preventive** strategy (anticipation of pests)
4. Developing tools for **monitoring pests** and the environment
5. Reinforcing **biological regulation** in **soil** and **landscape**
   - mobilising **agroecological** principles,
   - including temporal and spatial **diversification**

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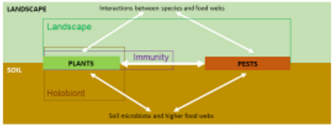
Three disruptive strategies of chemical pesticide-free crop protection in 2050



Cropping systems	Strengthening the **immunity** of cultivated plants	Managing the crop **holobiont** by strengthening **host microbiota interaction**	Designing **complex and diversified landscapes** adapted to local contexts and their evolution

By using plant defence stimulators, biostimulants, biocontrol (Zhang et al., 2020), plant breeding (resistant varieties), by reinforcing interactions with microbiota, other crops and plant services

By developing microbial biodiversity, in order to strengthen the adaptability of the holobiont and the functions of microbiota (Tosi et al., 2020; Simon et al., 2019), by modulating the existing microbiome through agricultural practices, crop choice, inoculations of microorganisms (Berg et al, 2021) and plant breeding (Wallenstein, 2017)

By promoting biological regulations by increasing biodiversity and agrobiodiversity over space and time, building complex landscapes with 20% of the land with semi-natural habitats (Garibaldi et al., 2021; Tscharntke et al., 2021), a changeable mosaic of diversified crops (Alignier at al, 2020; Sirami et al, 2020), and crop diversification at plot level (Tibi et al., 2022; Thomine et al., 2022), and through plant breeding

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Three scenarios of European chemical pesticide-free agriculture in 2050

Scenario 1 (S1) : Global and European food chains based on digital technologies and plant immunity for a pesticide-free food market

Food value chain	Global value chains producing pesticide-free food as a food safety standard	Local, European and global value chains producing healthy foods for a healthy diet	Territorial and regional value chains for food preserving human and environmental health and contributing to diversified landscape
Farm structures	Specialisation and financialisation of farm structures with residual family farms	Regional diversity of farm structures	Territorialisation and diversification of farm structures
Cropping systems	Strengthening the immunity of cultivated plants	Managing the crop holobiont by strengthening host microbiota interactions	Designing complex and diversified landscapes adapted to local contexts and their evolution
Agricultural equipment and digital technologies	Autonomous robots to act on each plant	Pooling of equipment, sensors and data (landscape and organisation scale)	Modularity of equipment for adaptation to practices

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Scenario 1 (S1) : Global and European food chains based on digital technologies and plant immunity for a pesticide-free food market

Durum wheat production in Tuscany (Italy) in 2050

- Global food chains
- Private certifications and international standards for pesticide-free production
- Specialisation and financiarisation of farm structures
- Tools for monitoring pests and individual plant health in the plot
- Robots acting on each plant
- Reinforcing plant immunity through biocontrol and plant defence stimulators
- BAU Diets

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Scenario 2 (S2) : European food chains based on plant holobiont, soil and food microbiomes for healthy foods and diets

Food value chain	Global value chains producing pesticide-free food as a food safety standard	Local, European and global value chains producing healthy foods for a healthy diet	Territorial and regional value chains for food preserving human and environmental health and contributing to diversified landscape
Farm structures	Specialisation and financialisation of farm structures with residual family farms	Regional diversity of farm structures	Territorialisation and diversification of farm structures
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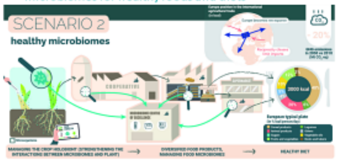
Scenario 2 (S2) : European food chains based on plant holobiont, soil and food microbiomes for healthy foods and diets



Vegetable production in South-East Romania in 2050

- Consumer demand for healthy foods
- European value chains without chemical pesticides
- Impact on the whole food system
- Monitoring of microbiomes: soil, plant, food storage and processing, and final food product
- Crop diversification to respond to the target of healthy diets
- Reinforcing interactions between host plants and microorganisms (management of the holobiont) for crop protection
- Transition to healthy diet, more diversified diets: less calories, less animal products and sugar, more fruits and vegetable, more pulses, diversified cereals

Scenario 3 (S3) : Complex and diversified landscapes and regional food chains for a One Health European food system

Food value chain	Global value chains producing pesticide free food as a food safety standard	Local, European and global value chains producing healthy foods for a healthy diet	Territorial and regional value chains for food preserving human and environmental health and contributing to diversified landscape
Farm structures	Specialisation and financialisation of farm structures with residual family farms	Regional diversity of farm structures	Territorialisation and diversification of farm structures
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Agricultural equipment and digital technologies	Autonomous robots to act on each plant	Pooling of equipment, sensors and data (landscape and organisation scale)	Modularity of equipment for adaptation to practices

Scenario 3 (S3) : Complex and diversified landscapes and regional food chains for a One Health European food system

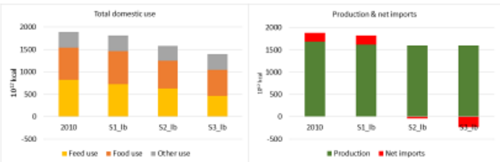
Cereals and oilseeds production in South Finland in 2050

Wine production in Bergerac-Duras (France) in 2050

- Territorial and regional food value chains
- Food protecting human health and environment (One Health)
- UE transition towards One Health approach
- Territorial coordination to reinforce biological regulation (landscape) and relocate value chains
- Complex landscapes with 20% of land dedicated to semi-natural habitats
- Adaptation of the mosaic of crops to the issues of crop protection, temporal diversification of crops
- Monitoring of the environment and anticipation of pests
- Transition to healthy and sustainable diets: less calories, less animal food and more pulses, less sugar

Impacts of the scenarios on European production, trade and GHG emissions

How does the 3 scenarios impact domestic use, production and net imports in Europe?

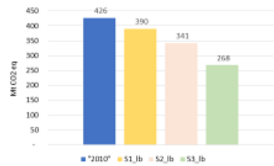


Resource-use balance in "2010" and in 2050 in S1, S2 and S3 (10^{12} kcal)

→ Two scenarios have a positive impact on the European agricultural trade balance in calories

Scenarios contribute to improve the European balance of GHG emissions

- All scenarios (but S1_ub) contribute positively to **decrease European agricultural GHG emissions relative to "2010"**



-8% with S1_lb

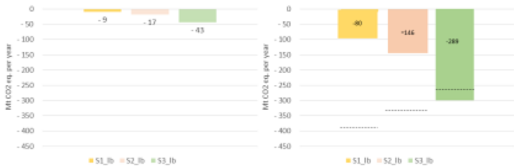
-20% with S2_lb

-37% with S3_lb

Agricultural GHG emissions in Europe in "2010" and in 2050 in S1, S2 and S3 (Mt CO2 eq.)

