CropLife Europe

Changes to Non-target Arthropod Risk Assessment for Plant Protection Products: Potential Impacts on Agronomic Practice

Impact assessment

Date: 25 June 2026

ADAS

ADAS GENERAL NOTES

Project No.: 1030541

Title: Changes to Non-target Arthropod Risk Assessment for Plant Protection Products: Potential Impacts on Agronomic Practice – Impact Assessment

Client: CropLife Europe

Date: 25 June 2026

Status: Final Version

Author	Jim Dimmock	**Principal Consultant**	25 June 2026
	Helena Crosland	**Associate Technical Director; Ecotoxicology and risk assessment**	
	James Masvongo	**Consultant**	
Technical reviewer	Sarah Wynn	**Managing Director**	25 June 2026
	Nadine Taylor	**Director**	

RSK ADAS Ltd (ADAS) has prepared this report for the sole use of the client, showing reasonable skill and care, for the intended purposes as stated in the agreement under which this work was completed. The report may not be relied upon by any other party without the express agreement of the client and ADAS. No other warranty, expressed or implied, is made as to the professional advice included in this report.

Where any data supplied by the client or from other sources have been used, it has been assumed that the information is correct. No responsibility can be accepted by ADAS for inaccuracies in the data supplied by any other party. The conclusions and recommendations in this report are based on the assumption that all relevant information has been supplied by those bodies from whom it was requested.

No part of this report may be copied or duplicated without the express permission of ADAS and the party for whom it was prepared.

This work has been undertaken in accordance with the quality management system of RSK ADAS Ltd.

MANAGEMENT SYSTEM CERTIFICATION DNV ISO 9001 · ISO 14001 ISO 45001

EXECUTIVE SUMMARY

Background

In 2024, the EU Commission mandated EFSA to update the risk assessment methodology for the assessment of active substances and plant protection products (PPPs) with respect to their potential effects on non-target arthropods (NTAs) other than bees, in-soil organisms and non-target terrestrial plants (NTTPs) outside of the treatment area. It is anticipated as part of that process, more stringent Specific Protection Goals (SPGs) are likely be introduced.

Previous work by CropLife Europe and Bremmer et al. (2020) set out to develop an impact assessment (IA) framework to assess the implications of changes in SPGs for non-target terrestrial plants (NTTPs). This framework identified the key ecosystem services (ES) that are relevant to the NTTPs and created scenarios to assess how crop production might change as a result of increased protection of NTTPs both in-field and off-field, and the consequences on wider ecosystem services.

The analysis in this present report adapts the work of Bremmer et al. (2020) and applies it to non-target arthropods (NTAs). In this approach, we took the following steps:

1. Develop crop management scenarios that reflect current practice and potential future practices, following the adoption of more stringent in-field and/or off-field SPGs for NTA protection.
2. Identify those ESs that may be impacted by changes in crop management practices resulting from increased protection of NTAs
3. Develop metrics for measuring the impact on ESs from changes in pest and disease management, resulting from increased protection of NTAs
4. Select crop-country case studies to evaluate the impact of the scenarios on crop management practices and, consequently, those ESs predicted to be impacted by the aforementioned changes.
5. Synthesise the findings into a broader discussion.

Development of scenarios

This analysis applies the following four simplified and illustrative crop management scenarios to represent how changes in Specific Protection Goals (SPGs) might be delivered in terms of changes to crop management. At their simplest, the scenarios aim to show the following, although how this is delivered will differ by crop and location;

- **Scenario 1** – Current practice (up to 2026): This scenario, based on ESCORT2 NTA Guidance, reflects current production practices, yields and costs of production against which to compare changes in crop management to reflect delivery of future SPGs.
- **Scenario 2** – Increased in-field protection of NTAs: This scenario represents increased in-field protection of NTAs and was informed by the non-binding goal from the 2020 Farm to Fork strategy of reducing PPP application rate or risk by 50%*. For this scenario, we assumed a 50% reduction in insecticides and fungicides application volumes on an annual basis to reduce impacts on in-field NTAs.
- **Scenario 3** – Increased off-field protection of NTAs: This scenario assumes that volumes of PPP application are maintained in the cropped area, but there is a 50% increase in the untreated buffer zone applied around the treated area in a measure intended to increase protection of off-field NTAs*.

- **Scenario 4** - Increased in-field and off-field protection for NTAs: This scenario combines the assumptions in scenarios 2 and 3 to give both a 50% reduction in use of insecticides and fungicides in the cropped area and a 50% increase in the buffer width.

*Note – a 50% reduction in PPP volume, or 50% increase in buffer zone width does not necessarily equate to a 50% increase in mitigation.

Prioritisation of Ecosystem Services

This Impact Assessment (IA) Framework evaluates how adjustments in agricultural practices influence ESs associated with agricultural systems. It builds on publications from EFSA (2015; 2025) to determine how changes in PPP use, crop management and landscape features may affect both in-field and off-field ecological functions. Since levels of protection for NTAs differ across farming scenarios, the framework provides a structured basis for identifying, prioritising and safeguarding the ecosystem services most at risk.

This project considered all Ecosystem Services related to agricultural ecosystems that may be affected by changes in plant protection product (PPP) application practices, or via other changes in pest/disease control practices. The relevance of NTAs for each ESs was estimated. A prioritisation activity was undertaken to assess anticipated changes in ES delivery (both in- and off-field) across the scenarios, with focus directed toward those ESs expected to undergo significant change.

Case Study Key Findings

Impacts of the illustrative crop management scenarios were assessed using four case study crops in different geographies distributed across Europe to understand how farmers might adapt to the scenarios, and the implications on the cost and volume of production. This analysis combined literature reviews with local crop production expertise provided by a network of regional agronomists coordinated by RSK ADAS and SAGEA Group. The case studies were winter wheat in the UK, apples in Poland, vines in Italy and cabbages in The Netherlands. Findings for case studies at national level are summarised in Table 1-1, with further projections for EU-wide impacts shown in Table 1-2.

Despite efforts to increase use of various elements of IPM, including utilising resistant varieties and increased labour to manage the crop more intensively, increased in-field NTA protection, if it resulted in 50% reductions in both insecticide and fungicide usage, would have large negative impacts on yield, particularly in crops with high pest and disease pressure such as apples, vines and cabbages.

The adoption of increased widths of untreated buffer strips would result in a reduction in the area of land available for production, with farming systems reliant on small fields such as the small scale apple production in parts of Poland and niche vineyard production in parts of Italy, being more significantly affected that large scale arable crops, with larger fields.

Table 1-1. Summary of national crop and financial impacts (to field gate) under Scenarios 2-4

Case Study		Wheat (UK)	Apple (Poland)	Vines (Italy)	Cabbage (Netherlands)
Scenario 2 (50% PPP reduction)	Crop loss (t)	1.42 million	1.24 million	1.70 million	35,000
	Percentage	-11%	-36%	-20%	-30%
	Impact (€ million)	**-310**	**-371**	**-3,680**	**-11.6**
Scenario 3 (50% buffer increase)	Crop loss (t)	0.26 million	1.67 million	1.20 million	26,000
	Percentage	-2%	-49%	-11%	-23%
	Impact (€ million)	**-55**	**-500**	**-1,910**	**-8.0**
Scenario 4 (Scenario 2 + Scenario 3)	Crop loss (t)	1.65 million	1.88 million	2.40 million	57,000
	Percentage	-12%	-56%	-28%	-48%
	Impact (€ million)	**-359**	**-565**	**-4,730**	**-17.9**

Table 1-2. EU-27 projection of crop losses and financial impacts (to field gate) under Scenarios 2-4

Scenario		Wheat	Apple	Vines	Cabbage
2024 Data (Eurostat, 2026)	EU-27 Total (Mt)	111.6	11.6	20.5	3.8
	Average price €/t	238	1049	800	1010
	Farm Gate Value (€ bn)	26.6	12.2	29.4	3.80
Scenario 2 (50% PPP reduction)	Impact on yield	-11%	-36%	-20%	-30%
	Crop loss (Mt)	12.3	4.2	4.1	1.1
	Impact (€ billion)	**-2.92**	**-4.38**	**-5.88**	**-1.15**
Scenario 3 (50% buffer increase)	Impact on yield	-2%	-49%	-11%	-23%
	Crop loss (Mt)	2.2	5.7	2.3	0.9
	Impact (€ billion)	**-0.53**	**-5.96**	**-3.23**	**-0.88**
Scenario 4 (Scenario 2 + Scenario 3)	Impact on yield	-12%	-56%	-28%	-48%
	Crop loss (Mt)	13.4	6.5	5.7	1.8
	Impact (€ billion)	**-3.19**	**-6.81**	**-8.23**	**-1.84**

Losses of this magnitude could threaten sector viability but with all other crops likely to be affected in similar ways there will be few alternative crops that farmers and growers can swap to. Substantial increases in farm gate prices to balance reduced yields and increased costs can be expected, or they risk leaving agricultural production, which could further exacerbate reductions in production.

Meanwhile, substitute crops will need to be grown elsewhere, i.e. in other regions of the world, impacting on local biodiversity and potentially increasing global impacts by increasing transport emissions.

PPP resistance implications

Scenarios 2 and 4 are both likely to increase the risk of pesticide resistance development in crop pests and diseases by reducing the number and flexibility of available control options. A 50% reduction in insecticide and fungicide use (Scenario 2) is likely to concentrate selection pressure on a smaller set of remaining active substances and modes of action, undermining established resistance-management strategies such as rotation and mixture. This situation is expected to accelerate resistance development, particularly in high-pressure seasons and in crops already reliant on repeated fungicide use.

Scenario 4 further exacerbates resistance risks by combining reduced pesticide availability with expanded untreated buffer zones. While untreated areas may theoretically act as refugia, in practice they are likely to function as persistent sources of reinfestation, increasing pest and disease pressure within the treated crop. This, in turn, can drive more frequent or repeated use of the limited remaining products, intensifying spatial and temporal selection pressure. Across both scenarios, the accelerated loss of efficacy of existing pesticides would reduce the resilience of crop protection systems and increase the vulnerability of agricultural production to pest and disease outbreaks, unless effective alternative control tools become widely available.

Conclusions

This Impact Assessment (IA) evaluates the impact of increasing protection for NTAs on ecosystem service delivery and agricultural production across Europe:

- Nine ecosystem services were prioritised based on anticipated changes across scenarios: food production, wild foods, freshwater quality, soil fertility/erosion and control/carbon sequestration, pollination, biological control, genetic biodiversity, habitat provision, and cultural services (tourism, spiritual experience, sense of place).

- Four representative cropping systems were assessed: UK wheat, Polish apples, Italian vines, and Dutch cabbages—to illustrate potential impacts across climates, production systems, and market structures.
- Stricter in-field and off-field protection measures consistently reduce yields, increase costs and threaten the viability of both arable and high value horticultural systems.
- Scenario 4 (combined 50% PPP reduction and 50% buffer expansion) results in the largest losses, with national production impacts ranging from –12% (UK wheat) to –56% (Polish apples).
- Scenarios 2 and 4 are likely to accelerate pesticide resistance by concentrating control on fewer tools and increasing pest and disease pressure, ultimately undermining the long-term resilience of crop protection systems. The lack of sufficient suitable tools will also be limiting the use of integrated pest management, as the therapeutic control at economic threshold level is only possible if efficient products are available.
- The impact of buffer expansion is disproportionately greater in production systems with smaller plot sizes, often family-run horticultural enterprises, and is further exacerbated in systems with elongated fields/strips such as those typically seen in traditional Polish apple orchards.
- EU-wide projections show substantial crop losses under all scenarios examined, exceeding 50% in more vulnerable crops. In practice, these losses would be likely to lead to the loss of Europe's export surplus and substantially increased reliance on food imports to maintain food security. For perspective, EU-wide losses are projected under Scenario 4 for each case study food commodity (See Table 1-3).
- While environmental benefits such as improved pollination or natural pest control may arise in some contexts, these benefits do not outweigh economic and food security risks without major investment in alternative pest management strategies.
- More stringent protection goals could generate unintended global effects if increased EU import demand drives land use change or weaker environmental practices in exporting countries.
- Permanent cropping systems (orchards, vineyards) are at particular risk of abandonment, with mixed long-term impacts on biodiversity and cultural ecosystem services.
- The findings highlight the need for the development of balanced SPGs that address NTA protection, while also safeguarding food production, economic resilience and wider environmental outcomes.

Table 1-3. Projected EU-27 impacts of Scenario 4 on case study food commodity production

	Wheat	Apple	Vines	Cabbage
Impact on yield	-12%	-56%	-28%	-48%
Crop loss (Mt)	13.4	6.5	5.7	1.8
Lost food production	**20 billion loaves of bread**	**32 billion apples**	**5 billion bottles of wine**	**1.5 billion cabbages**
Annual loss/person (EU-27 450 million)	**44 loaves** (ECIU, 2025)	**72 apples** (Südtirol Apfel, 2026)	**12 bottles** (Food & Wine, 2023)	**3.5 cabbages** (Agro-Market24, 2026)

These conclusions are summarised in Table 1-4.

The following recommendations are made to ensure that all risks associated with revised SPGs are fully considered:

Strategic and policy assessment

- Conduct national and EU-wide impact assessments to evaluate the implications of new measures prior to the establishment of revised SPGs.
- Develop a comprehensive understanding of the global direct and secondary consequences of adopting new SPGs, including environmental, economic and social dimensions.

Food security, markets and competitiveness

- Review the implications for food security, recognising that reduced domestic production may deplete strategic reserves, increase vulnerability to supply disruptions and undermine system resilience.
- Evaluate likely changes in EU international competitiveness and import/export balances arising from SPG changes.

Environmental and land-use consequences

- Assess biodiversity impacts resulting from (a) widespread shifts from permanent cropping systems to arable rotations and (b) agricultural land abandonment, including risks of unintended development pressure or reversion to unmanaged scrubland.

Farm viability and rural communities

- Analyse consequences for farmers and rural communities, including (a) loss of skilled labour and long-term implications for sector capability and resilience, and (b) rural poverty limiting the ability to maintain environmental standards.
- Assess the risk of making family-run farming businesses uncompetitive, leading to land consolidation into larger holdings and potentially negating benefits associated with widened buffer zones.

Resistance management and crop protection resilience

- Maintain awareness of the importance of managing pest and disease resistance through ensuring the availability of sufficient modes of action to enable effective rotation of plant protection products.

Table 1-4. Impact assessment summary for increased NTA protection scenarios

Indicator	Impact: Scenario 1 v. Scenario 4				Unintended Consequences
	Wheat	Cabbages	Apples	Vines	
Employment	+	+	-*	-*	Increased manual labour leads to detrimental impact on farm worker health
Labour costs	-	-	-	-	Increased cost of production will increase food prices
Machinery costs	-	-	-	-	Increased cost of production will increase food prices Forced adoption of digital and precision technologies
Yield / Food production	-	-	-	-	Reduced yields increase land needed to produce equivalent food calories Reduced exportable surplus across all EU countries; Reduced import/export between EU countries; Negative impact on EU food security
Commodity price†	-	-	-	-	Commodity price would need to increase to ensure farm economic viability
Soil quality	+	+	+/-	+/-	Soil quality impacts uncertain but could be detrimental, e.g. tillage requirements when moving from permanent orchards/vines to annual crops
Pollination	+	+	+/-	+/-	Reduced PPP use is assumed to have positive impacts but could have unintended negative impacts: • Forcing a switch to annual crops or land-use change e.g. building would lead to a loss of pollination, biocontrol, wild food and habitat as well as have negative effects on GW, SW and cultural services • Increased buffers increase reservoirs for pest & transmission between crops & increase need for vegetation management (e.g. mowing, hand weeding)
Biological control	+	+	+/-	+/-	
Genetic Diversity	+	+	+/-	+/-	
Wild foods	+	+	+/-	+/-	
Groundwater & Surface water	+	+	+	+	
Habitat	+	+	-	-	
Cultural services	+/-	+/-	-	-	

Key: + Positive impact; +/- uncertain/neutral impact; - negative impact

**Employment declines in apples and vines because Scenario 4 is projected to reduce production.*
†Commodity price rises are assessed here as negative impacts

CONTENTS

EXECUTIVE SUMMARY I
CONTENTS VII
Glossary of Terms ix
Abbreviations x
Referenced Species x
1 INTRODUCTION 13
2 STRUCTURE OF THE IMPACT ASSESSMENT FRAMEWORK 15
2.1 Development of Crop Protection Scenarios 15
2.1.1 NTA risk assessment framework 15
2.1.2 The crop protection scenarios 16
2.2 Ecosystem Services 17
2.2.1 Ecosystem Services prioritisation 17
2.2.2 Metrics for measuring impacts on ecosystem services 24
3 APPLICATION OF THE IMPACT ASSESSMENT FRAMEWORK TO CASE STUDY CROPS 26
3.1 Approach 26
3.1.1 Overview 26
3.1.2 Crop management scenarios 26
3.1.3 Questionnaires 27
3.2 Winter wheat – Case Study UK 29
3.2.1 Spatial and temporal context 29
3.2.2 Scenario 1 – Current practice 30
3.2.3 Scenario 2 – Increase in-field protection 34
3.2.4 Scenario 3 – Increase off-field protection 35
3.2.5 Scenario 4 – Increase in-field and off-field protection 35
3.2.6 Impacts on production and economics 35
3.2.7 Conclusions (wheat) 38
3.3 Apple – Case Study Poland 38
3.3.1 Spatial and temporal context 39
3.3.2 Scenario 1 - Current practice 41
3.3.3 Scenario 2 – Increase in-field protection 42
3.3.4 Scenario 3 – Increase off-field protection 43
3.3.5 Scenario 4 – Increased in-field and off-field protection 44
3.3.6 Impacts on production and economics 44
3.3.7 Conclusions (Apples) 46
3.4 Vines – Case Study Italy 46

3.4.1 Spatial and temporal context 47
3.4.2 Scenario 1 - Current practice 48
3.4.3 Scenario 2 – Increased in-field protection 50
3.4.4 Scenario 3 – Increased off-field protection 51
3.4.5 Scenario 4 – Increased in-field and off-field protection 52
3.4.6 Impacts on production and economics 53
3.4.7 Conclusions (Vines) 54
3.5 Cabbage – Case Study Netherlands 55
3.5.1 Spatial and temporal context 55
3.5.2 Scenario 1 - Current practice 56
3.5.3 Scenario 2 – Increased in-field protection 59
3.5.4 Scenario 3 – Increased off-field protection 60
3.5.5 Scenario 4 – Increased in-field and off-field protection 60
3.5.6 Impacts on production and economics 61
3.5.7 Conclusions (Cabbages) 63
4 ANALYSIS 64
4.1 Impact on Ecosystem Services 64
4.1.1 Food (in-field crop production); 64
4.1.2 Wild foods 66
4.1.3 Freshwater (groundwater and surface water) 66
4.1.4 Erosion prevention, maintenance of soil fertility and carbon sequestration and storage 67
4.1.5 Pollination 67
4.1.6 Biological control 68
4.1.7 Maintenance of genetic biodiversity 68
4.1.8 Habitat for species 69
4.1.9 Spiritual experience and sense of place, tourism 69
5 CONCLUSION 71
5.1 Recommendations 72
6 REFERENCES 74
7 APPENDIX 1 – ECOSYSTEM SERVICE EVALUATION 81
7.1 Relevance of Ecosystem services to NTAs 81
7.2 Changes in Ecosystem services across scenarios 90
8 APPENDIX 2 – QUESTIONNAIRE 100

Glossary of Terms

Term	Definition
In-field	In-field = cropped area and its managed boundaries e.g. crop-free zone, buffer strip, it contains the crop and also non-crop elements.
Off-field	The area outside the managed "in-field" area. Includes adjacent habitats such as neighbouring fields with other crops, semi-natural features (hedgerows, field margins, drainage ditches, fallows), and natural habitats (woodlands, grasslands, wetlands).
Non-target arthropod	Insects, spiders, mites and other invertebrates that are either beneficial to the crop or neutral to it. They are not the target of pest management programs. They may provide services such as pest control or pollination.
Farm gate margin	The difference between the total revenue received from sales and the total variable costs associated with producing a specific product at the farm level – excluding on farm processing or storage.
Specific Protection Goal	A Specific Protection Goal (SPG) defines the precise, measurable environmental safety boundaries for a product such as a PPP, by specifying what must be protected (e.g., population vs. individual), where, for how long, and to what magnitude.
Ecosystem Service	The benefits people obtain from ecosystems. (IPBES, 2021)

