European Parliament

The future of crop Protection in Europe

Appendix 2 – Societal Assessment

STUDY

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The future of crop protection in Europe

Appendix 2: Societal Assessment

One way of avoiding societal rejection of crop protection practices is to design them in line with stakeholders' priorities and preferences. This report describes the involvement in crop protection and the opinions regarding the use of plant protection products (PPPs) for the following stakeholder groups: (1) the stakeholders who primarily look at crop protection from a *consumption* perspective (i.e. consumers, retailers and the food industry), (2) the stakeholders who look at crop protection from a *production* perspective (i.e. farmers and growers), (3) the stakeholders who look at crop protection from a *supply chain* perspective (i.e. crop protection industry, plant breeders and other suppliers), and (4) the stakeholders who look at crop protection from a *societal* perspective (i.e. citizens and NGOs).

Four explorative scenarios were developed that look at ways in which existing and emerging crop protection practices might be combined to ensure plant pests and diseases are effectively controlled. These scenarios were discussed in a brainstorming meeting with relevant stakeholders. For each scenario, the potential implications of the crop protection practices for different stakeholder groups (farmers, consumers, industry, NGOs) as well as the identification of their hopes and fears (i.e. potential positive as well as negative knock-on effects) were identified.

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Executive summary

The world population is growing continuously. It is expected that by the end of the 21st century, around 11 billion people will need to be fed. A corresponding increase in food production is required to sustain this huge future population. The growth in food production can be achieved with the use of more farmland and an increase in yield per hectare (ha). However, increasing land use for food production significantly contributes to loss of biodiversity, which is very undesirable from the point of view of sustainability. Consequently, the pressure to improve food productivity per ha increases.

One of the important means to bring about a high yield per ha is the use of plant protection products (PPPs), such as herbicides, insecticides, and fungicides, which help protect plants from harmful pests, diseases and weeds. However, the use of PPPs is subject to societal concerns due to the risks to human health (of users, consumers and in some cases bystanders) and the environment (loss of biodiversity).

A key question arises as to whether the use of PPPs can be reduced while maintaining or increasing yields. This question relates not only to global crop production with its wide range in yields, but also to the European Union (EU) with its generally high levels of productivity.

The Panel for the Future of Science and Technology (STOA) of the European Parliament commissioned this study with the overall objective to present an overview of crop protection options for European farmers such that they might be able to work sustainably while securing food production, preserving biodiversity and supporting farmers' incomes.

The overall objective of *The Future of Crop Protection* project is to present an overview of crop protection options for European farmers such that they might be able to work sustainably while securing food production, preserving biodiversity and supporting farmers' incomes. In Report 1, current crop protection practices as well as possible alternative crop protection practices have been reviewed and assessed. This overview shows that several crop protection practices are under continuous development and have potential to improve crop protection in future in Europe. However, at the same time, these (technological) developments are important, but only effective when they will be implemented by the farmers and accepted by other societal stakeholders. This will mean understanding stakeholders' opinions and preferences, and addressing these, is crucial when designing crop protection practices of the future. This report therefore presents the societal assessment and has the following three objectives:

- To present an overview of the stakeholders and an analysis of their opinions.
- To develop four scenarios (narratives of the future) based on the review described in Report 1; to guide brainstorming regarding the potential impacts of the possible courses of action related to plant health protection.
- To analyse and report the reflections and perceptions of the public and other stakeholders on the assessed crop protection practices (based on a brainstorming meeting with relevant stakeholders, technical experts, and social scientists).

Chapter 1 describes the background and objectives of the study on the future of crop protection.

Chapter 2 analyses the stakeholders and their views on crop protection. It describes the involvement in crop protection and the opinions regarding the use of PPPs for the following stakeholder groups:

1) stakeholders who primarily look at crop protection from a consumption perspective (i.e. consumers, retailers and food industry);

2) stakeholders who look at crop protection from a production perspective (i.e. farmers and growers);

3) stakeholders who look at crop protection from a supply chain perspective (i.e. suppliers, including the chemical industry developing and producing PPPs, and also breeders producing new crop varieties), and;

4) stakeholders who look at crop protection from a societal perspective (i.e. citizens and non-governmental organisations (NGOs) representing citizen groups or societal interests, and also public bodies responsible for formulating policies).

In Chapter 3, the development of the four explorative scenarios has been described, in which existing and emerging crop protection practices are combined in ways that control crop pests, diseases and weeds effectively.

- In the 'Status Quo' scenario, crop protection continues to be based on current developments. This means that no additional efforts will be made to adjust crop protection practices.
- In the 'Mitigation of Impacts' scenario, biocontrol agents and precision agriculture help mitigate the impacts on human health and the environment.
- The 'Pragmatic Adaptation' scenario allows for a pragmatic approach to adjust to the changed climate conditions.
- In the final 'Disruptive Shift to Sustainability' scenario, all possible means to stop biodiversity loss and climate change are allowed, which provides plenty of room for radical innovation.

Finally, Chapter 4 presents a synthesis of the outcomes of a brainstorming meeting with relevant stakeholders. This meeting was held online on 16 June 2020, in close cooperation with STOA staff. The objective of the brainstorming was to discuss the explorative future scenarios and envisage a wide range of possible impacts of future crop protection practices in 2050 from the perspectives of different stakeholders.

For each scenario, the potential implications of the crop protection practices for different stakeholder groups (farmers, consumers, industry, NGOs) as well as the identification of their hopes and fears (i.e. potential positive as well as negative knock-on effects) were identified.

The 'Status Quo' scenario evoked the greatest number of concerns and fears among the participating stakeholders. For example, these concerns related to difficulties for farmers, vulnerability to climate change and continued dependency on agrochemical PPPs.

Both the 'Mitigation' and 'Adaptation' scenarios occupy an intermediate position that would facilitate opportunities for innovation, diversification of businesses and new players to enter the market, but also raised some concerns.

The 'Disruptive' scenario presents the most opportunities and is expected to have the greatest impact, albeit not without some major challenges; for example, challenges related to investments and skills needed to make such a significant transition.

Taken together, the overview of public and stakeholders' opinion with respect to existing practices and the implications for stakeholders based on potential future crop protection scenarios that are presented in this report, may serve as a basis for future crop protection policy development. In the main report of the study, these different policy options including impact assessment are presented.

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Abbreviations and Acronyms

BUEC	Bureau Européen des Unions de Consommateurs
CEJA	European Council of Young Farmers
CEMA	European Agricultural Machinery Association
COGECA	General Confederation of Agricultural Cooperatives
COPA	Committee of Professional Agricultural Organisations
DNA	Deoxyribonucleic acid
DSS	Decision support systems
ECPA	European Crop Protection Association
EFFoST	European Federation of Food Science & Technology
EFSA	European Food Safety Authority
EPRS	European Parliamentary Research Service
ETC	Action Group on Erosion, Technology and Concentration
EU	European Union
EUFIC	European Food Information Council
GM	Genetically modified
GMO	Genetically modified organism
GPS	Global positioning system
Ha	Hectare
IBMA	International Biocontrol Manufacturers Association
IOBC	International Organisation for Biological Control
IPM	Integrated pest management
ISF	International Seed Federation
NGO	Non-governmental organisation
PAN	Pesticide Action Network
PPP	Plant protection product
Q&A	Question & Answer
RISE	Rural Investment Support for Europe
STEEPED	Society, Technology, Economy, Ecology, Politics, Ethical, Demographics
STOA	Panel for the Future of Science and Technology
WTP	Willingness to pay
WWF	World Wildlife Fund

1. Introduction

1.1. Context and background

The world population is growing continuously. It is expected that, by the end of the 21st century, around 11 billion people will need to be fed. A corresponding increase in food production is required to sustain this huge future population. The growth in food production can be achieved with the use of more farmland and an increase in yield per hectare (ha). However, increasing land use for food production significantly contributes to loss of biodiversity, which is very undesirable from the point of view of sustainability. Consequently, the pressure to improve productivity per ha increases.

One of the important means to bring about a high yield per ha is the use of plant protection products (PPPs) – such as herbicides, insecticides, and fungicides – which help protect plants from harmful pests, diseases and weeds[1].

However, the use of PPPs raises societal concerns due to the risks to human health (of users, consumers and in some cases bystanders) and the environment (loss of biodiversity and the emergence of pesticide resistance).[2] Recent concerns include debates about the relationship between the use of glyphosphate and cancer, and the relationship between the use of neonicotinoids and the decline of pollinators. These concerns have led to a huge public debate and a society-wide desire to reduce the use of PPPs, which has been reflected in existing legislation.

A key question arises as to whether the use of PPPs can be reduced while maintaining or increasing crop yields. This question applies both to the wide range of yields seen globally, as well as within the European Union (EU) with its generally high levels of productivity.

To discuss these concerns, the Panel for the Future of Science and Technology (STOA) of the European Parliament organised a workshop 'Farming without agro-chemicals' on the 6th of March 2019. The workshop enabled participants to gain a better understanding of the impact of PPPs on food production and to explore the perspectives of different stakeholder groups.

On request of STOA, researchers from KU Leuven University in Belgium have produced a scientific background report in order to stimulate further discussion. The report explores whether it is possible to grow plants without using herbicides, fungicides and insecticides. It concludes that a policy aimed at reducing the use of PPPs on its own will have negative trade-offs if the yield reduction is compensated by an expansion of farmland. This will lead to more biodiversity loss.

The report notes that, despite the doubling of PPP use since 1980, the environmental impact has been significantly reduced by application of stricter registration policies, replacement of broad-acting PPPs by more specific PPPs, avoiding impacts on non-target organisms, and the use of more advanced application technology. Without the use of PPPs, including biopesticides, the food security of 11 billion people would be threatened.

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[1] Types of pesticides such as insecticides, herbicides, fungicides, and organophosphates represent large classes of pesticides used mainly in agricultural practices. The term "pesticides" refers to plant protection products as defined in Regulation No. 1107/2009 of the European Parliament and of the Council. In contrast, bio-pesticides are a group of products that contain biocontrol agents—such as natural organisms or substances derived from natural materials, including their genes or metabolites—that are used to manage agricultural pests by means of specific biological effects rather than as broader chemical pesticides (Petrescu-Mag et al., 2019).

[2] The seminal work detailing the potentially negative impacts of pesticide use is – arguably – the publication of Silent Spring by Rachel Carson in 1962. Carson presented evidence not only that pesticides were having negative ecological impacts, but also suggested that injudicious use of these chemicals ultimately leads to pesticide resistance and consequently food insecurity (Frewer, 2017; Heckel, 2012).

Based on the outcomes of the workshop and the scientific background report, STOA decided to commission this study on options for European farmers to work in a sustainable manner while securing overall food production, preserving biodiversity and supporting farmers' incomes.

1.2. Objectives

The overall objective of *The Future of Crop Protection* project is to present an overview of crop protection options for European farmers such that they might be able to work sustainably while securing food production, preserving biodiversity and supporting farmers' incomes. In Report 1 Overview of Existing and Emerging Crop Protection Practices, current crop protection practices as well as possible alternative crop protection practices have been reviewed and assessed.

One way of avoiding societal and stakeholder rejection of crop protection practices is to design them in line with stakeholders' priorities and preferences. This will mean understanding stakeholders' opinions and preferences, and addressing these when designing scenarios for crop protection practices of the future.

This report presents the societal assessment and has the following three objectives:

- To present an overview of the stakeholders and an analysis of their opinions (Chapter 2).
- To develop four scenarios (narratives of the future) based on the review described in Report 1, to guide the brainstorming regarding the potential impacts of the possible courses of action related to plant health protection (Chapter 3).
- To analyse and report the reflections and perceptions of the public and other stakeholders on the assessed crop protection practices (based on a brainstorming meeting with relevant stakeholders, technical experts, and social scientists) (Chapter 4).

2. Relevant stakeholders and their views on crop protection

This chapter describes four stakeholder groups that have an interest in crop protection:

1) stakeholders who primarily look at crop protection from a consumption perspective (i.e. consumers, retailers and food industry);
2) stakeholders who look at crop protection from a production perspective (i.e. farmers and growers);
3) stakeholders who look at crop protection from a supply chain perspective (i.e. suppliers, including the chemical industry developing and producing PPPs, and also breeders producing new crop varieties), and;
4) stakeholders who look at crop protection from a societal perspective (i.e. citizens and non-governmental organisations (NGOs) representing citizen groups or societal interests, and also public bodies responsible for formulating policies).

The interests of these stakeholder groups with regard to PPPs will be analysed. The results of the analysis will be presented in a structured way describing:

- How crop protection and the use of PPPs relates to the interest of the stakeholder group;
- The group's view on crop protection and the use of PPPs and the background to this view.

2.1. Consumption perspective (consumers, retailers and the food industry)

2.1.1. How crop protection and the use of PPPs relates to the interest of consumers, retailers and the food industry

Crop protection and the use of PPPs is mainly of interest to consumers regarding the safety of pesticide residues and the toxicological risks from foods treated with PPPs. It is necessary to assess whether actual risks align with the risk perceptions held by consumers (Frewer, 2017).[3]

This issue is also relevant for retailers as most retailers are vulnerable and responsive to consumer concerns (Levidow & Bijman, 2002). Retailers want to give consumers a safety

Box 1: Health effects of PPPs on consumers

Most of the previous studies on the health effects of pesticide use are related to people with direct exposure, such as farmers. Research on health effects on consumers is much harder to find.

Most of the statistically significant health effect[redacted] (such as some types of cancer, respirat[redacted] and neuropsychopathological disorde[redacted] the literature are pesticide [redacted] possible to generalise the health effects of pesticides.

Furthermore, the existing research findings are often in disagreement. There is a lack of data to improve the reliability of results, and there are some methodological issues that could be improved to address the low number of cases and potential regional effects or biases (Tago et al., 2014).

[3] Note that, for consumers, environmental aspects (e.g., biodiversity loss) may also be a concern in choosing which products to buy. However, in order to identify different stakeholder interests, we make a distinction here between consumption-related concerns that relate to health, and societal concerns that relate to environmental issues such as biodiversity.

guarantee, particularly for fresh produce as this is an important product category with regard to company identity and customer loyalty.

2.1.2. Consumer opinions about crop protection and the use of PPPs

Consumer concern about pesticides has emerged as a major issue over recent decades. For example, Dunlap and Beus found in 1992 that consumers have concerns over the safety of pesticides. Note, however, that scientific evidence differs concerning the harm to human health (see Box 1 'Health effects of PPPs on consumers' on p.3) and that, in turn, consumer assessments of risks based on their perceptions differ from scientific views (see Box 2: 'Why consumers want to pay more for pesticide-free products' on p. 4).

Willingness to pay for crop protection practices

Since it is very difficult to determine from market data how much consumers are actually prepared to pay for safe and healthy food, researchers tend to rely on non evaluation techniques to monetise individual preferences (Tago et al., 2014).[4] One of these methods is to measure individuals' willingness to pay (WTP) for crop protection practices, either by asking consumers directly what they want to pay for a specific product or by means of an indirect approach in which WTP is calculated on the basis of consumers' choices among several product alternatives.

As a result, there is abundant literature concerning consumers' WTP for pesticide reduction. Basically, these studies distinguish between WTP for two product categories: (i) products that ensure the total elimination of certain pesticides (i.e. organic and 'pesticide residue-free' products), and (ii) products that show a decrease in pesticide use (i.e. 'Integrated pest management' (IPM) and eco-labelled products) (Bazoche et al., 2014).

With regard to the first category (pesticide-free products), several studies show that consumers have a higher willingness to pay for these (e.g. Chen et al., 2018; Cranfield & Magnusson, 2003; Haghiri & McNamara, 2007). For example, Cranfield and Magnusson (2003) found that over 65 per cent of their

Box 2: Why consumers want to pay more for pesticide-free products

The scientific literature reveals a number of different factors that may explain consumers' willingness to pay higher prices for products which are produced with reduced use of pesticides:

Risk perception

Consumers make different risk assessments than experts, tending to overestimate relatively small risks and underestimate more serious risks. For example, there is evidence that people underestimate the risks from natural carcinogens but that they nevertheless overestimate the risks from carcinogenic pesticides (Tago et al., 2014).

Experts often fail to understand the psychological factors which determine consumer responses to specific risks. Risk communication focuses on the irrationality of consumer risk perceptions and dismisses non-technical concerns as irrelevant. Also, in the context of pesticides, effective responses by consumers have been dismissed as irrational (Frewer, 2017).

Naturalness

Consumers' perception of naturalness seems to be a recurrent issue in agrifood production. Research in various subareas has shown that people prefer natural products over products made by human intervention (Rozin, 2005). Stronger fears are evoked by the ingestion of unnatural substances (Duncan 2011) and a lack of perceived naturalness of food technologies leads to lower perceived benefits of these technologies (Siegrist et al. 2016).

[4] Note that the ability of consumers' attitudes and intentions to predict real life behavior is debatable, including the domain of ecofriendly products (Papista and Krystallis, 2013), and there also exists a gap between stated willingness to pay and actual price paid by consumers (Barber et al., 2012).

respondents indicated a willingness to pay a price premium of between one and ten per cent for pesticide free food products.

Other studies examine the impact of restricted use of pesticides as a potential positive feature of new breeding technologies and show that pesticide-free food products are preferred even if they are produced using genetically modified (GM) inputs. For example, Edenbrandt et al. (2017) found that some respondents prefer pesticide-free bread from cisgenic crops – where gene transfer is restricted to sexually compatible organisms – over traditional crops produced using pesticides.[5] Grebitus et al. (2018) found similar results with dates: dates labelled as pesticide-free had a greater impact on consumer choices than GMO-free labelled dates.

With regard to the second category (pesticide-reduced products), Chen et al. (2018) examined consumer willingness to pay for fresh strawberries grown with various sustainable production methods. While consumers are willing to pay more for fresh strawberries produced with sustainable practices, the premiums differ with the production method. The highest WTP premium was for fresh strawberries produced with reduced pesticide use. In a European study, Bazoche et al. (2014) found that consumers rank organic apples first, apples produced using conventional pesticide practices last, and apples with Integrated Pest Management certifications in-between.

Consumers are not always willing to pay more for these products. Tonsor and Shupp (2009) evaluated consumers' WTP for products marketed with 'sustainably produced' labelling claims. They concluded that US consumers are not willing to pay a positive premium for tomatoes or apples labelled as 'sustainable production' because this information is vague and not clearly associated with production practices.

A critical note can be made on these WTP studies: most do not determine the precise amount that consumers are willing to pay for pesticide reduction or other alternative crop protection practices. For example, regarding WTP for organic products, the premium that consumers are willing to pay may reflect a number of concerns, such as better taste, environmental issues, and support for locally grown produce. Even if it is known which attributes attract a price premium, it is difficult to assess their shares of the premium (Tago et al., 2014).

A further complication is that individual behaviour differs with regard to WTP for pesticide-free products. For example, health and environmental concerns, willingness to switch grocery stores and youth are important characteristics of consumers who would be willing to pay higher premiums (Cranfield and Magnusson, 2003). Furthermore, there is evidence to suggest that the extent to which consumers are prepared to eat food treated with pesticides varies geographically, across different demographic segments, and with time (Yiridoe, Bonti-Ankomah and Martin, 2005; Thøgersen et al., 2015; Simonne et al., 2016).

Role of food labelling and marketing in consumer awareness of pesticide use

While most WTP studies show that consumers are willing to pay more for reduced pesticide use, Parker (2015) disputes that pesticide use might be an issue for consumers. Most consumers may take it for granted that they have to wash fruit and vegetables under running water before consumption, without considering further consequences. According to the author, this also has to do with the fact that no information or warning about pesticides used in the production and storage or fruits and vegetables can be found in most retail locations.

[5] Note that in this study, participants are provided with descriptions and examples of the breeding technologies (i.e. transgenic or cisgenic). According to the authors (p. 124) "The descriptions and illustrations were designed to be an unbiased, informative and easily understood 'translation' of the highly sophisticated scientific concepts."

It can be argued that consumers' knowledge, and the choices available to them, are largely framed by the food labels, retail displays and marketing material they see when they shop (Guthman 2007; Hartlieb and Jones 2009)[6].

An additional problem is that consumers may not be aware of the full meaning of different claims, labels and logos, if labels or claims are used at all. For example, products produced with integrated pest management lack any special recognition in most supermarkets (Levidow & Bijman, 2002). As a consequence, consumers tend to shop with their own individual perceptions of food safety in their minds (Frewer, 2017).

Crop protection practices in relation to other product attributes

Food safety and potential health impact are just two of the motives that consumers have when choosing food products. Taste is repeatedly considered to be the most important consumer food choice motive (Onwezen et al., 2019). Bazoche et al. (2014) found that environmental certification is not a guarantee of a price premium when consumers experience taste disappointment.

Similarly, Combris et al. (2010) measured the trade-off between taste and the the reduction of pesticide use due to integrated pest management for pears in Portugal. While information on pesticide reduction influences consumers' willingness to pay, taste plays an even more important role in driving buying behaviour.

Another important issue concerns the appearance of products. Roosen et al. (1998) showed that, while pesticide-free status increases WTP, cosmetic damage decreases WTP. Along the same lines, Yue et al. (2009) showed that appearance and cosmetic damage affect consumer WTP for organic fresh products more than for the conventionally produced product.

To summarise, consumers generally show a willingness to pay premium prices for products grown without using pesticides or with low use of pesticides. However, individual and regional differences, the role of food labelling and marketing, and other food choice motives (such as taste) should be taken into account when looking at the consumer perspective on crop protection.