Scenarios contribute to improve the European balance of GHG emissions

- All scenarios lead to a **decrease in land-use change emissions in Europe**



Land-use change emissions in Europe with S1, S2 and S3 (Mt CO2 eq. per year), under assumption that freed pastureland shifts to schrubland (left panel) or is used to afforestation (with max values for carbon stocks in forest biomass)

Some key messages from the foresight study

- The entire food system, **committing all its actors**, must be considered to build a European chemical pesticide-free agriculture in 2050
- In addition to the shift towards chemical pesticide-free agriculture: **Three scenarios** would contribute to **improving the greenhouse gas balance**, biodiversity and overall ecosystems health in Europe.
  Two scenarios would contribute to **improving food sovereignty** in Europe, human **nutrition and health**
- Key role of **dietary changes** in the transition
- The **diversification** of crops in time and space, the development of **biocontrol** products, bio-inputs, adapted **selected** varieties, agricultural **equipment** and digital tools, and **monitoring** schemes of pests dynamic and environment are key elements to be combined for **an efficient chemical pesticide-free crop protection**. **Biological regulations at the soil, crop and landscape** levels should be favoured, as **prophylactic** actions
- Several chemical pesticide-free cropping systems are possible depending on whether they rely on a **high level of external inputs**, or on **a high level of diversification** and **ecosystem services**
- The transition towards chemical pesticide-free agriculture requires **a mix of coherent public policies** related to **pesticides use**, articulated with other policies such **as food policies**; it involves a transformation of the **Common Agricultural Policy** (CAP) and economic instruments to support the transition ; finally, **trade agreements** at the European Union's borders must be set up to ensure the development of chemical pesticide-free markets
- The transition must also involve **risk sharing** among actors, **co-conception** of technologies and cropping systems, and transformations in the **upstream and downstream sectors** of agriculture

Thank for your attention

More information on the foresight (abstracts, videos, report):

https://www.inrae.fr/en/news/european-pesticide-free-agriculture-2050

Contact: olivier.mora@inrae.fr and chantal.le-mouel@inrae.fr

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A focus on the hypotheses on breeding and monitoring in the three crop protection micro-scenarios

Hypotheses on breeding in the three crop protection micro-scenarios

➢ **Classical selection on the basis of durable resistance criteria**

Breeding programmes aimed at improving the resistance of crops to pests. Focus on other traits: response of the crop to biocontrol, plant defence stimulators, biostimulants, etc.

Selection of tolerant varieties

➢ **Selection on new criteria integrating soil and microorganisms**

Breeding programmes focused on the ability of plants to interact with the soil microbiome to recruit microorganisms that enable plants to better defend themselves against pests and limit their development in the soil

Selection aimed to strengthen interactions between plants and soil microorganisms, to produce seeds with a microbial population adapted to the local environment (in the plot) and to cropping practices, or to improve plant nutrition thanks to microorganisms.

➢ **Selection on new crop diversification criteria**

Breeding programmes aimed at creating varieties adapted to mixtures, 'population varieties' or species adapted to associations and to local contexts

Selection of varieties for their own value and also for their capacity to be mixed and to optimize (positive) interactions between neighbouring plants within the cultivated plot

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Table [illegible]: The monitoring hypotheses in the three crop protection micro-scenarios

Crop protection micro-scenario	*Managing the holobiont of cultivated plants*	*Designing complex and diverse landscapes*	*Strengthening the immunity of cultivated plants*
Monitoring and surveillance hypothesis	**Monitoring of the holobiont, microbial biodiversity and microbiota**	**Monitoring of biological regulations and biodiversity at the landscape scale and anticipating their effects on crops**	**Monitoring the health of the plant (immune and physiological state) and its environment**
Purpose of monitoring	*Microorganisms and their relationships with the cultivated plant (microbiota including soil)* - Characterising reservoirs of microbial diversity and their dynamics over time - Characterising the functions of the microbiota ('core' microbiota) - Characterising the adaptability of the holobiont (ability to recruit microorganisms)	*Biological regulations and their effects on crops and biodiversity at the landscape scale* - Evaluating and explaining the effects of interactions between pest population dynamics, biodiversity, practices and climatic context on crops	*Immune and physiological state of cultivated plants and their biotic and abiotic environment* - Characterising the immune and physiological state of cultivated plants - Characterising the state of the biotic and abiotic environments of cultivated plants
Scale	Plot	Landscape/Plot	Plant/Plot/Landscape
Monitoring indicators	- Indicators of the functions carried out by microbiota, to identify situations where there is an absence of microorganisms from the 'core' microbiota crucial for plant defences - Markers characterising healthy or sick plants (dysbiosis situations) - Markers for **pathogen presence** (bacteria and fungi)	- Indicators of effects on crop yields (damage and/or crop losses with redefined damage thresholds) and on **biodiversity** (other living organisms not harmful to crops) - Indicators explaining these effects: • indicators relating to pest population dynamics • indicators relating to biodiversity (beneficials and agrobiodiversity) • indicators relating to agricultural practices, composition and configuration of the crop mosaic • indicators relating to the climatic context	- **Molecular** indicators of the immune and physiological state of cultivated plants (concentration of certain pigments or metabolites, etc.) - **Optical** indicators; **biological** indicators (characterisation of seed, aerial and soil microbiota; growth and senescence of cultivated plants; presence of pests, pathogens or weeds) and **agronomic** indicators (crop successions and cropping practices, weed state, varieties, rootstock) - **Physico-chemical** indicators of the state of the aerial and soil abiotic environment of cultivated plants (weather conditions, soil characteristics, VOC contents, etc.)

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Crop protection micro-scenario	*Managing the holobiont of cultivated plants*	*Designing complex and diverse landscapes*	*Strengthening the immunity of cultivated plants*
Monitoring and surveillance hypothesis	**Monitoring of the holobiont, microbial biodiversity and microbiota**	**Monitoring of biological regulations and biodiversity at the landscape scale and anticipating their effects on crops**	**Monitoring the health of the plant (immune and physiological state) and its environment**
Monitoring and information processing methods	*Soil microbiota diagnostic tools* - **Metagenomic tools through sequencing of** microorganisms to identify the diversity of pathogens and commensal or mutualistic microorganisms - **Automated analysis based on interpretation algorithms** to characterise the functions of microorganisms within the microbiota - Tools to characterise the presence of **mycorrhizae** in soils - **Shared proximity detection** tools to detect the presence of symptoms in plants *Monitoring actors:* - **Participatory monitoring** by farmers' groups	*Diagnostic tools for biological regulations and their effects:* - **Automated monitoring with sensors** (high temporal and spatial resolution) **combined with rapid monitoring** (less precise, more qualitative observations) - **Inter- and intra-annual monitoring** of relationships between indicators - Models for **mapping the spatio-temporal diffusion** of pests *Monitoring actors:* - **Participatory monitoring** by landscape stakeholders (citizens, agricultural supply chain stakeholders, non-agricultural stakeholders), action funders	*Diagnostic tools for the immune and physiological state of cultivated plants:* - **Genomic and molecular analyses** (destructive methods) of cultivated plants to quantify molecular indicators - **Electronic noses** under development to quantify olfactory indicators - **Sentinel plants** (trap plants) established in the plot or landscape - **Proxidetection** (e.g. ground sensors, drones, etc.) at the local scale (plant and its immediate environment) or remote sensing (e.g. drones, satellites, etc.) at large spatial scales to quantify optical indicators *Monitoring actors:* **Collective organisation and management** of observation tools, digital information processing technologies, data and results produced by monitoring
Mobilisation of monitoring for crop protection	- **Systemic and historical approach**: thinking about crop successions based on knowledge of (1) the state and history of the soil microbiome, (2) the cropping system and (3) indicators of soil fertility in order to select microorganisms favourable to crops (e.g. symbioses) - **Collective learning approaches** for new tools within groups of farmers to build knowledge for the interpretation of data and design of *in situ* holobiont management strategies	- **Systemic and adaptive approach**: learning about the interactions and transformations operating within landscapes, **capitalising year on year** to transform experience into decision rules - **Sharing of risks and benefits at the landscape scale**, accountability of landscape stakeholders for the effects of their actions - **Network for the exchange** of experiences and knowledge within and between landscapes	- **Thinking about** successions and cropping practices based on past and present data on the immune and physiological state of cultivated plants, pest presence and the state of the biotic and abiotic environment of cultivated plants - **Training and collective learning systems for farmers and other agriculture-linked territorial stakeholders** for the acquisition/processing/use of data and results, so as to enable them to share advice, data and agricultural equipment to assess the immune status of plants and intervene preventively rather than curatively

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Transition pathways towards European chemical pesticide-free agriculture by 2050

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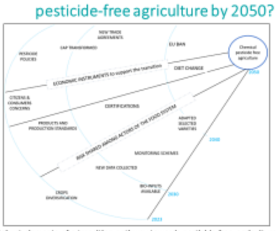
Is there a highway to support the transition towards European chemical pesticide-free agriculture by 2050?