Abbreviations

Abbreviation	In full
AI	Active Ingredient
BYDV	Barley Yellow Dwarf Virus
CLE	Croplife Europe
CSM	Conceptual Site Model
CpGV	Cydia pomonella Granulovirus
EC	European Commission
EFSA	European Food Safety Authority
ERO	Ecological Recovery Option
ES	Ecosystem Service
ESCORT2	Evaluation and Standardisation of Catch and Observations for Regulatory Testing
ETO	Ecotoxicological Threshold Option
FRAC	Fungicide Resistance Action Committee
GS	Growth Stage
GTD	Grapevine Trunk Disease
IA	Impact Assessment
IPM	Integrated pest management
MoA	Mode of Action
NTA	Non-Target Arthropod
NTTP	Non-Target Terrestrial plants
NTTO	Non-Target Terrestrial Organism
NDVI	Normalised Difference Vegetation Index
OWBM	Orange Wheat Blossom Midge
PPP	Plant Protection Product
PPR	The Panel on Plant Protection Products and their Residues
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
SDHI	Succinate dehydrogenase inhibitor
SPG	Specific Protection Goal
SPU	Service Providing Unit
WBF	Wheat Bulb Fly

Referenced Species

Common Name	Scientific Name	EPPO Code	COmment
Apple ermine moth	*Yponomeuta malinellus*	HYPNMA	Insect pest
Apple rust mite	*Aculus schlechtendali*	VASASD	Insect pest
Apple sawfly	*Hoplocampa testudinea*	HOPLTE	Insect pest
Apple scab	*Venturia inaequalis*	VENTIN	Fungal disease
Alternaria leaf spot	*Alternaria brassicae* / *A. brassicicola*	ALTEBA / ALTEBI	Fungal disease
Bird cherry-oat aphid	*Rhopalosiphum padi*	RHOPPA	Insect pest

Common Name	Scientific Name	EPPO Code	COmment
Black rot (apple)	*Xanthomonas campestris* pv. *campestris*	XANTCA	Bacterial disease
Black rot (vine)	*Guignardia bidwellii*	GUIGBI	Fungal disease
Botrytis fruit rot	*Botrytis cinerea*	BOTRCI	Fungal disease
Brown rot	*Monolinia fructigena*	MONIFC	Fungal disease - apple and other fruits
Brown rust	*Puccinia triticina*	PUCCRT	Fungal disease
Cabbage root fly	*Delia radicum*	HYLERA	Insect pest
Cabbage aphid	*Brevicoryne brassicae*	BRVCBR	Insect pest
Clubroot	*Plasmodiophora brassicae*	PLADBR	Phytomyxea disease
Codling moth	*Cydia pomonella*	CARPPO	Insect pest
Diamondback moth	*Plutella xylostella*	PLUTMA	Insect pest
Downy mildew (vines)	*Plasmopara viticola*	PLASVI	Fungal disease
European red mite	*Panonychus ulmi*	METTUL	Mite pest
European grapevine moth	*Lobesia botrana*	POLYBO	Insect pest
Fire blight	*Erwinia amylovora*	ERWIAM	Bacterial disease
Frit fly	*Oscinella frit*	OSCIFR	Insect pest
Fusarium	*Fusarium spp.*	GIBBZE	Fungal pathogen
Gout fly	*Chlorops pumilionis*	CHLPPU	Insect pest
Grain aphid	*Sitobion avenae*	MACSAV	Insect pest
Grapevine phylloxera	*Daktulosphaira vitifoliae*	VITEVI	Insect pest
Large cabbage white	*Pieris brassicae*	PIERBR	Insect pest
Leafhopper - Flavescence dorée vector	*Scaphoideus titanus*	SCAPLI	Insect pest
Orange wheat blossom midge (OWBM)	*Sitodiplosis mosellana*	SITDMO	Insect pest
Leafhoppers (vines)	*Empoasca vitis, Zygina rhamni*	EMPOFL / ERYTRH	Insect pest
Powdery mildew (wheat)	*Blumeria graminis f. sp. tritici*	ERYSGT	Fungal disease
Powdery mildew (apple)	*Podosphaera leucotricha*	PODOLE	Fungal disease
Powdery mildew (vine)	*Erysiphe necator*	UNCINE	Fungal disease
Powdery mildew (cabbage)	*Erysiphe cruciferarum*	ERYSCC	Fungal disease
Red-belted clearwing moth	*Synanthedon myopaeformis*	SYNAMY	Insect pest
Rosy apple aphid	*Dysaphis plantaginea*	DYSAPL	Insect pest
Septoria (tritici blotch)	*Zymoseptoria tritici*	SEPTTR	Fingal disease
Thrips	*Thrips tabaci*	THRITB	Insect pest
Two-spotted spider mite	*Tetranychus urticae*	TETRUR	Mite pest
Vine mealybug	*Planococcus ficus*	PLANFI	Insect pest
Wheat bulb fly	*Delia coarctata*	HYLECO	Insect pest

Common Name	Scientific Name	EPPO Code	COmment
Wirestem / damping-off	*Rhizoctonia solani*	RHIZSO	Fungal disease
Woolly apple aphid	*Eriosoma lanigerum*	ERISLA	Insect pest
Yellow rust	*Puccinia striiformis f. sp. tritici*	PUCCSI	Fungal disease

1 INTRODUCTION

Objectives and Approach

In 2024, the EU Commission mandated the EFSA to update the risk assessment methodology for the assessment of active substances and plant protection products (PPPs) with respect to their potential effects on non-target arthropods (NTAs) other than bees, in-soil organisms and non-target terrestrial plants (NTTPs) outside of the treatment area. This process will require revision of the Specific Protection Goals (SPGs) and the associated Terrestrial Guidance Document that currently defines the risk assessment scheme for each organism class. The EFSA published a Scientific Opinion addressing the state of the science on the risk assessment of PPPs for NTAs in 2015. This Opinion proposes more stringent SPGs and conservative risk assessment approaches that are predicted to limit the ability to register PPPs in the EU, increase the need for label mitigations and higher-tier risk assessment solutions, such as ecological and landscape level modelling, and ultimately change the availability of PPPs to growers.

This project was initiated to evaluate the wider impact of these proposed changes on agricultural systems and food production, beyond the intention to protect NTAs. For this purpose, the project used an Impact Assessment (IA) framework that was previously developed by the PPP industry (specifically, CropLife Europe, CLE) working in conjunction with Wageningen University and Research (WUR) and Ramboll (Bremmer et al 2020). This framework was developed in the context of the Better Regulation Guidelines (European Commission, 2021), in which both environmental and socio-economic impact of proposed changes are simultaneously addressed in a balanced way to protect Specific Goals such as NTTPs and NTAs, while also safeguarding the competitiveness of EU agriculture. The IA framework uses an ecosystem service approach to define potential future SPG scenarios for cropped areas (in-field) and adjacent habitats (off-field) and then evaluates the impact of those scenarios on the availability of PPPs to growers and predicts consequent changes to cropping systems in terms of the agronomic and chemical approaches used for pest control. The IA framework then investigates the impact of the changes in crop management on socio-economic and environmental factors deemed relevant to the cropping systems under evaluation, allowing holistic identification of trade-offs between the SPG scenarios, resulting adjustments to pest control methods used by growers and broader consequences for food production.

For this project, the IA framework developed by Bremmer et al. (2020) for non-target terrestrial plants was refined to incorporate those ecosystem services considered relevant to the protection of NTAs (EFSA et al., 2025) i.e. pollination, biological control, soil fertility and biodiversity maintenance, alongside provisioning services like food production for humans. These services underpin both environmental health and agricultural productivity, making them central to policy debates on PPP reduction and biodiversity conservation.

Since the focus of this IA framework is NTAs, the scope is informed by the relative toxicity of plant protection products. Beaumelle et al. (2023) observed that as insecticides are specifically designed to kill insects, certain insecticides can cause high, immediate mortality in beneficial arthropods. Additionally, some fungicides, whilst targeted at fungal pathogens, also display high direct toxicity to arthropods. Contrastingly, herbicides are generally indirectly toxic to insects, with harm more likely to arise from impact on NTA habitats and food sources. Therefore, this analysis focuses only on impacts of insecticides and fungicides on NTAs. This analysis does not specifically distinguish between insecticides or fungicides that cause more or less harm, instead taking a simplistic approach of simply halving the rate applied.

The report provides a comprehensive evaluation of trade-offs between environmental and economic objectives via the steps as shown in

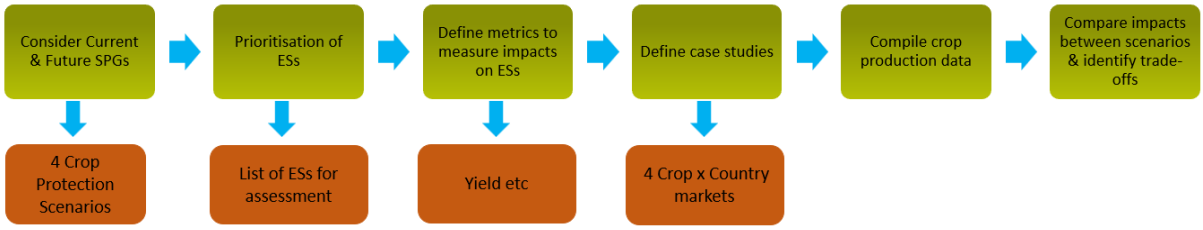

Figure **1-1**.

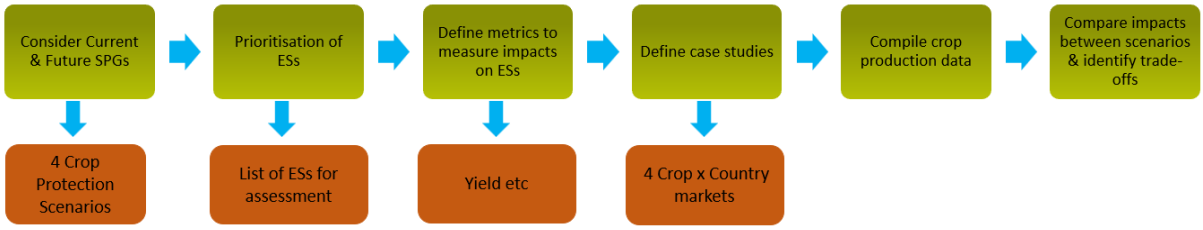

Figure 1-1. Impact assessment of potential guidance changes for NTAs

Step 1 - The evolution of regulation is likely to result in changes in the specific protection goals for NTAs. The EFSA is currently proposing options for these SPGs. For the purpose of this analysis, four scenarios were developed to represent potential outcomes of more stringent SPGs for NTAs on the use of plant protection products (PPPs) and the associated crop pest and disease management practices.

Development of future crop protection scenarios (Chapter 2):

- **Scenario 1 – Current Practice (up to 2026):** reflects the status quo, where crop protection relies on integrated pest management (IPM) as needed whilst incorporating conventional insecticide and fungicide use within existing legal requirements.
- **Scenario 2 – Increased In-Field Protection:** aligns with EU Farm to Fork objectives by reducing PPP (insecticide and fungicide) use by 50%, prioritising NTA protection over maximum yield. *N.B. a 50% PPP in use does not necessarily result in 50% mitigation of impacts*.
- **Scenario 3 – Increased Off-Field Protection:** expands buffer zones by 50% and drift-reduction measures intended to protect NTAs in off-field habitats. *N.B. a 50% increase in buffers does not necessarily result in 50% mitigation of PPP impacts*
- **Scenario 4 – Increased protection, in-field and off-field:** combines both in-field and off-field protection as described in Scenarios 2 and 3.

Step 2 – Identification of the Ecosystem Services (ESs) for assessment. For this purpose, those ESs that are directly relevant to NTAs were prioritised for assessment as well as those ESs that may be impacted by the changes in agricultural practice that are necessary to protect NTAs. (Chapter 2).

Step 3 – In order to understand how these ESs might be affected by the changes in management practices identified as a result of implementing specific protection goals (SPGs), it was necessary to identify what metrics would be used to measure impact.

Step 4 – Selection of case studies. In order to understand the impact of changing SPGs on crop production in Europe, the four scenarios were applied to four case study crops in different geographical locations across Europe. This application of the framework to four representative cropping systems is shown in Chapter 3: the selected systems were - winter wheat in the UK, apples in Poland, vines in Italy and cabbages in The Netherlands. These systems were chosen for their economic importance, varying cropping systems and geographic diversity.

Step 5 – For each case study, an evaluation of the environmental, economic and operational implications of the scenarios was completed, supported by quantitative modelling and expert judgment.

Step 6 – The final step was the synthesis of these findings into a discussion of broader implications for policy, food security and biodiversity, concluding with actionable recommendations for risk management and innovation (Chapter 3).

By considering NTA protection within a holistic assessment of ecosystem services and agricultural viability, this report aims to inform evidence-based decision-making for sustainable crop protection strategies across Europe.

2 STRUCTURE OF THE IMPACT ASSESSMENT FRAMEWORK

2.1 Development of Crop Protection Scenarios

The first step in this project was to derive the pest and disease management scenarios to be assessed using the ecosystem services framework. This step requires consideration of the likely impact of changes in the NTA risk assessment framework on the availability and use of PPPs by growers.

2.1.1 NTA risk assessment framework

The existing NTA risk assessment framework, and its' associated protection goals, has not changed for many years. However, in the future, more stringent SPGs are likely to be introduced for NTAs. In 2024, the European Commission (EC) mandated the European Food Safety Authority (EFSA) to work on a proposal for Specific Protection Goals (SPGs) for Non-Target Terrestrial Organisms (NTTOs) as part of the review of the Terrestrial Ecotoxicology Guidance document and the development of guidance on assessing indirect effects on biodiversity. In June 2025, EFSA published Part 1 of their analysis of the evidence to support the definition of SPGs for terrestrial organisms and outlined their proposed strategy for supporting Risk Managers in the definition of the SPGs. This publication relied on previous Scientific Opinions of the Panel on Plant Protection Products and their Residues (PPR), in which SPG options were explored. The outcome was an identification of key aspects requiring consideration, mainly pertaining to the definition of the magnitude of acceptable effects and the related timescale. The basis of the EC mandate, and resulting publications and future work (i.e. to develop guidance for assessing potential indirect effects on biodiversity), is anticipated to result in the definition of more conservative SPGs than the goals currently covered by the risk assessment guidance for NTAs. Based on this assumption of more stringent SPGs, this report has made assumptions on the impact on PPP availability and their use (including mitigation measures such as buffers).

In order to make predictions on the impacts of more stringent SPGs, potential SPGs were compiled, taking into consideration the EFSA (2025) publication and the framework developed by Bremmer et al., (2020). Next, a prioritisation activity was performed to provide a short list of prioritised ESs based on anticipated changes in ecosystem service delivery across the agricultural scenarios explored in this report.

The SPG attributes identified were:

- The ecological entity and attributes to protect (as defined by the ecosystem services prioritised by EFSA);
- The magnitude of effects and
- The temporal and spatial scale of effects.

Whilst the primary focus of this assessment report is on direct impacts of these SPG attributes, e.g., via chemical impacts from insecticides and fungicides, the impacts of changes in agricultural practices, other than chemicals, was also considered. EFSA et al., (2025) propose a strategy for developing SPGs, discussing the importance of considering spatial scale in setting SPGs for non-target terrestrial organisms (NTTOs), including non-target arthropods (NTAs). The strategy emphasises the need to address both local (field/edge-of-field) and landscape scales, though defining tolerable effect thresholds at the landscape level remains challenging. Population models could help but are not yet routinely used as standalone tools.

The report suggests a pragmatic approach for future risk assessments:

- If the ETO (Ecotoxicological Threshold Option) is used (negligible local effects), local-scale assessment may suffice.

- For the ERO (Ecological Recovery Option), landscape-level considerations are crucial because recovery often depends on recolonisation from untreated areas (population dynamics including source-sink dynamics). This may require predefined landscape configurations or mitigation measures like adjusting land use.

Additionally, the spatial aspect of SPGs is described as a matrix with two dimensions:

1. Scale: Local vs. landscape.
2. Location: In-field vs. off-field.

For the purposes of this report, the terms “in-field” and “off-field” are used as defined by EFSA et al. (2025) and as shown in Figure 2-1. As thresholds for tolerable effects at landscape level are not yet quantitatively defined, the current focus for defining protection goals is the local agricultural scale, considering both the in- and off-field locations. Future scientific and regulatory developments, such as the incorporation of population models, may allow for the validation of SPGs to confirm their protectiveness at the landscape level.

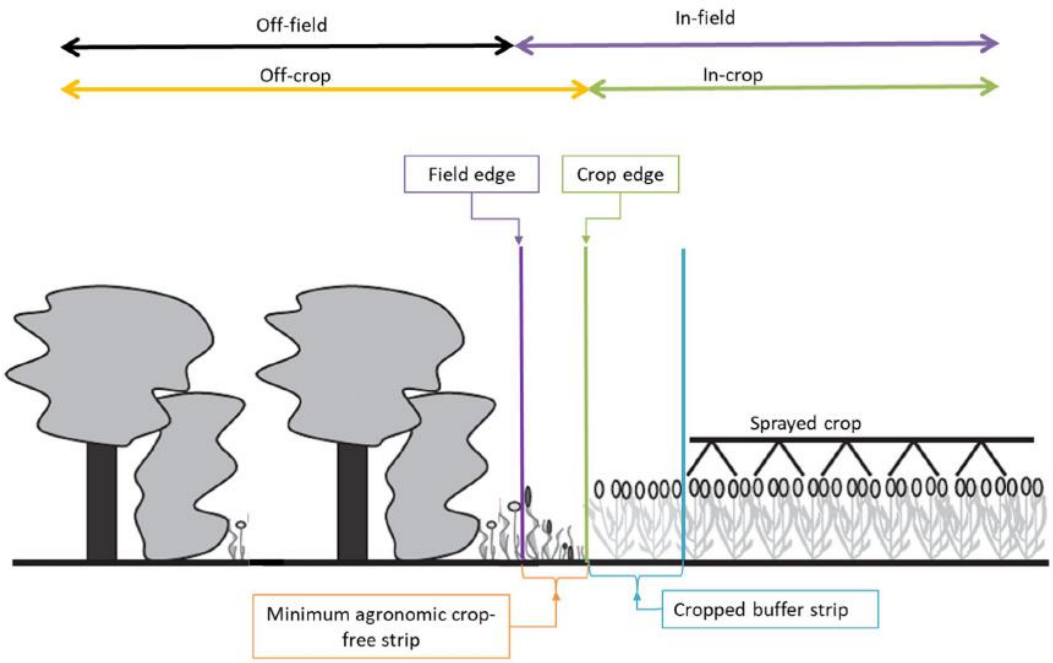

Figure 2-1. Graphical illustration of the differences between in-field versus off-field and in-crop versus off-crop and unsprayed strips as set out in (EFSA et al., 2025). Adapted from Alix *et al.* (2012) and Van de Zande *et al.* (2012) and cited in Adriaanse (2022).

2.1.2 The crop protection scenarios

At the time of writing, future SPGs have not been published by EFSA. For the purpose of this analysis, four hypothetical crop protection scenarios were developed that reflect the potential impact of potential future SPGs on the availability of crop protection tools to growers. This analysis also considers the implications of these crop protection scenarios on the ability to manage key pest and disease species in commercial crop production.

These scenarios are as follows:

Scenario 1 – Current Practice (up to 2026): Reflects the status quo, where crop protection relies on integrated pest management (IPM) whilst incorporating conventional insecticide and fungicide use within existing legal requirements based on ESCORT 2 (Evaluation and Standardisation of Catch and

Observations for Regulatory Testing) guidance, that permits up to 50% initial in-field effects on NTAs provided that the population shows a potential for recovery within one year in the treated area (Candolfi et al., 2001). Following the ETO approach, negligible effects are permitted in the off-field area. In this scenario, the ecosystem service focus is on the in-field production of crops/food, although the risk assessment triggers provide a level of protection for NTAs in the in-field and off-field environments.

Scenario 2- Increased in-field protection of NTAs relative to Scenario 1. In this scenario, increased protection of NTAs in-field is assumed to be achieved by lowering the risk from fungicide and insecticide inputs by reducing the volume of products applied to crops by 50% in alignment with policy objectives stated by the European Commission (2020) in their *Farm to Fork Strategy*. Reductions can be delivered through one or more of the following: reduction in application rate, reduction in number of applications or increased use of precision application that results in a smaller proportion of the crop area being treated.

Scenario 3- Increased off-field protection of NTAs relative to Scenario 1. This scenario reflects the minimum legal requirements for pest and disease management described in Scenario 1 while adding increased protection of off-field NTAs by using spray drift reduction technology and precision application techniques. The ecosystem service of crop production is fully maintained in-crop and increased protection of off-field NTAs is assumed to be delivered by an increase of 50% in buffer widths applied to the cropped area in line with the aims of the EU's Biodiversity Strategy for 2030 (European Commission, 2025).