2.1.3. Retailer and food industry opinions on crop protection and the use of PPPs

Retail

With the rise of private labels, retailers increasingly 'find themselves absorbing more responsibility and risk in the maintenance of food quality' and become more vulnerable and responsive to consumer concerns (Levidow & Bijman, 2002). As a result, the researchers found that retailers have developed common practices or criteria for lower-pesticide products, which aim to (p. 42):

- maintain consumer confidence in product quality;
- establish Europe-wide supply chains that meet common or minimum standards;
- make supplies interchangeable, and;
- avoid competition for low-pesticide products that are defined in various ways.

[6] In this respect, Parker (2015) is quite sceptical about consumers' influence in the food system. The author states that too much emphasis is placed on the consumer as a regulatory authority making food policy choices in the food system. For example, if consumers value lower pesticide agriculture, then they will seek out and pay a premium for food labelled and sold as "organic", pesticide-free or low pesticide use. This "shopping for change" is then supposed to change the behaviour of industry, retailers and relationships up and down the supply chain (Roff 2007). However, Parker concludes that, in practice, the consumer lacks the opportunity to see and engage with regulatory and production decisions made earlier in the food chain which limit and define the political choices available at the point of purchase.

Retailers have set up their own quality and safety control systems for their supply chains, including requirements for the use of inputs like seeds and pesticides. To avoid becoming too dependent on particular suppliers, retailers seek to develop quality standards that can be broadly implemented by numerous suppliers across Europe (Brouwer and Bijman, 2001).

Food processing industry

Food processing companies have also accommodated consumer concerns. For pesticide reduction, some companies have helped to fund research on pest-resistant seeds and alternative chemical agents. Some have also promoted precision (rational) agricultural methods, as distinct from integrated pest management and integrated crop management methods.

At the same time, food processors have relatively greater interest in differentiating their products from competitors in other respects. Unlike retailers, they search for novel seeds and other inputs which may provide consumer benefits and gain public acceptability, while seeking exclusive control over such products.

2.1.4. Relevant organisations and their opinions

The table below shows a list of the relevant European organisations who look at crop protection from a consumption perspective (i.e. consumers, the retail and food industry). The table describes the role of the organisation, its relation with crop protection and the background of its opinion about crop protection.

Table 2.1: List of relevant consumption-related organisations

Name organisation	Role of organisation	Relation between crop protection and interest of the organisation	Opinion about crop protection and use of PPPs and background of opinion
BEUC (Bureau Européen des Unions de Consommateurs)	BEUC represents consumer organisations at European level and acts as their umbrella group in Brussels. Its main task is to defend the interests of all Europe's consumers.	BEUC supports the empowerment of consumers through competitive markets complemented by health and safety safeguards. Food safety is one of the issues where PPPs are considered.	BEUC supports making European Food Safety Authority (EFSA) scientific assessments more transparent, as this can help strengthen consumer trust in the EU food regulatory system. The background for their opinion is motivated by standing up for the interests of consumers.
EUFIC (European Food Information Council)	EUFIC is a non-profit organisation established in 1995. Its mission is to provide engaging science-based information to inspire and empower healthier and more sustainable food and lifestyle choices. It covers a wide range of topics on nutrition, lifestyle and health, food safety, food quality,	EUFIC's relation with crop protection is mainly providing information about crop protection/ pesticide use to consumers. For example, its website has a Question & Answer (Q&A) section about pesticides and health.	The main mission of EUFIC is to provide objective science-based information. It does not take an explicit position itself. It has a special focus on human health risks and provides information on pesticide approvals carried out by European authorities, which include strict safety assessments

	legislation, and food risk communication.		and are reviewed by Member States and EFSA.
EuroCommerce	EuroCommerce is the voice for six million retail, wholesale, and other trading companies. Its members include national commerce federations and leading retail and wholesale companies. Its role is to bring the whole commerce sector (retail, wholesale, international trade) together and to advocate their position on EU legislation and policies.	One of EuroCommerce's policy areas is food, nutrition and health. Assuring product safety and consumer trust in food is an absolute priority for the retail and wholesale sector. This includes crop protection issues.	Retailers need to establish sustainable relationships with farmers, who can help them differentiate and deliver to consumers the competitive and innovative products consumers want. In this regard, retailers have long supported the growth in organic produce, and established partnerships to support the development of other products that meet consumer demand, including local products and those with fewer antibiotics, fewer pesticides, and high animal welfare standards.
FoodDrinkEurope	FoodDrinkEurope (formerly known as CIAA – Confederation of Food and Drink Industries of the EEC) represents the European food and drink industry.	The organisation promotes its members' interests in areas such as food safety and science, nutrition and health, consumer trust and choice, competitiveness, and environmental sustainability.	The background of its opinion is motivated by standing up for the interests of the food and drink industry. Given that the industry's raw materials are grown in the natural environment, and the industry purchases and processes 70% of EU agricultural production, it is essential that agricultural practices are sustainable.

2.2. Production perspective (farmers and growers)

2.2.1. How crop protection and the use of PPPs relates to the interest of farmers and growers

Farmers and growers have a dual relationship with PPPs.

On the one hand, farmers benefit from PPPs to protect and secure their produce (and income). In Europe, actual yield losses of the major crops from diseases and pests vary from 18 to 45% depending on the region, and potential losses from 32 to 71% (Oerke, 2006).

In a more recent global study on yield losses for major crops as a result of diseases and pests, the average yield loss is estimated to be 20% (Savary et al, 2019). Without crop protection, these losses would be much greater.

From the farmers' perspective, PPPs not only have a quick and visible impact, they are also very cost-effective. According to a report of the Rural Investment Support for Europe (RISE) Foundation, "The pay-back to the very real costs of buying and applying these products (PPPs) is quite quickly and visibly seen in most cases." (Buckwell et al., 2020). These products are therefore of vital importance to farmers.

On the other hand, farmers are directly exposed to these products when they mix and spray pesticides, sow pesticide treated seeds, weed and harvest sprayed crops, and clean and dispose of pesticide containers. In addition, members of farming families and other people in rural communities where there is an intensive use of pesticides may be indirectly exposed to pesticides (Tago et al., 2014).

There have been a lot of studies focusing on the health effects on those who are directly exposed to PPPs (for an overview, see Tago et al., 2014). However, most of the statistically significant health effects found in the literature (such as some types of cancer, respiratory disorders and neuropsychopathological disorders) are specific to certain pesticides, so it is not possible to generalise regarding the overall health effects of pesticides (Tago et al., 2014). Furthermore, the research findings are often inconsistent, there is a lack of data to provide more reliable results, and there are some methodological issues that could be improved to deal with low numbers of cases as well as potential regional effects or biases.

2.2.2. Producer opinions about crop protection and the use of PPPs

Farmers recognise the need to reduce their dependency on agrochemicals. They are aware of changing public opinion about PPPs and the consequences for their 'licence to produce'. Nevertheless, they are reluctant to switch to alternative crop protection practices as in many cases alternative methods are less efficient than chemical control. For example, Petrescu-Mag et al. (2019) indicate that one of the main hindering factors to the use of biocontrol agents is their low perceived efficiency compared to conventional pesticides.

According to the RISE report (Buckwell et al., 2020, p. 15), farmers' organisations list three consequences of a reduced synthetic PPP toolbox:

- fewer available PPPs will create dependence on a smaller range of products and consequently faster development of resistance in crop pathogens;
- reduced capacity to protect crops leading to lower, more volatile yields and reduced EU agricultural outputs, and higher risks of microbial contamination of foods impacting human health;
- reduced competitiveness of EU agriculture with less viable farm businesses.

So, farmers are concerned about reductions in their incomes due to lower crop yields and poor quality resulting from damage caused by pests, diseases and weeds. In contrast, the benefits of PPPs are clear as they have relatively quick and visible effects and are demonstratively cost-effective (Buckwell et al., 2020).

Another important issue is that alternative crop protection strategies need to be combined in order to reach similar levels of control efficacy as achieved by PPPs. For example, regarding integrated pest management, convincing farmers to re-design their farming systems to adopt combinations of preventive measures for pest management would be a difficult task. This is because current systems are optimised for economic profitability and adoption of IPM-based principles would probably reduce profitability (see The Future of Crop Protection in Europe – Overview of current and emerging crop protection practices).

In addition, switching to more sustainable systems poses heavy initial costs. As such, the prevailing agricultural system has 'locked in' farmers, which has resulted in their 'entrapment' in pesticide use (Wilson & Tisdell, 2001).

Moreover, switching to sustainable alternatives increases the complexity of farm management and requires additional decision-making (Lechenet et al., 2017). It demands strong motivation to switch to sustainable systems and gain an understanding of the underlying ecological principles. Once biocontrol methods are deployed, farmers cannot quickly revert to synthetic chemicals without losing their investment in the new methods and agents (Buckwell et al., 2020).

On the other hand, a study that investigated farmers' perceptions and behaviours concerning the use of bio-pesticides in strawberry production in Italy, Germany, and Israel revealed that farmers were aware of the positive aspects of those products and they used biocontrol agents with different levels of satisfaction (Moser et al., 2008).

Farmers' risk perceptions of the use of agrochemicals may play a role. For example, in a study among Romanian farmers, Petrescu-Mag et al. (2019) found that the perceived negative effects of agrochemicals on health and on the environment are rather weak. However, another study carried out among farmers in Europe revealed that Greek farmers' knowledge of pesticides and pesticide hazard control were associated with safety compliance (Damalas & Koutroubas, 2017). Remoundou et al. (2014) assessed perceptions of risks associated with pesticide exposure in Greece, Italy, and the UK, and found that operators and workers adopted self-protective behaviours.

Farmers are increasingly under pressure to reduce conventional (chemical) pesticide usage, for two main reasons:

Firstly, they must comply with tighter EU regulations on pesticides. According to Bonanno et al. (2017), EU farmers face a challenge since the number of newly approved active ingredients for pesticides has declined. The number is expected to decline even further due to more stringent pesticide regulations and to the slowdown in the development of alternative solutions caused by the stringent regulation.

Secondly, food retailers and processers exert pressure upon farmers to reduce pesticide usage. According to Levidow & Bijman (2002): "Given the strong consumer signals in some countries, food companies have been changing their supply-chain practices throughout Europe. Likewise, farmers have come under pressure from food companies based in other countries or marketing products there. In such ways, pressures on farm inputs become Europe-wide, for both companies and farmers."

As a result, farmers' organisations feel increasingly pressurised towards the use of non-chemical crop protection methods, despite lacking the necessary knowledge, information, and availability of suitable products.

2.2.3. Relevant organisations and their opinions

The table below shows a list of relevant organisations representing European crop producers (i.e. farmers and growers). The table describes the role of the organisation, its relation with crop protection and its (background of) opinion about crop protection.

Table 2.2: List of relevant production-related organisations

Name of organisation	Role of organisation	Relation between crop protection and interest of organisation	Opinion about crop protection and use of PPPs and background of opinion
COPA (Committee of Professional Agricultural Organisations) and COGECA (General Confederation of Agricultural Cooperatives)	Comprises COPA and COGECA and is the united voice of farmers and their cooperatives in the European Union	Some supporters are involved in crop protection. Farmers need safe and effective tools to combat pests and diseases so as to guarantee both food safety and security for the current and future world population.	COPA COGECA supports measures which contribute to a more sustainable use of PPPs taking into account competitiveness issues, financial viability for farmers and the long-term sustainability of European agriculture by: • Stimulating availability and use of Integrated Pest Management (IPM) tools; • Advocating a science-based risk assessment where both hazard and exposure are taken into consideration; • Advocating the use of biological control agents and micro-organisms.
IFOAM EU	IFOAM EU is the European umbrella organisation for organic food and farming.	Organic farming only uses substances already occurring in the natural environment and substances chemically identical to molecules occurring in nature.	The organic regulation allows only the use of specific PPPs, when duly justified and when preventive measures are not enough. Organic farming rejects the unpredictable risks coming from the release of artificially designed molecules (e.g. "synthetic" pesticides) and GMOs into the environment.
European Council of Young Farmers (CEJA)	CEJA acts as a forum for communication between young farmers and European decision-makers. Its main objective is to promote a younger and more innovative agricultural sector across the EU and to create good working and living conditions for young	The "Young farmers' call for climate action" position paper states that young farmers must play a role in ensuring a sustainable and resilient agriculture sector for the future. Three key areas of climate action are identified: • Adaptation (on-farm practices, knowledge, technology and	The need for financial stability and security to invest in long-term projects cannot be understated and, as the debate unfolds, young farmers' voices need to be heard because they will be implementing the necessary measures in the decades to come.

	farmers and other young people involved in farming.	innovation, investment aid, and risk management) • Emissions reduction (the livestock sector, energy and the bio-economy, the food supply chain and consumers, and trade) • Carbon sequestration (forestry, peatlands and organic soils, land use management, land use change, and carbon farming tools) Crop protection is mainly related to the first area.	

2.3. Supply chain perspective (crop protection industry, plant breeders and other suppliers)

2.3.1. How crop protection and the use of PPPs relates to the interest of the crop protection industry and other suppliers

Crop protection industry

The use of PPPs is obviously in the interest of the crop protection industry as these are its products. The global market for agrochemical pesticides has grown steadily since 2006, although sales in Europe remained relatively stable over this period.

Simultaneously, leading agrochemical companies have entered a period of significant consolidation through mergers and acquisitions. Overall, the European PPP industry is characterised by larger companies and a key component of the market's structure is its concentration (Bonanno et al., 2017). A report by the Action Group on Erosion, Technology and Concentration (ETC) (ETC Group, 2013) indicates that, in 2011, six firms had a share of three-quarters of the global agrochemical market.

Due to rising research and development costs to meet a growing demand for safer agrochemicals and tightening of regulations by authorities, major crop protection companies have diversified their businesses. This includes breeding genetically modified (GM) seeds to an extent that accounts for a considerable proportion of their total sales (Nishimoto, 2019).

Recently, these companies have started exploring other new areas (e.g. precision agriculture and crop stress management) as well as introducing novel technologies (e.g. genome editing) that will further improve agricultural productivity (Nishimoto, 2019). Increasingly, the big companies in the crop protection industry also focus on biocontrols.

Other suppliers

In addition to the traditional crop protection industry, other suppliers also have an interest in crop protection. Principally, new players entering the market focus on biocontrol technologies.

Biocontrol technologies originate from nature and can be used to manage pests, weeds and diseases. Biocontrol entails all methods, tools, measures and agents of plant protection that rely on the use of beneficial organisms. These organisms use their natural mechanisms and interactions to determine the relationship between biological species in the natural environment.

Biocontrol includes augmentative control, conservation biocontrol, and the use of biopesticides, semiochemicals and plant defence stimulators (Lamichhane et al., 2017). The biocontrol industry supports sustainable agriculture, allowing farmers to grow healthy and environmentally friendly crops.

Other companies focus on developing new plant breeding techniques. These techniques can assist breeders in a more efficient and precise adjustment of the genetic composition of crops. They include genome editing techniques, which have made tremendous progress since the introduction of CRISPR-Cas in 2012. Companies working in this area support plant breeders in improving important crop traits that have previously been difficult to improve by traditional cross breeding.

From a supply chain perspective, there is an increasing role for companies that develop and sell technologies to improve crop protection. Some companies provide 'hardware' for precision agriculture, such as object identification technology, sensors, global navigation satellite systems, connectivity and other information and communication technology, robotics and autonomous navigation. Other companies provide 'software' in the form of decision support systems.

2.3.2. Supply chain opinion about crop protection and PPPs

The crop protection industry sees itself forced into a defensive position by increasing societal pressure for a substantial reduction in the use of PPPs. The industry argues that PPPs can be safely used within responsible limits and contests the contribution of PPPs to biodiversity decline. It claims that health and the environment are now sufficiently protected from impacts of PPPs by a stringent regulatory system (Buckwell et al., 2020; Parker, 2015).

The crop protection industry is confronted with regulations that have been tightened over recent years. In the European Union, the criteria for safety and environmental impact assessment were switched from risk-based to hazard-based in 2011, leading to a decline in the number of registered chemical products (Nishimoto, 2019).

Industry representatives argue that legislative requirements have increased over time, including the re-registration of active ingredients in agrochemicals.

The industry criticises the hazard-based approach to environmental impact assessment for its lack of scientific basis (Hunka et al., 2015). It would prefer that it is based more on probabilistic risk assessment.

The reduced number of active substances leads to greater use of those that remain. A limited set of PPPs increases the risk of weeds, insects and pathogens developing resistance, which reduces their effectiveness. At the present time, the industry sees no viable alternatives to agrochemicals and fears that current trends will lead to lower crop yields and product quality (Buckwell et al., 2020; Seufert et al. 2012).

Box 3: Criticism of the regulatory framework

The RISE foundation report makes comments on the EU regulatory framework regarding the use PPPs, as listed below. Note that different stakeholders have different criticisms.

1. There is ambiguity between reducing harm attributable to PPPs and reducing their use.
2. The ultimate aim of regulations is not clearly stated. For example, the fact that such products are accepted as a final resort under the Sustainable Use of Pesticides Directive, and that there is a list of PPPs available to organic farming suggests elimination of PPP use is not the long term goal.
3. There are no clear indicators or mechanisms for measuring and balancing unwanted impacts on EU agricultural competitiveness.
4. The approval process is complex, it is not well administered nor sufficiently resourced to work within the time periods and criteria set in legislation. This creates uncertainty and costs for applicants.
5. The consequential frequent resort to emergency and temporary authorisations introduces uncertainty for all stakeholders, most directly for farmers and the PPP industry, and it undermines public confidence in the regulations.
6. There are concerns amongst conventional farming organisations and the PPP industry that the last stage of the approval process is too open to what they regard as non-scientific, political, considerations.

(Source: Buckwell et al., 2020, p. 33)

The industry is concerned about the rising cost and time for getting PPPs approved by the EU regulatory system. This threatens its ability to develop more sustainable alternatives for the European market (Buckwell et al., 2020). Box 3 lists a number of criticisms of the EU regulatory framework for PPPs.

Although it is critical towards societal pressure and the regulatory system, the crop protection industry is committed to respond to demands to make product safety data more accessible to the public, to provide greater transparency, and to increase trust in the approval process. For example, the European Crop Protection Association (ECPA), CropLife International and their member companies have launched their own transparency commitment to ensure that more data related to the safety of their products are made publicly available (Blake, 2019).

Biocontrol

Biocontrol industry representatives also criticise the current regulatory system and label it as limiting the uptake of biocontrol methods for crop protection. For example, the International Organisation for Biological Control (IOBC) identified the following limitations to biocontrol uptake (Barratt et al., 2018, p. 155):

- risk averse and unwieldy regulatory processes;
- bureaucratic barriers to access biocontrol agents;
- insufficient engagement and communication with the public, stakeholders and growers of the benefits of biocontrol, and;
- fragmentation of biocontrol sub-disciplines.

Given this unsatisfactory situation, the biocontrol industry strongly argues that Regulation (EU) 1107/2009, which was designed for synthetic active substances and products, is not appropriate for the approval and authorisation of biological plant protection products (Ecorys, 2018). A separate route for approval of biologically active substances and PPPs is requested by industry spokespersons.

In contrast to the EU, the US regulatory framework is better adapted to biopesticides, allowing for faster authorisation for biocontrol products (Frederiks and Wesseler, 2019). It is argued that criteria for approving biological substances are often too stringent for products of natural origin.

Nevertheless, caution is necessary as biocontrol products can also carry environmental risks. For example, an EFSA report on *Bacillus thuringiensis* shows that a biocontrol product can be toxic to non-target species (EFSA, 2013).

2.3.3. Relevant supply chain organisations and their opinions

The table below shows a list of relevant European organisations that look at crop protection from a supply chain perspective. The table describes the role of the organisation, its relation with crop protection and the background to its opinion about crop protection.