Robust elements of a transition pathway towards pesticide-free agriculture

In all the scenarios, **strong and coordinated measures** are required for a successful transition:

- Key role of **consumers**, citizens and inhabitants in the transition. Concerns about impacts of chemical pesticides. Shift of their **dietary patterns** (S2 and S3).
- **Mix of public policies**: **regulatory policies** for reducing and ultimately banning chemical pesticides, **sectoral policies for supporting farmers transition** (a redesign of the **Common Agricultural Policy**), **environment policies**, **food and nutrition policies** to support transition to healthy diets (S2 and S3).
- New **trade agreements** with non-European partners in order to develop a pesticide-free European market.
- New production **standards**, enabling the **certification** of productions, and their valorisation through food **labels.**
- Mechanisms for **sharing the risks** among the different actors involved in the value chain through market contracts, or in the territory.
- Agricultural, knowledge and innovation systems for knowledge **creation and co-conception** with farmers, of pesticide-free cropping systems (inc. Living labs).

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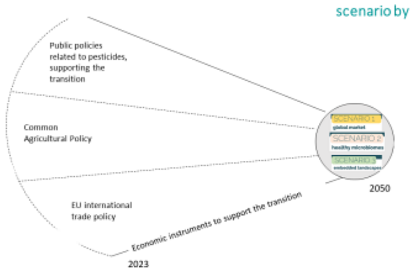
Building coherent hypotheses of public policies for the transition to each scenario by 2050



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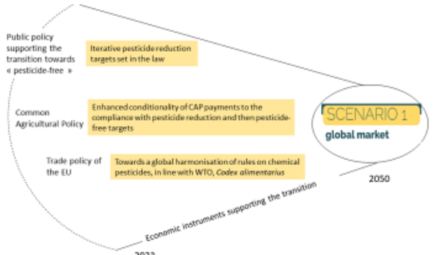
Hypotheses of public policies for the transition towards scenario 1



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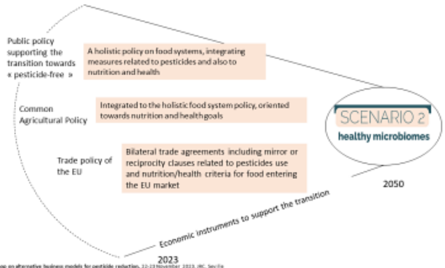
Hypotheses of public policies for the transition towards scenario 2



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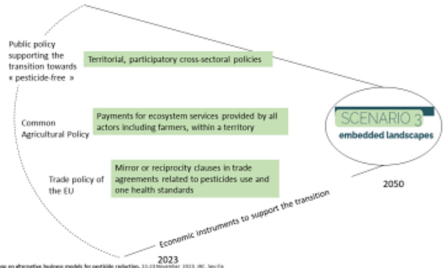
Hypotheses of public policies for the transition towards scenario 3



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Knowledge and technologies needs to support the disruptive strategies in crop protection by 2050

Strengthening the immunity of cultivated plants (S1)

- Existing knowledge on molecular mechanisms of action and on partial resistance to pests (plant defence stimulators, service plants, or flash UV-C)
- Knowledge needs to cover the **interactions between the various levers to stimulate plant immunity**, identify **plant immunity markers**, and **map resistance genes** to the main pests

Managing the crop holobiont by strengthening host microbiota interaction (S2)

- Existing knowledge on mycorrhization, and tools for assessment of the genetic diversity and the detection of microorganism
- Knowledge needs to understand better the **link between a specific microbial community structure and its functional traits**, identify the **microbial communities** that are important for the different crops and their dynamics, and determine the ways to **modulate the soil microorganisms**

Designing complex and diversified landscapes adapted to local contexts and their evolution (S3)

- Existing knowledge on the principles and mechanisms linked to crop diversification and landscape design
- Knowledge needs on **modelling tools** for anticipating the **quantitative impacts of crop diversification** and **semi-natural habitats** on biological regulations and the quantitative **impacts of pests on crops** as well as **working out solutions for perennial crops**

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GlobAgri, AE2050 version

- Biomass balance model: no price, no economics
- **One resource-use equation per product and per geographical region:**
  - Total use (food+ feed+ other) + Exports = Production + Imports
  - Linkages between equations, e.g., animal products and crops equations linked through feed
- Imports : fixed share of total use
- Exports : fixed share of world market
- **One trade balance equation per product**
- **One constraint per geographical region:**
  - cropland ≤ max cultivable area
  - Binding constraint: export coefficients reduced; import coefficients increased
- Pastureland area adjusts freely
- AE2050 version of GlobAgri:
  - AE2050 : Place des agricultures européennes dans le monde en 2050 (Tibi et al., 2020)
  - 21 broad world regions, including **8 European sub-regions**
  - 38 agri-food products
  - Base year: **"2010" (average 2009-2010-2011)**

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GlobAgri, AE2050 version

- GlobAgri simulates the impacts of changes in uses (food and other) on:
  - Agricultural production and trade
  - Agricultural land area (cropland and pastureland)
  - GHG emissions (agricultural emissions and land-use change emissions)
- **Simulating a scenario to 2050 requires to assign a quantitative value for 2050 to each input variable/parameter of the model.** That is in GlobAgri to:
  - Population, diets, other uses
  - Import coefficients, export coefficients
  - Crop yields, cropping intensities
  - Livestock efficiencies, grazing intensities
  - Maximum cultivable areas
- For each input variable/parameter of the model, assumed **quantitative values for 2050 are different**:
  - according to **products**
  - across **geographical regions (incl. 8 European sub-regions)**
- For non-European regions, input quantitative values:
  - are based on the AE2050 study
  - are the same in all scenarios

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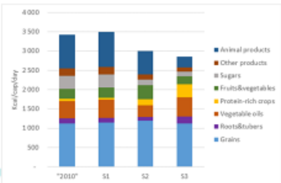
European diets in 2050 in the 3 scenarios

- Where our assumptions come from?

Scenarios	S1	S2	S3
Assumptions for diets in 2050	Trend	Healthy	Healthy and environmental friendly
Based on literature review and expert interviews (2)	FAO (2018)	Agrimonde-Terra (2018) & AE2050 (2020)	Willet et al. (2019) Eat Lancet FLEX



- What are the implications of our assumptions on the average European diet in 2050?

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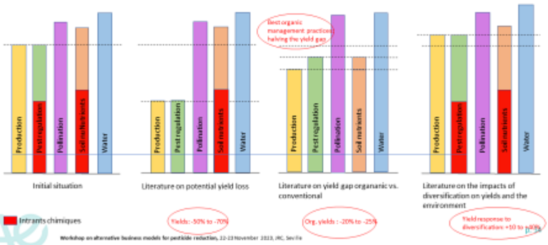
p. 33

Crop yields in Europe in 2050 in the 3 scenarios

- Where our assumptions come from? (inspired from Bommarco et al., 2013)



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Crop yields in 2050 in Europe in the 3 scenarios

- Where our assumptions come from

Scenarios	S1	S2	S3
Assumptions for crop yields in 2050	**Reference:** AE2050 low yields **Lower-bound (lb) :** Based on yield gaps organic vs. conventional AE2050 low yields – ½ yield gaps **Upper-bound (ub) :** Based on the yield response to diversification set at 20% Lower-bound + 50% yield response to diversification	**Reference:** AE2050 low yields **Lower-bound (lb) :** Based on yield gaps organic vs. conventional AE2050 low yields – ½ yield gaps **Upper-bound (ub) :** Based on the yield response to diversification set at 20% Lower-bound + 75% yield response to diversification	**Reference:** AE2050 low yields **Lower-bound (lb) :** Based on yield gaps organic vs. conventional AE2050 low yields – ½ yield gaps **Upper-bound (ub) :** Based on the yield response to diversification set at 20% Lower-bound + 100% yield response to diversification
Based on literature review, quantification group and one expert interview	Bommarco et al. (2013) Yield gaps org. vs conv.: De Ponti et al. (2012) Yield response to diversification: Tibi, Martinet, Vialatte et al. (2022)	Bommarco et al. (2013) Yield gaps org. vs conv.: De Ponti et al. (2012) Yield response to diversification: Tibi, Martinet, Vialatte et al. (2022)	Bommarco et al. (2013) Yield gaps org. vs conv.: De Ponti et al. (2012) Yield response to diversification: Tibi, Martinet, Vialatte et al. (2022)

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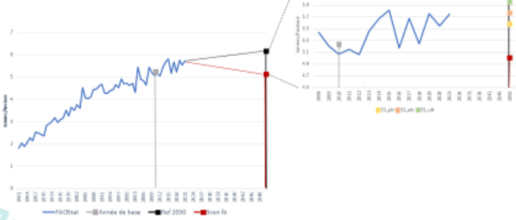
Crop yields in 2050 in Europe in the 3 scenarios

- What are the implications of our assumptions on average wheat yield in Europe?