Scenario 4- Increased in-field and off-field protection of NTAs relative to Scenario 1. This scenario provides protection of both in-field and off-field NTAs by combining the restrictions outlined in Scenarios 2 and 3. All ecosystem services in-field except food production are prioritised through using a mix of pest and disease control technologies, which means that yield losses are accepted.

Scenarios 2 to 4 aim to demonstrate the trade-offs resulting from increased NTA protection either in-field and/or off-field and the impact on the ability of farmers to maintain productivity. As specific protection goals are not yet defined, these scenarios represent plausible scenarios, based on a high level of protection.

2.2 Ecosystem Services

2.2.1 Ecosystem Services prioritisation

Note: Detailed tables for this section of the report are included in Chapter 7 Appendix due to their size and complexity, with shorter versions included in this chapter for context.

The background for this work begins with The Millennium Ecosystem Assessment (MA, 2005) that classified ecosystem services (ES) into provisioning, regulating, cultural and supporting categories, providing a foundational framework for assessing environmental impacts. The Economics of Ecosystems and Biodiversity (TEEB) (Kumar, 2011) builds on this categorisation by emphasising economic valuation of ES, promoting their integration into policy decisions. These approaches directly influence Regulation (EC) 1107/2009 (European Parliament, 2009) on plant protection products (PPPs) by informing environmental risk assessments (ERA). Under the regulation, general protection goals (e.g., "no unacceptable effects" on the environment) are translated into Specific Protection Goals (SPGs) using ES concepts, focusing on key drivers like microbes, plants, and invertebrates to maintain ES at population or functional levels.

The Better Regulation Guidelines (European Commission, 2021) oversee implementation through impact assessments and evaluations that integrate environmental, biodiversity and sustainability

considerations aligned with WHO (2015) sustainable development goals (SDGs) and 'do no significant harm' principles. This approach ensures evidence-based oversight, fitness checks for coherence, and stakeholder-inclusive processes, embedding MA/TEEB-derived ES valuation to balance regulatory efficiency with ecosystem protection.

As stated in the Scientific Opinion addressing the state of the science on risk assessment of plant protection products for non-target arthropods (EFSA, 2015), "*the first step in the definition of a specific protection goal is the identification of important ecosystem services that are provided by agricultural ecosystems. By means of describing services that mankind receives from ecosystem performance, abstract ecological entities and processes become explicit*." Therefore, Ecosystem Services (ESs) have been identified and a prioritisation activity performed to select the most relevant ESs. This activity was primarily based on anticipated changes to the ES across the crop protection scenarios, i.e. those services that were anticipated to be the most impacted by changes in crop protection activities across the four scenarios were given priority. For the selection and definition of ESs, the ESs as identified in EFSA et al. (2025) were considered as listed Table 2-1.

Table 2-1. Prioritised ecosystems services for Non-Target Arthropods (EFSA et al., 2025)

Ecosystems Service
1. **Biodiversity, genetic resources.** NTAs are an extremely diverse organism group that contributes highly to biodiversity in agricultural landscapes.
2. **Education, inspiration and aesthetic value.** Several NTAs in agricultural landscapes are highly valued for their cultural services (e.g. butterflies) and/or are listed as rare species with a species conservation status.
3. **Regulation of arthropod pest populations.** NTAs are valuable antagonists of pests affecting crop plant species. Moreover, NTAs are also antagonists of pests and parasites of mammals; for example, several ant species are known to be tick predators and certain coleopterans are predators of cattle parasites.
4. **Food provision.** NTAs are the most significant and crucial part of the diet for organisms at higher trophic levels, e.g. amphibians, reptiles, birds and small mammals.
5. **Pollination.** NTAs are – as well as bees – effective pollinators of several plant species in- and off-crop.

In order to assess the wider impact of the potential changes in SPGs beyond the intention to protect NTAs, this project followed the approach taken by Bremmer et al., (2020) and considered all ecosystem services as defined by Kumar (2011). The reason for this wider consideration of ecosystems services beyond those listed by EFSA et al. (2025) is that alteration of SPGs for NTAs may impact other ecosystem services via changed inputs of PPPs and altered agronomic practices such as alternative pest management methods. Examples include the ES of surface water, which may be impacted via reduced PPP use or increased fertiliser use and, importantly, the ES of food production for humans which could be impacted by a reduction in PPP applications due to increased pest or disease pressure resulting in a reduction in yield.

The full list of ESs considered is provided in Table 7-1 in the appendix.

A prioritisation activity was then performed on these ESs by identifying those services that are likely to be impacted by changes under each of the crop protection scenarios. The activity was performed in combination by ecotoxicology and agronomy experts using existing knowledge and ad hoc literature

searches. A specific scoring system was not used and the assigned weighting was qualitative. Those ESs which were considered the most likely to be impacted by the changes were prioritised for further assessment.

For this purpose, the following aspects were taken into account:

- Anticipated presence or absence of ES in-field and/or off-field
- Relevance to beneficiaries who may include the farmer, local community or consumer (relevance to those who may be affected by the change in ecosystem service provision)
- Anticipated changes in ecosystem service across crop protection scenarios (priority was given to material changes)
- Regulatory requirements (relevance to legal requirements)

The relevance of NTA to ES provisioning was considered but did not directly influence the prioritisation process. Data availability was not used as a criterion for ES prioritisation, as it is not indicative of a lack of impact. A comprehensive assessment is provided in Table 7-2 (in the appendix). The findings are summarised in Table 2-2 where material changes in ESs across scenarios are indicated with 'Y', and non-material changes as 'N' - unless otherwise indicated, e.g. 'Y (negligible change)'.

Table 2-3. Anticipated changes in ecosystem service delivery across scenarios. Scenario 1 = Current practice in 2025, Scenario 2 = Prioritising in-field NTA protection over ES food production. Scenario 3 = Balancing ES food production but with increased focus on off-field NTA protection and Scenario 4 = Prioritising NTA protection over ES food production and increased focus on off-field environmental protection – full table 6-2 in Appendix. Colouration reflects prioritisation context – green = in-field, blue – off-field, amber = both, grey = not prioritised for either.

ES code	Ecosystem service (ES)	Relevance of NTAs to ES provision (None, Low, Moderate, High) and explanation	Scenario 1: Current situation 2025 Presence Y/N	Scenario 2: increased in-field protection, status quo off-field Change Y/N	Scenario 3: increased off-field protection, status quo in-field Change Y/N	Scenario 4: increased in-field and off-field protection Change Y/N	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
Provisioning Services (ES that describe the material or energy outputs from ecosystems, including food, water and other resources)								
ES1a	**Food (in-field crop production)**	**None**: NTAs do not directly provide food for humans. They have minor contributions through harvested insect products, but in an SPG context, this is irrelevant.	Y	Y	Y	Y	Y	N (ES not present)
ES1b	**Raw materials (in-field)**	**None**: Not provided by NTAs in arable fields.	Y	Y	Y	Y	Y	N (ES not present)
ES2	**Wild foods**	**Low**: NTAs may directly provide food for humans, especially in some societies with traditions of consuming invertebrates. They also have minor contributions through harvested insect products.	Y	N	Y	Y	N	Y
ES3	**Freshwater (groundwater)**	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.	Y	Y	Y	Y	Y	Y
ES4	**Freshwater (surface water)**	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.	Y	Y	Y	Y	Y	Y
ES5	**Medicinal resources (off-field)**	**Low**: Some arthropods are sources of medicinal compounds, but it is negligible in this context.	Y	N	Y	Y	N (ES not present)	N (considered alongside 'wild food')
Regulating Services (services that ecosystems provide by acting as regulators, such as, regulating the quality of air and soil or by providing flood and disease control)								
ES6	**Local climate and air quality**	**Low**: NTAs have a negligible role compared to plants and soils.	Y	Y (negligible change)	Y (negligible change)	Y (negligible change)	N (ES not present)	N

ES code	Ecosystem service (ES)	Relevance of NTAs to ES provision (None, Low, Moderate, High) and explanation	Scenario 1: Current situation 2025 Presence Y/N	Scenario 2: increased in-field protection, status quo off-field Change Y/N	Scenario 3: increased off-field protection, status quo in-field Change Y/N	Scenario 4: increased in-field and off-field protection Change Y/N	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
ES7	**Erosion prevention and maintenance of soil fertility. Carbon sequestration and storage**	**Low**: Surface-active detritivores and soil arthropods contribute to litter breakdown, soil structure, and fertility. These are considered in-soil organisms and not NTAs unless PPPs are directly applied to the soil, and are covered under their own guidance requiring their own consideration of SPGs. There is not typically a litter layer in an agricultural setting (perhaps minorly in-field borders or permanent crops such as orchards, for example), thus their influence is minor.	Y	Y	Y	Y	Y	Y
ES8	**Moderation of extreme events**	**None**: No direct role for NTAs.	N/A	N/A	N/A	N/A	N/A	N/A
ES9	**Waste-water treatment**	**Low**: Dung beetles, for example, aid in waste removal, reducing pathogens, and improving nutrient cycling. Other arthropods that do this are considered in-soil organisms, not NTAs. However, this is negligible compared to microbes, plants, and soils.	Y	Y (negligible change)	Y (negligible change)	Y (negligible change)	N (change is negligible)	N (change is negligible)
ES10	**Pollination**	**None-High (context dependent)**: NTA pollinators **(**flies, beetles, butterflies, moths, wild bees etc.**)** provide pollination services to some crops and wild plants. Relevance in-field is crop dependant **(**e.g. monocots are wind-pollinated, so no relevance**)**. Without insect pollination, 12% of global crops would not or hardly produce, 28% would see a substantial reduction in quantity or quality and for 52% of the crops, pollinators only provide limited or no contribution **(**remaining 8% unknown**)**. In terms of global production volumes, 60% of production comes from crops that do not depend on animal pollination **(**e.g., cereals and root	Y	Y	Y	Y	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES provision (None, Low, Moderate, High) and explanation	Scenario 1: Current situation 2025 Presence Y/N	Scenario 2: increased in-field protection, status quo off-field Change Y/N	Scenario 3: increased off-field protection, status quo in-field Change Y/N	Scenario 4: increased in-field and off-field protection Change Y/N	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
		crops**)**, 35% of production comes from crops that depend at least in part on animal pollination and 5% have not been evaluated **(**established but incomplete**)**. If this is translated to agricultural productivity 5-8% of global crop production depends on pollinators (IPBES, 2016).						
ES11	**Biological control**	**Low-Moderate**: Predatory and parasitic NTAs regulate pest populations, but relevance in-field is crop-dependant. For example, flower strips can enhance pest control services in adjacent fields by 16% on average. However, effects on yield may be variable (Albrecht et al., 2020).	Y	Y	Y	Y	Y	Y
Cultural Services (non-material benefits people obtain from contact with ecosystems, including aesthetic, spiritual and psychological benefits)								
ES12	**Spiritual experience and sense of place (off-field)**	**Low**: Certain NTAs used to feature in cultural symbolism and traditional practices. This can include scarab beetles in Egypt, bees in many religions like Hinduism and Islam, and dragonflies in Japan. However, the reverence for these NTAs is largely not practiced today in EU, thus the influence of NTAs on this ES is minor.	Y	Y	Y	Y	Y	Y
ES13	**Tourism**	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance ecotourism. NTAs could also have negative impacts on tourism e.g. presence of biting insects or those attracted to waste.	Y	Y	Y	Y	Y	Y
ES14	**Aesthetic appreciation and inspiration for culture, art, design**	**Low-High (context dependent):** Attractive NTAs provide aesthetic value and cultural inspiration.	Y	Y	Y	Y	Y	Y
ES15	**Recreation and mental and physical health**	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance recreation and mental health. NTAs could also have negative impacts e.g. presence of	Y	Y	Y	Y	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES provision (None, Low, Moderate, High) and explanation	Scenario 1: Current situation 2025 Presence Y/N	Scenario 2: increased in-field protection, status quo off-field Change Y/N	Scenario 3: increased off-field protection, status quo in-field Change Y/N	Scenario 4: increased in-field and off-field protection Change Y/N	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
		biting insects or those attracted to waste, which may also spread disease.						
Habitat or supporting services (underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals)								
ES16	**Maintenance of genetic biodiversity**	**Low-High (context dependent):** NTA species richness and functional diversity provide resilience, redundancy, and future options for ecosystems and agriculture. Pollinators can ensure gene flow between plant populations. Plant pollination by NTAs can ensure diverse plant populations reproduce.	Y	Y	Y	Y	Y	Y
ES17	**Habitat for species (functioning of ecological components of the agro ecosystem)**	**Low-High (context dependent):** NTAs form part of farmland biodiversity, creating prey and microhabitats for higher trophic levels and sustaining ecosystem function.	Y	Y	Y	Y	Y	Y

The ecosystem services that were identified as likely to incur a material change following possible changes in SPGs for NTAs are listed below.

- Food (in-field crop production);
- Raw materials;
- Wild foods;
- Freshwater (groundwater);
- Freshwater (surface water);
- Erosion prevention and maintenance of soil fertility, Carbon sequestration;
- Pollination;
- Biological control;
- Cultural Services
- Maintenance of genetic biodiversity;
- Habitat for species (functioning of ecological components of the agroecosystem).

It should be noted that the baseline level of service provision, and magnitude of changes, are context-dependent. For example, the importance of biological control and pollination services provided by NTAs will be highly crop-specific (for example, many major crops such as cereals are wind-pollinated), and potentially also specific to the wider landscape setting (e.g. climate, location etc.). These uncertainties have been acknowledged in the analysis wherever possible. As a result, the prioritised ESs are considered a short-list and further context-specific filtering to remove ESs may be necessary on a case-by-case basis.

2.2.2 Metrics for measuring impacts on ecosystem services

To assess the impact of the potential SPGs for each scenario, it is necessary to identify indicators for each prioritised ES, and a metric that provides a measurable impact. The indicators and metrics for the prioritised ESs are summarised in Table 2-4. It is not applicable to provide a formal quantitative measure of these impacts without defined SPGs, however, it should be noted that the magnitude of effects for each category is anticipated to vary based on crop and landscape context, and should be considered on a case-by-case basis.

Table 2-4. Proposed indicators and metrics for ES impacts under changing SPG driven scenarios

Code	Ecosystem Service (ES)	ES Indicators	Index or Metric
Provisioning Services (ES that describe the material or energy outputs from ecosystems, including food, water and other resources)			
ES1a and ES1b	**Food (in-field crop production) and Raw materials (in-field)**	Yield (food security). Quality of fresh produce (influence of quality on price)	Crop yields (tonne/ha; tonne dry matter/ha; MJ/ha). Quality (tonnes per class). Crop area, buffer zone and margin
ES2	**Wild foods**	Availability of wild foods	Area or plant cover of indicator species used for harvested quantities, unless data is available for most commonly foraged wild foods in each area (kg collected or traded)
ES3	**Freshwater (groundwater)**	Groundwater quality (drinking water resource)	Groundwater impact or risk index; failures of the European Drinking Water Standard (groundwater monitoring data)
ES4	**Freshwater (surface water)**	Surface water quality (all relevant freshwater organisms)	Surface water risk index EQS failures (field monitoring data or aquatic organism performance)
Regulating Services (services that ecosystems provide by acting as regulators, such as, regulating the quality of air and soil or by providing flood and disease control)			
ES8	**Erosion prevention and (primarily) maintenance of soil fertility**	Ground-level detritivores	Soil health index relating to overarching parameters indicative of soil fertility, including; general biodiversity, microbial biomass and activity, plant growth, soil fauna and soil physical/chemical assessment
ES11	**Pollination**	NTA pollinators	Successful pollination of crops reliant on non-honeybee pollinators; successful pollination of NTTPs. Maintenance of NTTP fertility and genetic diversity

Code	Ecosystem Service (ES)	ES Indicators	Index or Metric
ES12	**Biological control**	Predatory and parasitic NTAs	Successful regulation of in-field crop pest species. Off-field non-cropped areas may act as a refuge/sink for predatory and parasitic NTAs
Cultural Services (non-material benefits people obtain from contact with ecosystems, including aesthetic, spiritual and psychological benefits)			
ES13	**Spiritual experience and sense of place**	Certain NTAs and plant species (crop and NTTPs), trees, patches of vegetation and ecosystems as landscape features, landscape elements/habitats	Maintenance and development of certain habitats, ecosystem and landscape features. Not limited to off-field, as the agronomic landscape (including fields) also contributes to a sense of place. This will vary between individuals and cultures
ES14	**Tourism**	Attractive plants and vegetation, plant species that provide habitat to vertebrates (e.g. bird watching) and attractive NTAs (e.g., butterflies, dragonflies)	Maintenance and development of certain habitats, ecosystem and landscape features. Attraction of certain enigmatic species which encourage eco-tourism
ES15	**Aesthetic appreciation and inspiration for culture, art, design**	Certain plant species such as flowering plants (also attractive NTAs and vertebrates attracted by the habitat provided by plant species), structures constructed and/or modified by their typical biota.	Maintenance and development of certain habitats, ecosystem and landscape features. Preference for landscape will vary, but in general, a mosaic landscape and wide species diversity is likely to provide greatest opportunities for aesthetic appreciation
ES16	**Recreation and mental and physical health**	Attractive NTAs and appreciated agricultural landscapes (e.g. fields bordered by hedgerows) and semi-natural habitats, wild foods providing foraging opportunities for local population and recreational users (crop and NTTPs)	Maintenance and development of certain habitats, ecosystem and landscape features. Increase in 'off-field' environment may increase opportunities for recreation and health. Increase in some (human pest) species may negatively impact this
Habitat or supporting services (underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals)			
ES17	**Maintenance of genetic biodiversity**	NTA species richness and functional diversity. NTTP genetic diversity facilitated by NTA pollinators	Species diversity indicators such as species number, species richness, population densities etc.
ES18	**Habitat for species (functioning of ecological components of the agro ecosystem)**	NTAs as a part of biodiversity, creating prey (mainly) and microhabitats for other trophic levels and sustaining ecosystem function	Habitat diversity indicators: Habitat impact index, habitat richness, habitat diversity, average size of habitat patches etc.

The proposed ES metrics were used in the context of the application of the impact assessment framework to case study crops to help in quantifying the impact of the different scenarios on the prioritised ESs. In the context of this project, only qualitative assessments have been possible for most ES other than food production for humans. A qualitative assessment would likely require a dedicated project for each ES due to the complexity of potential impacts. Nevertheless, the assessments presented in chapter 3 of this report for these ESs are considered a valuable starting point.

3 APPLICATION OF THE IMPACT ASSESSMENT FRAMEWORK TO CASE STUDY CROPS

3.1 Approach

Impacts of the crop management scenarios were assessed for four case study crops in different geographies distributed across Europe to understand how farmers might adapt to the scenarios and the implications on the cost and volume of production. This analysis combined literature reviews with local crop production expertise provided by a network of regional agronomists coordinated by RSK ADAS and SAGEA Group.

3.1.1 Overview

The case studies selected for study are shown in Table 3-1 and cover cereal, vegetable and fruit production systems across a range of southern, central and northern European countries.

The crops were selected to characterise diverse production systems where pest and disease control play important roles. Wheat and cabbage are grown in annual arable/horticultural rotations whereas apples and vines are grown in permanent plantations. The country markets were selected based on the importance of the crop to the national economy - - and to provide locations across Europe. UK wheat and Dutch cabbage represent western maritime conditions while Polish apples represent the central/northern continental climate and Italy provides insights for Mediterranean environments. Details are provided in Table 3-1.

Table 3-1. Overview of case study crops (2024)

Crop	Country	Area (kha)	Annual value (€bn)	EU-27 area (kha)	EU-27 Value (€bn)
Apples	Poland	148	1.0	500	11.6
Cabbage	Netherlands	2.10	0.04	120	3.8
Vines	Italy	973	12.1	3,200	29.0
Winter wheat	United Kingdom	1,700	3.0	22,000	26.6

3.1.2 Crop management scenarios

Process for assessing impacts

The assessment of the impacts of the crop management scenarios was initiated with definition of current practices under Scenario 1. This work included a review of academic and industry literature to determine typical pest and disease management practices across each of the four case study crops and geographies. This task involved identification of the key pest and disease species that impact yield and quality, the distribution of those pests and diseases and the relative yield and quality impacts if control fails. In addition, information was collected on the main methods used for the control of key pests and diseases, both chemical, in the form of volume of plant protection products (PPPs) used, and the frequency of application, as well as non-chemical controls such as rotation, mechanical and biological controls.

Validation of baseline data

For each case study, the baseline data were validated and elaborated where relevant using in-country agronomists from RSK ADAS Ltd and SAGEA Group who have practical expertise of farming and as well as advising farmers and growers in the countries where the four case studies were based. A questionnaire was used for this purpose

3.1.3 Questionnaires

Data on crop production were collated by local agronomic experts, using an Excel-based questionnaire that was adapted from Bremmer et al. (2020); (see Appendix 2). The questionnaire was structured across four worksheets, that were designed to capture information on crop management practices and their potential implications for non-target arthropods.