Table 2.3: List of relevant supply-chain organisations

Name of organisation	Role of organisation	Relation between crop protection and interest of the organisation	Opinion about crop protection and use of PPPs and background of opinion
ECPA (European Crop Protection Association)	Represents the crop protection industry in Europe. Corporate members are from industrial organisations developing and producing PPPs: Corteva, Nufarm, FMC, Syngenta, Adama, Bayer CropScience, BASF.	ECPA's mission is 'More with Less'. It encourages sustainable farming practices and the responsible use of crop protection technology important for the sustainable intensification of agriculture. Members are continuously investing in new technologies - be it biopesticides or an ever-greener profile of pesticides, which allow farmers to produce safe and high-quality food while using fewer natural resources and safeguarding the environment.	ECPA supports the crop protection industry by fostering innovation and encouraging competitiveness. It believes policy should be informed by science and designed to manage risk. It advocates for a predictable and proportionate EU regulatory environment that fosters innovation and encourages competitiveness. *"While the product authorisation process is the essential assurance to farmers and consumers that crop protection products meet the highest standards for safety, efficacy and quality, the effective transparency of safety data submitted to regulatory agencies can further enhance public confidence and strengthen the understanding of the stringent safety standards of crop protection products, as well as enhance trust in the product authorisation process."*
CEMA (European Agricultural	To represent the agricultural machinery industry in Europe.	Precision Farming is about managing variations in the field	CEMA's opinion on crop protection is driven by its role in promoting the

Machinery Association)	Agriculture 4.0 (Precision farming and digital farming) and Smart Farm Machines are drivers for efficiency and competitiveness in modern sustainable farming.	accurately to grow more food using fewer resources (including PPPs) and reducing production costs. Efficiency can be improved using technology such as high precision positioning systems (e.g. GPS and Galileo), geomapping, automated steering systems, sensors and remote sensing, integrated electronic communications, and variable rate technology.	efficient use of agricultural machinery.
CropLife International	CropLife International represents the plant science industry.	It promotes innovation in crop protection and plant biotechnology to support and advance sustainable agriculture.	It supports science and risk-based regulatory frameworks that enable access to innovation for farmers around the world. This includes working with other stakeholders within the value chain to highlight the importance of frictionless regulation of inputs. Regulation should meet the needs of society by providing access to technology in a controlled but predictable manner based on the associated risks. Regulation provides an opportunity to encourage innovation and enterprise that benefits all of society while setting standards for safety and sustainability. CropLife International is committed to data transparency.
IBMA (International Biocontrol Manufacturers Association)	To represent the biocontrol technologies industry.	IBMA encourages the development and marketing of biocontrol technologies based on proportionate regulation. Its prime focus is effective biocontrol technologies, supported by suitable	IBMA considers biocontrol technologies to be crucial for advancing sustainable agriculture.

		agronomic practices, monitoring, digital, and physical methods. IBMA's view is that chemical PPPs should only be used as a last resort.	
International Organisation for Biological Control (IOBC)	IOBC promotes environmentally safe methods of pest and disease control. It is a voluntary organisation of biological control workers.	IOBC promotes the development of biological control and its application in integrated pest management programmes. It encourages international cooperation to these ends. IOBC collects, evaluates and disseminates information about biological control. It promotes national and international action concerning research, training, coordination of large-scale application, and public awareness.	IOBC sees biocontrol technologies as crucial solutions for developing sustainable agriculture.
International Seed Federation (ISF)	ISF represents the global seed industry.	The seed industry is committed to developing better seed for a better quality of life. Better seed brings economic, environmental and health benefits. Improved seed that is resistant to drought and disease reduces the risk of crop failure thus supporting sustainable agriculture and global food security.	ISF maintains that plant breeding helps to produce more with less, improving resource-use efficiency and reducing pressure on the environment. Accelerating genetic improvement through the development of new germplasm and other technologies is critical to achieving sustainable increases in productivity.
EuroSeeds	Euroseeds is the voice of the European seed sector. It represents the interests of those active in research, breeding, production and marketing of seeds of agricultural, horticultural and ornamental plant species.	EuroSeeds aims to contribute to: 1) Fair and proportionate regulation of the European seed sector; 2) Freedom of choice for customers (farmers, growers, industry, consumers) by supplying seeds developed using innovative, diverse technologies and production methods;	EuroSeeds considers that plant breeding innovation is a major driver to increasing the availability of food. This is achieved by strengthening resistance to plant diseases and improving the tolerance of crops to stresses, drought and floods. EuroSeeds view is that the European seed sector

		3) Effective protection of intellectual property rights relating to plants and seeds.	should play a role in both securing Europe's food supply and contributing to world food supply, by for instance, reducing Europe's dependence on imports.

2.4. Societal perspective (citizens and NGOs)

2.4.1. How crop protection and the use of PPPs relates to the interest of citizens and society

The use of PPPs is subject to societal concerns because of the risks to human health (of users, consumers and in some cases bystanders) and the environment (loss of biodiversity and the emergence of pesticide resistance).

According to Frewer (2017), there are two issues which need to be understood in relation to societal response to pesticide use.

The first issue relates to the safety of pesticide residues in foods, and whether this corresponds with toxicological risk assessments as well as with risk perceptions held by citizens.

The second issue concerns pesticide emissions to the environment (air, soil and water), which may have negative environmental and agronomic impacts (e.g. on biodiversity and on the emergence of pesticide resistance).

2.4.2. Public opinion about crop protection and the use of PPPs

Food safety and human health

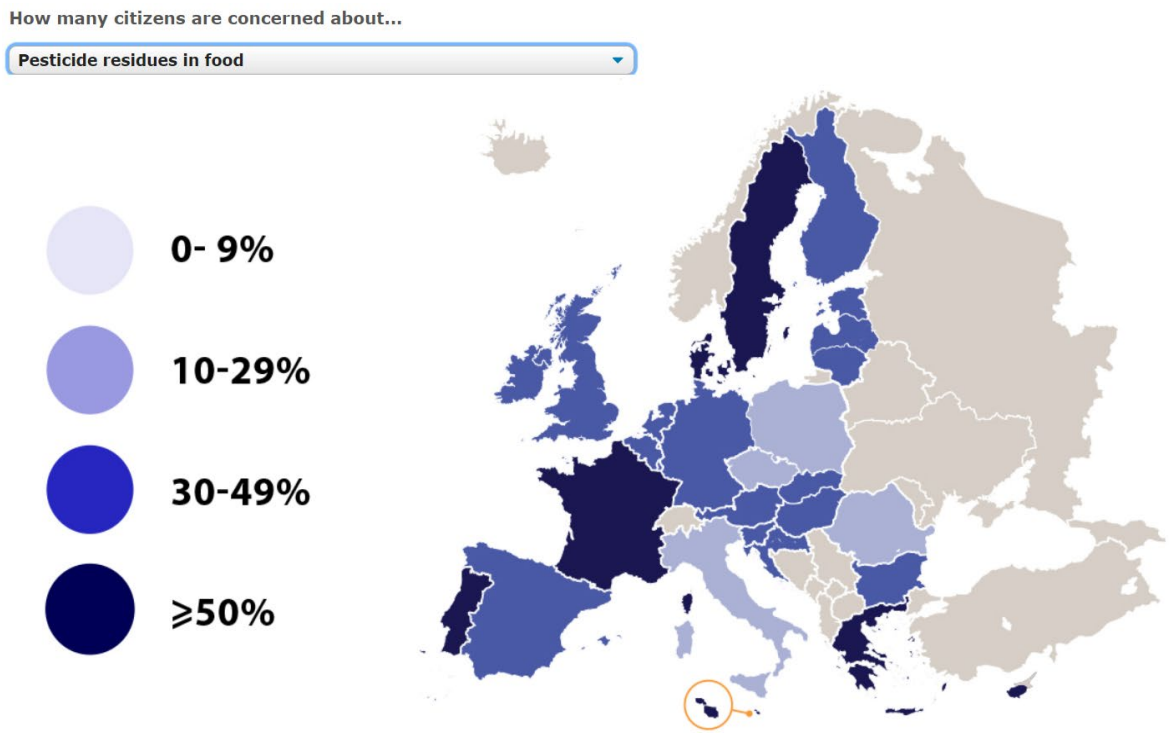
With regard to food safety and human health, there is overlap with the perspectives of stakeholders that focus on food consumption (Section 2.1).

This is illustrated by the EFSA-initiated Eurobarometer study that focused on food safety perceptions and sheds an interesting light on societal concerns (European Commission, 2019). The study was conducted by an external contract research company in all 28 EU Member States on a representative sample of 27 655 respondents from different social and demographic groups. The results showed that 39% of the respondents were concerned about pesticide residues in food.

Pesticide residues are one of the most frequently reported food safety concerns of European citizens, together with antibiotics, hormones and steroids in meat, environmental pollutants, and food additives.

The Eurobarometer study found that pesticide residues in food was the topic chosen most frequently as a concern in five countries: Greece (by 67% of citizens), Cyprus (60%) and France, Portugal and Sweden (all 57%). Figure 2.1 provides an overview of public opinion across European countries.

Figure 2.1: Public concerns about pesticide residues in food



Source: Eurobarometer 2019 (https://www.efsa.europa.eu/en/interactive-pages/eurobarometer-2019)

Similar results were found in a study by BEUC, the European consumer organisation. In this study, about 43% of consumers spontaneously associated 'sustainable food' with "use of GMOs and pesticides to be avoided" (BEUC, 2020).

Environmental impact

The Rise Report (Buckwell et al., 2020) provides information on the environmental impact of plant protection products:

Most environmentalists and many scientists are concerned that Europe is not acting sufficiently strongly or fast enough to reduce biodiversity loss by what they see as a necessary system change in farming methods.

Environmentalists argue that the current food production system with its high degree of dependence on synthetic PPPs is unsustainable. They advocate stronger ambitions to reduce PPP use and even to abandon them altogether.

However, the multiplicity of organisms potentially affected by PPPs and the complexity of their interactions with each other and with all other aspects of human activity involved in food production make it hard to determine the actual impact of PPPs.

The role of public trust

A risk assessment by Hunka et al. (2015) found that the most trusted information sources on food safety risks were health professionals (84%) followed closely by consumer organisations, scientists and environmental NGOs. Regulators were trusted to a lesser extent. More than half of the study participants trusted European and national food safety authorities (64%). The finding that a substantial proportion of citizens believed that regulators were not independent from industry lobbying is not helpful in gaining their trust.

The lack of scientific consensus on the effects of pesticide use on human health and the environment has a negative influence on public trust in related policies (Aklin and Urpelainen, 2014).

In this respect, an interesting observation from Frewer (2017, p. 688) is that "*the scientific controversy associated with the possible impacts of pesticides potentially signalled that their use may be 'out of control', and thus human health and environmental impacts may be unanticipated, unintended and unpredictable. Affective factors influence peoples' acceptance of pesticide use, disgust being an influential factor associated with consumer decision-making across different applications of agrifood technologies.*"

Dismissing affective (emotional) responses by citizens as irrational has further fuelled public distrust in regulators and the associated industries, and, as a consequence further communication about the topic is likely to be disregarded (Frewer, 2017).

NGOs

Citizen concerns are represented by NGOs, which may or may not have activist agendas. Some NGOs focus on single societal issues, such as human health or the environment. The NGOs with an interest in crop protection are mainly environmentalists, such as the Pesticide Action Network (PAN), and organic groups, such as the UK Soil Association.

These NGOs often support or ask for more stringent regulations in a drive towards a pesticide-free Europe (Hillocks, 2012). They report that the environment is inadequately protected by the current system because: the impacts of PPPs are not assessed for all groups of species; tests on individual species do not reveal the impacts on ecosystems, and; the potential interactive 'cocktail' effects of multiple PPP use are not taken into account (Buckwell et al., 2020). As a consequence, the NGOs urge citizens to avoid purchasing products produced with the aid of pesticides and encourage the development of alternatives (see for example, Friends of the Earth 2012).

Consumer-oriented NGOs that focus on food safety and health are less prominent in the crop protection debate. A screening of their websites shows that their main focus is mainly on other issues like food labelling rather than crop protection and pesticide use.

2.4.3. Relevant societal organisations and their opinions

The table below shows a list of the relevant European organisations that look at crop protection from a societal perspective (i.e. citizens and NGOs representing citizen groups or societal interests, and also public bodies responsible for formulating policies). The table describes the role of the organisation, its relation with crop protection and the background of its opinion about crop protection.

Table 2.4: List of relevant societal organisations

Name of organisation	Role of organisation	Relation between crop protection and interest of the organisation	Opinion about crop protection and use of PPPs and background of opinion
Pesticide Action Network (PAN) Europe	PAN is a network of over 600 NGOs, institutions and individuals in over 60 countries worldwide. PAN works to minimise the negative effects of hazardous pesticides and to replace their use with ecologically sound and socially just alternatives.	PAN works to eliminate dependency on chemical pesticides and to support safe, sustainable pest control methods. It undertakes advocacy, policy analysis, networking and campaigning activities on pesticides. PAN Europe is committed to bringing about a substantial reduction in pesticide use throughout Europe.	PAN Europe's vision is of a world in which high agricultural productivity is achieved by truly sustainable agricultural production systems in which agrochemical inputs and environmental damage are minimised, and where local people control local production using local varieties.
Friends of the Earth Europe	Friends of the Earth Europe is the largest grassroots environmental network in Europe, uniting more than 30 national organisations with thousands of local groups. It campaigns on today's most urgent environmental and social issues; challenges the current model of economic and corporate globalisation, and; promotes solutions that will help to create environmentally sustainable and socially just societies.	Nature, food and agriculture is one of the organisation's focal areas. It considers that Europe's current model of farming and food consumption is destroying the environment and hurting people.	Friends of the Earth Europe has a vision of farming that respects the world's finite resources and is fair to farmers and consumers. It is part of the European Citizens' Initiative to Save Bees and Farmers, which was launched November 2019 and aims to phase out synthetic pesticides by 2035. The initiative will support farmers and save bees and nature.
WWF Europe	WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.	Agriculture and food is one of the topics of WWF. WWF considers the current situation of food production and consumption is unsustainable and is a primary cause of biodiversity loss, land use change, depletion of natural resources and climate change.	WWF believes that, as a major global actor, Europe has a key role in the transition towards resilient, equitable and sustainable agri-food systems. WWF welcomes the decision by the European Parliament to ban the use of pesticides in Ecological Focus Areas and to launch an initiative to tackle the

			rapid decline of pollinators in Europe.
European Federation of Food Science & Technology (EFFoST)	EFFoST facilitates knowledge and technology exchange among food professionals. More than 130 societies, institutes and universities across Europe are affiliated to the non-profit organisation.	EFFoST supports the further development of food science and technology. Through collaboration, disciplines such as microbiology, chemistry, physics, engineering and materials science can increase innovation, especially in co-operation with food producers. EFFoST offers knowledge and independent advice to the European Commission to support an effective strategic research agenda.	No specific information is available on crop protection.

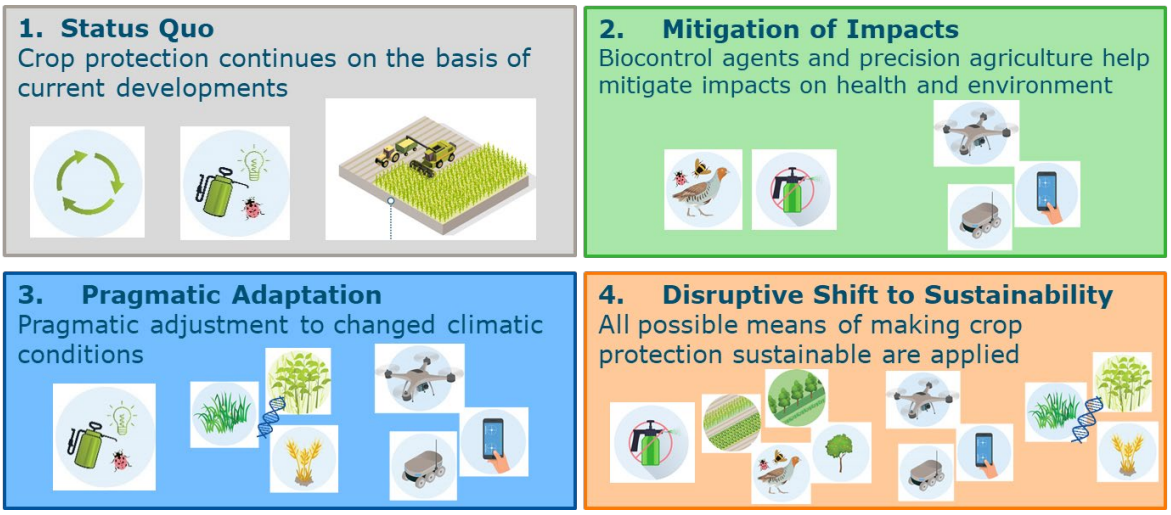
3. Four explorative scenarios about the future of crop protection in 2050

Scenarios can be used as a tool to enable dialogue with and between different stakeholders, and for reflection on policy options from a long-term perspective. Report 1 of the study provided an overview and review of existing and emerging crop protection activities, as well as an assessment of their impacts using the STEEPED[7] approach (see Van Woensel, 2020).

This overview can be used as a basis for the development of four explorative scenarios, in which existing and emerging crop protection practices are combined in ways that control crop pests, diseases and weeds effectively. This chapter describes the scenarios that are developed.

The following infographic summarises the scenarios:

Figure 3.1: Four explorative scenarios



Source: Wageningen University and Research, Field crops

Full descriptions of the scenarios can be found in Appendix 2. The following sections provide information about the scenario development and a short summary of each scenario.

3.1. Scenario development

3.1.1. Key factor identification

The development of the scenarios started with the identification of key factors. Identifying key factors before starting to develop scenarios helps to reduce the set of potential influencing factors to a set of top priority 'key factors'. Having key factors underlying the scenarios provides transparency on how scenarios are created.

Once the list of key factors is finalised, different projections for each key factor were identified and described (based on the time horizon of 2050).

[7] STEEPED: Society, Technology, Economy, Ecology, Politics, Ethical, Demographics

Guiding questions for drafting the projections were: How could this key factor develop until 2050? and; In what other ways can we imagine that this factor may develop? Consistent 'bundles of projections' can then be used to construct scenarios.

In the construction of the four scenarios for the future of crop protection, we distinguished the following key factors, ordered by the STEEPED approach:

Table 3.1: List of key factors

Key factors shaping the future of crop protection in 2050	
Society	▪ Requirements to human health
Technology	▪ New breeding technologies ▪ Biocontrol ▪ Precision agriculture
Economy	▪ Globalisation
Ecology	▪ Requirements to maintain ecosystem services ▪ Coping with climate change
Politics	▪ Need for food security
Ethical	▪ Ethics: moralism vs pragmatism
Demographics	This future projection is assumed to be rather clear and the variation of the factor is low. Therefore, these so-called "Givens" are integrated in the scenario process but they are not included in the scenario construction)

Full descriptions of the key factors can be found in Appendix 1.

3.1.2. Scenario development

Different scenarios were developed, based on the key factors and the projections.[8] For each scenario, key characteristics were described and a more detailed description of "*What Crop Protection in Europe Looks Like in 2050*" was developed. The descriptions help to make the scenarios understandable and provide information needed for their use in policy development.

Alongside these descriptions, a narrative storyline was developed for each scenario to "bring the scenario to life". Full descriptions of the scenarios can be found in Appendix 2.

3.2. The four scenarios

3.2.1. Status Quo

In this scenario, crop protection continues based on current developments. This means that no substantial additional efforts would be applied to change crop protection practices. The control of pests, diseases and weeds in Europe primarily would take place with agrochemicals.

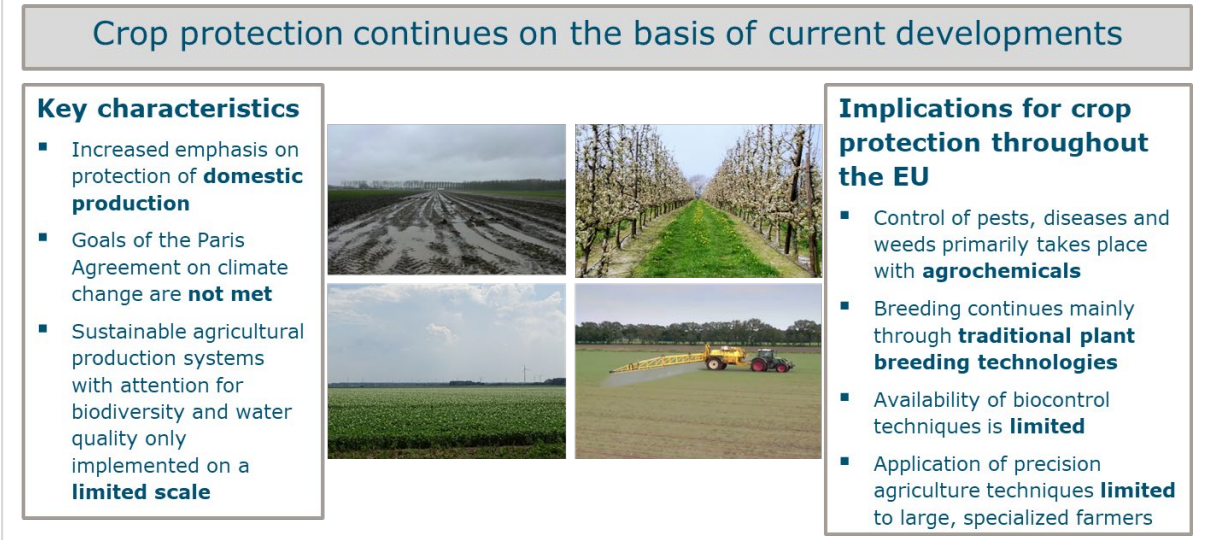
The availability of biocontrol techniques for field crops would be limited, while the efficacy and reliability of available tools, measures and agents would remain insufficient. Genetic and breeding

[8] Raw scenario bundles were calculated based on the arithmetic mean of scores of a 'consistency scoring' of the key factors. For the calculation of raw scenario bundles the analytical and genetic algorithms of the ScenLab scenario software in version 1.8.1 were utilised, as well as analysis tools (multi-dimensional scaling, clustering, etc.) provided by the software.

technologies would not be applied in the EU. Breeding would continue mainly through traditional plant breeding technologies.

The graphic below summarises this scenario.