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confidential

VITIREV
Insurance policy to cover yield losses from diseases in vineyard along with reducing pesticides use

Dimitri LELY, head of agricultural department (GCA) – DLELY@groupama-ca.fr
Baptiste DUBOIS, in charge of agricultural climate insurance (GMA) – baptiste.dubois@groupama.com

Groupama

Political context

- French government has launched from 2010 a national **program of investment for future**
- It includes a financing for regional administration
- French region « **Nouvelle Aquitaine** » has started a project named « **VitiREV** » to promote global change in **wine production** :
  - Environment care
  - Society challenges
  - Protection of biodiversity

Groupama 2

Context : the insurance part

- **Goal to achieve**
  - Experiment an insurance contract to protect wine producers against new risks coming from transition toward a more sustainable way to grow vineyard
- **Issues**
  - Multi-Peril Climate Insurance (MPCI) as the only protection against risks but only for climate losses (the premium is partly subsidized)
  - Wine producers are still challenging MPCI's benefit : less than a half are insured
  - Pesticides are cheaps and don't weight a lot in the cost of production of wine
  - Pesticides are the easiest way to prevent from diseases damages
  - In case of severe event, farmers often get financial help from the government (ex : 2023 mildew)
- **Targets**
  - A decrease of 50% in pesticides use compared to 2017-2019 mean
  - 60% of wine producers insured
  - 90% of customer satisfaction
  - 10% claims

Groupama 3

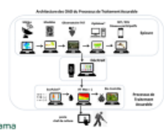
Context : project members

- « Nouvelle-Aquitaine » regional administration
- French Institue of Wine (IFV), head of the project
- 2 wine coopératives : Buzet and Tutiac, field support
- University of Bordeaux
- Groupama (Centre-Atlantique and Groupama Mutuelles Assurances), the insurer

Groupama 4

The insurance contract

- **Special coverage provided against yield losses from main diseases in vineyard**
  - If a specific pesticides plan is followed by the farmer, calibrated to reduce pesticides use by 50%
  - It requires to be insured with an MPCI contract
- **Insurance policy :**
  - Yield losses
  - Caused by mildew and/or black-rot and/or powdery mildew, the three main diseases in vineyard
  - If the farmer follows the advice from the IFV's tool regarding pesticides use : « Decitrait »



Inputs : weather, wineyard growth, pest development, models

⇒Powered in the tool « Decitrait »

Output : advice for pesticides use along with a reduction of 50% of the total amount of fungicides

Groupama 5

The insurance contract

How to manage the 2 different insurance policies taking into account the expectations of the wine producers

- 2 different yields insured :
  - MPCI : best yield between five-year olympic mean and three-year mean
  - Insurance policy against diseases risk : best yield from the past 5 years
- 2 different deductibles :
  - MPCI : between 20 and 30%
  - Insurance policy against diseases risk : no deductible
- Loss adjustment : based on the official statement to French administration made by each wine producer every year

Expectation from wine producers

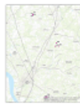
Expectation from wine producers

Groupama 6

The experimental plan

Plots

- 2019 / 2020 / 2021 / 2022 : 4 plots
  - Cooperative 1 : 3 plots => 30 ha
  - Cooperative 2 : 2 plots => 26 Ha (conventional) et 1 plot => 10 ha (bio)

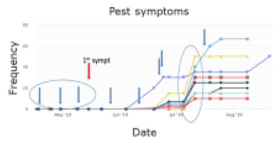


Data collected

- Weather conditions (rainfall, temperature)
- Pest symptom
- Agricultural tasks
- Vineyard growing period
- Yield components

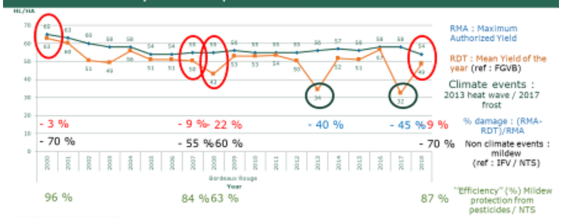
Goal

Collect as much data as possible in order to :
- calibrate a pricing model
- build an index based insurance



Groupama 7

Yield variability : example of Bordeaux red wine



Insurance results

- 2019 / 2020 / 2021 : good efficiency of the pesticides plan adviced by Decitrait (decrease by 50% of the pesticides use without any yield loss)
- 2022 : dismatch between rainfall data from MeteoFrance *vs* individual data => not enough amount of pesticides adviced by Decitrait, which led to significant damage on the vineyard

Year	Premium	Payouts	Loss ratio
2019	0	0	0
2020	13,6 k€	13,7 k€	101 %
2021	19,5 k€	0	0%
2022	12,8 k€	123,4 k€	968%
Total	45,8 k€	137,1 k€	299%

Groupama 9

Assessment

- **Significant payouts for farmers : enable them to start a new production cycle after important losses**
- **Reduction in pesticides use**
- **To be improved**
  - Many difficulties from the coexistence of 2 different contracts
    - Interaction between climate and pest
    - Not easy, even impossible, for a loss-adjuster to split the damage between the different perils
    - Payout for diseases damages are complicated to assess and always challenged by farmers
    - Experimental plan impossible to spread out at a large scale
  - Tool for treatment advice « Decitrait » has to be improved
    - Not enough sensibility tests to challenge the variability of the advice
    - Not enought data about the efficiency of the treatment advice
      - Too many constraints to get a control sample untreated in each plot
      - Significant variability between 2 different plots
  - A system is required to be able to record the treatment application by the farmer (date, amount and type of pesticide) to challenge if effective or not
    - Pesticides applied in right conditions : damage covered
    - Pesticides not right applied du to lack of time, machinery unavailable, etc. : damage not covered

Groupama 10

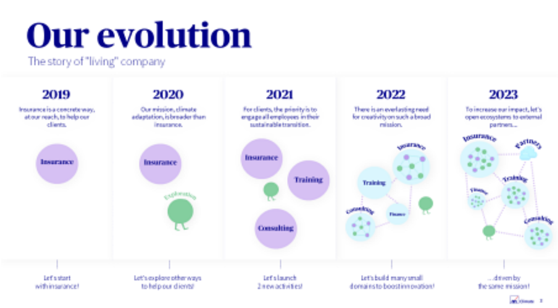
Target for an insurance contract

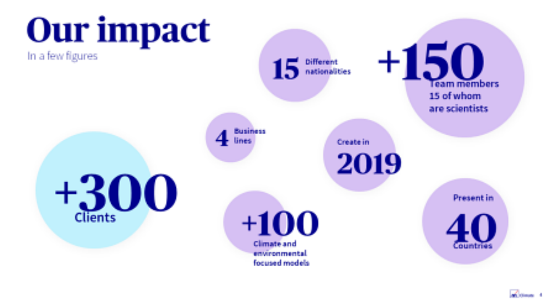
- Keep recording data : sensors, weather conditions, etc. to finaly get an index based insurance
- Same coverage for both insurance contracts
  - Same deductible from climate losses and pest losses, same yield insured, same areas insured
  - Lost-adjustment based on the official statement to French administration
- Challenge and communicate the economic issues regarding pesticides cost vs insurance premium
  - Amount of pesticides saved using Decitrait
  - Improve the pricing model of the insurance policy
  - Get subsidized from French government as an additional coverage to MPCI
  - Keep encouraging farmers to reduce their pesticides use (Ecophyto)
- Make/Keep the link with other projects in progress or to be started
  - VitiDATA to gather together all data related to wine production
  - Tools to record agricultural practices (ex : Ekylibre)
  - Vinovert : link between wheather conditions and pest spreading
  - Spread out to other vineyards and/or more areas