The first worksheet comprised generic questions intended to establish the broader agronomic and landscape context for each case study. This included identification of the crop and location, description of the surrounding landscape and land use, farm structure and field configuration, the presence and management of field margins, machinery used, and an overview of the main crops and fields. Respondents were also asked to describe the overall pest and disease management strategy applied in the system.

The second worksheet focused on current pest and disease management practices under Scenario 1 that are most relevant to NTA exposure. Experts were asked to describe the insecticide and fungicide programmes in place, including the types of products applied, application methods, machinery used, and the relative contribution of labour to pest and disease control. In addition, information was collected on the presence of non-crop habitats and features in-field and off-field (e.g. margins, hedgerows, buffer strips) that may support NTA communities. Questions in this section explored how crop protection measures were implemented in practice, including application timing, frequency, and the use of alternative or non-chemical control measures within integrated pest management (IPM) systems.

The third worksheet was designed to capture changes in insecticide and fungicide use and associated mitigation measures under Scenarios 2, 3 and 4. Experts were asked to describe how pest and disease management would be adjusted under each scenario, the likely intermediate effects on crop health and pest pressure, and the key differences between scenarios. The minimum-requirements scenario was treated as a realistic worst-case baseline aligned with the legal framework set out in Regulation (EC) No 1107/2009., recognising that this does not necessarily reflect common farming practice. In reality, growers typically apply a broader range of IPM measures than reliance on a single plant protection product, as required under EU IPM obligations since 2014. The final part of this worksheet captured anticipated social and economic impacts associated with the scenario-specific changes in crop protection.

The fourth worksheet considered the consequences of all scenarios for a subset of prioritised ecosystem services relevant to NTA protection (see Table 2-1).

To ensure consistency, a set of explanatory worksheets was included with the questionnaire. These instructions provided additional guidance on scenario assumptions, as well as a simplified conceptual site model (CSM) illustrating in-field and off-field elements such as cropped areas, field boundaries and margin strips. This was intended to promote a shared understanding of spatial distinctions relevant to NTA exposure and protection. A final worksheet allowed respondents to add supplementary information, such as climatic or seasonal factors, where relevant to changes in pest and disease management or their potential implications for non-target arthropods.

A completed example questionnaire workbook is available in Appendix 2.

Impacts of the crop protection scenarios

The expert agronomists from RSK ADAS Ltd and Sagea Group were asked to consider impacts of the four scenarios and how the changes in insecticide or fungicide usage and/or changes in buffer zone width would impact the way that farmers would manage pest and disease in each of the case studies. The agronomists provided their perspective on changes in management practices and the potential

implication for future crop production in terms of yield losses from pest damage and the economic risks of growing the crop.

Considerations for respondents included the following:

- Defining types of pest/disease management practices employed – rates and weights/volumes of active substances used.
- The influence of a preceding crop on pest and disease pressure and the efficacy of pest and disease treatments in a crop rotation context.
- Description of habitats, including management actions such as buffer strips or flower margins
- Defining NTA communities for crop production scenarios
- Holistic consideration of potential impact pathways that may affect environment, social and farm economic factors
- Assessment of how pest and disease control may change over time, including likely shifts in pest populations and the development of resistance to PPPs arising from changes in product application rates and frequency of use.

Analysis of results and summary of findings

The resultant information from the in-country agronomists was analysed and combined with information from the literature review to create each case study as presented below.

3.2 Winter wheat – Case Study UK

3.2.1 Spatial and temporal context

Wheat is the leading arable crop in the UK. Between 2021 to 2015, the five-year average crop area was 1.7 million hectares across the UK, ranging from 1.53-1.81 million hectares depending on the season, with lower areas reflecting difficult autumn drilling conditions (Defra, 2025a). Wheat represents approximately 45% of the total UK arable area (Ridley et al., 2022).

This study assumes that a typical UK arable field is 10 hectares (100,000 m^2). The 10 ha field is assumed to be square with each side being 316 m long, with grass margins and hedgerows on all sides and off-field surrounding habitats that include surface water bodies and woodland. Arable fields can also include public footpaths but these were not included in the spatial calculations in this assessment as they would not be directly impacted by the scenarios. Dimensions and key observations for the in-field features are as follows:

- Hedgerow of 1.5 m width within the field boundary, equivalent to 0.09 ha.
- Large-scale uptake of Countryside Stewardship measures and the Sustainable Farming Initiative mean that the most common field margin width in UK wheat is 6.0 m. This area is a crop-free margin, usually planted with grasses or specific plant mixes to benefit biodiversity. This area is assumed to be incorporated in Scenarios 1 and 2 and is equivalent to 0.37 ha in a 10 ha field.
- Field margins are increased by 50% to 9.0 m in Scenarios 3 and 4, leading to a total margin area equivalent to 0.56 ha.
- Cropped area is 9.53 ha in Scenarios 1 and 2 and 9.35 ha in Scenarios 3 and 4.

Total non-cropped area is 5% of the model field in Scenarios 1 and 2 and 7% in Scenarios 3 and 4.

The temporal scale for this case study is a one-year winter wheat crop cycle (Figure 3-1). Typical UK winter wheat crops are sown between mid-September and mid-November, with optimal timing for establishment in the first half of this window. In high pest or disease pressure scenarios, sowing can delayed and compensated with slightly higher seed rates to achieve optimal establishment. Late drilling is associated with increased risk of heavy rain in October which can make access to fields for crop drilling challenging. This issue has occurred in recent wet autumns where the area of winter wheat established dropped to 1.3 million hectares due to difficult drilling conditions in mid to late autumn. Insecticide applications are typically made in the autumn, especially in warm autumns that favour aphid reproduction and population expansion.

The crop then goes through a period of establishment and early tillering (foundation) over the winter months. As conditions improve in the spring, stem elongation begins (construction) and the leaves that will form the final yield start to emerge. These leaves are targeted for fungicide applications to ensure that leaf surface area is maintained to maximise photosynthesis. Ears typically emerge in early June and once pollination is complete, the grains start to ripen. The crop will then senesce and harvest will start in late July (Southern England) and last through until late August (Northern England and Scotland) occasionally into September in wet seasons and further north.

Figure 3-1 shows the typical crop calendar and the timings of key insecticide and fungicide applications. For each of the scenarios, it also shows where changes in insecticide and fungicide programs will occur. These changes are discussed in more detail under each of the scenarios.

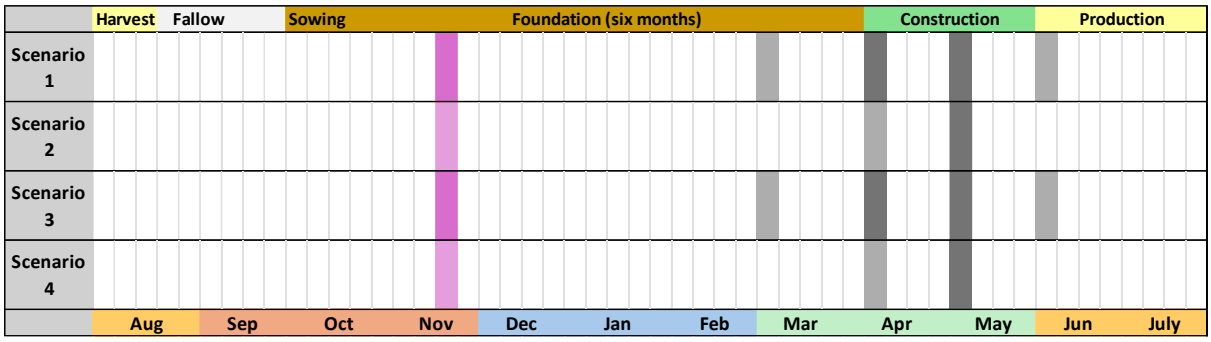

Figure 3-1. Winter wheat crop cycle and timings of pest and disease management

Key to PPP Use: Scheduled Fungicide Optional Fungicide Scheduled Insecticide Optional Insecticide

Timings are indicative for this case study and will vary depending on weather conditions, crop development and pest and disease pressure.

3.2.2 Scenario 1 – Current practice

Scenario 1 reflects the common current practice in the UK with one insecticide and three or four fungicide treatments, with 75% of applications made using spray drift reduction nozzles and a 6m wide in-field margin.

Current (2025) pest management strategy

According to the most recent UK PPP usage surveys in 2020 and 2024, the area of cereals treated with insecticides of any type ranges from 27% in 2020 to 41% in 2024, reflecting how farmers respond to different levels of pest pressure in the season. Of those crops receiving an insecticide application, between 87-90% received a single near full rate insecticide treatment. Approximately 10% of treated crops received a second insecticide application and less than 1% of treated crops received a third application (Chantry et al., 2024; Ridley et al., 2022). The weight of insecticides (kg) used on UK cereal crops (including winter wheat, winter and spring barley and oats) has declined over the last 30 years as shown in

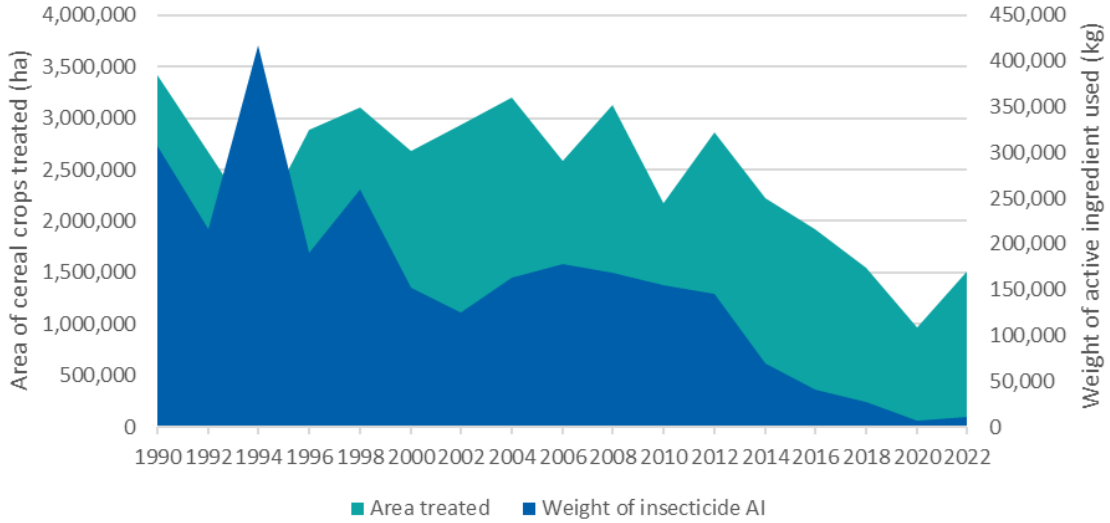

Figure **3-2**. A significant decrease was seen in 2019, following the withdrawal of neonicotinoid seed treatments, with use continuing to fall and area treated also declining as farmers find ways of managing pest risk with fewer active substances available.

The average insecticide application rate in wheat was 0.003 kg active ingredient (AI) per hectare in 2022 UK Pesticide Usage Survey (PUS) (i.e. the official national monitoring programme that collects and reports data on pesticide applications across agricultural, horticultural and other crops in the UK.

(Ridley et al., 2022)). The 2024 UK PUS shows similar usage, with 27% of the wheat area treated, using 2.6 tonnes of active ingredient, giving an average application rate of 0.005 kg AI/ha for insecticides (Chantry et al., 2024).

The key target pest species for insecticide control are aphids. The two main species of concern, in the autumn, are the bird cherry-oat aphid (*Rhopalosiphum padi)* and grain aphid *(Sitobion avenae*) as they are potential vectors of Barley Yellow Dwarf Virus (BYDV) (White et al., 2023). BYDV affects yield in a variety of ways and in the worst-affected, untreated crops, yield losses of up to 84% have been reported, although losses of this extent are rare.

Historically, control was provided by neonicotinoid seed treatments until their withdrawal in 2019. Since 2019, the main control method has been via foliar pyrethroids. A survey of arable farmers in 2018 found that more than 75% of farmers used at least one foliar insecticide to control aphids (Holland et al., 2019).

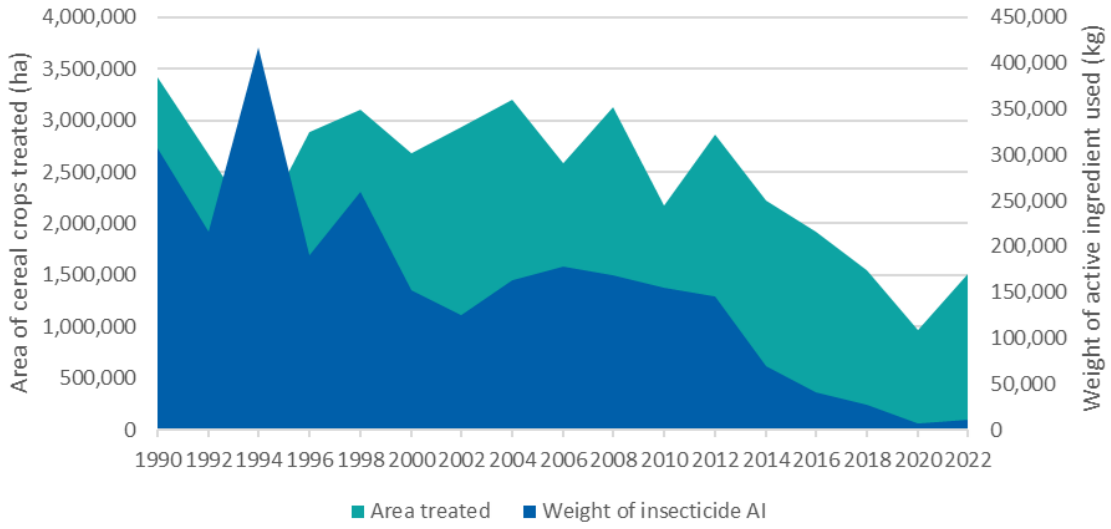

Figure 3-2. Insecticide-treated area of cereal crops (winter wheat, spring and winter barley and oats) in spray hectares and the weight of active substance used across the last 30 years. *Note if a crop is sprayed twice that is two spray hectares.* Extracted from Fera (2026).

White et al. (2023) report that integrated pest management approaches available for aphid control include:

- Delayed drilling – crops drilled from mid-September onwards have a lower risk of infection compared to those drilled in the first week of September.
- Management of the green bridge (grass weeds and volunteers) to reduce habitat for aphids between crops – recommendations are to cultivate at least 5 weeks before sowing to minimise risk. Careful monitoring of vegetation prior to drilling is needed where grass cover is maintained up to sowing.
- Minimum tillage reduces aphid activity, potentially due to increased predator and parasitoid activity.
- Use of resistant varieties – there have been recent introductions (2023) of commercial wheat varieties that have resistance to BYDV – including RGT Wolverine.
- Companion or intercropping to disrupt aphid behaviour and decrease ability of migrating aphids to find the wheat crop.

Other insect species that can cause economic damage to UK wheat crops include wheat bulb fly (WBF) (*Delia coarctata)*, frit fly (*Oscinella frit)*, gout fly *(Chlorops pumilionis)* and orange wheat blossom midge (OWBM) (*Sitodiplosis mosellana).* However, outbreaks tend to be localised, and these species are generally not routinely targeted for treatment. Where present and unmanaged, they have the potential to cause losses in both yield and quality (Dewar et al., 2016).

Current (2025) disease management strategy

The UK PPP usage surveys show that on average just over 95% of UK winter wheat (i.e. the entire conventional area) is treated with fungicides. Based on data for the last 10 years, 16% of the total treated area is treated once, 33% twice, 23% three times and 24% four times. A small area, i.e. less than 3%, is treated four or more times (Fera, 2026).

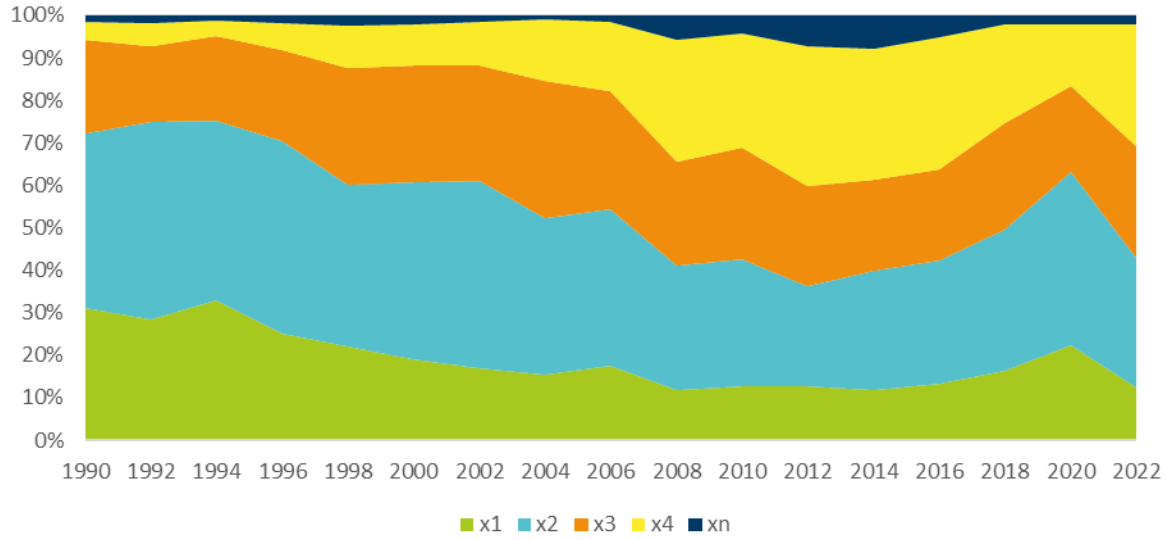

Figure 3-3. Proportion of crop area receiving different number of fungicide applications in UK cereal crops (including winter wheat, spring and winter barley and oats). Adapted from Fera (2026).

Unlike insecticides, the usage of fungicides used across UK cereal crops (including winter wheat, spring and winter barley and oats) has remained largely stable over the last 30 years. However, 2020 saw a reduction in both the area treated and the weight of active ingredient applied. This change partly reflects the overall reduction in crop area that year. In 2022, despite the increase in treated crop area, the applied weight of active substance declined, potentially reflecting a change in practices, or a reduction in application rates due to lower disease pressure. More data are needed to determine if these changes were caused by other factors or are part of an ongoing trend.

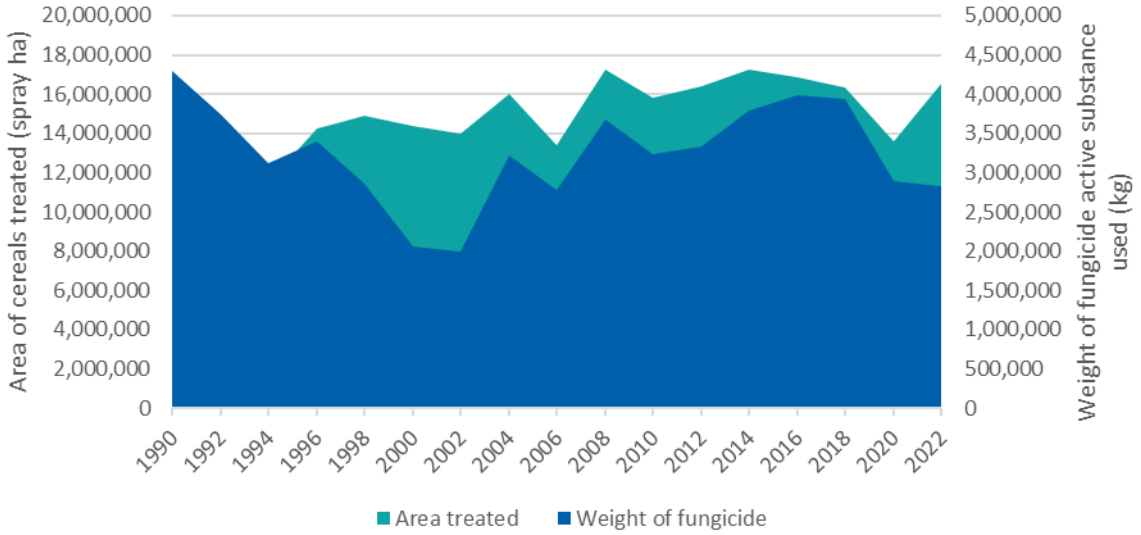

Figure 3-4. Fungicide treated area of cereal crops (winter wheat, spring and winter barley and oats) in spray hectares and the weight of active substance used across the last 30 years. *Note if a crop is sprayed twice that is two spray hectares.* Extracted from Fera (2026).