Figure 3.2: Status Quo scenario



Source: Wageningen University and Research, Field crops

3.2.2. Mitigation of Impacts

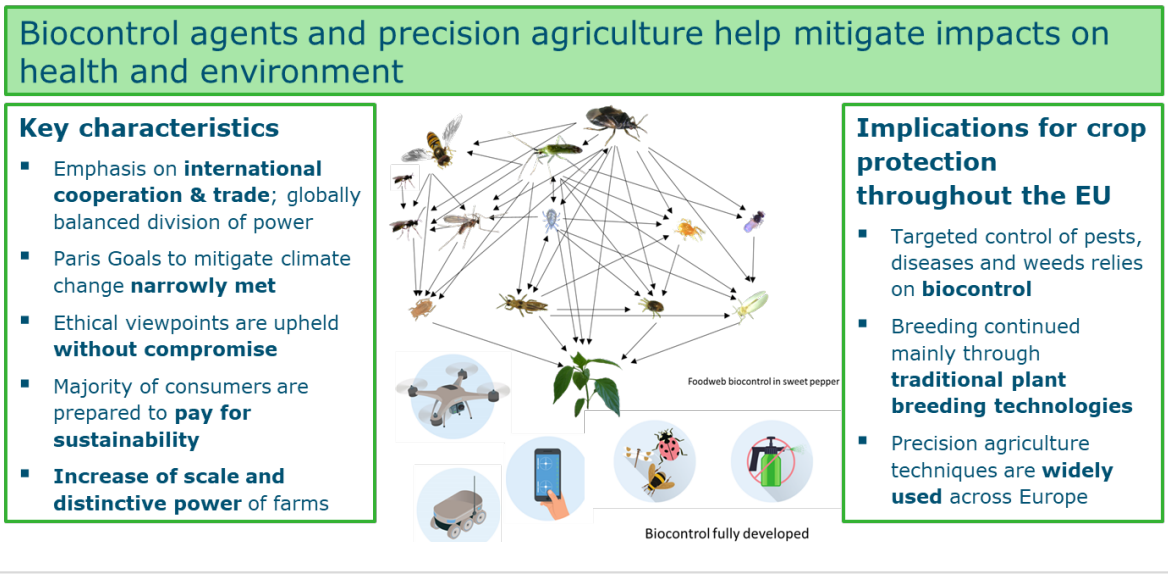
In the second scenario, the need to mitigate climate change, and protect and improve ecosystems would be realised by means of a transition towards sustainable agri-food systems.

Consumers awould be fully aware of the ecological effects of their consumption, and consumption patterns would be adapted in a more sustainable way.

The targeted control of pests, diseases and weeds would rely on biocontrol. Precision agriculture techniques would be used in all field crops in Europe. However, new genetic and breeding technologies would not be applied in the European Union in 2050 due to ethical concerns. Plant breeding since 2020 would continue to rely mainly on traditional plant breeding technologies.

The graphic below summarises this scenario.

Figure 3.3: Mitigation of Impacts scenario



Source: Wageningen University and Research, Field crops

3.2.3. Pragmatic Adaptation

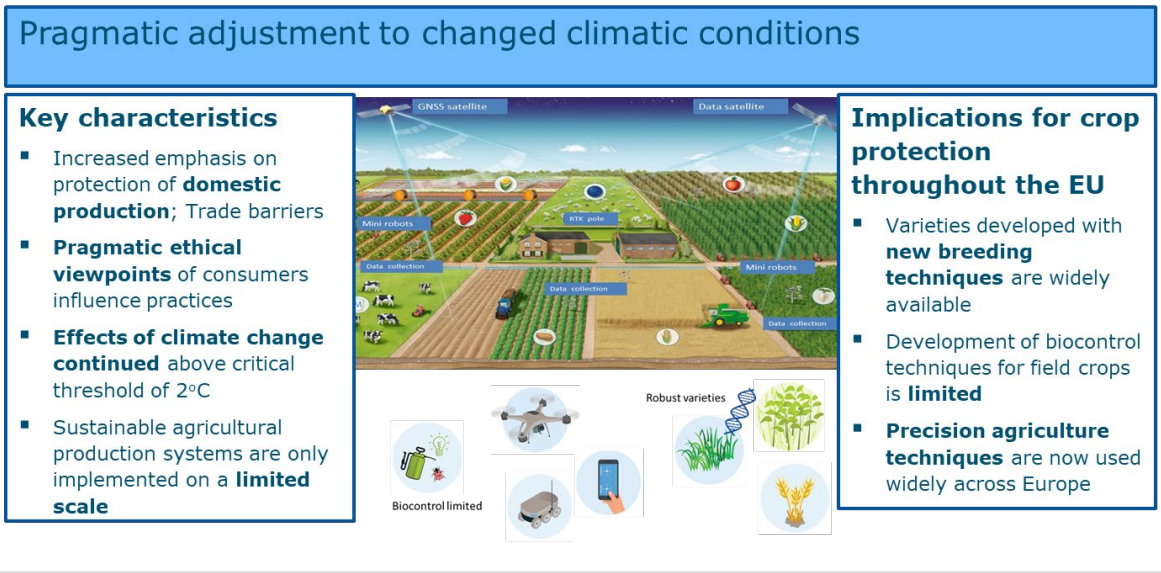
The effects of climate change would continue under the most likely scenarios, with an average temperature increase of more than 2°C by 2050. Farmers would have to adapt to the conditions.

Cropping systems would be redesigned to create plant production systems that are diversified and resilient to pests, diseases and weeds. Varieties developed with new breeding techniques would be widely available and precision agriculture techniques would be used in all field crops in Europe.

However, the development of biocontrol techniques for field crops would be limited. There would be a lack of insight on potential beneficial organisms that could form the basis for biocontrol outdoors.

The graphic below summarises this scenario.

Figure 3.4: Pragmatic Adaptation scenario



Source: Wageningen University and Research, Field crops

3.2.4. Disruptive Shift to Sustainability

In the final, disruptive, scenario, all possible means to stop biodiversity loss and climate change would be applied, with wide scope for radical innovation.

New techniques for altering plant DNA would not be subject to any limitations. As a consequence, varieties developed with new breeding techniques would be widely available. The application of biocontrol agents and techniques would be based on real-time monitoring of pests, diseases, weeds and crop status.

The increased need to protect and improve biodiversity, and the demand for food security for all would lead to the development and implementation of biodiverse farming systems.

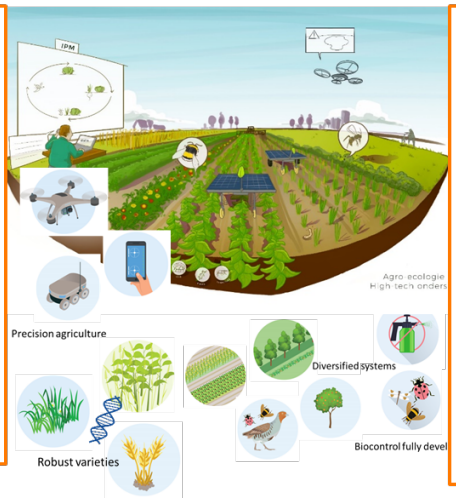
The graphic below summarises this scenario.

Figure 3.5: Disruptive Shift to Sustainability scenario

All possible means of making crop protection sustainable are applied

Key characteristics

- Emphasis on **international cooperation and trade**; globally balanced division of power
- Net-positive sustainability becomes the **societal and economic guiding principle**
- **All means** to stop biodiversity loss and climate change are pushed, which drives radical innovation (e.g. as in biodiverse farming systems)



Implications for crop protection throughout the EU

- Development and implementation of **biodiverse farming systems**
- Varieties developed with new breeding techniques **widely available**
- Discovery of beneficial organisms and **development of biocontrol techniques**
- **Precision agriculture techniques** widely used across Europe

Source: Wageningen University and Research, Field crops

4. Brainstorming meeting with stakeholders, technical experts and social scientists

A brainstorming meeting with relevant stakeholders was organised on the 16th of June 2020 in close cooperation with STOA staff. The meeting was held online and involved 29 stakeholders, technical experts and social scientists [9].

The objective of the meeting was to discuss the future scenarios and envisage a range of impacts of future crop protection practices in 2050 from different stakeholder perspectives. In order to do that, three break-out groups were organised in which each group was assigned to two scenarios.

Group members had to consider the potential implications of the crop protection practices described for each scenario on the different stakeholders (farmers, consumers, industry, NGOs). In addition, the likely hopes and fears (i.e. potential positive and negative knock-on effects) of the different stakeholders were identified.

It is important to note that, in reporting the results, comments were not attributed to participants. This was for two reasons:

Firstly, the format of the online workshop enabled participants to contribute ideas across a range of stakeholder groups. This was particularly beneficial for the stakeholder perspectives in which there were minimal or no representatives.

Secondly, comments are very rarely attributed to participants in this type of foresight workshop. The aim is to encourage the free flow of conversation and ideas, and to bring the participants together as equal contributors.

The materials related to the brainstorming meeting (agenda, presentation, output from the break-out groups, scenario evaluations, and a list of participating organisations) can be found in Appendix 3.

The following sections provide a synthesis of the outcomes of the brainstorming meeting regarding the implications for the different stakeholder groups. Additionally, this chapter ends with the overall conclusions of this part of the study.

4.1. Implications of the scenarios for different stakeholders

As described below, the implications of each scenario for the different stakeholder groups were discussed, based on the outcomes of the brainstorming meeting.

4.1.1. Status Quo scenario

Implications for farmers Participants expressed fears that, in this scenario, working in the agricultural sector would not be very attractive due to very limited scope for technological development and innovation compared to other economic sectors.

The focus on the protection of domestic production would put EU farmers at a competitive disadvantage compared to other countries, which would have more incentive to make more

[9] Due to the COVID-19 pandemic we had to organise an online meeting instead of a real-life meeting at the STOA office in Brussels, which was the initial plan. For the plenary sessions Google Meet was used, whereas for general communication throughout and interaction in the breakout sessions the tool Slack was used. To collaborate in the breakout / working groups on a single document and collect participants' input Google docs was used.

progress in developing new crop protection practices. Under this scenario, farmers would have a continuing dependency on chemical PPPs.

Those wishing to adapt their farms to new crop protection techniques would not be encouraged or supported. Farmers would be in a position where they do not have the financial means, or do not want to take the financial risk, to break out of the 'chemical lock-in'.

There were fears that the unchanging production methods would not be resilient to the expected impacts of climate change (including biotic changes, such as new pests; and abiotic changes, such as variable weather patterns and shocks).

However, some participants disagreed. They considered that this scenario would still allow farmers to use alternative crop protection methods and resistant cultivars without simply relying on chemical solutions.

There was also hope that the food system would offer opportunities for resilience to the expected impacts of climate change, and farmers would have flexibility as well as financial and other means to adapt.

Implications for consumers Participants expressed the hope that this scenario would provide clear (i.e. well-labelled and understandable) information to enable consumers to make well-informed decisions when purchasing food. Some participants went further, suggesting that this scenario would provide more options for buying food than just 'regular' and 'organic'. They felt that customers would receive more nuanced information on the restricted use of PPPs.

On the other hand, there was a fear that consumers would not be able to make informed choices and that the use of chemical PPPs (and therefore their negative impacts) would remain high due to little development of alternative strategies.

Participants disagreed on whether or not the reliance on domestic production under this scenario would be beneficial for consumers.

Implications for the PPP industry There was a hope that adequate information on the benefits and risks of PPPs would be conveyed to the public. This would increase further with greater transparency.

There was also a hope for more development of new, greener, PPPs under this scenario. Climate change will give rise to new and bigger crop protection problems, making such developments a necessity. Such development would also be motivated by the possibility for companies to gain new market share in a more competitive market.

Conversely, there was a fear that the industry would face losses due to stricter regulatory requirements for chemical PPPs and decreased innovation of alternative crop protection methods. In this case, the PPP industry would be outperformed by competitors from outside the EU.

Implications for NGOs In this scenario, NGOs foresee that their actions and publicity for reducing the use of chemical crop protection products would not led to changed practices.

Nevertheless, some participants felt that NGOs would hope for greater restrictions in the use of agrochemicals. These restrictions could be implemented by regulation, or by supply chain members (particularly retailers) responding to consumer demands.

NGOs may also fear that they would be excluded from discussions about crop protection policies in the EU. In this case, they may feel they have no alternative but to adopt more aggressive approaches in their lobbying and campaigning.

4.1.2. Mitigation of Impacts scenario

Implications for farmers There was a general consensus among participants that this scenario would pose challenges for farmers as they would need to adapt to new farming systems. For example, if little or no use is made of multi-site agrochemicals, then more field operations would be needed to control weeds, pests and diseases.

The view of participants was that the costs of crop production would increase under this scenario, resulting in more consolidation of farms into larger units that are in a better position to benefit from precision agriculture.

The wide use of precision agriculture would reduce the need for traditional manual and machinery work on farms. Together with the overall increase in farm size, this would put many small-scale and family farms out of business. As a consequence, farming at this level may not be seen as an attractive career, and the demographics of rural communities may change.

Despite these challenges, participants expressed the hope that the mitigation scenario would lead to fair competition and financial returns for all producers in the EU, with less dominance from global markets and retailers.

A distinction has to be made between the outlook for small and medium-sized farms as described above, and large-scale farms with the ability to benefit from precision agriculture and economies of scale. Such large farms would be more likely to provide attractive career opportunities for well-educated and well-trained young farmers and professional managers.

However, fears were expressed that farmers would not be able to keep pace with the spread of new diseases and pests across Europe as a result of climate change. The need to develop resilient cropping systems without using chemical controls would create a fear for some farmers that they would not have full control over all threats to their crops from weeds, pests and diseases.

There was also a fear that continuous pressure from NGOs and public opinion would be applied to farmers who protect their crops with plant protection products, albeit biopesticides.

Implications for consumers In this scenario, consumers would have more choice between various product options, allowing them to focus on their personal priorities for the environment. This would make them less concerned about the food they eat. However, the price of food may increase, since the risks of yield and quality losses will increase.

Some groups of consumers, such as those with relatively low incomes, may be excluded by price from the full range of choices.

Participants also raised a fear that the information communicated to consumers may be "green washing" or inaccurate.

Implications for PPP industry Greater use of biocontrol would increase the market potential for these products and foster further development.

The scenario would allow new players to enter the market for crop protection products, particularly companies innovating biocontrols. The system envisaged in this scenario would allow for thorough checks of new technologies regarding their safety towards health and the environment, but would not put EU industry and farmers at a competitive disadvantage with third countries.

On the other hand, participants expressed a fear that there would be a loss in profits for PPP companies that are not able to meet the new demands for different types of products.

Moreover, strong ethics would make it more difficult to use the latest techniques which would partly replace chemical PPPs. This would increase the risks of yield and quality losses.

In relation to the ethics, there was a fear that some innovative technologies would be welcome in the EU, while others would not. This would make other parts of the world more attractive market for developing and implementing new crop protection products.

Finally in this scenario, international cooperation would be essential, but at the same time dependency on a single country for certain products would also make businesses vulnerable.

Implications for NGOs In this scenario, there was a hope that the actions of NGOs would bring results.

The mitigation approach would lead to: minimising environmental impacts from crop protection; greater public "sustainability awareness", and; societal approval as agriculture plays its part in mitigating climate change and halting the collapse of ecosystems.

However, according to one participant, 2050 could see a 'battle' between NGO groups strongly supporting and advocating particular biocontrol or precision agriculture methods and opposing others.

4.1.3. Pragmatic Adaptation scenario

Implications for farmers In this scenario, participants thought that farmers would seek to combine all available technologies to achieve safe, high-yielding and high-quality production. This would be the best way to ensure food security for consumers, considering that rapid world population growth would continue.

Novel breeding techniques would give farmers more independence and control over production. Safe and effective tools would be available to combat pests and diseases that become worse as a result of climate change. Increased emphasis on protecting domestic production would provide opportunities for new farming communities, for instance in regional and urban farming.

However, participants considered that climate change would present a big risk under this scenario. Biotic and abiotic shocks would affect the volatility (in quantity and quality) of food supply, and prices.

Climate change would lead to changes in crops that could be grown in certain areas. It would also have implications for the European farming model, as small and family farms would become less competitive and find it difficult to survive.

As solutions would have to be found quickly, there may not be enough time to assess all risks.

This scenario would provide limited technical and market options for farmers wishing to embrace sustainable agriculture. This could worsen the public image of farmers as "polluters of the environment", especially should other sectors of the economy become relatively more sustainable.

Implications for consumers This scenario would provide stronger support for regional and local production, and stronger links between cities and rural areas. This would be a consequence of the emphasis on the protection of domestic production.

The emphasis on domestic production would give access to local produce, strengthen food security in times of crisis, and increase willingness to pay higher prices for local products. Participants expressed the hope that this scenario would result in environmentally-friendly, affordable and healthy food.

However, participants indicated that this scenario would result in climate change having a greater impact on daily lives.

Failed harvests could lead to higher prices and increased price volatility. In these circumstances, consumers may be less able to pay for sustainable food products, and may experience a lack of variety or even scarcity.

This means that consumers would have an increased need for understandable information about the climatic impacts on food supply and the environment (e.g. on biodiversity) to inform their purchase choices.

Participants felt that this scenario may also result in a fear of the unknown among consumers: what does it mean if a food crop is produced using precision agriculture or new breeding techniques?

Implications for PPP industry Under this scenario, the PPP industry would need to focus on domestic markets and face trade barriers when operating internationally.

The domestic focus would create a risk of losing access to international markets for trading both production inputs and plant protection products.

The biocontrol sector would not thrive under this scenario. Agrochemicals would continue to be the dominant method of crop protection. Farmers would be offered limited alternatives and there would be little benefit from new technologies.

On the positive side, scientists and technologists would have opportunities to develop new products, diversify businesses and develop new business models.

However, innovating would be difficult without support from society, which may lead to a focus on short-term developments and innovations rather than a long-term outlook.

Implications for NGOs Climate change wouid be a major issue for NGOs in this scenario. Although new breeding techniques and precision agriculture would lead to efficiency gains and diminished impact, agriculture would continue to exert an excessive negative influence on the climate and nature.

NGOs would therefore continue their actions against excessive and unwise pesticide use. This would include advocating products with a low environmental impact.

NGOs would face a dilemma concerning their support for new climate-resilient crop varieties bred with genetic technology. Whilst new varieties may lead to lower pesticide use, seed companies could gain market dominance through patents on the new breeding technologies.

Nevertheless, NGOs may hope under this scenario that the effects of climate change would lead to raised awareness among farmers, industry and consumers that there is an urgent need to convert to more climate-friendly food production methods. Protection of domestic production would enable a rise in sustainability standards for EU agriculture, and the internalisation of the environmental costs of harmful practices would correct the price signals in the markets.

4.1.4. Disruptive Shift to Sustainability scenario

Implications for farmers Participants saw a lot of positive implications for farmers in this scenario. They would get more power in the food supply chain and regain autonomy in taking decisions. There would also be fair and open competition for imported raw materials through international cooperation and trade.

The scenario would encourage greater appreciation and financial incentive for sustainable production. Sustainable food products would generate more added value for producers. The food production system created under this scenario would be profitable for all farm sizes – from small-scale specialists to large-scale producers.

However, this scenario also raises questions and concerns for farmers. Farm inputs may become more expensive, raising the question of how to make an economic return. There would also be a fear that farmers may not be able to repay their investment in new technologies and changed farming methods.

This is by far the most complex scenario and farmers would need to acquire very different skills and knowledge to plan and implement biodiverse farming systems. There is therefore a fear that they would not have enough technical support during the transition phase.

Another concern would be the compatibility of new technologies – like precision agriculture – with the European agricultural model, with its family farms and relatively small farm size compared to other major producers.

From a market perspective, there would be a question of how to differentiate between levels of sustainability, and whether new breeding techniques would be accepted and considered sustainable by consumers.

Implications for consumers Participants anticipated good implications for consumers. In this scenario, there would be an enormous variety of choice. Consumers would be able to make their own choices about saving the planet and safeguarding their own health.

New labelling systems would provide details on the sustainability of products. Consumers would hold a greater appreciation for farmers and a decreased ideological distance.

Potentially, more seasonal and local produce would shorten supply chains, including consumers buying directly from producers.

However, a negative aspect for consumers would be the risk of large increases in food prices.

Another concern to be addressed would be the way in which consumers could trust the safety of crops grown by new breeding techniques. Technical solutions that are reached without the involvement of consumers might increase the distance between farmers and consumers, encouraging the fear that the new technologies are not genuinely sustainable.

Implications for PPP industry This is a positive scenario for the PPP industry as it would allow the full potential of biological control to be realised.

This would bring opportunities for business expansion through diversification and specialisation. Diversifying from chemical to biological plant protection products would improve the reputation of the industry, leading to increased approval by society.

The EU would have a crucial role in a rapid transition through the introduction of specific regulations for risk-based biocontrol methods and the removal of barriers to the development of the new technologies.

Participants vented the concern that the existing regulatory framework is slow to adapt to new developments, with too strict regulation on new products that jeopardises business opportunities and investment on research and development.

Implications for NGOs In this scenario, NGOs would have a more active role in shaping food systems. A hope for NGOs is that, due to their efforts, agriculture would come to be seen as supporting the environment.

However, participants thought that NGOs would still fear whether the new system of agriculture would be resilient to climate change, and also political change.

Also, NGOs still have concerns regarding gene editing, the origins and sources of newly discovered beneficial organisms and biocontrol agents, and the risks from invasive species and pests.

4.2. Scenario evaluation

The following table summarises the most important hopes and fears of the different stakeholders in key words for each scenario:

Table 4.1: Summary of hopes and fears for each scenario

1. Status Quo **Hopes**: Flexibility and (financial) means to adapt to climate change; Adequate information conveyed to the public about benefits and risks of PPPs. **Fears**: Sector is vulnerable to biotic & abiotic shocks; Limited technological development and innovation; Continuing dependency on chemical PPPs; ecosystem collapse; More vulnerability to climate change.	**2. Mitigation of Impacts** **Hopes**: Fair competitiveness and fair prices; Farming is attractive profession again; Increased consumer trust in food; Introduction of new technologies and new players to market; Successful minimization of environmental impact from crop protection. **Fears**: Upscaling needed as smaller operations cannot survive competition; Continuous pressure from NGOs and public opinion; Price increases and 'green washing'; Not all innovative technologies are allowed on EU market.
3. Pragmatic Adaptation **Hopes**: Having safe and effective tools to combat pests and diseases; Access to local, affordable and healthy products; Opportunities for diversification (e.g. new gentech) and new business models; Focus on domestic production allows raising sustainability standards of EU. **Fears**: Major concerns about climate change; Loss of access to international markets due to trade and regulatory barriers; Concentration of power at seed companies.	**4. Disruptive Shift to Sustainability** **Hopes**: Farmers getting more power and autonomy; Level-playing fields with imported raw materials; More choice opportunities for consumers; Opportunities for expanding businesses through diversification; Full potential of biocontrol allowed to develop; Agriculture viewed as supporting the environment. **Fears**: High investment into new technologies; Need to acquire new skills and knowledge; Increasing food prices; Regulatory framework slow to adapt to new technological possibilities due to high diversity of systems.