Groupama 11

OUR INTENTION TODAY

1. Intro AXA Climate
2. Case study
3. Q and A





Our mission: to de-risk the transition to regenerative agriculture

Our expertise: data driven experts of innovative risk-transfer solutions

Insurance to Derisk the Regenerative Agriculture Transition

23% of greenhouse gas (GHG) emissions from agriculture using 38% of land as crop yields and biodiversity decrease and populations increase

Regenerative techniques help to **sequester carbon**, and reduce scope 3 emissions to deliver on Science Based Targets for reporting but are hard to quantify

The transition to regenerative farming is **cost intensive** with payback and improved soil health only possible after the first few years, hurting farmers

De-risking the transition to regenerative farming will increase speed of adoption, generate long term returns, and embedded emissions reduction

$100 Billion Opportunity

in shift to regenerative agriculture and decarbonization to 2050 with need for investors and corporations to take the lead and be regulation ready

Insurance to Derisk the Regenerative Agriculture Transition

23% of greenhouse gas (GHG) emissions from agriculture using 38% of land as crop yields and biodiversity decrease and populations increase

$100 Billion Opportunity

Main reason for no transition are:
- Lack of knowledge
- Financial risk

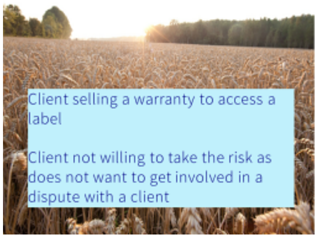
De-risking the transition to regenerative farming will increase speed of adoption, generate long term returns, and embedded emissions reduction

the lead and be regulation ready

Challenges we face

- Internal (not willingness to insure new things)
- Scientific (little knowledge of the risk)
- Willingness to pay

Regen case study #1 Wheat



Client
Input provider XXX helping farmers receive "No Pesticide Residue Label" (SRP – in France)

Challenge
Encouraging farmers to change pesticide practices

Commodity
Soft wheat

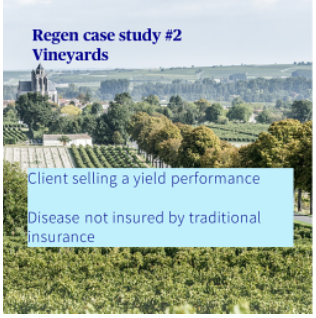
Solution
Commercial guarantee to cover potential revenue loss for farmers using new pesticide protocol

Benefit
Incentivize farmers to adapt pesticide use and increase revenue

Methodology
Definition of clear agronomic guidelines and verification of the absence of pesticide residue on site

Next step
Following up on renewal

Regen case study #2 Vineyards



Client
Rémy Cointreau Wine Producer

Challenge
Risk of disease outbreak when suppliers switch to bio control

Solution
AXA Climate consulting climate adaptation assessment

Hybrid insurance solution covering disease outbreak for grape producers

Benefit
Greater acceptance of transition to bio control, less pollutants in water, less impact on biodiversity

Methodology
In field disease occurrence measurement with remote or on-site loss adjustment

Next step
Claims payment and scaling in other markets

Nature Insurance Product Roadmap: Agri, Carbon, Forestry Focus

Focus on row crops, exploring specialty crops, carbon markets, diversifying into forestry, new geographies

Stage 1 Scaling Team: 2023
Regen Ag Yield/Revenue Loss Insurance
Pesticide Reduction/Label Insurance
3 France pilots, securing new pilots
Speiro claims management platform
Yield database, eDNA biodiversity pilot

Stage 2 Scaling Pilots: 2024
Forestry Peril Insurance
Testing with Belgian client
Agri Green Score Incentive
Testing with brokers in Americas

Stage 3 Scaling Partners: 2024
Agriculture Fund to Support Scale Pilots
Investor outreach
Input, equipment, MRV partners

Stage 4 Piloting Carbon: 2024
Agro-Forestry Carbon Credit Guarantee
Cover perils, emergence risk
Credit shortfall cover via cash/credits
Mambok reforestation project in Brazil
TBC

Stage 5 Piloting NBS: 2025
Other Nature Based Solutions
Coral, mangroves, biochar, silvopasture
Co developing offering with consulting

Stage 6 Scaling Distribution: 2026
Derivatives Product Offering
Testing with banks and commodity buyers

Covering grape diseases under biocontrol treatement

Covering risk of disease outspread when you switch from conventional fungicides toward biocontrol

Use of decision support tool
Decitrait from IFV

- What is covererd?
  - Yield losses linked with the outspread of wine disease (mildew, powdery mildew (oidium), black rot)
- What are the condition for the coverage to be valid?
  - Pest management strategy is based almost exculsively on biocontrol treatements
  - The grapes are appropriately protected using the biocontrol treatment (the use of a decision support tool is mandatory)
- How are the losses assessed?
  - Physical loss adjustement is performed in the grapes at specific development stages to asses yield losses
  - Correct usage of the biocontrol treatement is evaluated using a set of rules that relies on comparing actual applications with the recommendation of the descision support tool

Our recommendation for scaling these initiaves

1. Clearer pan European standards are needed to define requirements for labels such as no pesticide use. Similar harmonization of organic, regenerative, or emissions reduction labels or standards is also needed to make it easier for growers and consumers to understand.

2. Education and Training support for the food industry, farmers, and consumers to help them to understand how to reduce pesticide use and to introduce more regenerative practices would help to scale these initiatives.

3. Insurance subsidies condition to sustainable agriculture practice and/or subsidies to agriculture insurance products supporting the agriculture transition. EU farm subsidies scheme could help to encourage more farmers to adopt these practices by helping to de risk the process.

4. Digitalization of agriculture would help controlling farming practices and thus not only controlling sustainable farm management practices but also losses estimation for faster insurance payment

5. Support for scientific research is also needed to help to further digitize the monitoring of pesticide use and modelling to show how this impacts biodiversity and soil health.

Insurance pilot 2023

- Covering 20ha+ on two different sites
- Insured value of 21700€/ha

Situation 2023

- Exceptionally challenging situation in south western France
- The Cognac region was slightly better than Bordeaux, but still very high pressure, especially when renouncing to use chemical fungicides

Q & A

Climate

Regenerative Agriculture Examples

Client projects ongoing demonstrating insurance helps growers to transition

Client	Transition Insurance Projects
Cooperative scaling transition program introducing more eco-friendly agriculture practices	**Challenge:** Convincing growers to change practices and participate in transition program **Solution:** Yield reduction coverage following implementation of cover cropping, nitrogen reduction, residue management **Benefit:** Maintaining grower participation and trust in cooperative **Methodology:** Yield comparison between transition and reference groups
Wine producer increasing growers introducing bio control with disease outbreak coverage	**Challenge:** Risk of disease outbreak when switching to bio control inputs **Solution:** Covering disease outbreak for grape producers supplying the wine industry **Benefit:** Greater acceptance of transition to bio control following claims payment **Methodology:** In field disease occurrence measurement, introduction of decision support tool to verify biocontrol use
Input provider helping farmers receive "No Pesticide Residue Label" with revenue loss insurance	**Challenge:** Encouraging farmers to change pesticide practices **Solution:** Commercial guarantee to cover potential revenue loss for farmers using new pesticide protocol for soft wheat **Benefit:** Incentivize farmers to adapt pesticide use and increase revenue **Methodology:** Definition of clear agronomic guidelines and verification of the absence of pesticide residue