During the annual cropping cycle, UK wheat typically receives three fungicide applications of between a half and two-thirds of the label rate, averaging 1.09 kg AI/ha in 2022. The 2024 UK PUS shows similar usage (i.e. 1.02 kg AI/ha for fungicides), despite extended periods of inclement weather impacting field access for drilling and crop protection (Chantry et al., 2024). Assuming that UK winter wheat crops receive three fungicide applications per year, the average application is 0.35 kg AI / ha per application across the two assessment periods.

Disease management in wheat is a complex process, with a range of diseases prevalent across the UK including septoria (*Zymoseptoria tritici)*, yellow rust (*Puccinia striiformis* f. sp. *tritici*), brown rust (*Puccinia triticina*), powdery mildew (*Blumeria graminis* f. sp. *tritici*), and fusarium (*Fusarium* sp.). Disease management strategies use a combination of integrated pest management techniques alongside conventional fungicide spray programs (AHDB, 2024b).

In the absence of control, septoria and yellow rust can result in yield losses of over 50% (AHDB, 2025d, 2025a), with wet weather during May and June contributing to increased septoria disease pressure through rain splash spreading spores up the developing plant. These diseases are widespread across the UK, with the majority of crops requiring protection. Where fusarium control is poor, fusarium ear blight can cause reductions in yield and a loss of quality caused by the production of mycotoxins in grain, including immunotoxic deoxynivalenol (DON) and estrogenic zearalenone (ZON), which have strict legal thresholds to protect human health. Contaminated grain cannot be sold for human food, while use of contaminated grain for animal feed is limited to protect stock as some species, e.g. pigs, are highly vulnerable (AHDB, 2024b).

The key focus of most disease management strategies is to protect the leaves, particularly leaf 1 (flag leaf) and leaf 2, from infection to facilitate photosynthesis and grain formation. Key timings for fungicide application against septoria are:

- T1, which is applied at growth stage (GS) 32, just as leaf three has fully emerged, to protect leaf 3 and minimise spread of disease to leaves 1 and 2
- T2, which is applied at GS39, just as the flag leaf has fully emerged and aims to protect that leaf and leaf 2.

These two treatments are particularly targeted at septoria control but depending on the active substances used, can also be used to aid control of other diseases including the rusts (*Puccinia* sp.).

Where powdery mildew or rust pressure is high early in the season, fungicide applications may be made at T0 (GS30), to protect the lower leaves and reduce inoculum. The fourth potential fungicide application (T3) is made to the ear (GS63-65) to protect against diseases such as Fusarium to minimise the risk of mycotoxin contamination in high-risk years (AHDB, 2024b).

Fungicide programs use a combination of azole, succinate dehydrogenase inhibitors (SDHI) and strobilurin modes of action, combined with a multi-site fungicide to provide a range of modes of action and to manage resistance risk. In high-pressure years, product use is likely to be at full label rates, with increased investment in more expensive and more effective active ingredients, whilst in lower pressure years, there is the opportunity to reduce rates and use more cost-effective active substances.

There are a range of IPM measures that can be used to support disease management in UK wheat crops, which include:

- Reducing inoculum through the management of stubbles and residues from previous crops.
- Managing volunteer cereals in neighbouring crops that may harbour spores of pathogens such as mildew and rust.
- Use of resistant varieties. A range of resistance traits is available in UK wheat varieties. Data from the AHDB Recommended List (AHDB, 2025c) provides information on the level of varietal resistance to different pathogens including mildew, yellow rust, brown rust, septoria, eyespot and fusarium ear blight. This information allows growers to select varieties that have resistance to the pathogens that are most important in their cropping system. However, varieties rarely have high levels of resistance to all diseases, and, therefore there is always a compromise to be had.
- Drilling timing – avoiding early drilling will reduce septoria risk through limiting green bridge transmission from the previous crop.

3.2.3 Scenario 2 – Increase in-field protection

Headline impacts –

Reduction in insecticide usage would affect 27% of the wheat area and cause a forecast yield loss of 8%. Reduction in fungicide usage would affect 89% of the wheat area and cause a forecast yield loss of 10%. There would be 11% of the wheat area affected by both pest and disease losses, resulting in a forecast 18% reduction in yield. Average yield impact on treated area estimated at 11% reduction.

Halving fungicide and insecticide use in UK wheat production would necessitate a major shift in crop protection strategies to maintain viable yields, necessitating increased IPM measures such as enhanced monitoring and forecasting, real-time disease and pest surveillance using sensors, weather data and utilisation of predictive models to apply insecticide and fungicide applications only when thresholds are met. For fungicides, a shift from prophylactic applications, where spray applications are planned as preventative to prevent infection, to an increased reliance on managing infection once it occurs, would be required.

Precision technologies that allow patch applications could help to target outbreaks more effectively but would require scouting technologies that enable disease and pest identification. This approach has questionable value in cereal crops as by the time the patches become visible, the optimum time for application has often passed and the high mobility of pests and diseases increases the need for extended treatment areas around the outbreak patches.

The leading threat to wheat yields from insect pests is the transmission of BYDV, which is estimated to affect up to 82% of winter crops, with one study showing untreated affected crops suffered average losses of around 8% (McKirdy, 2018), although severe cases are capable of reducing yields by up to 84% (White et al., 2023). Despite the widespread risk of BYDV transmission, insecticide use data

already indicates that less than a third of the winter wheat area receives an insecticide application, demonstrating that farmers are already finding ways of managing pests with lower reliance on insecticides, although in higher pest pressure years they may struggle. The introduction of BYDV resistant varieties such as RGT Wolverine, provides an additional tool to manage wheat without insecticides in high-risk situations.

For this scenario, only the 27% of crops currently treated with insecticides were assumed to be impacted by the reduction in insecticide usage and that the reason for treatment was an economical important yield threat from aphids and BYDV. In this scenario, it was therefore assumed that on these crops, changes in the availability of insecticides would result in a yield loss from BYDV. Since data suggest that average UK wheat crops receive a single insecticide application at or close to the maximum field rate, a reduction in the application rate was unlikely to achieve sufficient efficacy, resulting in forecast yield losses averaging 8% on the area currently managed with insecticides.

Data from the UK PPP usage survey (PUS) shows that overall fungicide usage across cereal crops has remained relatively consistent across the last 30 years, with minor fluctuations linked to crop areas and possibly high or low disease pressure seasons. These data show the heavy reliance on fungicides for disease control. In this scenario, it is assumed that the total weight of fungicides that can be applied per year reduces from an average of 1.055 kg AI/ha across three treatments to 0.52 kg AI/ha per crop. Based on the PUS, as 16% of crops are already under this threshold, the reduction in rate would affect 84% of the wheat area.

Under this scenario, increased dependence on disease-resistant wheat cultivars will be necessary, together with optimising crop rotations, sowing dates and field hygiene to minimise pest build-up. However, these cultural practices may be limited by weather conditions.

This scenario would require significant up-front investments in equipment and training and increased labour for scouting and logistics, which is particularly challenging for smaller farms, where there is a lower acreage and yield to spread the investment costs across. Resistance management could improve long-term due to diversified tactics but risks of pest and disease outbreaks are likely to increase.

A multi-site French study by Hossard et al. (2014) estimated 5–13% wheat yield losses would result from a 50% PPP reduction. These findings are applicable to much of the UK given climate similarity and disease prevalence and are supported by extrapolation from full PPP removal scenarios, e.g. Berry et al. (2008) showed that fungicides prevent an average loss of 1·78 t/ha (18%) across all UK wheat cultivars. Additional work (AHDB, 2025c; Andersons, 2011; Gianessi & Williams, 2011) reinforces these findings, extrapolating to 5-15% yield losses A conservative yield loss of 10% is therefore assumed in Table 3-2.

IPM may help to mitigate yield losses but wheat production generally operates on very small margins. Hence, additional costs can make production impracticable, particularly on small farms in high-disease (generally wetter) areas. The ability of farmers to manage major outbreaks of pests and disease – such as those that periodically arise when yellow rust evolves to overcome resistance genes used in widely-grown wheat varieties – will be significantly impacted. This will result in increasing unpredictability of yield within and between crops and seasons, placing higher levels of financial risk on arable farmers. Reductions in annual yields and total production have the potential to threaten food security.

3.2.4 Scenario 3 – Increase off-field protection

Headline impacts – No change in yield on the treated crop area, however untreated in-crop buffer area would increase to 2% of the field area and would suffer 50% reduction in yield if cropped. At this level of yield loss, given the in-crop buffer may become a source of disease inoculum, it is assumed the area will be left uncropped, resulting in complete productivity loss on that area.

Scenario 3 has a similar pest and disease control strategy to Scenario 1, albeit delivered using 95% spray drift reduction nozzles instead of 75%, together with 50% wider buffer strips for reducing NTA exposure to PPPs in off-field habitats.

In terms of economic impact, additional production costs are incurred through investment in low-drift sprayer technology and use of adjuvants, while loss of 2% of production area in the 10 ha model field means reduced food production and, therefore, reduced financial returns to the grower.

3.2.5 Scenario 4 – Increase in-field and off-field protection

Headline impacts – In-crop yield losses aligned with scenario 2, averaging 11% across the in-crop area plus a 2% reduction in cropped area resulting in a 12% reduction in wheat production.

Combination of Scenarios 2 and 3 means the addition of further costs and a 2% reduction in productive farmed area on top of the yield loss projections already forecast in Scenario 2.

3.2.6 Impacts on production and economics

Headline impacts – changes in crop management practices to increase in-field protection would result in an estimated 11% reduction in production, whilst increasing off-field protection would reduce production by a forecast 2%. At a field gate level, gross margin (minus labour) would reduce by 17.7% due to increased in-field protection and 5% for off-field protection.

National wheat production could reduce by 1.65 million tonnes in an 'average' year if changes in management practices required both a 50% reduction in volume of insecticides and fungicides applied and a 50% increase in untreated buffers were required to deliver increases in both in-field and off-field protection.

The impacts of changing crop management practices to deliver increased in-field and off field protection of NTAs are shown in the tables below. Table 3-2 focuses on the reduction in available cropping area and subsequent yield at field level. The loss of PPPs envisaged in Scenario 2 and resultant ability of growers to reliably defend their food crop against pest and disease attack is likely to result in a reduction in wheat yield of at least 10%. Under Scenario 3, the reduced cropping area reduces production by 2% from Scenario 1, whilst Scenario 4, combining both reduced PPP options and smaller production area results in a 12% loss of marketable output.

Table 3-2. Impact of Scenarios 1-4 on UK wheat production area and production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
In-field area	**ha**	10	10	10	10
Boundary length	**m**	1,264	1,264	1,264	1,264
Off-crop in-field crop free strip	**m**	6	6	6	6
In-crop - untreated buffer	**m**	-	-	3	3
In-crop - treated area	**ha**	9.53	9.53	9.35	9.35
In-crop - untreated area*	**ha**	-	-	0.18	0.18
Uncropped area	**ha**	0.47	0.47	0.47	0.47
Treated crop yield	**t/ha**	8.3	7.4	8.3	7.4
Production	**t/field**	79.1	70.7	77.6	69.4
Change in production	**t/field**		-8.4	-1.5	-9.7
Change in production	**%**	-	-11%	-2%	-12%

*It is assumed that yield loss is complete on the untreated buffer zone, as leaving crop on that area untreated risks it forming a disease reservoir for the rest of the crop.

In terms of economic impact there are three main points of impact;

- The change in cost of production – scenarios 2 and 4 see a decrease in PPP costs due to the reduction in volume used, whilst scenarios 3 and 4 see an increase due to investment in low drift nozzles and increased use of adjuvants.
- Change in volume of production – both changes in yield and also changes in area result in a change in the total production from the field and therefore the income generated.
- Change in labour requirements – Scenarios 2 and 4 assume a 25% increase in labour requirements as farmers invest more time and effort into scouting and utilising decision support systems to improve timing and accuracy of the fungicide applications they can make.

Table 3-3 shows a marked fall in predicted field gate gross margins, with Scenario 2 cutting returns by 11.8%, Scenario 3 by 4.6% and Scenario 4 by 16.1%. Once the cost of labour is accounted for, the reduction in margin increases to 17.7% for scenario 2, 5% for scenario 3 and 22.3% for scenario 4.

Table 3-3. Impact of Scenarios 1-4 on the cost of UK wheat production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cropped area	**ha**	**9.53**	**9.53**	**9.35**	**9.35**
Marketable yield	**t/ha**	8.30	7.42	8.30	7.42
Cost of production*	**£/ha**	655	597	680	622
Change in PPP costs*	**£/ha**	-	-58	-	-58
Change in other costs	**£/ha**	-		25	25
Farm gate price	**£/t**	190	190	190	190
Production per field	**t/field**	79.1	70.7	77.6	69.4
Field gate value	**£/field**	15,029	13,442	14,745	13,188
Cost of production per field	**£/field**	6,242	5,689	6,358	5,816
Field gate gross margin	**£/field**	8,787	7,752	8,387	7,372
Field gross margin impact	**%**	-	-11.8%	-4.6%	-16.1%
Labour	**SWD (8hrs)/ha**	1.00	1.25	1.00	1.25
Field labour cost	**£/field**	1215	1519	1192	1490
Field gross margin - labour cost	**£/field**	7572	6233	7195	5882
Impact including labour	**%**	-	-17.7%	-5.0%	-22.3%

*Sourced from Redman (2024), SWD = Standard Work Days (8hr day)

Table 3-4 shows the projected impact on the value of the UK wheat industry, currently worth over £2.5 billion (€2.9 billon). The reduction in production area in Scenario 3 has a limited impact, reducing the value of the industry by a forecast £48 million (€55 million). However, the inability to reliably control BYDV and major fungal pathogens is forecast to reduce the value of the industry by at least £270 million (€312 million) under Scenario 2 and £313 million (€361 million) under Scenario 4.

Table 3-4. Impact of Scenarios 1-4 on the UK wheat industry at national scale

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
UK wheat area inc uncropped	**ha**	1,700,000	1,700,000	1,700,000	1,700,000
Cropped area*	**ha**	1,620,100	1,620,100	1,589,500	1,589,500
Change in cropped area			-30,600	-30,600	0
Treated yield	**t/ha**	8.30	7.42	8.30	7.42
Production	**Mt**	13.45	12.03	13.19	11.80
Reduction in production	**Mt**	-	1.42	0.26	1.65
Change in production	**%**	-	89%	98%	88%
Farm gate price	**£/t**	190	190	190	190
Value of production	**£ million**	2,555	2,285	2,507	2,242
Change in value	**£ million**	-	-270	-48	-313
Percentage change	**%**	-	-10.6	-1.9	-12.3

*based on modelled square fields of 10 ha.

3.2.7 Conclusions (wheat)

The changes in crop management practices identified in Scenarios 2 and 4 will impact the viability of the UK wheat industry and will be felt most strongly by farmers in wetter and warmer areas of the UK that favour the spread of fungal diseases. The increased buffer zones modelled in scenarios 3 and 4 will have the greatest impact on farmers with smaller fields, who will be required to take a greater proportion of their land out of production through the use of wider field margins.

The modelled losses resulting from the reduction in PPP usage in this study, are conservative, being based on 'average' yield impacts in a typical year. However, in years with high disease pressure, impacts on yields from uncontrolled infections could be much greater, with uncontrolled BYDV capable of causing 84% crop losses (White et al., 2023), severe septoria infections reducing yield by 20-50% (AHDB, 2025a; Fones & Gurr, 2015) and yellow rust resulting in losses of up to 70% (Hayes, 2025). The loss of sufficient chemical tools to manage these risks will place farms under high level of financial risk, from uncertain harvests.

In addition to the threat from poorly-controlled disease outbreaks, UK arable farming operates on small profit margins, with average farms seeing only 5–15% net profit margins in recent years (AHDB, 2024a; Defra, 2025b; Strutt & Parker, 2023). Wheat is typically one of the more profitable crops in a UK arable rotation and given that these impacts would likely be felt across the rotation, the overall impact on arable production in the UK would be significant.

When combined with similar impacts across European crop production, there would need to be a significant increase in wheat (and other commodity cereal prices) to compensate for the increased costs and decreased returns. Wheat prices would need to increase by up to 12.5% in scenario 4 to balance the reduction in production and increase in costs. This increase would have implications for consumer food prices.

In addition, UK domestic wheat consumption averages 14.3 million tonnes (2021-2025), with about 2,200 tonnes of that supplied by imports of high-quality milling wheat (AHDB, 2025b). On average, the UK exports about 500,000 tonnes and aims to hold about 2 million tonnes in stock to carry over for future years. When UK domestic production drops below 12 million tonnes, the stocks that can be held over as a buffer are reduced, the surplus for available for export is reduced and demand for imports is increased.

Further reductions in wheat production would result in the UK moving from being largely self-sufficient in wheat production to becoming increasingly reliant on imports. If similar impacts are seen on yield and area across Europe, this situation will be replicated across the continent, resulting in imports of cereals from other parts of the world. This increased demand in the EU could lead to increased deforestation or land use change to create more agricultural land, or increased intensification, in locations that do not have environmental protection goals that are as strict.

In poor wheat growing years, such as those seen in 2024 and 2025 where crop areas were significantly reduced because of poor planting conditions followed by yields losses caused by drought, there was a depletion of stocks and lack of surplus for export. If these situations happened in a scenario where wheat yields were further depressed by pest and disease impacts and stocks were already depleted, this would have further implications for UK food security.

Losing 12% of the value of the industry, alongside greater risks of substantial crop losses, is likely to make cereal production untenable for many UK farmers and may present a substantial threat to national food security.

3.3 Apple – Case Study Poland

Agricultural land in Poland is approximately 47.4% of national land area with permanent crops, including fruit trees, comprising 1.24% of this total (Index Mundi, 2019). Poland is the world's fourth

largest apple growing nation and is the EU's leading apple producer. It has 80,500 orchards, which cover 165,000 hectares and produce around 3.2 million tonnes of apples annually, of which over 800,000 tonnes are exported (SAGEA, European Council, 2024).

SAGEA report that current use of PPPs in Polish apple production averages 13.2 kg/ha of fungicides and 1.9 kg/ha of insecticides annually.

3.3.1 Spatial and temporal context

The model orchard

Apple production in Poland is split between two systems, with the majority of growers running small family-owned apple orchards of around one hectare, although there is an expanding commercial sector with operations ranging from 5 to 20 hectares. Field layouts also vary substantially; Doermann (2025) observes that many traditional Polish field systems consist of elongated strips (Figure 3-5) although commercial producers are moving towards using high density grid patterns on larger orchards (Gorlach et al., 2018).

Figure 3-5. Field pattern around Sułoszowa, northwest of Kraków (Doermann, 2025).

Polish orchards are often integrated into diverse agricultural landscapes, typically surrounded by crops such as cereals (e.g. wheat and barley), rapeseed and vegetables. They may be bordered by hedgerows or tree lines, which serve as windbreaks while also enhancing biodiversity and protecting soil integrity. Additionally, many orchards are near to small woodlands, hedges or streams, which provide habitats for beneficial insects and birds. To further support pollinators and natural pest predators, some growers sow *Phacelia* or wildflowers within or around their orchards. *Phacelia* is particularly attractive to pollinators and has been shown to enhance insect visitation rates to apple flowers, promoting pollinator health and resilience (Steele et al., 2022).

Table 3-5. Characteristics of Polish apple orchards

Aspect	Older Orchards	Modern, High-Density Orchards	Additional Practices
Row spacing	1–2 metres	3–4 metres	Allows tractors and harvesters to pass
Pathway surface	Bare soil or minimal vegetation	Often bare or compacted by machinery	Some have mulched strips or permanent grass alleys
Purpose	Basic access	Machinery and harvesting efficiency	Reduce soil erosion, maintain soil health

Although the small strip orchards represent about 77% of farms producing apples in Poland, the larger commercial producers represent about 80% of the volume produced. This analysis seeks to provide a working mean for orchard size, since many larger growers operate a mixture of production systems with blocks of intensive orchard alongside older plots, which are upgraded over time. However, the median production system in Poland is narrower than the model orchard and, as such, is likely to be more severely impacted by off-field protection measures due to their long, narrow structure and the resulting low ratio of field area to border length. Impacts on these smaller farms will have an impact on a greater number of individuals than impacts on the larger farms. For the purpose of this analysis, the modelled orchard size is 1 ha, measuring 200 m x 50 m. Typical crop management activities and their timings are shown in Table 3-6 and Figure 3-6.