The 'Status Quo' scenario evoked most concerns and fears among the participants, particularly concerning the vulnerability to climate change and the continued dependency on agrochemical PPPs.

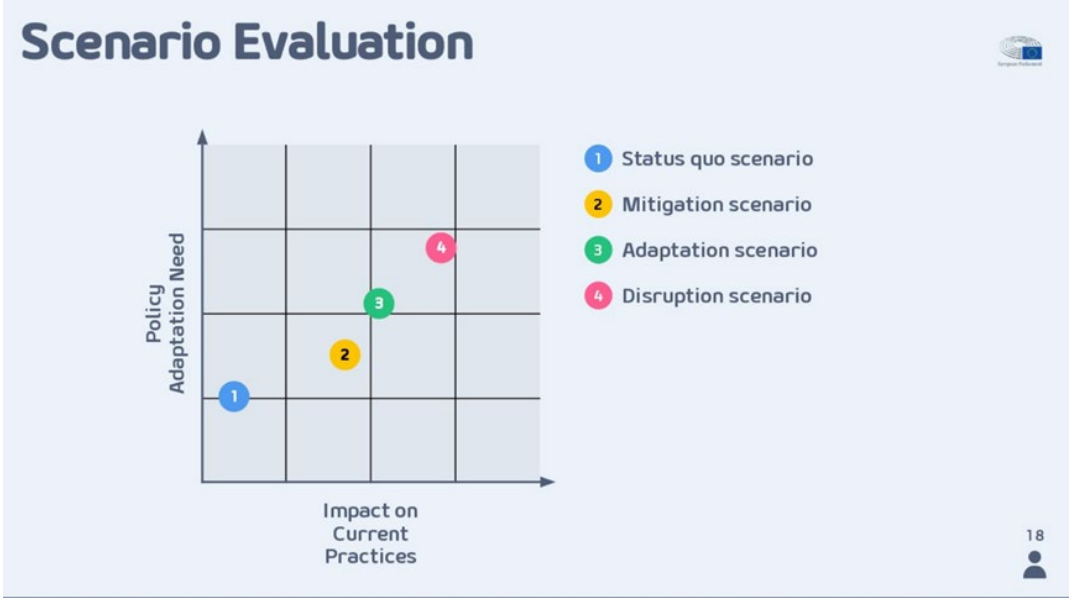
Both the 'Mitigation' and 'Adaptation' scenarios present opportunities for innovation, diversification of businesses, and new players entering the market, but also still evoked some concerns.

The 'Disruptive' scenario presents most opportunities and is expected to have greatest impact, but not without some major challenges. Specific concerns included the investments and skills that are needed to make such a transition.

At the end of the brainstorming meeting, participants were asked to rate each scenario on a 10-point scale with respect to policy adaptations that would be required compared to current policy (on a scale from minimal to extensive), and impact on current practices (on a scale from low to high).

This exercise was carried out using Mentimeter, an online tool for real-time voting. The figure below shows the results of the scenario evaluation:

Figure 4.1: Scenario evaluation



The 'Status Quo' scenario would clearly involve the least policy adaptation and would also have the lowest impact on current practices.

The 'Disruptive' scenario would have the greatest impact, but would also need most policy adaptation.

The 'Mitigation' and 'Adaptation' scenarios occupy an intermediate position, with the 'Adaptation' scenario having somewhat more impact, but also somewhat more policy adaptation.

The spread in participant scores was sometimes quite high, especially for the 'Mitigation' and 'Adaptation' scenarios. This implies that there was less consensus among the participants on impact and policy adaptation for these scenarios as compared to the 'Status Quo' and 'Disruptive' scenarios.

It appeared that some participants did not rate some scenarios at all (hence there were some zero values). For further details, see Appendix 3, which shows a more detailed overview of scores for each scenario.

4.3. Overall conclusions

4.3.1. Stakeholders' view on crop protection

The overall objective of *The Future of Crop Protection* project is to present an overview of crop protection options for European farmers such that they might be able to work sustainably while securing food production, preserving biodiversity and supporting farmers' incomes. In Report 1, current crop protection practices as well as possible alternative crop protection practices have been reviewed and assessed. This overview shows that several crop protection practices are under continuous development and have potential to improve crop protection in future in Europe. However, at the same time, these (technological) developments are important, but only effective

when they will be implemented by the farmers and accepted by other societal stakeholders. This will mean understanding stakeholders' opinions and preferences, and addressing these, is crucial when designing crop protection practices of the future.

The first part of this report therefore presented the relevant stakeholders and their views on crop protection. Four stakeholder groups can be distinguished, namely those who look at crop protection from: (1) a consumption perspective (i.e. consumers, retailers and food industry), (2) a production perspective (i.e. farmers and growers), (3) a supply chain perspective (i.e. crop protection industry), and (4) a societal perspective.

First, consumers generally show a willingness to pay premium prices for products grown without using pesticides or with low use of pesticides. However, individual and regional differences, the role of food labelling and marketing, and other food choice motives (such as taste) should be taken into account when looking at the consumer perspective on crop protection. Retailers and food processing companies have accommodated consumer concerns by developing common practices or criteria for lower-pesticide products or by differentiating their products.

Farmers recognise the need to reduce their dependency on agrochemicals; they are aware of changing public opinion about PPPs and the consequences for their 'licence to produce'. Nevertheless, they are reluctant to switch to alternative crop protection practices as in many cases alternative methods are less efficient than chemical control. In addition, switching to more sustainable systems poses heavy initial costs and increases the complexity of farm management and requires additional decision-making.

The use of PPPs is obviously in the interest of the crop protection industry as these are its products. Although the industry is critical towards societal pressure for a substantial reduction in the use of PPPs and the stringent regulatory system, it is committed to respond to demands to make product safety data more accessible to the public, to provide greater transparency, and to increase trust in the approval process.

Finally, the use of PPPs is subject to societal concerns because of the risks to human health (of users, consumers and in some cases bystanders) and the environment (loss of biodiversity and the emergence of pesticide resistance). These concerns are represented by NGOs, which may or may not have activist agendas. In any case, they often support or ask for more stringent regulations in a drive towards a pesticide-free Europe.

4.3.2. Four scenarios to explore possible futures

Current farming systems have been developed to maximize the output and require relatively many inputs to keep production at maximum levels. A possible lever is to redesign farming systems and develop crop protection systems that reach a sustainable level of production, have a natural resilience towards pests, diseases and weeds and are economically viable, have limited environmental impact and help increase biodiversity. Report 1 elaborated on technologies such as new plant breeding techniques or other genetic technologies, precision agriculture and new mechanization, that enable the development of these systems.

Based on these technologies, and together with a number of other identified key factors, in this report four explorative scenarios were developed that can be used as a tool to enable dialogue with and between different stakeholders, and for reflection on policy options from a long-term perspective:

- In the 'Status Quo' scenario, crop protection continues to be based on current developments. This means that no additional efforts will be made to adjust crop protection practices.

- In the 'Mitigation of Impacts' scenario, biocontrol agents and precision agriculture help mitigate the impacts on human health and the environment.
- The 'Pragmatic Adaptation' scenario allows for a pragmatic approach to adjust to the changed climate conditions.
- In the final 'Disruptive Shift to Sustainability' scenario, all possible means to stop biodiversity loss and climate change are allowed, which provides plenty of room for radical innovation.

4.3.3. The outcomes of the brainstorming meeting

To elaborate on the impact and implications of the possible developments summarized into the four scenarios for different stakeholders, on 16 June 2020, an online brainstorming meeting was organised with representatives of different stakeholder groups. The objective of the brainstorming was to discuss the explorative future scenarios and envisage a wide range of possible impacts of future crop protection practices in 2050 from the perspectives of different stakeholders. For each scenario, the potential implications of the crop protection practices for different stakeholder groups (farmers, consumers, industry, NGOs) as well as the identification of their hopes and fears (i.e. potential positive as well as negative knock-on effects) were identified.

The **'Status Quo'** scenario would need the least policy adaptation and would also have the lowest impact on current practices. However, it seems that this scenario evoked the most concerns and fears among participants in the brainstorming meeting.

One concern is that crop production under this scenario would be vulnerable to biotic and abiotic shocks as a result of climate change. Furthermore, there would be a continued dependency on agrochemical PPPs, and limited technological development and innovation.

Both the **'Mitigation'** and **'Adaptation'** scenarios occupied an intermediate position in terms of impact on current practices and the need for policy adaptation. These scenarios would facilitate innovation, diversification of businesses, and the entry of new players to the market, but they also raise some concerns.

In the 'Mitigation' scenario, not all innovative technologies would be permitted on the EU market (in particular, new plant breeding technologies are excluded for ethical reasons). Another concern is that smaller farms would not survive competition and would need to increase in scale.

The concern about the use of all innovative technologies also applied to the 'Adaptation' scenario (in this case, development of biocontrols would be limited). Additionally, participants expressed major concerns about climate change. The PPP industry may face a possible loss of access to international markets due to trade and regulatory barriers. There were concerns about a concentration of power by seed companies.

The **'Disruptive'** scenario presented the most opportunities and would most likely have the greatest impact on current practices, but it would also need the most policy adaptation.

Under this scenario there would be a hope that farmers gain more power and autonomy, and consumers are offered more choice options. This scenario would enable the development and implementation of the full range of alternative crop protection methods, including: biocontrols, precision agriculture, new plant breeding technologies, and biodiverse farming systems. This would not be achieved without some major challenges, particularly regarding the investment and skills needed to make such a major transition.

Concluding remark

The overview of public and stakeholders' opinion with respect to existing practices and the implications for stakeholders based on potential future crop protection scenarios that are presented in this report, may serve as a basis for future crop protection policy development. These different policy options including impact assessment are presented in the main report of this study.

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Appendix 1: Key Factors

<table>
<tr><td colspan="7">Key factor name: Application of new breeding technologies in the EU</td></tr>
<tr><td colspan="7">STEEPED-Field</td></tr>
<tr><td>Society</td><td>Technology</td><td>Economy</td><td>Ecology</td><td>Politics</td><td>Ethical</td><td>Demographics</td></tr>
<tr><td></td><td>x</td><td></td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>Definition</td><td colspan="6">The development of new genetic and breeding techniques that give the possibility for scientist to genetically modify plants and animals more precisely.</td></tr>
<tr><td colspan="7">Dimensions covered
• Political decisions on the admittance of new breeding techniques
• Implementation of new breeding techniques and subsequent development of varieties</td></tr>
<tr><td colspan="7">Projection 1: Plant breeding status quo
“Continuation of existing trends until 2050” (i.e. things continue to develop as they have in previous decades)
The developed genetic and breeding technologies are not applied in the European Union in 2050. Breeding continues mainly through traditional plant breeding technologies. The development of new varieties as a base for crop protection practices continues at the current speed. Depending on the crop, it will take 10-20 years before varieties with the required traits will be available in the market. As a result, the number of available varieties with the required (resistance/tolerance) traits for pest management is not a sufficient base for crop protection.</td></tr>
<tr><td colspan="7">Projection 2: Varieties developed with new breeding techniques available
“Possible development until 2050”
Varieties developed with new breeding techniques are allowed in the European Union in 2050. Different traits are combined into varieties: multiple resistance to diseases and pests, and tolerance of weeds. These varieties form a solid base for diversified cropping systems that require minimum control of pests, diseases and weeds.</td></tr>
</table>

Key factor name: Biocontrol for Plant Protection						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
	x					
Definition	*All methods, tools, measures and agents of plant protection that rely on the use of beneficial organisms as well as their natural mechanisms and interactions which steer the relationship between biological species in the natural environment (reference: Jay Ram Lamichhane et al 2017)*					
Dimensions covered • *Discovery of beneficial organisms that interact with major pests and diseases in agriculture* • *Formulation of effective products, tools, methods or measures based on these organisms* • *Stability and reliability of efficacy of these products*						
Projection 1: Limited Biocontrol *The development of biocontrol techniques for field crops is limited. There is a lack of insight in potential beneficial organisms that could form the base for biocontrol outdoors. Efficacy and reliability of available tools, measures and agents is insufficient. Targeted control of pests, diseases and weeds primarily takes place with agrochemicals.*						
Projection 2: Biocontrol Breakthrough *Major effort is put into the discovery of beneficial organisms and the subsequent development of biocontrol techniques for field crops. The efficacy and reliability of available tools, measures and agents is good. The targeted control of pests, diseases and weeds relies on biocontrol. These agents, tools, measures and methods form an important tool to restore the balance of the diverse sustainable cropping systems in 2050 after introduction of a pest, disease or weed.*						

Key factor name: Development of precision agriculture						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
	x					
Definition	*Precision agriculture aims at giving crops the right treatment at the right time and smallest scale possible in order to optimise inputs and yield in a more sustainable (for people, planet, profit) way (Reference: Kempenaar et al.)*					

Dimensions covered

- *Underlying technological developments*
  1. *Object identification technology*
  2. *Sensors*
  3. *Global navigation satellite systems*
  4. *Connectivity and information & communication technology*
  5. *Robotics and autonomous navigation*
- *Cost- benefit of precision agriculture technologies*
- *Data ownership*
- *Decision rules for major pests, diseases and weeds*

Projection 1: Limited use of Precision agriculture applications for crop protection "Continuation of existing trends until 2050"

Precise control of pests, diseases and weeds is limited to large highly specialised farmers, and applied only in major crops. The perceived complexity of precision agriculture technologies by farmers, the uncertainty of data ownership and the limited development of tools that recognise pests and diseases, the lack of decision support rules for pests, diseases and weeds hamper further uptake of precision agriculture by farmers in Europe.

Projection 2: Precise control of pests, diseases and weeds in all field crops "Possible development until 2050"

Precision agriculture techniques are used in all field crops in Europe. Development of object identification technology, sensors and connectivity technology enables the real time detection of pests, diseases and weeds and links that information to decision support systems. These systems are based on the relationship between pest, disease and weed densities, potential crop damage and the efficacy of control measures. The precise application of targeted control is executed with small autonomously navigating robots.

Key factor name: Requirements for human health						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**					
Definition	*Human health is defined not only by physical state of individuals; rather it is a state of complete physical, psychological, and social wellbeing (Brinkel et al., 2009). Potential impact on human health leads to requirements regarding food safety and health.*					

Dimensions covered

- *Political decisions on food safety and health*
- *Implementation of diagnostic tools and technologies*
- *Consumer empowerment and decision making*

Projection 1: Continuation of current regulations with regard to food safety and health "Continuation of existing trends until 2050"

Necessary precautions are taken by actors in the food system to ensure that food is safe to eat and that consumers have the necessary information to safely prepare food at home. Furthermore, consumers are provided with clear, understandable and reliable information regarding food safety and health, for example through product labels. Only innovations that contribute to a more healthy food system are introduced.

Projection 2: Increased awareness of relationship between food, safety and health "Possible development until 2050"

Where consumers cannot be empowered, regulatory measures protect their interests. Rules on food safety will be reviewed to take into account new production methods. Furthermore, more radical innovations are introduced that contribute to a more healthy food system. For example, by tailoring diagnostic tools to critical points in the production chain and by predicting and preventing microbiological, particularly zoonotic, and chemical threats entering the food system. To avoid future pandemics, such as COVID-19, particular attention is paid to transmissable diseases related to the food system. At the consumer level, healthy and safe choices are stimulated, for example by making use of consumers' health status information to provide personalised food choice advice. In relation to this, at the consumer level, increased attention is paid to other aspects of health, such as psychological and social wellbeing.

Key factor name: Requirements to maintain ecosystem services						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x?**		**x**			
Definition	*Ecosystem services are the many and varied benefits to humans gifted by the natural environment and from healthy ecosystems. The current modes of food consumption and production affect ecosystems and constitute a primary cause of biodiversity loss, land use change, water pollution and depletion of natural resources.*					

Dimensions covered

- *Political decisions on biodiversity and ecosystems*
- *Implementation of sustainable agricultural production systems*
- *Consumer empowerment and decision making*

Projection 1: Ecosystem services status quo
"Continuation of existing trends until 2050"

Implementation of sustainable agricultural production systems continues on a limited scale and sustainable food products remain a niche market. Only necessary regulations, mainly based on environmental risk assessments, are implemented, for example with regard to pesticide use.

Projection 2: Increased need to protect and improve ecosystem services
"Possible development until 2050"

The need to protect and improve ecosystem services is realised by means of a transition towards sustainable agri-food systems. High agricultural productivity is maintained by systems in which agrochemical inputs and environmental damage are minimised, and where locality is key (i.e. local production using local varieties). Consumers are fully aware of the ecological effects of their consumption, and consumption patterns are adapted in a more sustainable way.

Projection 3: Decreased need to protect and improve biodiversity
"Possible development until 2050"

A global recession (due to COVID-19 pandemic) led to an increased focus on solving short term economic problems and, as a result, decreased attention for environmental issues, like the need to protect biodiversity and ecosystems.

Key factor name: Coping with climate change						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**		**x**			
Definition	*Climate change is the unprecedented (in terms of both rate and scale) rise of the average temperature of the Earth's climate system (i.e. global warming) together with changes in precipitation.* NB. The projections below are mainly based on the goals as set by the Paris Agreement. The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.					

Dimensions covered
• *Political decisions on climate*
• *Implementation of sustainable agricultural production systems*
  • *Mitigation: all efforts oriented at the reduction of greenhouse gas emissions such as CO_2, CH_4 and N_2O*
  • *Adaptation: the actions that have to be executed to continue plant production and to safeguard the level of yield and production under the new circumstances.*
• *Consumer empowerment and decision making*						

Projection 1: Goals of Paris Agreement are (narrowly) met **"Continuation of existing trends until 2050"** *Each country tries to reach its Paris Agreement targets by taking the necessary mitigation policies. The policies include carbon taxes, emissions trading systems, taxes on individual fuels, energy efficiency incentives, and others. However, although the goals of the Paris Agreement are narrowly met, further adaptation to climate change is necessary. This has consequences for crop selection and cultivation methods.*						
Projection 2: Goals of Paris Agreement amply met **"Possible development until 2050"** *More effort is put in to reaching the Paris Agreement goals by introducing more stringent mitigation policies. For example, extensive work has been done in relation to the protein transition (i.e. less meat, more plant-based food), the use of renewable resources over fossil-based resources and the circular economy. This also has implications for agriculture and land use. Note that as a by-effect of the global recession due to COVID-19 pandemic, greenhouse gas emissions decreased due to less travel and progress was made in making the industry and agriculture more sustainable.*						
Projection 3: Goals of Paris Agreement not met **"Possible development until 2050"** *In this scenario, discussions between NGOs and politicians about climate change continue, although fundamental actions to change will not be taken. Furthermore, due to a global economic recession in the 2020s, climate change receives less attention (as compared to human health issues) and industry, agriculture and travel (particularly aviation) continues in a 'business as usual' mode. By consequence, climate change continues under the most likely scenarios unless interventions are made. This implies that the goals of the Paris*						

Agreement are not met and the effects of climate change continue. For the EU, this means that the average temperature increases, severe winters become more seldom and precipitation occurs less evenly (more dry summers, heavy showers). As a consequence, crop protection has to adapt to the introduction of new pests and diseases..
Projection 4: Climate change: adaptation accepted **"Possible development until 2050"** *In this projection, the emphasis of the developments is oriented to adaptation to climate change. This implies that crop selection, cultivation practices and crop protection will be adjusted to the new climatic conditions.*

Key factor name: Globalisation						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**	**X**		**x**		
Definition	Globalisation implies increased intertwining and cooperation between countries.					

Dimensions covered

- *Economic: import and export play an increasing role in the economy. Trade barriers between countries will be removed. Many product components are produced by multinationals. Foreign investors participate in financing industries.*
- *Technological: innovation and technical change occur beyond boundaries. This requires international cooperation.*
- *Cultural: due to travelling and emigration, countries become increasingly multi-cultural.*

Projection 1: Globalisation status quo
"Continuation of existing trends until 2050"
In this projection, there is internationally an increasing emphasis on protection of domestic production due to individualism and populism. The consequence is that trade barriers will be created, disturbing existing balances between demand and supply.

Projection 2: No boundaries
In this projection, the emphasis lies on the recovery of international relationships. International trade, international cooperation and reduction of cultural contradictions are important.

Projection 3: Domestic production stimulated
In this projection, the emphasis lies on domestic production, which is contradictory to globalisation. This can be triggered by individualism, but also by a need to reduce vulnerability. In severe crises, it can be important to secure food supply independently of foreign production. This has major consequences for the crops grown in the EU.

Key factor name: Need for food security						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**	**X**		**x**		
Definition	Food security concerns the need for sufficient food of good quality for all consumers. It also includes the need for sufficient variety and affordability.					

Dimensions covered

- *Sufficient quantity of food for the whole population*
- *Sufficient quality of food for the whole population*
- *Sufficient variety of food for the whole population*
- *Affordable food for the whole population*

Projection 1: Food security status quo
"Continuation of existing trends until 2050"

In this projection, we see that the quantity of food for the whole population worldwide increases, but that the poverty gap still exists. Furthermore, the quality and variety of food is still below an acceptable level for large numbers of consumers in developing countries.

Projection 2: Food security for everyone.