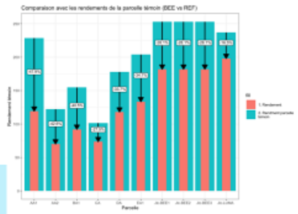
Outcome 2023

- Plots with biocontrol treatment systematically have lower yield than the ones with conventional treatment
- Strong heterogeneity in the losses, even if all plots are from the same varieties (Ugni Blanc)
  - One site more affected than the other (slightly different situation in term of precipitation)
  - Younger plot seems to be more affected than older ones

The impact of not using chemical fungicides is particularly strong in challenging years like 2023

Final **payout of 107'000€** to compensate losses related to renunciation to chemical fungicides

"After a year like this one the insurance is reassuring us, and we can continue on our goal to reduce the usage of chemical pesticides"
Responsible of the vineyard R&D department at Remy Cointreau



What's next for 2024

- Further expansion of the area without chemical pesticides on the Remy Cointreau domain
- First tests with the deployment to external wine growers that deliver to Remy Cointreau

Outcome 2023

- Plots with bi… systematical… with conven…
- Strong heter… plots are fro…
  - One site … different …
  - Younger … older one…

Very diffficult and inneficient loss adjustment process

Need to automate claim payment to scale

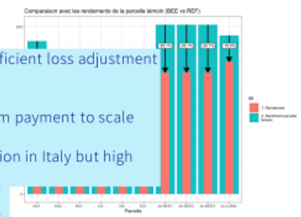
There is an index solution in Italy but high basis risk

The impac… particularly strong in challenging years like 2023

Final **payout of 107'000€** to compensate losses related to re…

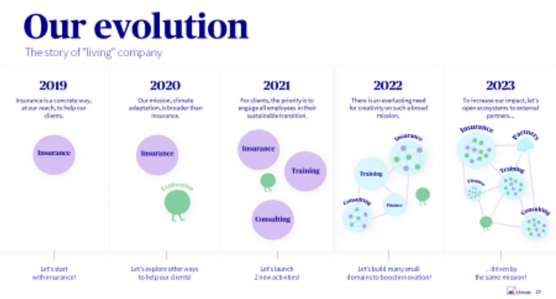
Only study cited in the WWF sustainable insurance report for agriculture

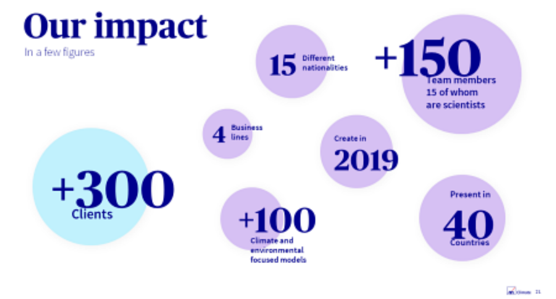
"After a yea… reassuring us, and we can continue on our goal to reduce the usage of chemical pesticides"
Responsible of the vineyard R&D department at Remy Cointreau



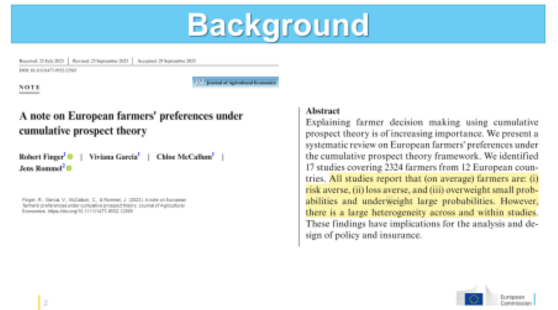
…2024

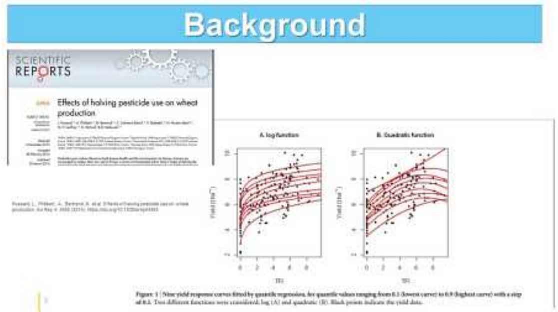
- …a without chemical pesticides on the Remy Cointreau domain
- First tests with the deployment to external wine growers that deliver to Remy Cointreau

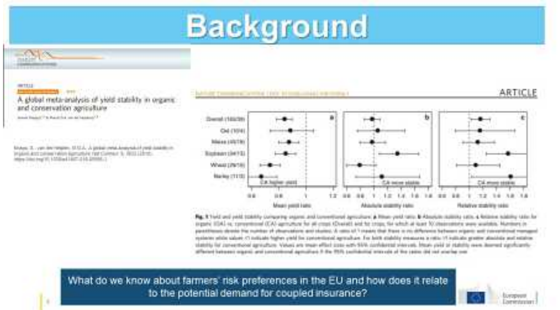

Our evolution
The story of "living" company
2019
Insurance is a concrete way, at our reach, to help our clients.
Insurance
Let's start with insurance!
2020
Our mission, climate adaptation, is broader than insurance.
Insurance
Exploration
Let's explore other ways to help our clients!
2021
For clients, the priority is to engage all employees in their sustainable transition.
Insurance
Training
Consulting
Let's launch 2 new activities!
2022
There is an everlasting need for creativity on such a broad mission.
Insurance
Training
Consulting
Finance
Let's build many small domains to boost innovation!
2023
To increase our impact, let's open ecosystems to external partners...
Insurance
Partners
Training
Finance
Consulting
...driven by the same mission!


Our impact
In a few figures
15 Different nationalities
+150 Team members 15 of whom are scientists
4 Business lines
Create in 2019
+300 Clients
+100 Climate and environmental focused models
Present in 40 Countries

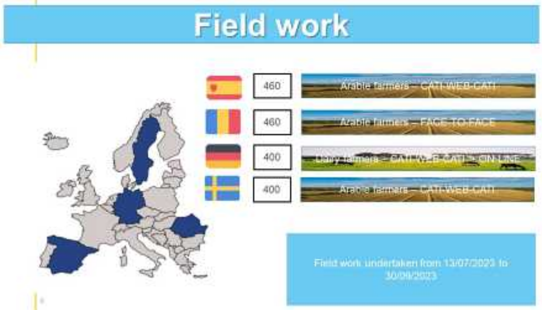

Can insurance increase the willingness of farmers to reduce pesticide use? Experimental evidence from 4 EU countries
Jesús Barreiro-Hurle[1]
[1] European Commission – Joint Research Centre (Seville)
Disclaimer: The views expressed are purely those of the authors and may not under any circumstances be regarded as stating an official position of the European Commission


Background
A note on European farmers' preferences under cumulative prospect theory
Robert Finger | Viviana Garcia | Chloe McCallum | Jens Rommel
Abstract
Explaining farmer decision making using cumulative prospect theory is of increasing importance. We present a systematic review on European farmers' preferences under the cumulative prospect theory framework. We identified 17 studies covering 2324 farmers from 12 European countries. All studies report that (on average) farmers are: (i) risk averse, (ii) loss averse, and (iii) overweight small probabilities and underweight large probabilities. However, there is a large heterogeneity across and within studies. These findings have implications for the analysis and design of policy and insurance.