Table 3-6. Apple production calendar with key pests/diseases and typical treatments

Growth Stage	Description	Typical Month	Targets	Recommended Treatments
Dormancy / Winter Rest	Trees are dormant; buds inactive.	Dec – Feb	Mite eggs, overwintering fungal spores (apple scab, powdery mildew)	Dormant oil spray (smothers insects/mites), Copper-based fungicide (reduces overwintering fungal spores)
Bud Swelling / Green Tip	Buds begin to swell; early growth signs.	Mar – early Apr	Early aphids, European red mites, fungal spores	Sulphur or copper fungicide (scab control), Insecticidal oil (mites/aphids)
Bud Break / Leaf Emergence	Buds open; leaves appear.	Apr	Aphids (green apple, rosy apple), codling moth eggs, apple scab, powdery mildew	Systemic insecticide (aphids/early pests), Contact fungicide for scab
Flowering / Full Bloom	Flowers bloom; pollination occurs.	Mid-Apr – May	Pollinators present so insecticides avoided, scab, powdery mildew	Avoid insecticides during bloom, fungicide if wet conditions (scab)
Petal Fall / Fruit Set	Petals fall; small fruits form.	May	Codling moth eggs, aphids, mites, apple scab	Codling moth pheromone traps, insecticide for larvae, fungicide for scab/mildew if wet
Fruit Development / Growing	Fruit enlarges; vegetative growth continues.	Jun – Jul	Codling moth larvae (1st gen), aphids, mites, apple scab, powdery mildew	Insecticide for codling moth/ /aphids, miticide for mites, fungicide only if conditions favour disease
Fruit Maturation / Colouring	Fruit changes colour; sugar content increases.	Aug – Sep	Codling moth (2nd gen), apple sawfly, fruit rots	Late-season insecticide if codling moth detected, fungicide to prevent rot, observe pre-harvest intervals
Harvest / Pre-Dormancy	Fruit ready for picking; leaves fall.	Aug – Oct	N/A	Avoid sprays close to harvest (PHI), sanitation: remove fallen fruits, prune diseased wood

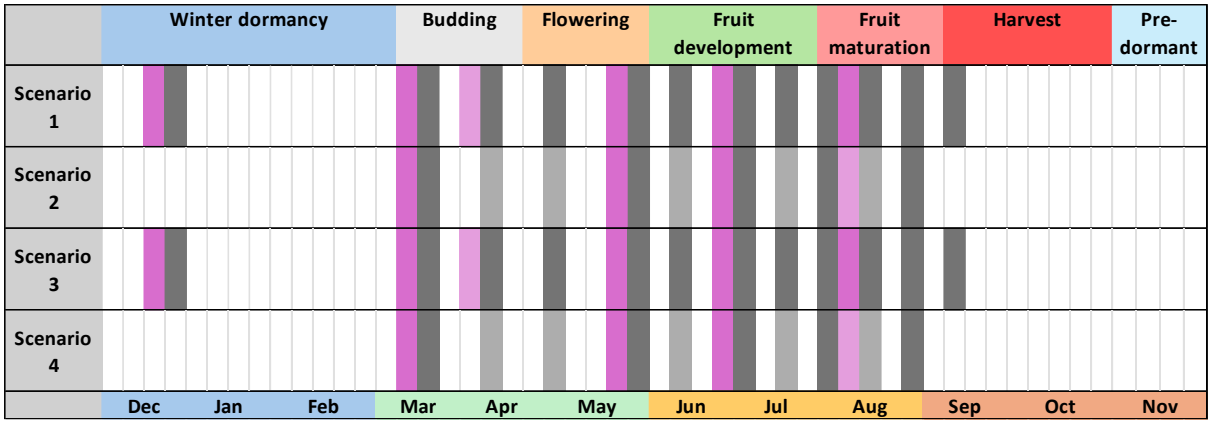

Figure 3-6. Polish apple production cycle and timings of pest and disease management
Key to PPP Use: Scheduled Fungicide Optional Fungicide Scheduled Insecticide Optional Insecticide

3.3.2 Scenario 1 - Current practice

Current pest management strategy

Poland's apple orchards contend with aphids, mites, fruit-boring moths and sawflies. Management relies largely on routine PPP use and applying dormancy sprays and trunk treatments.

Key target pest species for insecticide control in Polish apples include aphids, with rosy apple aphid (*Dysaphis plantaginea*) and woolly apple aphid (*Eriosoma lanigerum*) damaging shoots, leaves, and fruits. Lepidopteran pests include codling moth *(Cydia pomonella)*, which cause losses through larvae tunnelling into fruit to feed and, therefore, internal damage and premature fruit drop (Danelski et al., 2017). Red-belted clearwing moth larvae (*Synanthedon myopaeformis*) damage trees by tunnelling under the bark (Bąkowski et al., 2013) and apple ermine moth (*Yponomeuta malinellus*) defoliate trees, thereby negatively impacting fruit production (Cossentine & Kuhlmann, 2000).

Additionally, apple sawfly (*Hoplocampa testudinea*) is a significant pest that can cause substantial damage to fruit crops when larvae burrow under the skin of developing fruitlets and can affect up to 50% of apples in a field, if not controlled (Vincent & Lasnier, 2024).

Mites are also a problem, with the European red mite (*Panonychus ulmi*), two-spotted spider mite (*Tetranychus urticae*) and apple rust mite (*Aculus schlechtendali*) causing damage by sucking sap from leaves, flowers, and developing fruit. Mite infestations typically cause pale spots/bronzing on leaves, russeting, premature leaf fall and reduced fruit yield (Warabieda, 2015).

Control of aphids in apples is usually with systemic insecticides, although only one systemic insecticide product is currently registered for application after bud break in April in Polish apples. Natural predators (ladybirds/parasitoids) are used in May and horticultural oil in June.

Codling moth is managed after petal fall in May with diamide insecticides and *Cydia pomonella* Granulovirus (CpGV). Previously, these treatments were followed in June and July by neonicotinoid insecticides (withdrawn in August 2025) and insect growth regulators. Apple ermine moth is controlled using insecticides in July.

Mite outbreaks during hot, dry summer weather are controlled with insecticide and sulphur treatments.

Current disease management practice

Disease management in apple orchards is of essential economic importance. Inadequate control of apple scab (*Venturia inaequalis*) can result in devastating epidemics, with severe scab lesions on both fruits and leaves and the potential for severe defoliation of the tree by early autumn, leading to yield losses ranging from 20% to 70% (Antal et al., 2024). Control of this pathogen is challenging and during years with environmental conditions that encourage high disease pressure, up to 20 fungicide treatments can be needed to avoid losses (Masny, 2017).

Powdery mildew (*Podosphaera leucotricha*) is also a widespread disease in Poland, impacting leaves, shoots and fruit. Control measures include growing resistant cultivars, e.g. 'Odra'.

Brown rot (*Monolinia fructigena*) is a major economic threat to apple production. Infection causes a range of symptoms including blighting of blossoms and rotting of fruits, although the largest threat is from fruit losses following harvest, with 40% crop storage losses being reported. Botrytis fruit rot (*Botrytis cinerea*) can also cause similar post-harvest losses. These rots can be effectively managed with fungicidal application 1-3 weeks prior to harvest (Grabowski, 2020) and post-harvest fungicide treatments can also be effective (Büchele et al., 2022).

Fire blight, caused by the bacterium *Erwinia amylovora*, is a major threat to Poland's significant apple industry. Control measures are compulsory and generally focus on prevention and sanitation. The application of copper-based preparations during dormancy or at the bud break stage are the primary chemical control method (Sobiczewski et al., 1999).

3.3.3 Scenario 2 – Increase in-field protection

Headlines: Reduction in insecticide and fungicide usage by 50% would result in forecast yield losses averaging 36%.

Implementation of a 50% cut in PPP use will require Polish apple growers to shift from the use of routine chemical sprays, combined with IPM, to greater reliance on IPM methods, including increased crop monitoring with traps and frequent scouting, combined with pest forecasting and the adoption of low-dose applications when near economic injury thresholds. Under these constraints, local experts report that codling and other moth species could still be managed in low pressure years but would be increasingly difficult to manage in high pressure seasons. Aphids are predicted to become extremely difficult or impossible to control in most seasons, leading to substantial yield losses.

Disease management would move from calendar-based fungicide programs to risk-based, threshold-driven strategies supported by leaf wetness sensors, forecasting models, resistance inducers (e.g. phosphites), and bio-controls. In the first years of implementation, cutting sprays by 50% without full adoption of an alternative management program would cause uneven protection and rapid outbreaks of apple scab and fire blight, resulting in more spots, deformities and unmarketable fruit. Powdery mildew and grey mould might remain partially controlled through maintaining orchard ventilation via regular pruning of dense and crossing foliage. Long-term, repeated low-dose use of remaining chemicals will risk accelerated resistance in surviving pest/pathogen populations, although overall reduced selection pressure and rotation to biological-based products (i.e. those derived from natural sources such as living microorganisms or biochemicals) could eventually improve resistance management and allow access to premium low-residue markets.

Economic consequences are likely to be severe. While expenditure on PPPs would fall, total protection costs per hectare would rise substantially due to:

- Increased labour demand (+20–30% or more), especially burdensome on Poland’s highly fragmented orchards, where economies of scale are absent;
- Investments in precision equipment (sprayers, sensors, monitoring kits, forecasting subscriptions);

- Increased use of often more expensive biological products and adjuvants.

Highly susceptible varieties (e.g., Jonagold family, Gala) are predicted to become economically unviable for many growers. Small family farms and small exporters would be hit hardest, potentially forcing consolidation, farm exits and rural job losses. Globally, major non-EU producers, who face fewer restrictions, could exploit EU supply shortfalls to gain market share and depress prices, putting additional long-term pressure on Polish and European apple sectors. In summary, while offering potential environmental and biodiversity benefits plus niche marketing opportunities, significant chemical reduction, without adequate transitional support and affordable and efficacious alternatives, will risk significant production decline, quality loss, farm consolidation and competitive disadvantage for one of the world's largest apple industries. Ultimately, apple orchards are likely to be grubbed out and replaced by annual cropping systems or non-agricultural uses, resulting in the loss of biodiversity provided by permanent cropping systems in the landscape.

3.3.4 Scenario 3 – Increase off-field protection

Headlines: Increasing buffer widths in Polish apple production systems is likely to reduce apple production by 49%.

Expanding mandatory buffer zones to prevent PPP drift will create significant challenges to Polish apple production, most notably in the highly fragmented orchard landscape of central Poland (Mazovia), where most fields are small and the margins represent a large proportion of total area.

Pest management would become more challenging, because codling and other pest moth species could find refuge in untreated field margins, which would enable rapid infestation of the entire field during high-pressure seasons and lead to substantial yield and quality losses. Farmers would need to invest heavily in biocontrol (entomopathogens, natural enemies on field margins). Precision application systems, based on Light Detection and Ranging (LiDAR) technology, combined with forecasting models based on, for example, Normalised Difference Vegetation Index (NDVI) mapping could be used to detect and treat hotspots. Highly specialised, low-drift, shielded and recycling tunnel sprayers will be required, together with use of drift-reducing adjuvants.

Under this scenario, disease pressure would become more severe. Splash-dispersed pathogens such as apple scab and wind-dispersed, powdery mildew cannot be effectively controlled when large buffer zones remain unsprayed. Scab spores from untreated areas would repeatedly re-infect the orchard, although brown rot could still be managed inside the field with increased labour costs.

In the humid Polish climate, the first years after the implementation of extended buffers, would see frequent infection outbreaks originating from field margins, making premium fresh-market quality almost unachievable. Varieties sensitive to scab (e.g., Golden Delicious, Gala) would suffer most and could become economically unviable on small farms.

Economic and operational impacts would be substantial. Crop protection costs will increase because, although product uses in-field will be unchanged, additional costs will be incurred for adjuvants and specialised low-drift application machinery. Labour costs would rise sharply due to intensive border monitoring, buffer maintenance (cover crops, weeding) and complex spraying logistics. Small Mazovian growers, already operating on narrow margins, would be greatest affected because buffers can consume 10–20% of their limited field area.

Untreated refuges may preserve sensitive pathogen and pest populations, and, hence, dilute resistant strains and delay the development of resistance problems. However, this advantage is likely to be outweighed by immediate risks of overuse of the few remaining effective active substances inside treated zones and by persistent edge damage if adoption of new equipment and practices is slow.

In conclusion, significantly larger buffer zones would reduce orchard area, increase edge-driven pest and, especially, disease problems, as well as increase labour and equipment costs, Overall, the viability

of small-scale fresh-market apple production in Poland, would be threatened with particularly severe quality decline for premium grade apples.

3.3.5 Scenario 4 – Increased in-field and off-field protection

Headlines: Reduction in insecticide and fungicide usage by 50% while increasing buffer widths by 50% in Polish apple production systems, is forecast to reduce apple production by 56%.

An approach combining 50% reductions in insecticide and fungicide use with a 50% increase in untreated buffer zones will threaten the viability of Polish apple production, particularly for the country's many small and medium-sized orchards.

Specialist agronomists report that pest control systems are likely to collapse with lepidopteran pests harboured in untreated margins and rendered uncontrollable by inadequate in-field protection. Whilst untreated areas are likely to benefit beneficial arthropods, these predator/parasitoid populations respond retrospectively to increased pest populations.

Apple scab spore banks and fire blight bacteria in buffers are likely to rapidly infect entire orchards, and outbreaks are predicted to be uncontrollable. Botrytis and brown rots would also become challenging to manage consistently. Fresh-market quality would plummet, with dramatic drops in premium-grade fruit and yields could fall by 30–50% or more in high-pressure years.

Economic viability would be threatened for most growers, with costs involved in purchasing the wide range of necessary technologies and practices - such as real-time sensing networks, ultra-precise sprayers, shielded/low-drift machinery, drones, NDVI systems, spore traps, forecasting platforms, entomopathogens, flower strips and constant margin maintenance, being prohibitive without financial support.

Whilst costs would double or triple compared to either Scenario 2 or 3 alone, any further PPP savings would be minimal while labour demand would expand due to intensive scouting, buffer management and biological control applications. These activities would overwhelm family-run farms on small and fragmented orchards.

The apple variety portfolio would also shrink with highly susceptible cultivars (Idared, Jonagold family, Golden Delicious, Szampion) becoming commercially unviable. Many small fresh-market and export-oriented growers would be likely to exit the sector entirely, with surviving orchards likely to shift to processing apples sold at market-bottom prices.

The theoretical, long-term benefit of delayed resistance evolution due to increased refugia and forced rotations, would be irrelevant, as most farmers would suffer crippling losses long before any resistance slowdown materialised. In Poland's small-farm reality, this combined scenario is practically unimplementable and could trigger widespread abandonment of apple production within a few seasons.

3.3.6 Impacts on production and economics

Headlines: the impacts of Scenarios 2-4 will result in negative gross margins for growers, making apple production economically unfeasible in Poland

The impacts of changing the focus of ecosystem service provision on the ability of growers to produce apples are shown in the tables below. Table 3-7 focuses on the reduction in available cropping area and subsequent yield. The loss of PPPs envisaged in Scenario 2 and resultant ability of growers to reliably defend their food crop against pest and disease attack is likely to result in a reduction in marketable apple yield of around 36%. Under Scenario 3, the reduced production area and possible increase in pest and disease reservoirs in untreated buffer zones, reduces yields by an estimated 49%

from Scenario 1, whilst Scenario 4, combining both reduced PPP options and smaller production areas, results in a 56% loss of marketable output.

Table 3-7. Impact of Scenarios 1-4 on Polish apple cropping area and production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
In-field area	**ha**	1	1	1	1
Boundary length*	**m**	500	500	500	500
Off-crop in-field crop free strip	**m**	5	5	5	5
In-crop, untreated buffer	**m**	5	5	7.5	7.5
In-crop, treated area	**ha**	0.50	0.50	0.38	0.38
In crop - untreated area	**ha**	0.25	0.25	0.38	0.38
Uncropped area	**ha**	0.25	0.25	0.25	0.25
Crop yield	**t/ha**	22.90	14.55	15.52	13.58
Production	**t/field**	11.5	7.3	5.8	5.1
Change in production	**t/field**	-	-4.2	-5.7	-6.4
Change in production		-	-36%	-49%	-56%

*This field size represents a working mean - the median orchard size is narrower than the model so impacts will actually be worse than shown here for 'most' producers, but this field size represents the larger volume of production as seen on larger commercial farms.

In terms of economic impact, Table 3-8 show a catastrophic fall in field gate gross margins, with Scenario 2 reducing returns by €793 (255%), Scenario 3 by 206% and Scenario 4 by 249%.

Table 3-8. Impact of Scenarios 1-4 on the cost of Polish apple production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cropped area	**ha**	0.50	0.50	0.38	0.38
Marketable yield	**t/ha**	22.90	14.55	15.52	13.58
Cost of production	**€/ha**	5,850	5,950	6,095	6,095
Change in PPP costs	**€/ha**		-350	-105	-455
Change in other costs	**€/ha**		450	250	700
Farm gate price	**€/t**	300	300	300	300
Production per field	**t/field**	11.5	7.3	5.8	5.1
Field gate value	**€/field**	3,435	2,183	1,746	1,528
Cost of production per field	**€/field**	2,925	2,975	2,286	2,286
Field gate gross margin	**€/field**	510	-793	-540	-758
Field gross margin impact	**%**	-	-255%	-206%	-249%

The projected impact on the value of the Polish apple industry, currently worth over €1 billon per annum is shown in Table 3-9. Scenario 2 will reduce the value of the industry by €371 billion annually while Scenario 3 will halve its value to €517 billion per year and in Scenario 4, losses are projected to rise to €565 billion, or 56% of the value of the national apple industry.

Table 3-9. Impact of Scenarios 1-4 on the Polish apple industry at national scale

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cropped area*	**ha**	147,992	147,992	110,994	110,994
Change in cropped area	**ha**			36,998	36,998
Yield	**t/ha**	22.90	14.55	15.52	13.58
Production	**Mt**	3.39	2.15	1.72	1.51
Change in production	**Mt**		-1.24	-1.67	-1.88
Farm gate price	**€/t**	300	300	300	300
Value of production	**€ million**	1,017	646	517	452
Change in value	**€ million**	-	-371	-500	-565
Percentage change	**%**		-36%	-49%	-56%

*based on modelled fields of 1 ha (measuring 200m x 50m).

3.3.7 Conclusions (Apples)

The impact of Scenarios 2 and 3 on the viability of the Polish apple industry is marked, while the impact of Scenario 4, is likely to be devastating. The impact of increasing unsprayed buffers will reduce the available cropped area and increase the need for pest and disease management in the cropped area. Bearing in mind that this analysis uses a 1ha field measuring 200m x 50m, impacts will be much greater in narrower traditional strip cultivation systems used in many areas of Poland and particularly Mazovia (Doermann, 2025) and may force many family orchard growers out of business.

The loss of small family-scale production systems is likely to negatively impact on other ecosystem services (eg biodiversity) through consolidation of the existing diverse patchwork of small orchards into intensively-managed larger businesses, threatening high provenance traditional production systems such as those used for the 27 varieties of “Jabłka grójeckie” (Grójec apples), that currently have Protected Geographical Indication (PGI) status in Mazovia.

If consolidation cannot provide sufficient economies to compete with cheaper imports from less-regulated overseas competitors, orchard production systems are likely to be grubbed out and incorporated into large-scale arable rotations, with the loss of biodiversity, typically associated with permanent orchard crops.

As a result of changing crop management practices to increase protection of NTAs, there is an increased level of financial risk and uncertainty over yield and crop quality. This uncertainty could lead to unintended consequences in terms of wholescale changes in land use, where orchard production becomes unviable. This impact will also potentially have wider implications for trade, with Polish, and by read across European, apple production becoming uncompetitive on the global stage.

Wider impacts are discussed at the end of this report.

3.4 Vines – Case Study Italy

Agricultural land - pasture, arable and horticultural crops - covers 12.5 million hectares in Italy, representing 41% of the country’s total land area, with the major crops being grapes, olives, wheat, corn, tomatoes, fruits and rice. Annual Italian wine grape production has ranged between 5.8 – 7.5 million tonnes between 2015-2024 (Eurostat, 2026), producing an estimated world-leading 47.4 million hectolitres (6.3 billion bottles) of wine in 2025 (OIV, 2025a).

Italy’s main vine-growing regions and average yields are shown in

Table 3-10. These values demonstrate wide variations in average yield ranging from 6.5 t/ha in Sicily to 18.0 t/ha in Emilia-Romagna. The main factors determining grapevine yields in Italy are a combination of natural, regulatory and human-management elements, with the most important factor being appellation regulations (Disciplinari di produzione). These rules strictly cap maximum yield per hectare for specific types of grape (e.g., Barolo 8 t/ha, Prosecco DOC 18 t/ha, Chianti Classico 7.5 t/ha), with vineyard location/microclimate, variety and clone, vine density/training system and use of irrigation (if allowed) being among the key physical determinants.

The leading Italian vine varieties are currently Sangiovese (65 kha), Glera (39 kha), Pinot Grigio (32 kha), Montepulciano (31 kha), Trebbiano Toscano (27 kha), Merlot (19 kha) and Chardonnay (24 kha (OIV, 2025b).