In this projection, the global community takes responsibility for supply of sufficient and healthy food for everybody. The poverty gap will be reduced significantly.

Projection 3: Each for himself.

In this projection the need for food security will be limited to national borders. As a consequence, the poverty gap increases. Within the EU there are groups who do not have access to sufficient healthy food.

Key factor name: Ethics						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**		**x**		**X**	
Definition	Consumer ethics concern the moral evaluation of the consequences of developments in the economy, society and natural environment.					
Dimensions covered • *Ethics around the use of genetic technologies* • *Ethics around digital developments and data sharing* • *Ethics around depleting natural resources*						
Projection 1: Ethics status quo **"Continuation of existing trends until 2050"** *In this projection, ethics do not play an important role. Ethical discussion mainly takes place within NGOs but does not really have wider impact in society.*						
Projection 2: Moralism *In this projection, the ethics will be broadly discussed in society. Ethical standpoints tend to be conducted fundamentally. As a result, the emphasis will be laid on the prevention of undesired consequences, which implies that mitigation is strongly preferred.*						
Projection 3: Pragmatism. *In this projection, the ethics will also be broadly discussed in the society. However, ethical standpoints tend to be conducted more pragmatically. Consequently, the emphasis will be laid on compensation of undesired consequences, which implies that adaptation is accepted as being inevitable.*						

Key factor name: Demographic changes (NB. This is a "given", it is assumed this will take place under all circumstances)						
STEEPED-Field						
Society	Technology	Economy	Ecology	Politics	Ethical	Demographics
x	**x**	**X**		**x**		**X**
Definition	Demography involves the statistical analysis of populations. It covers elements such as age distribution, religion, education, household composition.					
Dimensions covered • *Age: the age structure of the population (e.g. ageing)* • *Increasing / decreasing populations* • *Role of migration*						
Projection 1: Ageing EU populations **"Continuation of existing trends until 2050"** *In this projection, the trend of ageing will continue due to low birth rates. This has consequences for the ratio between the working population and the non-working population (children, students and retired people). The desire to maintain or increase quality of life requires efficient food production with little labour input.*						

Appendix 2: Four scenarios for Crop Protection in Europe in 2050

Scenario 1 – Status Quo: Crop protection continues on the basis of current developments

Key Characteristics of the Scenario

- The EU is largely dependent on domestic food production to ensure food security, as a result of an increasing emphasis on protection of domestic production due to individualism and populism
- The goals of the Paris Agreement on climate change are not met
- The control of pests, diseases and weeds in Europe takes place primarily with agrochemicals
- Sustainable agricultural production systems are only implemented on a limited scale and sustainable food products remain a niche market. Price is of greater importance for wholesalers and retailers in their purchasing strategies
- Genetic and breeding technologies have not been applied in the EU. Plant breeding continues mainly using traditional technologies
- The availability of biocontrol techniques for field crops is limited, while the efficacy and reliability of available tools, measures and agents remains insufficient

"What Crop Protection in Europe Looks Like in 2050 (Scenario Details)"

Overall Societal, Economic and Ecological Situation in 2050

In this scenario, from a societal viewpoint, the trend of ageing continued, due to a lower birth rate. This had consequences for the ratio between the working population and the non-working population (children, students and retired people). Economically, there was an **increasing emphasis on protection of domestic production due to populism.** As a consequence, **trade barriers** have been created **disturbing existing balances between demand and supply**.

Due a to global economic recession in the 2020s, **climate change received less attention** and industry, agriculture and travel (particularly aviation) continued in a 'business as usual' mode. No fundamental actions to mitigate climate change were taken and the goals of the Paris Agreement are not met. As a result, the effects of climate change continued according the most likely scenarios (i.e. average temperature increases, and precipitation occurs less evenly). **The role of Europe and the US has shifted to China and India. The EU has fallen apart**.

Overall Situation in Agriculture in 2050

Sustainable agricultural production systems are implemented on a limited scale and sustainable food products remain a niche market. Only necessary regulations, mainly based on environmental risk assessment, are implemented. They include pesticide use. By consequence, developments in sustainability have been incremental to a large extent. **The protein transition has not materialised**. Price is more important for wholesalers and retailers in their purchasing strategy than sustainability.

With regard to food safety and health, necessary precautions are taken by actors in the food system to ensure that food is safe to eat and that consumers have the necessary information to buy and prepare food safely, for example through product labels. **Only necessary innovations are introduced concerning a more healthy and safe food system**.

Overall Situation for Farmers in 2050
Increased international trade disturbances at global level imply that Europe is to a large extent dependent on its domestic food production to ensure food security. Most of the production takes place on small to medium-sized family farms. **Farmers still have a limited influence in the food supply chain** and they continued to be price takers. **Their income remained marginal,** limiting their ability to innovate and to invest in sustainability.

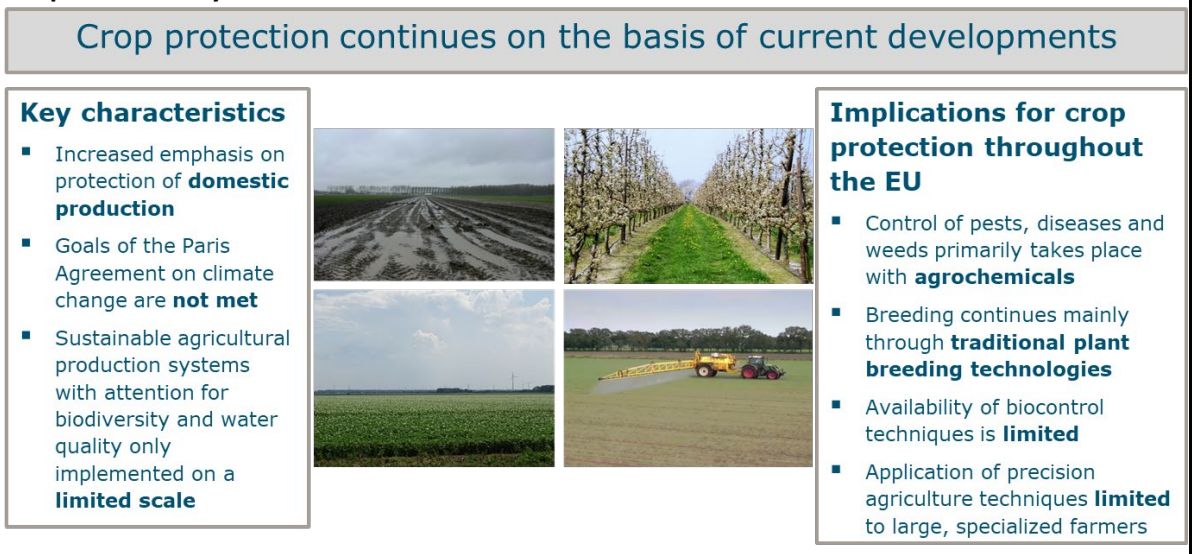
Crop Protection Situation in 2050
Genetic and breeding technologies that have been developed elsewhere have not been applied in Europe in 2050. Since 2020, plant breeding has continued mainly through traditional technologies. The development of new varieties as a base for crop protection practices has continued at the same speed as in 2020. For most crops, it has taken 10-20 years before varieties with the required traits became available in the market. As a result, the number of available varieties with the **required resistance/tolerance traits for pest management is not a sufficient base** for crop protection in 2050.

The **availability of biocontrol techniques for field crops is limited** in 2050. There is a lack of insight in potential beneficial organisms that could form the base for biocontrol outdoors. Efficacy and reliability of available tools, measures and agents is insufficient. **The use of biocontrol techniques by farmers in field crops remains the exception**.

Precise control of pests, diseases and weeds in 2050 is limited to large, highly specialised farmers and applied only in major crops. The perceived complexity of precision agriculture technologies by farmers, incompatibility of software systems, the uncertainty of data ownership, the limited development of tools that recognise pests and diseases, and the lack of decision support rules for pests, diseases and weeds has hampered further uptake of precision agriculture by the majority of farmers in Europe.

As a result, and taking into account the consequences of climate change, **the control of pests, diseases and weeds in Europe primarily takes place with agrochemicals**. For some major crop-disease combinations, breeding efforts have led to the development and implementation of resistant cultivars that limit the use of agrochemicals compared to 2020. Biocontrol is limited to some crop-disease combinations and precision agriculture techniques for crop protection purposes are applied by major farmers only.

Graphic summary



Narrative Storyline

Farmer Baker drives his tractor. The tractor pulls the sprayer. He looks over the field of potatoes. He looks worried. He is concerned about this year's yield. And when the yield will be good, he thinks the price per kg will be poor. The leaves of the crop do not have the shape that they should have. The crop looks similar to the past two years. During the last two seasons a new pest damaged his potatoes. Would it be the same this year? The product in the spray tank will not help completely. The new pest originates from Southern Europe. During the last 30 years temperatures have risen by almost 2 °C. Due to the mild winters the insects can survive nowadays. And the heavy showers in summer increase the problems with diseases during the growth of the potatoes.
A lot has changed, lately. The EU has fallen apart. The income support from the EU is replaced by the national government, but support is lower than before. Now that the most of his potatoes are produced for national food consumption, the market is less stable and export possibilities have largely reduced. Extending his farm by an additional 100 ha is not a viable option under the current conditions.
Farmer Baker does not like his dependency on pesticides. He yearns for new varieties that can withstand pests and diseases. He looks forward to the use of biocontrol products and biostimulants that increase the resilience of his crop and soil. If only his bank account allowed him to invest in automated sensors and precision tools to help him keep his crop healthy. What was the sustainability progress on his farm the last couple of years? Would the environmental impact have been reduced? He really doubts it.
In the distance he sees a few Egyptian geese flying. They thrive well nowadays. How long since he heard a lark singing?

Implications for stakeholders

- Opportunities for stakeholders representing vested interests in production and trade.
- The chemical industry still invests in the development of new active ingredients. PPPs are expensive.
- Farmers have still limited capabilities to produce more sustainably due to lack of sufficient income, lack of market demand and lack of innovations.
- Wholesalers and retailers still thrive, as they profit from their dominant position in the supply chain.
- Consumers are inward-looking, since they are not in a position to make a difference. Bystanders become ill when they are exposed to emissions caused by frequent and persistent pesticide use.
- Biodiversity is still at risk. Plant and animal species go extinct. NGOs are agitated, but powerless. It is hot outside.

Policy Perspective

- Issue: as the EU has collapsed, control over crop protection has returned to individual states.
- International cooperation in crop protection innovation (breeding, precision agriculture) has reduced considerably with a consequent decrease in progress to implement sustainable crop protection technologies.
- Public support of farm income by governments is still necessary to ensure that sufficient food of good quality is produced and that farmers are able to meet legislative requirements.

Scenario 2 – Mitigation of Impacts: Biocontrol agents and precision agriculture help mitigate impacts on health and environment

Key Characteristics of the Scenario

- Economically, import and export play an important role, since the emphasis lies on international trade and international cooperation
- The Goals of the Paris Agreement with regard to mitigating climate change are narrowly met
- Consumers are fully aware of the ecological effects of their consumption, and consumption patterns are adapted in a more sustainable way.
- Developed genetic and breeding technologies are not applied in the European Union in 2050 for ethical reasons. Breeding since 2020 has continued mainly through traditional plant breeding technologies.
- Precision agriculture techniques are used in all field crops in Europe.
- The targeted control of pests, diseases and weeds relies on biocontrol.
- Due to the increase in scale, the negotiating power of farms in the market has strengthened, enabling them to generate sufficient income and to invest in sustainability.

"What Crop Protection in Europe Looks Like in 2050 (Scenario Details)"

Overall Societal, Economic and Ecological Situation in 2050

In this scenario, ageing continues due to a low birthrate. Countries are increasingly multi-cultural as a result of travel and emigration. **Ethical viewpoints are upheld without compromise**. As a result, emphasis is put on the prevention of undesired consequences, which hinders radical innovation and implies that mitigation is strongly preferred.

Economically, import and export play an important role, since **the emphasis lies on international trade and international cooperation**. Many product constituents are produced by multinationals, and foreign investors participate in financing.

The Goals of Paris Agreement with regard to mitigating climate change are narrowly met by implementing necessary policies, including carbon taxes, emissions trading systems, taxes on individual fuels, and energy efficiency incentives. However, adaptation to climate change is still necessary.

There is a **balanced geopolitical and economic division of power** between the West (Europe and the US) and East (China, Japan). The European Union is still functioning, albeit that cooperation between countries is difficult at times.

Overall Situation in Agriculture in 2050

The need to protect and improve ecosystem services is realised by a transition to sustainable agri-food systems. High levels of agricultural productivity are maintained by systems in which agrochemical inputs and environmental damage are minimised. **Consumers are fully aware of the ecological effects of their consumption, and consumption patterns are adapted in a more sustainable way**. Mainstream food is supplied by well-organised supply chains that distinguish themselves on product quality, with sustainability being the dominant attribute.

With regard to healthy foods, regulations are tightened. **Only food products, which do not put at risk human health, future generations or the environment, are available on the EU market**. Innovations are introduced that contribute to a more healthy and safe food system. For example, by tailoring diagnostic tools to critical points in the production chain and by predicting and

preventing microbiological, particularly zoonotic, and chemical threats entering the food system. At the consumer level, healthy and safe choices are stimulated.

Overall Situation for Farmers in 2050
The increase in scale of farms has accelerated. As a result, most production comes from large farms that make use of modern cultivation techniques. Previous yield losses have been overcome through innovation.

The increased importance of sustainability and international trade have given farmers more opportunties for specialisation in specific market segments. **Consumers are prepared to pay for sustainability**. Due to the increase in scale and specialisation, **farms have greater negotiating power in the market and are able to generate sufficient income, and invest in sustainability**.

Crop Protection Situation in 2050
The developed **genetic and breeding technologies are not applied** in the European Union in 2050. Breeding since 2020 has continued mainly through traditional plant breeding technologies. The development of new varieties as a base for crop protection practices has continued at the same speed as in 2020. For most crops it has taken 10-20 years before varieties with the required traits became available in the market. As a result, the number of available varieties with the required resistance/tolerance traits for pest management is not a sufficient base for crop protection in 2050.

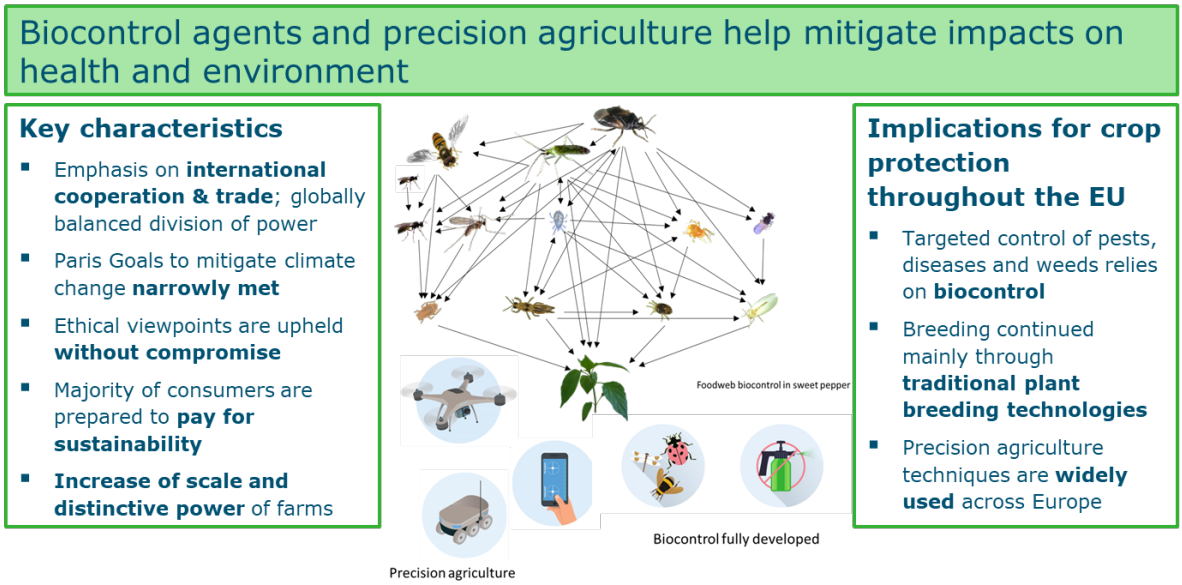
Precision agriculture techniques are used in all field crops in Europe. Development of object identification technology, sensors and connectivity technology enables the real time detection of pests, diseases and weeds and links that information to decision support systems. These systems are based on: the relationship between pest, disease and weed densities; potential crop damage; and the efficacy of control measures. The precise application of targeted control is executed with small autonomously navigating robots.

At the same time major effort is invested in the discovery of beneficial organisms and **the subsequent development of biocontrol techniques for field crops**. The efficacy and reliability of available tools, measures and agents is good. The targeted control of pests, diseases and weeds relies on biocontrol. These agents, tools, measures and methods form an important tool to restore the balance of the diverse sustainable cropping systems in 2050 after introduction of a pest, disease or weed.

The application of biocontrol agents and techniques is based on real time monitoring of pests, diseases, weeds and crop status. This data is loaded into decision support systems that help choose the correct control measure and biocontrol agents are subsequently applied with robots, drones or other autonomous vehicles.

Crop selection and cultivation methods have been adapted to the new climatic conditions.

Graphic summary



Narrative Storyline

Farmer Baker looks over his potato field. From a distance, he observes his robot. The device consists of a sensor that observes the crop at a level of detail than is beyond him. It carries a small tank with different compartments filled with several low risk crop protection products. The robot applies small drops of the most suitable product exactly at the right spot. Weeds are no longer an issue; the robots sensor recognises the weeds and cuts them immediately. Farmer Baker is satisfied; his potatoes are in good condition and only 3 centilitres of product were needed. The biocontrol agents can do their job just fine.

Fortunately, temperatures have stabilised and total temperature increase over the last 30 years is limited to 1 °C. It is a pity that crops still suffer from pests and diseases.

He muses upon all the changes during the last years, and concludes that most changes were for the better. A new balance has been developed between Member States of the EU. Income support from the EU has ceased, but is also no longer necessary. Farmer Baker gets a good price for his potatoes. The potatoes are already sold and will be exported soon. He has his regular customers and focuses on older, more prosperous consumers. As a result of the good yields and prices during recent years, it was possible to expand his farm to 500 ha.

His dependency on pesticides is minimal. He has a range of biological control agents at his disposal to reinforce the natural enemies that are located in environmental areas within and surrounding his field. The soil is healthy and resilient. The sustainability of his farm has increased tremendously. The detrimental impact on the environment must be reduced by at least 98%. At the edge of the field he sees young lapwings. They have been thriving lately. In the distance he sees a harrier approaching.

Implications for stakeholders

- Opportunities for stakeholder groups with clear ethical standpoints, including some NGOs. Consumers and retailers adopt the standpoints and arguments of NGOs.
- Opportunities for stakeholders representing environmental organizsations, organic producers and consumer interest groups.
- The chemical industry no longer invests in the development of new active ingredients and has shifted its activities to the development of biocontrol agents.

- International supply chains distinguish themselves on sustainability throughout the whole supply chain. They show how to take global responsibility.
- The reduction of biodiversity has stopped. NGOs have largely reached their goals, but insist that continued efforts to safeguard biodiversity and to stop climate change are necessary.
- Farmers have sufficient income and their voice is better represented in the supply chain.

Policy Perspective

- Support international market mechanisms that are paying for sustainability efforts.
- Enhance the removal of barriers for scaling up application of precision agriculture technology
- Make high requirements on the quality and safety of food products.
- Make the registration policy for PPPs more stringent and aim at a reduction of the environmental impact by 98% in 2050, with no incidents affecting human health in the period 2030 – 2050
- Efforts of the EU are not only focused on European farming but also on production in continents such as Asia and Africa, to bring them to the same sustainability level.

Scenario 3 – Pragmatic Adaptation: Pragmatic adjustment to changed climatic conditions.

Key Characteristics of the Scenario

- Economically, there has been an increased emphasis on protection of domestic production as a result of individualism and populism. Trade barriers have been created.
- The effects of climate change continued according the most likely scenarios, which forced adaptation.
- Pragmatic ethical viewpoints have been applied.
- Sustainable agricultural production systems continue to be implemented on a limited scale and sustainable food products remain a niche market.
- Plant varieties developed with new breeding techniques are widely available.
- Precision agriculture techniques are used in all field crops in Europe.
- The development of biocontrol techniques for field crops is limited. There is a lack of insight in potential beneficial organisms that could form the base for biocontrol outdoors.

Overall Societal, Economic and Ecological Situation in 2050

In this scenario, due to ageing the ratio between the working population and the non-working population (children, students and retired people) reduced. **From an ethical point of view, pragmatism has been the leading trend**. As a result, emphasis has been placed on compensation for undesired consequences. Adaptation has been accepted as inevitable.

Economically, there has been an **increased emphasis on protection of domestic production** due to individualism and populism. Trade barriers have increased, disturbing existing balances between demand and supply.

Regarding climate change, **the emphasis has moved to adaptation**. The effects of climate change continued according the most likely scenarios (i.e. average temperature increases and precipitation occurs less evenly), but efforts have been made to adapt to the new circumstances (e.g. flood prevention).

The role of Europe and the US at global level has reduced. The EU Member States have remained together, but **disagreement between Member States hampers progress towards policy aimed at agricultural sustainability**.

Overall Situation in Agriculture in 2050

Sustainable agricultural production systems have been implemented on a limited scale and sustainable food products remain a niche market. Only necessary regulations, mainly based on environmental risk assessments, are implemented, for example with regard to pesticide use.