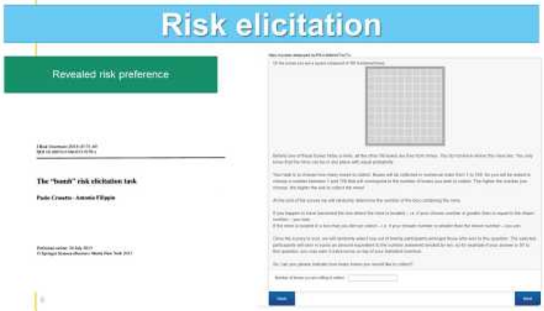

Background
SCIENTIFIC REPORTS
Effects of halving pesticide use on wheat production
A. log function
B. Quadratic function


Background
A global meta-analysis of yield stability in organic and conservation agriculture
ARTICLE
What do we know about farmers' risk preferences in the EU and how does it relate to the potential demand for coupled insurance?

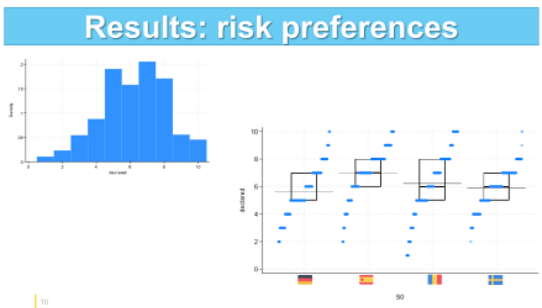

Background
Correspondence
Rapidly growing subsidization of crop insurance in Europe ignores potential environmental effects
What do we know about farmers' risk preferences in the EU and how does it relate to the potential demand for coupled insurance?


Field work
460
Arable farmers – CATI-WEB-CATI
460
Arable farmers – FACE-TO-FACE
400
Dairy farmers – CATI-WEB-CATI → ON LINE
400
Arable farmers – CATI-WEB-CATI
Field work undertaken from 13/07/2023 to 30/09/2023

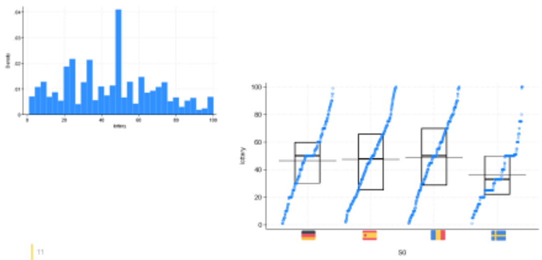

Risk elicitation
Stated risk preference
Back
Next


Risk elicitation
Revealed risk preference
The "bomb" risk elicitation task
Paolo Crosetto · Antonio Filippin

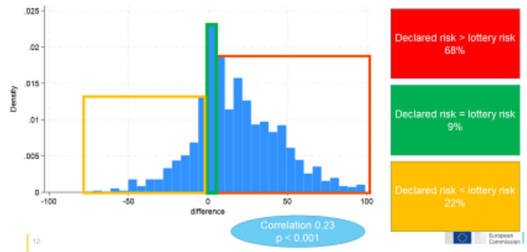

Willingness to reduce PPP use…
Back
Next


Results: risk preferences

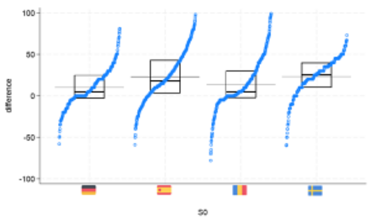
Results: risk preferences



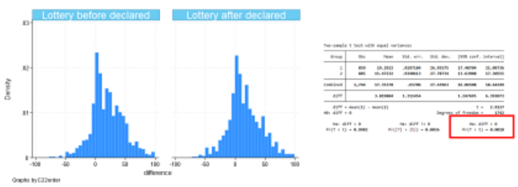
Results: risk preferences



Results: risk preferences

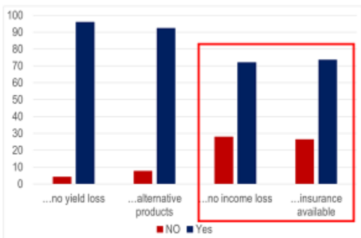


Results: risk preferences



Difference higher if lottery before declared

Willingness to reduce PPP use…

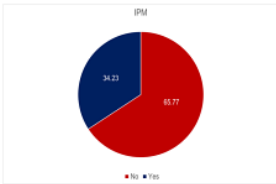


What role for risk preferences?

- Simple logistic regressions with one single explanatory variable capturing risk preferences (declared or as lottery)

	Declared risk	Lottery based risk
…no yield loss	n.s.	n.s.
…no income loss	n.s.	Reduced with higher risk aversion
… alternative products	n.s.	n.s.
… insurance for losses	Reduced with higher risk aversion	n.s

IPM declared use…



Significant **negative** impact of risk aversion on adoption of IPM both for declared and lottery based risk measures

Significant **positive** impact of using IPM in any of the 4 options to reduce PPP use – size of impact more or less the same

Conclusions (?)

- Farmers are risk averse? ✓
- Farmers are willing to reduce PPP use? ✓
- Willingness to reduce PPP is related to risk preferences? ✓ ✗
- Willingness to reduce PPP is related to IPM adoption? ✓

Thank you
and keep in touch

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Disclaimer: The views expressed are purely those of the authors and may not under any circumstances be regarded as stating an official position of the European Commission.

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JRC Seville, WORKSHOP ON ALTERNATIVE BUSSINESS MODELS FOR PESTICIDE REDUCTION Nov. 23rd, 2023:

„Crop insurance and pesticide use in European Agriculture"

Niklas Möhring (Production Economics Group, University of Bonn)

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Protecting crops is key for agricultural production

- Pest management is central for the production of safe food in sufficient quantities….

Example wheat Western Europe (Oerke 2006)

- Without pest management only 50% of yield potentials achieved
- Currently damages reduced to 15%
- Major shifts under climate change (Deutsch et al., 2018, Möhring et al., 2021)

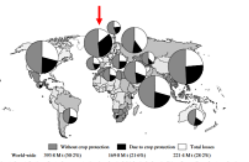

Fig. 3. Estimated contribution of actual crop protection (mechanical, biological, chemical) in safeguarding wheat production, by region, in 2001–03 (size of pies corresponds to attainable production).

2

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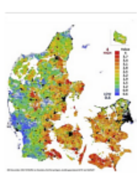
Current reliance on pesticides

- Reliance of global pest management on synthetic pesticides
- With adverse effects for the environment, human health and (long-term) agricultural productivity

Triazole Fungicides Can Induce Cross-Resistance to Medical Triazoles in *Aspergillus fumigatus*

The *Lancet* Commission on pollution and health



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A decade of pesticide (risk) reduction?

- **Globally substantial reduction targets for pesticides in the next decade:**
  - Global Biodiversity Framework (UN): 50% reduction until 2030 (Möhring et al., 2023)
  - EU From Farm to Fork – 50% use and risk reduction until 2030
  - Switzerland: reduction path pesticide risks – 50% until 2027
- But how to get there… ?

Möhring, N., Kanter, D., Aziz, T., Castro, I. B., Maggi, F., Schulte-Uebbing, L., … & Leadley, P. (2023). Successful implementation of global targets to reduce nutrient and pesticide pollution requires suitable indicators. *Nature Ecology & Evolution*, 1-4.

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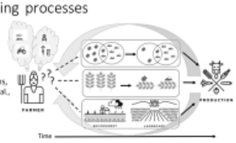
Key role of farmer decision-making processes

- General relevance: farmer behavior crucial for the uptake of sustainable production practices and technologies (Walter et al., 2017, Dessart et al., 2019)
- Especially for crop protection: Important role of uncertainty, risk, perceptions, preferences and further behavioral factors (Möhring et al., 2020 a,b,c, Bakker et al., 2021)
- Insurances as a solution to support the transformation to sustainable pest management and manage farmer's (income) risks?