Use of fungicides in Italian vine production currently averages 20 applications with a total of 19.5 kg/ha applied annually, with about 5 applications of insecticides totalling 0.3 kg/ha (CORDIS 2017, SAGEA 2025).

About 18% of the Italian vine area is organic and, in these vineyards, insecticide usage is reduced by 30-60%, with a more limited range of product options. Conversely, organic vineyards depend heavily on copper-based fungicides, with applications often averaging over 4 kg/ha of pure copper per year. EU legislation has recognised the importance of minimising further soil contamination due to ecotoxicological impact of accumulated heavy metals in vineyards, which may alter the structure and functioning of the ecosystem through undesirable effects on NTAs, including pollinators and natural enemies (Bernardi et al., 2022; Garinie et al., 2024).

Table 3-10. Areas and yields of major vine producing regions of Italy (average figures)

Region	Area under vines (ha)	Average yield (t/ha)	Volume for wine (t)	Volume for table (t)
Veneto	127,000	11.4	1,443,000	0
Sicily	121,000	6.5	630,000	155,000
Apulia	103,000	16.3	1,468,000	204,000
Tuscany	77,000	7.5	574,000	0
Emilia-Romagna	52,000	18.0	944,000	0
Piedmont	47,000	7.8	368,000	0
Other	200,000	7.4	151,000	49,000
Total	727,000	10.0	5,578,000	408,000

3.4.1 Spatial and temporal context

The model vineyard

Italy's premium wine areas are in hilly to mountainous terrain with underlying sedimentary rocks, calcareous soils (limestone, marl) and calcareous-clay mixes tending to be very important and widespread in high quality vineyards.

In terms of market structure, larger producers prefer international varieties that are better known than local varieties. Smaller producers tend to focus on cultivating rare and local varieties to create niche markets with higher prices.

Typical vineyards are around 2.5 ha, with individual parcels of land typically 1.6 ha with a boundary of 500 m, and an uncropped buffer zone of 3 m of grass or small hedges dependent on local regulations. In some areas, no physical boundary exists between neighbouring vineyards. Ground cover in vineyards is typically mown grass that is kept free of weeds and wild grapevines.

3.4.2 Scenario 1 - Current practice

Current pest management practices

Key insect pests in Italian vines are

European grapevine moth (*Lobesia botrana*), a major berry pest. Larval feeding causes wounds that promote fungal infections leading to 10–20% losses, with losses up to 30% in severe infestations.

Vine mealybug (Planococcus ficus), a sap-sucking pest and vector of grapevine leafroll viruses. Losses can range from 14–40%, with up to 60% in heavily infested vineyards.

Leafhoppers (*Empoasca vitis, Zygina rhamni*) also suck sap from leaves, reducing photosynthesis and plant vigour leading to 10–25% losses.

Flavescence dorée vector (*Scaphoideus titanus*) is a leafhopper species transmitting the phytoplasma that causes grapevine yellows disease (Flavescence dorée). Losses range from 20–80% and are mostly indirect losses due to disease transmission.

Grapevine phylloxera (*Daktulosphaira vitifoliae*) is a root-feeding insect that kills vines not grafted onto resistant rootstocks, leading to 50–100% yield losses on susceptible (i.e. ungrafted), untreated vines.

Control measures include monitoring and forecasting using pheromone traps and pest models with selective, reduced-impact PPPs applied only above economic thresholds. Mating disruption and mass trapping are used to control European grapevine moth. Cultural control practices include canopy pruning and sanitation (i.e. removal of prunings, leaf debris, shrivelled 'mummy' berries and other sources of pathogen inoculum) and growing cover crops between rows for biodiversity. Biological control with natural enemies and *Bacillus thuringiensis*, is also used although impacts are variable in outdoor growing systems and inherently does not to respond quickly to rapid changes in pest populations (Wilson & Daane, 2017).

Insecticide applications average five per season, depending on pest pressure (e.g. European grapevine moth, Vine mealybug), monitoring results and the use of alternative controls (e.g. mating disruption). Organic and IPM vineyards often reduce insecticide use by 30–60%.

- Early spring (March–April) treatments are used against overwintering pests (e.g. mealybugs, mites).
- Pre-flowering to fruit set (May–June): first European grapevine moth generation targeted with insecticides or *Bacillus thuringiensis*.
- Summer (July–August): control of second and third European grapevine moth generations; manage *S. titanus*
- Late summer (August–September): maintain control of virus vectors while avoiding applications near harvest time in order to avoid residue exceedances.

Residual protection ranges from a few days for biological controls like *Bacillus thuringiensis* (Bt), to a several weeks for synthetic insecticides. Mating disruption dispensers last 4–6 months, covering most of the growing season.

Disease management practices

Key fungal diseases in Italian vineyards are influenced by regional differences (e.g., humid conditions in the north vs. drier south) but are generally as follows:

Downy mildew (*Plasmopara viticola*): Polycyclic, high-risk pathogen causing leaf and bunch damage, exacerbated by rainfall.

Powdery mildew (*Erysiphe necator*): Thrives in warm, dry conditions, affecting photosynthesis and fruit quality.

Botrytis bunch rot (*Botrytis cinerea*): Impacts ripening grapes, especially in humid or wounded clusters.

***Aspergillus* rot** and **black rot** (*Guignardia bidwellii*) are also a growing threat.

Grapevine trunk diseases (GTDs) including Esca disease, *Eutypa* dieback, and *Botryosphaeria* dieback are a complex range of pathogens that are increasingly important and can be devastating to yield and quality (Kenfaoui et al., 2022).

Management practices include the use of forecasting models for downy and powdery mildews, to predict infection risk, based on rain, humidity and temperature. Treatments are applied preventively or curatively only when risk thresholds are met in order to reduce unnecessary sprays.

Conventional vineyards use mixtures, or alternate applications, of systemic and contact fungicides, typically 20 sprays per season depending on pressure, with rotation to manage resistance development.

Organic production relies on copper-based products for downy mildew and sulphur for powdery mildew. Copper use is capped by EU legislation, which limits applications to 28 kg of elemental copper per hectare over any 7-year rolling period to limit soil accumulation. This equates to an average of 4 kg/ha per year.

Cultural practices such as canopy management to reduce humidity and bunch contact, help to reduce *Botrytis* and mildew pressure, while sanitation and cover crops between rows suppress spore dispersal from soil and delay foliar epidemics (especially downy/powdery mildews).

Biocontrol agents (e.g. *Bacillus*-based) are included in some IPM programs but their use is not widespread because of limited efficacy.

Overview

Tractor-mounted sprayers (airblast or mist blowers) are used as standard for canopy coverage. Use of low-drift nozzles and electrostatic sprayers are common in modern systems. Pheromone dispensers or aerosol puffers are used for mating disruption. Spot or border treatments can be applied where pest pressure is localised.

Table 3-11. Vine production calendar with key pests/diseases and typical treatments (Caffini, 2025)

Growth Stage	Description	Typical Month	Targets	Recommended Treatments
Bud development	Woolly bud to bud break	March - April	Downy mildew, powdery mildew	Low-dosage copper-based products for downy mildew, sulphur for powdery mildew.
Expanded leaf stage	Vegetative growth acceleration	April-May	Downy mildew, powdery mildew	Systemic and contact fungicides for downy mildew and powdery mildew.
Pre-flowering and flowering	Flowers highly vulnerable to fungal infection	May-June	Downy mildew, powdery mildew, and botrytis. Mandatory *Scaphoideus titanus* spraying required	Fungicide mixtures based on copper, sulphur, and preventive anti-botrytis products. Pyrethroids/acetamiprid used against *S. titanus* or pyrethrins in organic vineyards
Fruit Set	Young berries begin to form – still vulnerable	June	Downy mildew, powdery mildew; moths or other pests. Mandatory *S titanus* treatment	Contact fungicides, insecticides if pests detected. *S. titanus* treatment as above.
Berry growth	Even spraying challenged by dense vegetation	June-July	Downy mildew and powdery mildew, botrytis	Systemic and contact fungicides, targeted products for botrytis.
Veraison	Berries changing colour	July-August	Botrytis, insect infestations	Selective anti-botrytis treatments; insecticide if pest present. Treatments must respect pre-harvest intervals.
Ripening	Harvesting	August-September	Fungal infections	Only if high disease pressure, and ensure harvest intervals observed
Post-harvest	Pruning & sanitation	October	Autumn infections	Copper-based products to disinfect plants
Dormancy		November-February	Overwintering pests and diseases	Lime, sulphur or mineral oil applications to lower pest and disease pressure

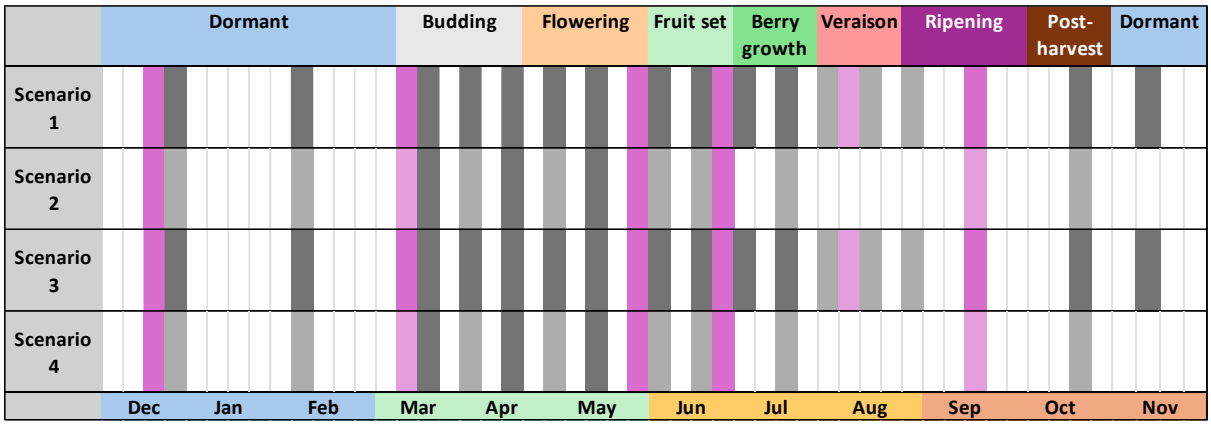

Figure 3-7 Italian vine production cycle and timings of pest and disease management

Key to PPP Use: Scheduled fungicide Optional fungicide Scheduled insecticide Optional insecticide

3.4.3 Scenario 2 – Increased in-field protection

Headlines: Reducing rates and applications of fungicides and insecticides in vines is forecast to reduce grape quality and reduce yields by 20% while increasing crop management costs.

A 50% reduction in insecticide and fungicide use in Italian vineyards would have significant consequences, which would vary by region and season.

- Insecticide reduction (currently 5–6 treatments/year, with at least two mandatory applications against *Scaphoideus titanus*), would likely lead farmers to perform only compulsory sprays or intervene only at high infestation levels. This reduction would result in increased pest numbers, reducing both grape quality and yield, and force the market to accept lower-quality fruit unless adequate alternative treatments become available.
- Fungicide reduction would be far more damaging in rainy northern and central Italy, where frequent treatments are needed against downy and powdery mildew. Longer spray intervals would trigger sharp rises in fungal diseases, severely reducing both productivity and quality, with the greatest losses on susceptible varieties and in high-pressure areas.
- Reduced PPP use could reduce the risk of pest and pathogen resistance, potentially preserving long-term efficacy of remaining products, but only if an adequate portfolio of MoAs remains available for growers to rotate treatments.
- To continue using PPPs at reduced volumes, growers would need to invest heavily in precision sprayers, advanced machinery and intensified cultural practices (canopy management, leaf removal, cover crops, bunch selection). These changes would significantly increase labour and equipment costs.
- Increased manual labour requirements negatively impact human health.

Overall, a forced 50% PPP cut would cause immediate declines in yield and quality, higher production costs and disproportionate damage in humid regions, unless accompanied by major technological and agronomic investment.

3.4.4 Scenario 3 – Increased off-field protection

Headlines: No change in yield in the treated area. Increased cost of production to manage larger untreated area, reduction in total production due to reduced treated area.

Increased buffer zones around Italian vineyards would bring clear environmental benefits by reducing PPP drift and run-off into off-field areas but would also create major practical and economic challenges.

Key impacts:

- Loss of productive land: Larger untreated strips mean that less area is available for vines. In Italy's highly fragmented, often tiny plots (average <2 ha), this loss will directly reduce income. On steep terraced or hilly vineyards (e.g., Valtellina, Amalfi Coast, Etna, Prosecco hills), larger buffers can make entire rows or terraces unusable and create soil erosion and stability risks that require costly restoration work.
- Higher management costs: Buffer zones must be mown or planted with cover crops, significantly increasing labour and machinery time, especially in narrow, non-mechanisable sites.
- Short-term pest and disease effects: Buffer zones can initially favour insect pests (e.g. leafhoppers such as *Scaphoideus titanus*) and act as reservoirs if not properly managed, potentially raising infestations near vines and reducing yield and quality in the early years.
- Long-term positive impacts: Reduced drift into off-field areas through the use of increased buffer zones will lower environmental impact and reduce overall PPP pressure, thereby

slowing the development of resistance in pests and pathogens and prolonging the efficacy of PPPs over time.

- Fungicide drift: Buffer zones are less critical for fungal diseases (downy/powdery mildew), as spores travel mainly by rain splash and wind over longer distances. Therefore, increased buffers have limited effect on the spread of pathogens.
- Overall, while environmentally desirable, compulsory large buffer zones (especially if increased by 50% or more) would be extremely difficult to implement in most Italian viticultural landscapes, leading to higher costs, reduced productive area and, in many cases, abandonment of marginal vineyards.

3.4.5 Scenario 4 – Increased in-field and off-field protection

Headlines: Smaller production area and reduced ability of growers to manage pests and diseases will increase production costs while reducing yields by 28%.

Combining a 50% reduction in PPP use with a 50% increase in buffer zones would create a particularly challenging scenario for Italian vineyards. In the short term, the effects would be strongly negative:

- Fewer insecticide treatments and wider untreated buffer strips could act counterproductively, turning buffers into pest reservoirs and sharply increasing insect pressure (leafhoppers, moths, etc.).
- Reduced fungicide applications on a smaller treatable area would dramatically lower treatment efficacy, especially in humid northern and central regions, leading to severe outbreaks of downy and powdery mildew on susceptible varieties.
- These impacts would be immediate and cause substantial drops in both yield and grape quality.

In the long term, drastic cuts in PPP pressure delivered by lower doses and reductions in areas treated is likely to slow resistance development, potentially preserving the usefulness of remaining active ingredients. However, these benefits are largely dependent on the availability of an adequate range of MoAs to enable rotation.

However, production costs would rise sharply on several fronts:

- Investment in precision spraying equipment to optimise reduced treatments.
- Intensified canopy management, mechanical or manual weed control, and insect-monitoring programmes.
- Higher labour and machinery costs to maintain large non-productive buffer zones (mowing, erosion control, etc.).
- More selective (and expensive) hand-harvesting to eliminate damaged bunches.

Given Italy's extremely fragmented vineyard landscape and the prevalence of small, steep or terraced plots, many growers would not be able to comply with these changes. Enlarged buffers would render numerous parcels of land uneconomic or physically unworkable and would accelerate the abandonment of marginal sites.

3.4.6 Impacts on production and economics

Headlines: the impact of a major reduction in the ability of growers to adequately protect their vine crops will be economically devastating to rural Italy, reducing farm gate margins by 39%. Increasing buffers will compound this issue, almost halving margins and reducing the value of the industry by nearly €5 billion.

The impacts of changing crop management practices to protect NTAs, on the ability of growers to produce grapes are shown in the tables below. Table 3-12 focuses on the reduction in available cropping area and consequent yield. The loss of PPPs envisaged in Scenario 2 and resultant inability of growers to reliably defend their food crop against pest and disease attack is likely to result in a reduction in marketable grape production of around 20%. Under Scenario 3, the reduced production area and possible increase in pest and disease reservoirs in untreated buffer zones reduces production by 11% from Scenario 1, whilst Scenario 4 reduces total production by 28% from current levels.

Table 3-12. Impact of Scenarios 1 to 4 on Italian vine cropping area and production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Infield area	**ha**	1.6	1.6	1.6	1.6
Boundary length	**m**	506	506	506	506
Off-crop in-field crop free strip	**m**	3	3	3	3
In-crop - untreated buffer	**m**	5	5	7.5	7.5
In-crop - treated area	**ha**	1.20	1.20	1.07	1.07
In crop - untreated area	**ha**	0.25	0.25	0.38	0.38
Uncropped area	**ha**	0.15	0.15	0.15	0.15
Crop yield	**t/ha**	10.0	8.1	10.1	8.1
Production	**t/field**	12.0	9.6	10.8	8.6
Reduction in production	**t/field**		2.3	1.2	3.4
Change in production compared to scenario 1	**%**		-20%	-11%	-28%

In terms of economic impact, Table 3-13 shows a series of marked reductions in farm gate value, with Scenario 2 cutting returns by 39%, Scenario 3 by 11% and Scenario 4 almost halving enterprise returns, with a 46% cut in vineyard gross margins

Table 3-13. Impact of Scenarios 1 to 4 on the costs of Italian vine production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cropped area	**ha**	**1.2**	**1.2**	**1.1**	**1.1**
Marketable yield	**t/ha**	10.0	8.0	10.0	8.0
Cost of production*	**€/ha**	4,425	4,600	4,425	4,600
Change in PPP costs*	**€/ha**	-	625	0	625
Change in other costs	**€/ha**	-	800	0	800
Farm gate price	**€/t**	€ 1,660	1,500	1,660	€ 1,500
Production per field	**t/field**	12.0	9.6	10.7	8.6
Field gate value	**€/field**	19,850	14,349	17,749	12,831
Cost of production per field	**€/field**	5,289	5,498	4,729	4,916
Field gate gross margin	**€/field**	14,561	8,851	13,020	7,914
Field gross margin impact	**%**		-39%	-11%	-46%

When projecting these losses to a national scale, Table 3-14 shows the projected impact of the value of the Italian vineyard sector, currently worth €12 billon. Scenario 2 will reduce the value of the industry by over €3.5 billion (30%) annually while Scenario 3 is likely to cause a loss of nearly €2 billion (16%) annually and Scenario 4 will devalue the Italian vine industry by nearly €5 billion, eliminating 39% of its value.

These values reflect the farm gate values of the unprocessed grapes and do not include the additional losses associated with the reduction in wine volume produced.

Table 3-14. Impact of Scenarios 1 to 4 on the Italian vine growing industry at national scale

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Italian vineyard area inc uncropped	**ha**	973,203	973,203	973,203	973,203
Cropped area*	**ha**	727,000	727,000	650,062	650,062
Change in cropped area	**ha**		0	76,938	76,938
Yield	**t/ha**	10.0	8.0	10.0	8.0
Production	**Mt**	7.3	5.6	6.1	4.9
Reduction in production	**Mt**		1.7	1.2	2.4
Production change	**%**		-23%	-16%	-33%
Farm gate price	**€/t**	€ 1,660	1,500	1,660	1,500
Value of production	**€ billion**	€ 12.07	8.40	10.16	7.35
Change in value	**€ billion**		-3.68	-1.91	-4.73
Percentage change	**%**		-30%	-16%	-39%

*based on modelled square plots of 1.6 ha.

3.4.7 Conclusions (Vines)

The impacts of the three crop management scenarios on the viability of the Italian vineyard sector industry are marked, and under Scenario 4 are likely to result in a loss to Italy's vine sector of €5 billion annually (at the farm gate), representing 39% of its value.

The impact on the wider economy would be amplified as Italy's wine sector is a cornerstone of its economy, producing around 45 million hectolitres annually (2024-2025), contributing €45.2 billion in total economic impact (1.1% of GDP), generating €17.4 billion in added value, and directly or indirectly supporting over 300,000 jobs. For example, wine tourism alone adds €2.6-2.7 billion yearly, involving 15 million visitors (Vinetur, 2026; Vinitaly, 2024).

A 39% income drop could force cost-cutting: reduced investments in sustainable practices, labour, or quality controls, leading to lower yields and potential quality erosion. Smaller producers might shift to bulk wine production or abandon iconic heritage vines, diluting the "Made in Italy" prestige.

Furthermore, socio-economic research conducted on behalf of the European Committee of Wine Companies (PwC, 2024) showed that vine removals due to viability issues could trigger the loss of many of the 300,000 jobs supported by the industry, which would have indirect impacts on suppliers (e.g. fertilisers, equipment) and tourism These effects could further accelerate rural depopulation. For example, PwC (2024) reported that areas with shrinking vineyard areas saw 6.5-fold higher population declines, i.e. 2.6% versus -0.4%.