With regard to food safety and health, necessary precautions are taken by actors in the food system to ensure that food is safe to eat and that consumers have the necessary information to buy and prepare safe food, for example through product labels**. Only innovations that contribute to a healthy and safe food system are introduced**.

Overall Situation for Farmers in 2050

The increase oin scale of farms has accelerated. Most production comes from medium to large farms that make use of modern techniques. **There are limited possibilities for farmers to distinguish themselves on sustainability.** Due to climate change, crop selection and rotation practices have changed significantly. **The emphasis for producers is on efficiency and quality**.

Consumers are no longer prepared to pay for sustainability. Farmers that are able to produce efficiently and to a high quality standard have sufficient income.

Crop Protection Situation in 2050

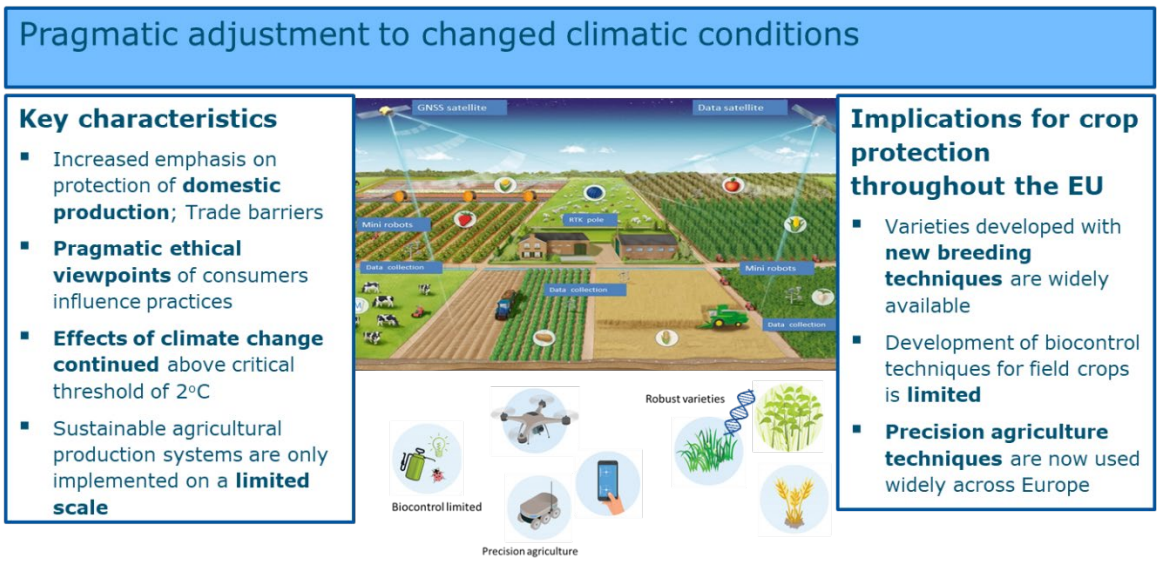
New plant breeding technologies and underlying genetic technologies have been developed. **This has led to the creation of new varieties** that are permitted in the European Union in 2050. Different traits are combined into the new varieties: multiple resistance to diseases and pests, and tolerance of weeds. These varieties form a solid base for management of pests, diseases and weeds in field crops.

Precision agriculture techniques are now used in all field crops in Europe. Development of object identification technology, sensors and connectivity technology enables the real time detection of pests, diseases and weeds and links that information to decision support systems. These systems are based on the relationship between pest, disease and weed densities, potential crop damage and the efficacy of control measures. **The precise application of targeted control is executed with small autonomously navigating robots.** Weed control is fully automated and mechanised. Weed management is based mainly on mechanical control – a limited number of herbicides are needed.

The development of biocontrol techniques for field crops is limited. There is a lack of insight on potentially beneficial organisms that could form the base for biocontrol outdoors. Efficacy and reliability of available tools, measures and agents is insufficient. **Targeted control of pests and diseases primarily depends on choosing the right variety, cultivation practices and agrochemicals.** Due to the development of new resistant varieties and precision agriculture techniques, the dependency on agrochemicals has been reduced compared to 2020. The new varieties have a limited need for control and the precision technologies enable farmers to apply small amounts of plant protection products exactly at the correct moment and place.

Crop selection, cultivation practices and crop protection have been adjusted to the new climatic conditions.

Graphic summary



Narrative Storyline

Farmer Baker drives his tractor. The tractor pulls the sprayer. For the first time this season, it is necessary to control a pest. He looks over his field of potatoes. The crop looks good. Unfortunately,

during the last two years a new pest has appeared. The pest emerged from an invasive insect. During the last 30 years temperatures have risen by at least 2 °C. Due to the mild winters, the insects can survive nowadays, but there are ample products available to combat them. Farmer Baker is pleased with his new potato variety. Despite the heavy showers in summer, the crop can withstand the diseases well. The autonomous weeder takes care of emerging weeds.

He muses upon all the changes during the last years. The EU Member States have remained together, but disagreements between Member States hampers progress towards policy aimed at agricultural sustainability. The income support from the EU is strongly reduced. His position in the supply chain has improved, fortunately. He is seen as a relevant partner. The market has become less stable now that production is mainly focused at the national level. It was possible to enlarge his farm to 1 000 ha during the last 30 years.

Due to the introduction of new, resistant varieties and developments in precision agriculture techniques, his dependency on pesticides has reduced. He does not need to spray that often. It is unfortunate though, that there is such a limited amount of biocontrol products on the market which can be applied on a large scale. He will be able to buy them when they come on the market. He wonders what he has achieved on sustainability during the last year? Would the environmental impact be reduced by 95%? A few pheasants flew up, together with some young ones. A buzzard is circling high in the sky.

Implications for stakeholders

- Opportunities for stakeholders representing technology development (both breeding and digitalisation).
- The chemical industry still invests in the development of new active ingredients. PPPs are expensive.
- Producing sustainably is the standard for farmers, although sustainability is perceived pragmatically. Farmers producing efficiently at a large scale are able to adopt innovations continuously.
- Wholesalers and retailers have less power in this scenario since they have lost their dominant position in the supply chain, and are no longer able to distinguish themselves on sustainability.
- Consumers are the winners in this scenario, but citizens are the losers.
- Biodiversity is still at risk. Not all plant and animal species survive due to climate change. NGOs have ambivalent opinions. They like the reduced impact of PPP use on biodiversity, but do not accept the climate change.

Policy Perspective

- Accept modern breeding techniques and underlying genetic technologies fully.
- Enhance the removal of barriers for scaling up application of precision agriculture technology.
- Invest in technology and plant cultivation systems to support adaptation.
- Apply the registration policy for PPPs according to current developments.
- Reduce the environmental impact of the application of PPPs by 90% in 2050.

Scenario 4 – Disruptive Shift to Sustainability: All possible means of making crop protection sustainable are applied

Key Characteristics of the Scenario

- An increasing emphasis on international cooperation and trade. A globally balanced division of power.
- Pragmatism is the leading ethical principle.
- All means to stop biodiversity loss and climate change are allowed, which provides plenty of room for radical innovation.
- The Paris Agreement goals on climate change have been met.
- The increased need to protect and improve biodiversity and the demand for food security for everyone have led to the development and implementation of biodiverse farming systems.
- Plant varieties developed with new breeding techniques are widely available.
- The application of biocontrol agents and techniques is based on real time monitoring of pests, diseases, weeds and crop status.

"What Crop Protection in Europe Looks Like in 2050 (Scenario Details)"

Overall Societal, Economic and Ecological Situation in 2050

In this scenario, the trend of ageing continued, as well as travel and emigration which led to countries becoming increasingly multi-cultural. In this scenario, pragmatic ethical standpoints have been applied in political decision making. By consequence, **all means to stop biodiversity loss and climate change are allowed, which provides plenty room for radical innovation**.

Economically, import and export play an important role, since **the emphasis lies on international trade and international cooperation**. Many product components are produced by multinationals, foreign investors participate in financing industries, and innovation and technical change occurs beyond boundaries.

The **Paris Agreement goals on climate change were met by introducing stringent mitigation policies**. For example, much has been achieved regarding protein transition (i.e. less meat, more plant-based food), the use of renewable rather than fossil resources, and the circular economy in machinery and international transport. As a byproduct of the global recession in the 2020s, progress was made in making industry and agriculture more sustainable.

There is a balanced geopolitical and economic division of power between the West (Europe and the US) and East (China, Japan). **The European Union is still functioning, with good cooperation between countries**.

Overall Situation of Agriculture in 2050

The need to protect and improve ecosystem services is realised by a transition towards sustainable agri-food systems. High levels of agricultural productivity are maintained by systems in which agrochemical inputs and environmental damage are minimised. **Consumers are fully aware of the ecological effects of their consumption, and consumption patterns are adapted in a more sustainable way**.

With regard to food safety and health, regulations regarding food safety and health are tightened. Only food products, which do not put at risk human health, future generations or the environment, are available on the EU market. **Furthermore, more radical innovations are introduced that contribute to a healthy and safe food system**. For example, by tailoring diagnostic tools to critical points in the production chain and by predicting and preventing microbiological, particularly

zoonotic, and chemical threats entering the food system. To avoid future pandemics, particular attention is paid to transmissable diseases related to the food system. At the consumer level, healthy and safe choices are encouraged, for example by making use of consumers' health status information to provide personalised food choice advice.

Overall Situation for Farmers in 2050

The increase oin scale of farms has accelerated. By consequence, most production comes from large farms that make use of modern techniques, such as electric tractors, biocontrol agents, early warning systems using drones, and plant varieties highly resistant to pests and diseases. Although farms are large, the fields and landscape show great biodiversity enabled by the technological developments. However, since sustainable production has become mainstream, the possibilities for making distinctions on sustainability have reduced. Therefore, the emphasis in production has been put on efficiency and quality. Consumers are no longer prepared to pay for sustainability efforts; **they pay for characteristics contributing to their health**. Farmers that are able to produce efficiently and to high quality standards have sufficient income.

Crop Protection Situation in 2050

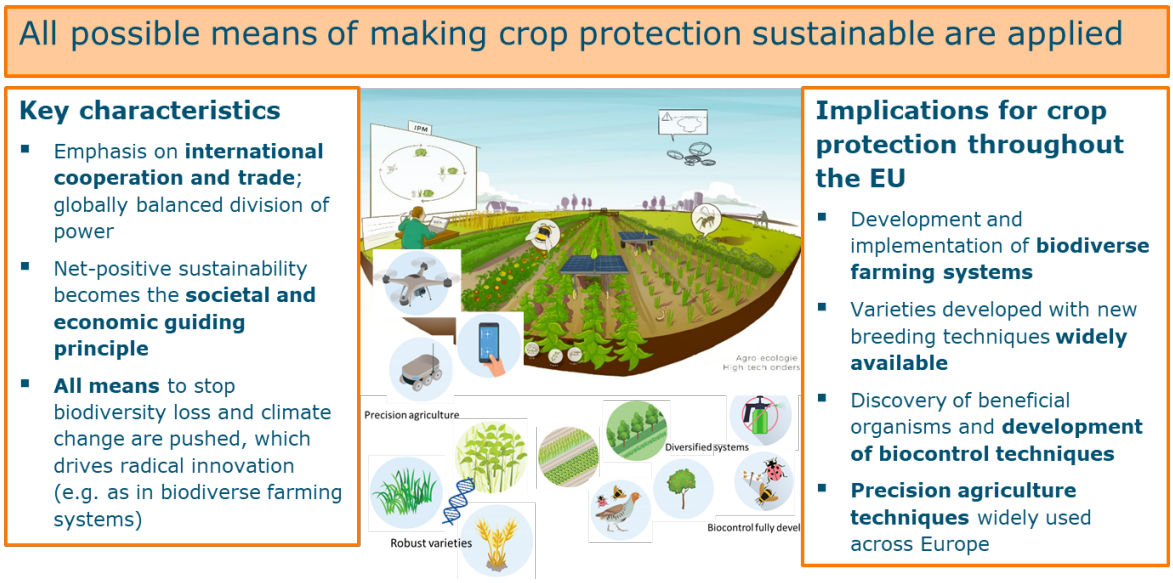
The increased need to protect and improve biodiversity and the demand for food security for everyone have led to **the development and implementation of biodiverse farming systems** for field crops and orchards. These farming systems have become possible due to the introduction of new plant breeding technologies and underlying genetic technologies, and also the rapid development of precision agriculture and biocontrol techniques.

New varieties have been developed using these technologies and have been introduced on European farms. **Different traits are combined into these varieties: multiple resistance to diseases and pests, and tolerance of weeds**. These varieties form a solid base for diversified cropping systems that require minimum control of pests, diseases and weeds, and contribute to biodiversity and global food security.

Precision agriculture techniques are used in all field crops in Europe. Development of object identification technology, sensors and connectivity technology enables the real time detection of pests, diseases and weeds and links that information to decision support systems. These systems are based on the relationship between pest, disease and weed densities, potential crop damage and the efficacy of control measures. The precise application of targeted control is executed with small autonomously navigating **robots. Precision agriculture systems enable the management of diverse systems**: they ensure an optimal balance of crops, other plants, birds, insects, mammals, and other important ecological groups within and outside field boundaries. Functional and non- functional biodiversity is managed with these techniques.

Major efforts are put **into the discovery of beneficial organisms and the subsequent development of biocontrol techniques for field crops**. The efficacy and reliability of available tools, measures and agents is good. The application of biocontrol agents and techniques is based on real time monitoring of pests, diseases, weeds and crop status. This data is loaded into decision support systems that help choose the correct control measures and biocontrol agents are subsequently applied with robots, drones or other autonomous vehicles.
Whenever a pest, disease of weed disturbs the balance of biodiverse farming systems and threatens crop yield, biocontrol agents, tools, measures and methods are used to restore the balance of the system.

Graphic summary



Narrative Storyline

Farmer Baker looks out over his fields through the window of his living room. He is pleased to see the fields of his farm as far as he can see. Despite the large area, the farm looks far from uniform fields of crops. The diverse cropping scheme ensures a large diversity of plants in the field, almost as if there was no cropping at all. In the distance, a drone scouts the field. It has been flying for a while now and he got a warning from the decision support system to take action. Last time, it was not necessary to use pesticides – biocontrol agents could do the job. The autonomous robot makes sure that weeds do not get a chance to grow in the field. Fortunately, the temperature rise has ceased and was limited to 1 °C over the last 30 years. The varieties he grows are well suited to withstand occurring pests and diseases and well adapted to the local conditions. A healthy soil forms an excellent base to grow his crops.

He muses upon all the changes during the last years. The EU is well organised and the trust between Member States has grown tremendously. The EU moved on quickly and developed progressive policies that benefitted agriculture. Baker's farm does no longer receives financial support. However, prices are good and stable. He was successful in establishing a good market share and now produces for a lucrative niche market: young professionals that appreciate a healthy lifestyle and at the same time like traditional products such as potatoes. His clients are spread over the whole EU. His farm has grown in size to 2 000 ha.

He has not used pesticides for years now. The rotation and increased diversity of crops, the use of biocontrol agents, and resistant varieties contribute to this achievement. The availability of advanced tools and techniques make sure that he can intervene early and effectively whenever necessary. His cropping system is balanced and natural enemies thrive and can be supported by a range of biocontrol agents. He is very content: all these developments and investments enabled him to reduce the environmental impact by 100%.

In the distance he sees a peregrine falcon approaching. When it approaches his field, a flock of partridges rises up. Get out of here, he thinks. And hopefully he will also leave the drone untouched!

Implications for stakeholders

- Opportunities for stakeholders representing environmental interests, organic producers and consumer interest groups, as well as technology development (both breeding and digitalisation).
- The chemical industry no longer invests in development of new active ingredients, but has shifted its activities to the development of biocontrol agents and new crop varieties.
- Producing sustainably is the standard for farmers. Farmers efficiently managing large areas of diversified land are able to innovate continuously.
- Wholesalers and retailers have less power in this scenario since they have lost their dominant position in the supply chain, and are no longer able to distinguish themselves on sustainability.
- Consumers and citizens are the winners in this scenario.
- Biodiversity is no longer at risk. Plant and animal species survive. NGOs have ambivalent opinions. They support the progress in sustainability, but are hesitant about the means that contribute to sustainability.

Policy Perspective

- Accept modern breeding techniques and underlying genetic technologies fully.
- Enhance the removal of barriers for scaling up application of precision agriculture technology.
- Ensure high standards on the quality and safety of food products.
- Make the registration policy for PPPs more stringent.
- Invest in the development of biocontrol technology.
- Remove international trade barriers.
- Efforts of the EU are not only focused on European farming but also on production in continents such as Asia and Africa, to bring them to the same sustainability level.
- Aim at a reduction in the environmental impact from pesticides by at least 99% in 2050.

Appendix 3: Virtual Scenario Brainstorming Workshop 16 June 2020, 09:00 - 12:30 hrs

Workshop Agenda

The Future of Crop Protection in Europe

VIRTUAL WORKSHOP AGENDA
16 June 2020, 09:00 - 12:30

Soft Launch – Plenary via Google Meet video link (all participants also logged into Slack)	
09:00 - 09:15	**Soft Launch** Exercise in #icebreaker Slack channel to serve as a first round of creative introductions
Opening Remarks & Project Results to date (facilitator: Cornelia Daheim) - Plenary via Google Meet video link	
09:15 - 09.45	**Cornelia Daheim** (Future Impacts)**:** Housekeeping, Workshop Flow, Intro to the Scenarios **Lieve Van Woensel** (STOA, EPRS): Short Introduction and Welcome **Johan Bremmer; Machiel Reinders; Marleen Riemens** (WUR)**:** Project Approach, Presentation of the Stakeholder Analysis, Key Future Issues and Scenarios for Crop Protection **All: Q & A**
09.45 - 10.00	**Short break**
Working Session 1: Focus on Stakeholder Perspectives & Impacts - Breakout groups via Slack and Google Docs Breakout into pre-assigned group channels on Slack. Participants will find a link to the worksheet in their group slack channels. Each group channel will have a facilitator on hand to answer any questions.	
10.00 – 10.45	Group work (Scenario discussion, incl. impact analysis & diff. stakeholder perspectives)
10.45 - 11.00	**Short Break**
Working Session 2: Focus on Stakeholder Perspectives & Impacts - Breakout groups via Slack and Google Docs Groups reconvene in pre-assigned group channels on Slack. Link to second worksheet will be found in the Slack group channel. Facilitators on hand to answer any questions.	
11.00 - 11.45	Group work (Scenario discussion, incl. impact analysis & diff. stakeholder perspectives) **Last 5 mins: Voting on Mentimeter (link found in group Slack channel)**
11.45 – 12.00	Group Reporters summarise main points (facilitators aid) - **Google Slides Summary template** Others – Short Break
Overview of Group Results & Closing Remarks (facilitator: Cornelia Daheim) - Plenary via Google Meet video link All reconvene in plenary via Google Meet video link	
12.00 - 12.30	**Groups Reporters:** Briefly share main results **All:** Chance for final comments / Q&A **Cornelia Daheim:** Final discussion (incl. scoring results), Wrap-Up and Next Steps **Lieve Van Woensel**: Closing Remarks
12.30	**Workshop End**

Introduction: Icebreaker question

At the start of the workshop, participants made the following contributions in response to the ice-breaker question shown below.

Note that these are literal quotes and therefore have not been corrected, either substantively or grammatically. They have been kept unaltered to gain the best idea of what was on participants' minds.

Icebreaker question: What key issues are important for the future of crop protection in the EU until 2050?

The participants' responses were as follows:

- "Consumer acceptance of and attitude towards (new) crop protection methods and technologies"
- "Development of precision agriculture, biocontrol and sustainable varieties"
- "Societal (lack of) acceptance of the use of agrochemicals to produce food"
- "Strict sustainability regulation (e.g. a high CO2 price and lifecycle bottom line reporting rules)"
- "How climate change develops and its impact on crops in terms of the introduction of new pests, changed weather conditions, etc."
- "Managing populations using a multi-technology approach based on biocontrol technologies"
- "CRISPR/CAS is not a more disruptive technique than classical breeding"
- "Farmers that have the financial means to lower use of pesticides and to ensure a stable farmers' income"
- "Health issues and effect on biodiversity"
- "Belief that crop protection is just a part of overall crop/ farm management, so when the importance of a system approach will be fully understood"
- "New crop varieties that are tailored to the demands of integrated pest management systems, including being disease resistant"

Presentation of project and scenarios

NB. Source of pictures: Wageningen University and Research, Field crops

The Future of Crop Protection in Europe

VIRTUAL BRAINSTORMING WORKSHOP

June 16, 2020

WAGENINGEN UNIVERSITY & RESEARCH

Approach of the project

- Foresight approach and STEEPED methodology (Social, Technological, Economic, Environmental, Policital/legal, Ethical and Demographic aspects) are central
- Three work packages:
  1. Review and explanation of existing and emerging crop protection techniques
  2. Societal assessment (brainstorming meeting being part of it)
  3. Reflections and policy options
- Team
  - Core team executing the project (Marleen, Machiel and Johan)
  - Wider circle of WUR experts from all relevant technical and social disciplines
  - Foresight specialists supervising scenario development, preparing and leading brainstorming meeting (Jessica, Cornelia and Marc)
  - External experts attending brainstorming meeting and reviewing results
  - Project direction by Remco Schrijver from VetEffect

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Stakeholder analysis: four groups of stakeholders

1. **Consumption perspective** (i.e., consumers, retail and food industry)
2. **Production perspective** (i.e., farmers and growers)
3. **Supply industry perspective** (i.e., PPP-, high-tech and biotech industry; breeders producing new crop varieties)
4. **Societal perspective** (i.e., citizens and NGOs; public bodies which are responsible for policies).