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Key role of farmer decision-making processes

- General relevance: farmer behavior crucial for the uptake of sustainable production practices and technologies (Walter et al., 2017, Dessart et al., 2019)
- Especially for crop protection: Important role of uncertainty, risk, perceptions, preferences and further behavioral factors (Möhring et al., 2020 a,b,c, Bakker et al., 2021)
- Insurances as a solution to support the transformation to sustainable pest management and manage farmer's (income) risks?
- Current relevance: rise in subsidized AgInsurance in EU (Dalhaus et al., 2023)
- Ambiguous results in literature - empirical evidence on this question is sparse in the European context (Möhring et al., 2020d)

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Potential Mechanisms: Crop insurance and pesticide use

Total Pesticide Use = Land Use $crop_i$ (ha) * Pesticide Use Intensity $crop_i$ (per ha)

[1] Wu (1999); [2] Goodwin et al. (2004); [3] Horowitz and Lichtenberg (1993); [4] Smith and Goodwin (1996); [5] Chakir and Hardelin (2014)

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Timeline: Insurance uptake and pesticide use

- Goodwin et al. (2004) : Farmers plan all decisions jointly
- Assess potential simultaneity of land use, insurance uptake and pesticide use decisions

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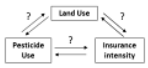
Identifying the structure of the decision making process



1. Formulate a full system of equations allowing for endogeneity:

- **Insurance intensity$_{it}$** = $Land_{it}$ + $Pesticides_{it}$ + $X_{farm,it}$ + $X_{farmer,it}$ + $X_{weather,it}$ + Insurance $intensity_{it-1}$ + $D_{region,it}$ + $D_{year,it}$ + ε_{it}
- **Land use$_{ijt}$** (j=ε{Grassland, Cropland}) = $Land_{it-1}$ + $Pesticides_{it}$ + $X_{farm,it}$ + $X_{farmer,it}$ + $X_{weather,it}$ + Insurance $intensity_{it}$ + $D_{region,it}$ + $D_{year,it}$ + ε_{it}
- **Pesticide Use$_{it}$** = $Land_{it}$ + $X_{farm,it}$ + $X_{farmer,it}$ + $X_{weather,it}$ + Insurance $intensity_{it}$ + $D_{region,it}$ + $D_{year,it}$ + ε_{it}

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Identifying the structure of the decision making process II

2. Sequentially estimate the equations
3. Test for sequence of land use, insurance and pesticide decisions empirically (C-Statistic, Davidson-MacKinnon test)

Results in line with observed behaviour/regulations:

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Estimate intensive and extensive margin effects

- Consistent estimation strategy: Wooldridge (2010)
- Estimate the 1st stage as 3 Tobit equations (accounts for censoring)
- Generate predicted values as instruments for endogeneous variables
- Solve the system «equation-by-equation» using 2SLS
- Use farm-level clustered errors
- Robustness checks: «linearized» 2SLS (Angrist and Pischke, 2009), GMM, G2SLS fixed effects

- **Interpretation of results as correlations not causal effects – instruments only based on ex/inclusion of variables**

Angrist Joshua, D., Pischke, J.S., 2009. Mostly harmless econometrics. In: An Empiricist's Companion. Princeton.
Wooldridge, J.M., 2010. Econometric Analysis of Cross Section and Panel Data. MITPress.

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Data

- Two case studies – France and Switzerland
- Crop farmers from 2009-2015
- Outlier cleaning with bacon algorithm

	Swiss dataset	French dataset
Data	field-level data, bookkeeping data and weather data	merged FADN data and weather data
Sample size	642 observations	9031 observations
Insurance type	hail insurance + other elementary perils, + climatic perils for selected cultures (not subsidized)	multiperil insurance: elementary and climatic perils (max. subsidization of 65%)

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Results

- Stat. significant and relevant associations between insurance and pesticide use
- In hypothetical «no insurance scenario» predicted pesticide use reductions of 6% (FR) and 11% (CH)
- Closely linked to characteristics of agricultural system
- CH: Results mainly driven by extensive margin
- FR: Results mainly driven by intensive margin

- Careful interpretation of results:
  - not causal,
  - not accounting for potential adaptation of farmers,
  - not accounting for «super-extensive» margins,
  - no switches between different crop/grassland types,
  - not pesticide risks

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Conclusions

- The reduction of pesticide risks is required and high on the policy agenda – but how to get there is still unclear.
- Farmer decision-making and risks are a key component.
- Insurances could be a tool to support the transformation to more (innovative) sustainable crop protection (production) systems
- But careful design is required – unintended (opposite) effects are possible – and can be considerable
- Critical: current growth of (subsidized) AgInsurance in Europe not considering potential environmental effects (Dalhaus et al., 2023)
- More (empirical) research needed on potential effects and design of insurance

Dalhaus, T. Wu, J., **Möhring, N.** (2023) Rapidly growing subsidization of crop insurance in Europe ignores potential environmental effects. *Nature Plants.* https://doi.org/10.1038/s41477-023-01569-9

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Annex 3: Agenda

AGENDA OF THE WORKSHOP ON ALTERNATIVE BUSSINESS MODELS FOR PESTICIDE REDUCTION

22&23 November 2023

Seville (Spain), Edificio Expo (Room Machado)

Organizer: European Commission's Joint Research Centre

DAY 1: 22 November		
14:00-15:00	Opening Session	
20 min	Welcome and background	Alessandra Zampieri, JRC
20 min	EU Regulatory framework	Gordon Rennick, SANTE
20 min	The sustainable use of pesticides and the Common Agricultural Policy (CAP)	Aymeric Berling, AGRI
15:00-15:15	Break (15 minutes)	
15:15-17:00	Session 1 (Part I): Existing and future business models for crop protection Chair: Manuel Gómez-Barbero (JRC)	
30 min	Service-based business models to incentivize the efficient use of pesticide in crop protection	Thomas M Chappell, Texas A&M University
30 min	Decision Support Systems	Antonio Vicent, IVIA
30 min	Outcome-based business models for CP reduction	Marius Wolf, Bayer
15 min	General discussion	All
Self-paid dinner at Restaurant Manolo León-GUADALQUIVIR, C/ Guadalquivir 8, Sevilla		
DAY 2: 23 November		
09:00-10:45	Session 1 (Part II): Existing and future business models for crop protection Chair: Manuel Gómez-Barbero (JRC)	
30 min	Innovations in Application Technology for Crop Protection	Peter Hloben, John Deere
30 min	Modelling policies towards pesticide-free agricultural production systems	Gabriele Mack, Agroscope
30 min	European Chemical Pesticide-Free Agriculture in 2050	Chantal Le Mouël, INRAE
15 min	General Discussion	All
10:45-11:00	Break (15 minutes)	
11:00-12:45	Session 2 : Linking pesticide reduction and insurance products: theory, institutions and experiences Chair: Jesús Barreiro-Hurle (JRC)	
30 min	How do non-life insurers think?	Francisco Sebastian, FIA
30 min	Insurance policy to cover yield losses from diseases in vineyard along with reducing pesticides use	Baptiste Dubois & Dimitri Lely, Groupama
30 min	Regenerative Agriculture Insurance Solutions	Sylvain Coutu - AXA Climate
15 min	General Discussion	All
12:45-14:00	Break (1 hour 15 minutes)	
14:00-16:15	Session 3 : What have agricultural economists found out about linking insurance and PPP reduction? Chair: Emilio Rodríguez-Cerezo (JRC)	
30 min	Can insurance increase the willingness of farmers to reduce pesticide use? Experimental evidence from 4 EU countries	Jesús Barreiro-Hurle, JRC
30 min	Crop insurance and pesticide use in European Agriculture	Niklas Mohring, University of Bonn
30 min	Green Insurance for Pesticide Reduction: Acceptability and Impact for French Wine Growing	Marianne Lefebvre, Universty of Angers & Yann Raineau, INRAE
30 min	The Interaction between Insurance and Protective Devices: The Case of Apples Producers in South Tyro	Marco Rogna, JRC
15 min	General Discussion	All
16:15-16:30	Break (15 minutes)	
16:30-17:00	Concluding Remarks	
15 min		Chantal Le Mouël, INRAE
15 min		Emilio Rodríguez-Cerezo, JRC

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