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Consumption perspective

Interest: Food safety (e.g., pesticide residues in foods) and gaining consumer acceptance

Opinion on crop protection

- Consumers **willing to pay more for reduced pesticide use**
  - Consumers' knowledge largely framed by food labels, retail displays and marketing materials
  - Food safety and potential health impact are just two of the many food choice motives that consumers have
- Retailers and food industry **address consumer concerns**
  - Retailers increasingly take more responsibility in food quality (private labels)
  - Food companies want to differentiate themselves by innovation

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Production perspective

Interest: Protecting and securing produce vs potential health effects due to exposure

Opinion on crop protection

- Farmers do **not have a strong incentive to search for alternative solutions**:
  - Lock-in effects (heavy initial costs of switching to more sustainable systems)
  - Risks: additional decision-making and farming management
  - Fear of reduced capacity to protect crops/ yield
  - Fear of reduced competitiveness
- Farmers are **increasingly being put under pressure** to reduce agrochemicals usage.
  - By regulations and by food industry/ retailers

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Supply industry perspective

Interest: To develop effective and commercially viable solutions for farmers to protect their crops

Opinion on crop protection

- PPP industry:
  - Agrochemicals can be used within responsible limits; contribution to biodiversity decline contested
  - No alternative to feed the world
  - Fear of rising costs, time and unpredictability of the EU regulatory system for getting product approval which undermines investment
- Industry shows **commitment** to improve transparency, responsibility and sustainability
- Biocontrol: criteria for biological substances are often too stringent for products of natural origin
- **Opportunities** for new technologies (genome editing and precision agriculture)

Societal perspective

Interest: Negative human health (i.e., toxicological risks) and environmental impacts of (mis)application of PPPs (e.g., impacts on biodiversity and emergence of pesticide resistance).

Opinion on crop protection

- Concerns that health and environment are **inadequately protected** in current debate:
  - Impacts are not assessed for all species and don't reveal impacts on ecosystems
  - potential interactive 'cocktail' effects of multiple PPP use not taken into account
- **Advocate stronger ambitions to reduce (or even abandon) PPP use**, urge consumers to avoid purchasing products produced with the aid of PPPs and/or encourage the development of alternatives

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Crop Protection in Europe in 2050: 4 scenarios

1. Status Quo
Crop protection continues on the basis of current developments

2. Mitigation of Impacts
Biocontrol agents and precision agriculture help mitigate impacts on health and environment

3. Pragmatic Adaptation
Pragmatic adjustment to changed climatic conditions

4. Disruptive Shift to Sustainability
All possible means of making crop protection sustainable are applied

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Key factors shaping the future of crop protection in 2050

Society	▪ Requirements to human health
Technology	▪ New breeding technologies ▪ Biocontrol ▪ Precision agriculture
Economy	▪ Globalisation
Ecology	▪ Requirements to maintain ecosystem services ▪ Coping with climate change
Politics	▪ Need for food security
Ethical	▪ Ethics: moralism vs pragmatism
Demographics	This future projection is assumed to be rather clear and the variation of the factor is low. Therefore, these so-called "Givens" are integrated in the scenario process but they are not included in the scenario construction)

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Scenario 1 in 2050: Status Quo

Crop protection continues on the basis of current developments

Key characteristics

- Increased emphasis on protection of **domestic production**
- Goals of the Paris Agreement on climate change are **not met**
- Sustainable agricultural production systems with attention for biodiversity and water quality only implemented on a **limited scale**

Implications for crop protection throughout the EU

- Control of pests, diseases and weeds primarily takes place with **agrochemicals**
- Breeding continues mainly through **traditional plant breeding technologies**
- Availability of biocontrol techniques is **limited**
- Application of precision agriculture techniques **limited** to large, specialized farmers

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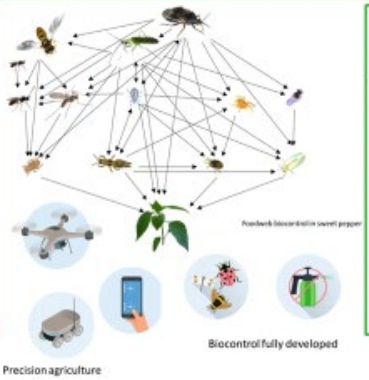
Scenario 2 in 2050: Mitigation of Impacts

Biocontrol agents and precision agriculture help mitigate impacts on health and environment

Key characteristics

- Emphasis on **international cooperation & trade**; globally balanced division of power
- Paris Goals to mitigate climate change **narrowly met**
- Ethical viewpoints are upheld **without compromise**
- Majority of consumers are prepared to **pay for sustainability**
- **Increase of scale and distinctive power** of farms



Implications for crop protection throughout the EU

- Targeted control of pests, diseases and weeds relies on **biocontrol**
- Breeding continued mainly through **traditional plant breeding technologies**
- Precision agriculture techniques are **widely used** across Europe

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Scenario 3 in 2050: Pragmatic Adaptation

Pragmatic adjustment to changed climatic conditions

Key characteristics

- Increased emphasis on protection of **domestic production**; Trade barriers
- **Pragmatic ethical viewpoints** of consumers influence practices
- **Effects of climate change continued** above critical threshold of 2°C
- Sustainable agricultural production systems are only implemented on a **limited scale**

Implications for crop protection throughout the EU

- Varieties developed with **new breeding techniques** are widely available
- Development of biocontrol techniques for field crops is **limited**
- **Precision agriculture techniques** are now used widely across Europe

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Scenario 4 in 2050: Disruptive Shift to Sustainability

All possible means of making crop protection sustainable are applied

Key characteristics

- Emphasis on **international cooperation and trade**; globally balanced division of power
- Net-positive sustainability becomes the **societal and economic guiding principle**
- **All means** to stop biodiversity loss and climate change are pushed, which drives radical innovation (e.g. as in biodiverse farming systems)

Implications for crop protection throughout the EU

- Development and implementation of **biodiverse farming systems**
- Varieties developed with new breeding techniques **widely available**
- Discovery of beneficial organisms and **development of biocontrol techniques**
- **Precision agriculture techniques** widely used across Europe

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Group Summaries (Top fears and hopes for each scenario)

The top fears and hopes for each scenario are presented. These were reported back from the working groups to the plenary meeting.

Scenario 1 in 2050: Status Quo

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: That the sector is vulnerable to biotic & abiotic shocks, and a loss of diversity of farm type.
Consumers: That the health & environmental risks of products are well labelled & understandable.
Industry: That the EU industry falls behind in terms of innovation, and "chemophobia" remains.
NGOs: Species extinction and ecosystem collapse leading to more vulnerability to climate change.

Scenario 2 in 2050: Mitigation of Impacts

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: That there is appropriate financial compensation for the services that farmers provide.
Consumers: That the increase in price does not marginalise the most vulnerable.
Industry: That the introduction of new technologies to market is facilitated and simplified.
NGOs: That new technologies are sufficient to sustainably uphold environmental achievements.

Scenario 2 in 2050: Mitigation of Impacts

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: Fear: Being attacked for their practices (whatever they do and use); Hope: Farming is an attractive profession again. **Consumers:** Hope: Increased trust and less worries about their food; Fear: Price increase and 'green washing'. **Industry:** Fear: Being left behind, as rest of the world is a more attractive market; Hope: Competition is not only on price as it makes environmentally friendly production unaffordable. **NGOs:** Fear: Dramatic biodiversity loss (as mitigation efforts insufficient); Hope: Successful minimisation of environmental loss from crop protection, better public "sustainability awareness"

Scenario 3 in 2050: Pragmatic Adaptation

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: Hope: Economic stability, involvement in decision-making for finding pragmatic solutions. **Consumers:** Fear: Biodiversity loss, risks of new technology that is applied; Hope: Affordable, healthy products; "technology will solve the problems". **Industry:** Fear: Long-term security supply, access to markets; Hope: Opportunities for diversification (e.g. new genetic technologies) and for new business models. **NGOs:** Fear: Concentration of power at seed companies; Hope: Raising sustainability standards.

Scenario 3 in 2050: Pragmatic Adaptation

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: Fear: To lose competitiveness as the playing field regarding availability of tools is not level with non-EU producers. Hope: Have safe and effective tools to combat pests and diseases which are worsened by climate change. Be able to show consumers that farmers are ready to meet their varying demands by adapting their practices **Consumers:** Lack of availability of affordable sustainable food. **Industry:** Loss of access to international markets due to trade and regulatory barriers. **NGOs:** NGOs might be afraid that new breeding technologies should lead to more power to seed companies by means of patents. Major concerns about climate change

Scenario 4 in 2050: Disruptive Shift to Sustainability

Top Fears (or Hopes) i.e. potential negative knock-on effects for different stakeholders
Farmers: • Level-playing fields with imported agricultural raw materials thanks to international cooperation and trade. • Gain more power in the food supply chain; Earn more through shorter supply chains and involvement in dedicated certification schemes. • High investment in technology, need to acquire very different skill sets. **Consumers:** Fear: Increasing costs for food. New technology does not increase sustainability. Hope: Higher appreciation of farmers by consumers and decreased distance between them. **Industry:** Fear: Regulatory framework slow to adapt to new tech possibilities due to high diversity of systems; Hope: Larger market creation and full potential of biocontrol allowed to develop. **NGOs:** Hope: Improved impact on food production; Agriculture viewed as supporting the environment.

Scenario Evaluation

Following the second working session, participants were asked to rate each scenario on a 10-point scale with respect to policy adaptations that would be required compared to current policy (on a scale from minimal to extensive), and impact on current practices (on a scale from low to high). This exercise was carried out using Mentimeter, an online tool for real-time voting.

Short conclusion:

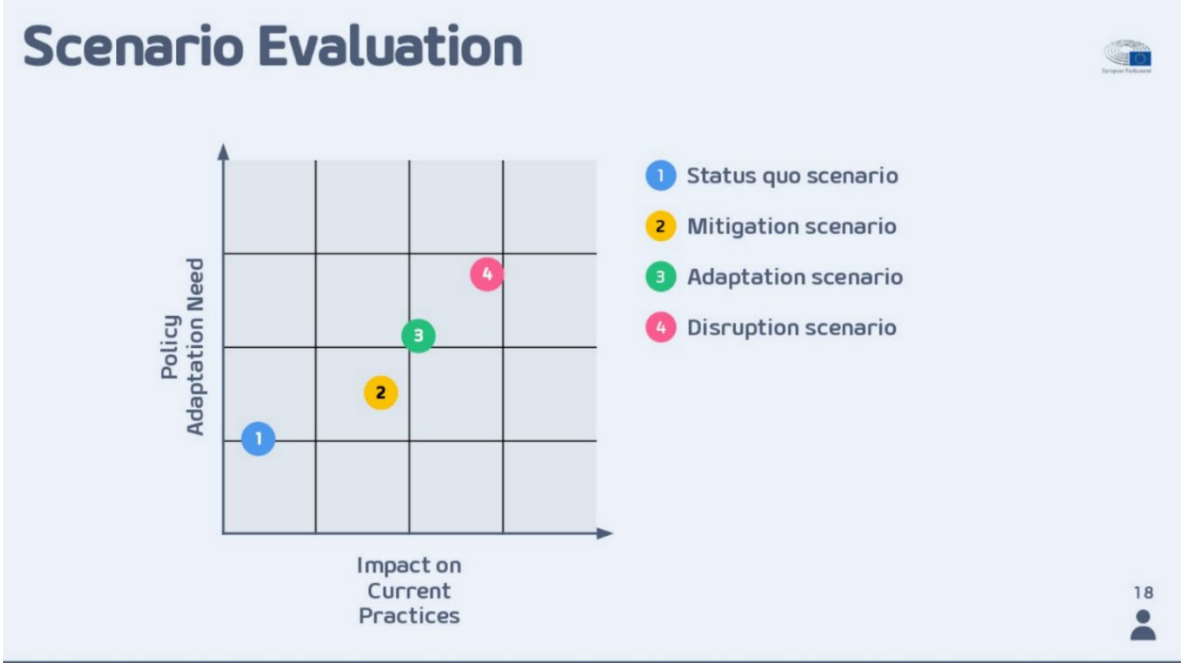
The 'Status Quo' scenario clearly needs the least policy adaptation and also has the lowest impact on current practices.

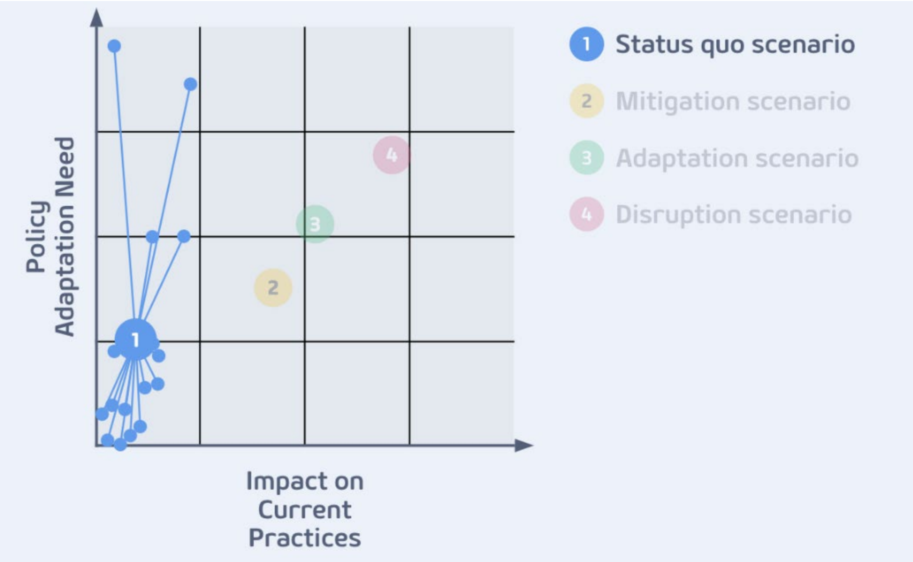
The 'Disruptive' scenario has the greatest impact, but also needs most policy adaptation.

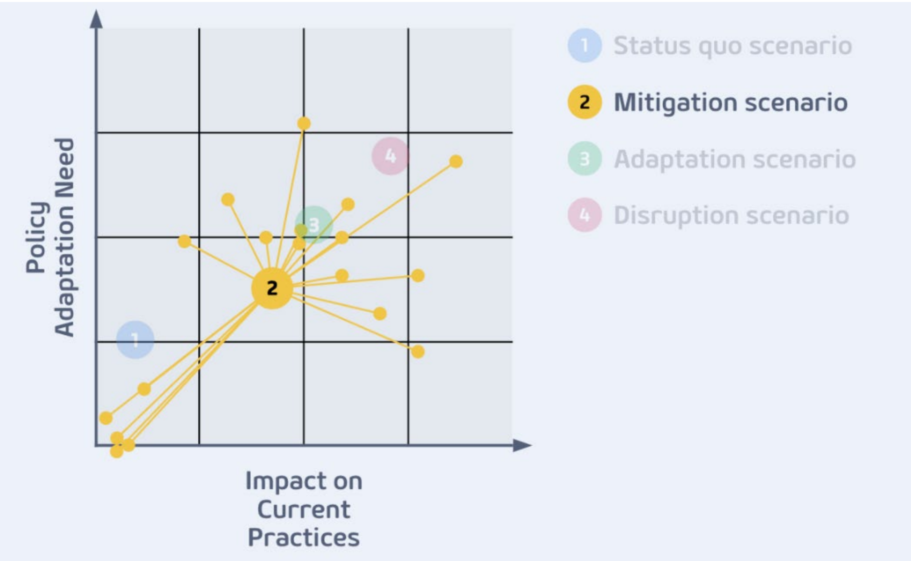
The 'Mitigation' and 'Adaptation' scenarios occupy an intermediate position, with the 'Adaptation' scenario having somewhat more impact, but also somewhat more policy adaptation.

As can be seen in the more detailed overview of scores for each scenario, the spread in scores was sometimes quite high, especially for the 'Mitigation' and 'Adaptation scenarios, which showed less consensus among participants compared to the 'Status Quo' and 'Disruptive' scenarios.

Note that some participants might not have rated the scenarios (hence a few zero values).




Policy
Adaptation Need
Impact on
Current
Practices
Status quo scenario
Mitigation scenario
Adaptation scenario
Disruption scenario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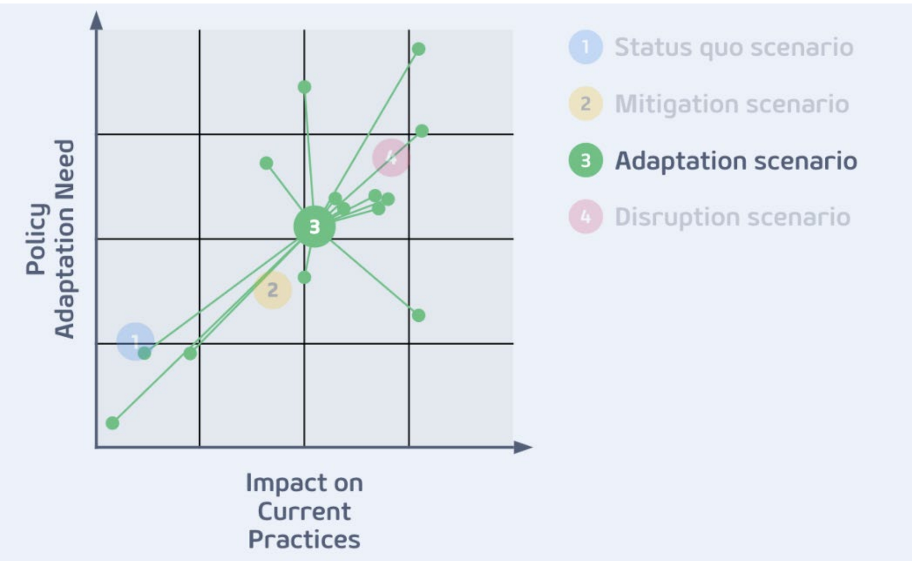
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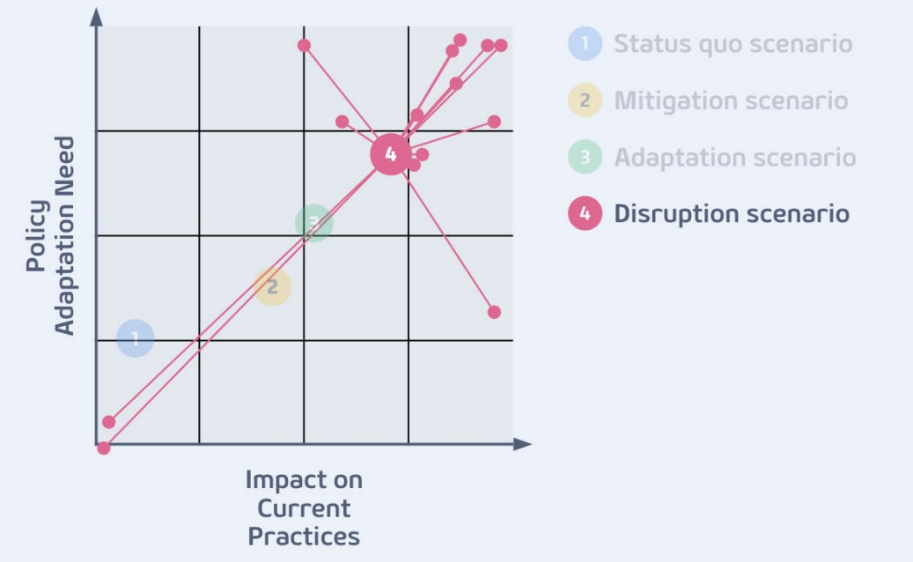
Policy Adaptation Need
Impact on Current Practices
1 Status quo scenario
2 Mitigation scenario
3 Adaptation scenario
4 Disruption scenario

List of participating organisations

Type	Organization
Project team	Wageningen University & Research
	VetEffecT
Foresight team	Foresight Impact
	Denamics
STOA team	EPRS / Scientific Foresight Unit
Representatives of the EP	European Parliament
	Adviser for the Greens working for the AGRI Committee
Stakeholders and experts	European Crop Protection Association (ECPA)
	CropLife International
	International Biocontrol Manufacturers Association (IBMA)
	European Council of Young Farmers (CEJA)
	Copa Cogeca
	European Agricultural Machinery Association (CEMA)
	FoodDrinkEurope
	WWF Europe
	Wageningen University & Research
	Aarhus University
	Scuola Superiore Sant'Anna (SSSA)

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One way of avoiding societal rejection of crop protection practices is to design them in line with stakeholders' priorities and preferences. This report describes the involvement in crop protection and the opinions regarding the use of plant protection products (PPPs) for the following stakeholder groups: (1) the stakeholders who primarily look at crop protection from a consumption perspective (i.e. consumers, retailers and the food industry), (2) the stakeholders who look at crop protection from a production perspective (i.e. farmers and growers), (3) the stakeholders who look at crop protection from a supply chain perspective (i.e. crop protection industry, plant breeders and other suppliers), and (4) the stakeholders who look at crop protection from a societal perspective (i.e. citizens and NGOs).

Four explorative scenarios were developed that look at ways in which existing and emerging crop protection practices might be combined to ensure plant pests and diseases are effectively controlled. These scenarios were discussed in a brainstorming meeting with relevant stakeholders. For each scenario, the potential implications of the crop protection practices for different stakeholder groups (farmers, consumers, industry, NGOs), as well as the identification of their hopes and fears (i.e. potential positive as well as negative knock-on effects), were identified.

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