These impacts could unintentionally affect biodiversity and ecosystem services in vineyard-dominated landscapes, particularly in regions like Tuscany, Piedmont, and Sicily. Economic pressure might prompt vineyard abandonment in marginal or low-profit areas, leading to short-term biodiversity gains with recolonization by native plants, birds, butterflies, and arthropods. However, medium- to long-term succession (shrub/forest encroachment) often reduces open-habitat specialists and overall diversity,

and threatens traditional farmland biodiversity (Quintas-Soriano et al., 2022). In terms of ES impacts, whilst vineyard abandonment can enhance soil carbon sequestration and erosion control, it risks hydrogeological instability (e.g., terrace collapse) and cultural service losses such as landscape heritage and tourism (Torquati et al., 2015; Vilumets & Kaasik, 2025).

3.5 Cabbage – Case Study Netherlands

Agricultural land covers 2.2 million hectares in the Netherlands, which represents approximately 54% of the country's total area. Cropping is highly diverse, with field production covering cereals, potatoes, vegetables, flower bulbs and a world-leading, protected cropping sector producing both edible and ornamental crops. There are about 11,700 ha of brassicas grown in the Netherlands each year, covering a range of different types including white cabbage, red cabbage, calabrese, Brussel sprouts, cauliflower, Chinese cabbage, green cabbage, kale and oxheart cabbage. Each of these brassicae have varying yields, cost of production and value, with about 55% of brassicas grown for the fresh market. For this analysis, the focus was on white cabbage which represents about 13.5% of the brassica area in the Netherlands.

White cabbage in the Netherlands is a traditional open-field vegetable crop, concentrated in regions with suitable soil and low risk of certain diseases. It is one of the oldest cabbage types, primarily grown for processing into sauerkraut but also for the fresh market, coleslaw and other uses.

Around 1,500 ha of white cabbage is grown annually (1,585 ha in 2024) with an average yield of 78.7 t/ha (CBS, 2025). The total annual weight of fungicide used annually is 2.3 kg/ha across 3-6 applications, with 0.4 kg/ha of insecticides also used across 3-6 applications.

In terms of growing material, Dutch breeders (e.g., Bejo, Enza Zaden) dominate the market, offering hybrid varieties for different uses:

- Early varieties for fresh market.
- Late, dense-headed types for sauerkraut and long storage (e.g., 'Roem van Enkhuizen', 'Langedijker Bewaar', 'Filderkraut').
- Pointed or flat-headed forms.

Producer/wholesale prices vary seasonally and according to quality but typically range between €200–400 per tonne in recent years (roughly €0.20–0.40 per kg). Export prices are often higher, around €600–800 per tonne on average in the late 2010s/early 2020s, although current retail prices are €0.79–2.43 per kg (equivalent to €790–2,430 per tonne). Prices fluctuate with supply, demand and export markets. (IndexBox global cabbage reports and Selina Wamucii market insights).

3.5.1 Spatial and temporal context

The model field

The main growing area is Noord-Holland (especially West Friesland), where sandy and marine clay soils naturally suppress clubroot (*Plasmodiophora brassicae*), a major disease which limits cultivation elsewhere. Some production occurs in Limburg and Noord-Brabant but with strict crop rotation to manage clubroot

Field sizes are relatively small, with large flat areas bounded by drainage ditches dividing land into individual parcels, typically of around 1.0 ha.

In the Netherlands, uncultivated field boundary buffer strips are primarily mandatory zones along watercourses, such as ditches and canals, to protect water quality from fertiliser and PPP run-off. The

width depends on the type of watercourse and is automatically calculated by the RVO (Rijksdienst voor Ondernemend Nederland) system but is commonly 5 m.

Given a 5 m uncropped field margin:

- Cropped area in Scenarios 1 and 2 is 0.90 ha and 0.86 ha in Scenarios 3 and 4.
- In-field unsprayed buffer width of 5.0 m, equivalent to 0.1 ha in Scenarios 1 and 2, with 7.5 m in Scenarios 3 and 4, equivalent to 0.14 ha.

3.5.2 Scenario 1 - Current practice

Insect pest management

Key pests and impacts:

- **Cabbage root fly** (*Delia radicum*): Larvae damage roots, causing wilting and plant death and potential yield losses of 20–30%.
- **Cabbage aphid** (*Brevicoryne brassicae*): Feeds on leaves and transmits viruses; untreated yield losses range from 20–50% in a typical year and up to 70% in severe outbreaks.
- **Diamondback moth** (*Plutella xylostella*): Larvae feed on leaves; typically causing 10–30% yield loss if uncontrolled.
- **Large cabbage white** (*Pieris brassicae*): Larval leaf defoliation and contamination; can cause 20–25% yield loss in untreated crops.
- **Thrips** (*Thrips tabaci*): Damage outer leaves, mainly cosmetic; yield impact usually <10%, but significant market quality reduction. (EU CAP, 2016).

Core IPM Strategies: Cabbage growers use a combination of IPM techniques alongside PPPs to ensure high levels of disease and pest control and high quality produce. Key elements of IPM that are routinely used include:

Crop Rotation and Sanitation: Rotate brassica crops every three to four years to prevent the buildup of soil-borne pests, particularly root flies. Additionally, remove crop residues after harvest to reduce pest survival and minimize future infestations.

Resistant Varieties and Planting Timing: Select cultivars that are tolerant or resistant to common pests. Adjust planting dates strategically to avoid periods when pest populations are at their peak, thereby reducing the likelihood of severe damage.

Physical Barriers and Monitoring Use insect nets or row covers to protect crops from pest entry. Regularly monitor fields through scouting and traps and apply threshold-based decision-making before considering any chemical interventions. There are different types of nets that can be used dependent on pest type, level of initial investment and level of risk.

Biological Control Introduce natural enemies such as parasitoids and predatory insects to help manage pest populations. Incorporate microbial agents like *Bacillus thuringiensis* (Bt) as part of an integrated pest management strategy.

Chemical Use in IPM:

Chemical use is an important tool to ensure consistent high quality produce, used alongside the IPM practices identified above. Insecticides are used to target caterpillars of lepidopteran pests, such as large cabbage white and diamondback moth, and other leaf-feeding larvae. Aphids are also key targets for insecticide applications. In organic production systems, *Bacillus thuringiensis* (Bt) remains a standard treatment for caterpillar control (CTGB, 2025).

Application methods typically involve tractor-mounted boom sprayers calibrated for low drift, while organic farms often rely on hand-held or mist sprayers to ensure precise coverage.

Seasonal Spraying Schedule

PPP applications are timed carefully throughout the growing season to target specific pests:

- Early Season (April–May): Soil treatments or early sprays are applied to control cabbage root fly.
- Mid-Season (June–July): Foliar sprays focus on diamondback moth, large cabbage white butterflies, and aphid infestations.
- Late Season (August–September): Treatments aim to manage thrips and secondary pests before harvest to maintain crop quality.

Widely used insecticides

- Spinosad for Cabbage root fly, *Pieris brassicae* and *Plutella xylostella* (caterpillars).
- Ryanoids for *Plutella xylostella* and leaf-eating larvae.
- Systemics for aphid control.
- Pyrethroids used sparingly for general pest knockdown.
- *Bacillus thuringiensis* (Bt) for biological caterpillar control, common in organic production.

Disease Management in Dutch White Cabbage Production

Main Diseases and Impact

- **Clubroot** (*Plasmodiophora brassicae*): causes swollen roots, stunting and wilting; When untreated, crops grown in infested soils can suffer 10-100% yield loss and, up to total crop failure in severe cases.
- **Black rot** (*Xanthomonas campestris* pv. *campestris*): causes yellowing and V-shaped leaf lesions affecting photosynthesis; the result is 10-30% yield loss if unmanaged.
- **Wirestem / damping-off** (*Rhizoctonia solani*): causes seedling stem rot resulting in poor establishment; reduced plant density can result in 15-25% yield loss if left untreated.
- **Alternaria leaf spot** (*Alternaria brassicae* / *A. brassicicola*): causes dark leaf spots, which reduce photosynthesis and quality and when uncontrolled can result in 5-15% yield loss.
- **Powdery mildew** (*Erysiphe cruciferarum*): Causes white fungal growth across the leaf surface, resulting in reduced head formation; when uncontrolled, it can result in 5-20% yield loss in humid conditions. (EU CAP, 2016).

Fungicide Use

On average, growers apply between three and six fungicide treatments per season. The exact number depends on weather conditions, variety susceptibility and disease monitoring results. Wet and warm conditions typically increase disease pressure, leading to more frequent applications, while dry years often require only two to three sprays.

Fungicide treatments are scheduled according to crop growth stages and disease risk:

- Seedling Stage (March–April): Treated seed or soil drenches may be used to prevent damping-off caused by *Rhizoctonia*.
- Vegetative Stage (May–June): Preventive sprays target *Alternaria* and downy mildew.

- Head Formation (July–August): Protective sprays are applied every 10–14 days to control black rot and *Alternaria*.
- Pre-Harvest (August–September): A final spray helps prevent storage rots and late-season *Alternaria* infections.

Applications are typically made using tractor-mounted boom sprayers calibrated for optimal leaf coverage.

Due to high investment in the crop and its' market value, the approach is primarily preventive rather than curative, especially where bacterial black rot is a threat. Decisions are supported by weather forecasts, field scouting, and forecasting models such as WUR ProPhy. Fungicide rotation across different FRAC groups is essential to delay resistance development.

Widely used fungicides

- QoI Group: Effective against *Alternaria*, downy mildew, and powdery mildew.
- SDHI Group: Targets *Alternaria* leaf spot.
- DMI Group: Controls *Alternaria* and leaf blight.
- Protectant multi-sites: Provide broad-spectrum preventive action.
- Organic/IPM Options: Copper hydroxide is used for bacterial suppression and secondary pathogens (CTGB, 2026).

Table 3-15. White cabbage production calendar with key pests/diseases and typical treatments

Growth Stage	Main Threats	Insecticides	Fungicides	Notes / IPM Tips
Seedling/ Transplanting (March–May)	Cabbage root fly, damping-off. Early aphids	Seed/soil drench against root fly. Early foliar if aphids present	Seed treatment or early soil drench (including biologicals) against damping-off.	Preventive root fly control essential; use collars or nets. Scout weekly.
Early vegetative (May–June)	Cabbage root fly (late generation), aphids, diamondback moth, flea beetles	1-2 foliar sprays if thresholds exceeded	1-2 preventive sprays against Alternaria leaf spot and downy mildew	Focus on early aphid control to prevent virus transmission. Use nets for physical barrier.
Mid-season / Head formation (June–August)	Caterpillars, aphids, thrips, Alternaria leaf spot, black rot, powdery mildew	2–4 sprays as needed. Rotate modes of action.	3–5 sprays every 10–14 day. Copper-based in organic/IPM for black rot suppression.	Highest disease pressure in humid weather. Rotate FRAC groups to avoid resistance.
Late season / Pre-harvest (August–September)	Late thrips, secondary caterpillars, storage rots (Alternaria, Botrytis)	1–2 sprays if needed	1–2 final sprays: protectants to prevent storage rots.	Last sprays 7–21 days before harvest; focus on quality for storage.
Overall season	Total applications	3–6 insecticides (often fewer with monitoring)	3–6 fungicides (reduced in dry years)	Total 6–12 sprays per season - netting increasingly common for sustainability.

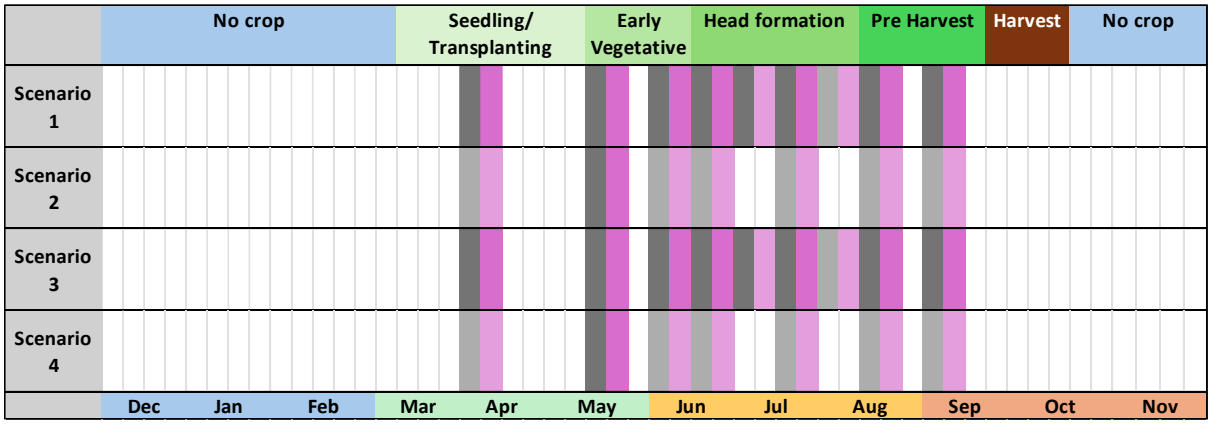

Figure 3-8. Netherlands cabbage production cycle and timings of pest and disease management
Key to PPP Use: Scheduled Fungicide Optional Fungicide Scheduled Insecticide Optional Insecticide

3.5.3 Scenario 2 – Increased in-field protection

Headlines: 30% reduction in yield forecasted as a result of decreased rates of insecticide usage, 25% reduction in yield due to reduction in fungicides. Overall yield loss assumed to be 30% across whole area.

A 50% reduction in insecticide use in Dutch cabbage production is likely to cause substantial pest damage, particularly during the early growth stages. Without adequate control, cabbage root fly, aphids, diamondback moth and other caterpillars would cause significant plant mortality, reduced head size and lower overall yield. Thrip damage would compromise market quality, leading to increased rejection rates.

Yield losses could reach up to 30% under such conditions, with additional economic impacts from lower marketable heads due to being undersized or damaged. Spot-spraying or precision application technologies (e.g., N-spray in the Netherlands) may be used to target crop plants and, therefore, reduce the area treated while maintaining efficacy. These technologies could theoretically reduce the treated area by up to 50% in the first six weeks post-planting.

In the absence of sufficient fungicide applications, foliar diseases (e.g., *Alternaria* leaf spot, black rot, powdery mildew) would increase, leading to reduced photosynthesis, poorer head quality and the higher incidence of storage rots. Yield losses could be limited to approximately 25% if planting and harvest dates are adjusted to minimise disease pressure.

It is expected that growers would invest in nets for protection against airborne insect pests, as well as other IPM approaches to manage both pest and diseases. Costs range between €4 to15K for nets, which will last between 5-15 years dependent on material. For the purposes of this analysis, netting is assumed to cost about €10,000 per hectare and assumed to last for 10 years (Crop Solutions, 2026), averaging €1,000 per use, and that the grower will to make the initial outlay in the first year. Labour for netting management and additional IPM needs were assumed to cost a further €400/ha.

Overall, a significant reduction in insecticide and fungicide use would make white cabbage production economically challenging, while less resilient brassica crops such as broccoli, Chinese cabbage and Brussels sprouts would become unviable. Farmers and their employees may face reduced income, potentially leading to diversification into other activities or off-farm employment.

3.5.4 Scenario 3 – Increased off-field protection

Headlines: 23% reduction in yield as a result of increased pest and disease pressure from untreated cropped areas in the wider buffer zone. 10% reduction in treated crop area.

Increasing buffer zones will decrease the growing area and increase the financial pressure on growers, with more economic damage for smaller growers with smaller fields.

Growers are likely to need to invest in nets to provide additional protection from certain insect species. Nets are assumed to cost €5,000 per ha (assuming a slightly lower specification of net is needed for this scenario than Scenario 2 given additional access to PPPs), with each net lasting about 10 years, giving an average cost of €500 per year. The farmer would need to make the initial investment in the first year. There would be additional IPM costs of €250, which includes labour for net management and costs of buffer establishment and maintenance. Typically buffers will consist of species-rich plant mixtures to provide nectar/pollen for adult parasitoids and predators (hoverflies, ladybirds, lacewings). Attractive brassica relatives can be planted in the 1–2 outer rows of the crop, thereby drawing pests away from the central cabbage plants and encouraging the build-up of natural enemies (Hatt & Döring, 2023; Stearns, 2021).

3.5.5 Scenario 4 – Increased in-field and off-field protection

Headlines: 40% reduction in yield as a result of increased pest and disease pressure from lower use of insecticides and fungicides in the treated area and increased reservoir of pest and disease species in untreated cropped area in the wider buffer zone. Reduction of 10% in treated crop area.

Combining a 50% reduction in PPP use with larger buffer zones would result in substantial difficulties for the Netherlands white cabbage sector and also for higher-value brassica growers. It is estimated

that yields would be reduced by about half due to a failure to adequately control both pests and diseases under lower PPP availability and increased pressure from untreated cropped margins.

It is anticipated that growers would need to invest in high quality fine gauge insect nets to protect crops. Nets can cost up to €15,000 a net (assuming the highest specification of nets are required), and have a lifespan of about 10 years, giving an average annual cost of €1,500. The full cost of the net would need to be made up-front. In addition, there would be additional costs for IPM practices such as netting deployment and buffer strip establishment and management that would increase costs by an estimated €500/ha.

3.5.6 Impacts on production and economics

Headlines: All three scenarios will cause major damage the economics of Dutch cabbage production, with Scenario 4 reducing field gross margins by 60%.

The impacts of changing crop management practices to enhance NTA protection on the ability of growers to produce white cabbage are shown in the tables below.

Table 3-16 shows the impact of the changes on yield and available cropping area and the consequent impact on production. The reduction in total weight of PPPs envisaged in Scenario 2 and resultant ability of growers to reliably defend cabbages against pest and disease attack is likely to result in a reduction in marketable yield of around 30%. Under Scenario 3, the reduced production area and possible increase in pest and disease reservoirs in untreated buffer zones reduces production by an estimated 23% from Scenario 1, whilst Scenario 4, combining both reduced PPP options and smaller production area, results in a 48% reduction in yield.

Table 3-16. Impact of Scenarios 1-4 on Netherlands cabbage area and production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Infield area	**ha**	1	1	1	1
Boundary length	**m**	400	400	400	400
Off-crop in-field crop free strip	**m**	2	2	2	2
In-crop - untreated buffer	**m**	5	5	7.5	7.5
In-crop - treated area	**ha**	0.72	0.72	0.62	0.62
In crop - untreated area	**ha**	0.20	0.20	0.30	0.30
Uncropped area	**ha**	0.08	0.08	0.08	0.08
Crop yield	**t/ha**	78	55	71	47
Production	**t/field**	56.4	39.5	43.7	29.2
Change in production compared to Scenario 1	**%**	-	-30%	-23%	-48%

In terms of economic impact, Table 3-17 forecasts a dramatic fall in field gate gross margins, with Scenario 2 reducing the margin by 40% relative to Scenario 1. Scenario 3 is predicted to cause a reductions of 27%, while Scenario 4 is predicted to cause reductions of 60% .

Table 3-17. Impact of Scenarios 1-4 on the costs of Netherlands cabbage production

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
In-field area	**ha**	**1.0**	**1.0**	**1.0**	**1.0**
Treated Crop area	**ha**	**0.72**	**0.72**	**0.62**	**0.62**
Marketable yield	**t/ha**	78.4	54.88	70.56	47.04
Cost of production	**€/ha**	3,000	3,675	3,500	4,175
Change in PPP costs	**€/ha**	0	-325	0	-325
Change in other costs*	**€/ha**	0	1,400	750	2,000
Farm gate price	**€/t**	300	300	300	300
Production per field	**t/field**	56.4	39.5	43.7	29.2
Field gate value	**€/field**	16,934	11,854	13,124	8,749
Cost of production per field	**€/field**	2,160	2,934	2,325	2,899
Field gate gross margin	**€/field**	14,774	8,920	10,799	5,851
Field gross margin change	**%**	-	-40%	-27%	-60%

* Change in other costs dominated by investment in nets, these have been averaged over 10 years. The type of net used in each scenario is different with the expectation that the higher the insect pressure the greater the level of investment in nets.

When projecting these losses to a national scale, Table 3-18 shows the forecast impact on the value of Dutch white cabbage production, currently worth over €35 million. Production volumes would reduce to 70%, 77% and 52% of current levels across Scenarios 2-4, respectively. When the increased costs of production are taken into account, the reduction in the national farm gate margin is predicted to be approximately €11, € 8.0 and € 17 million across scenarios 2-4, respectively. These estimates are based on conservative estimates of the increased cost of production, focusing on the cost of nets, even without the additional investment of time and cost of implementing IPM strategies which can be challenging to reliably quantify.

Table 3-18. Impact of Scenarios 1-4 on the Netherlands cabbage production industry at national scale

	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Dutch white cabbage area (including uncropped)	**ha**	2,083	2,083	2,083	2,083
Cropped area*	**ha**	1,500	1,500	1,292	1,292
Change in cropped area		-	0%	-14%	-14%
Yield	**t/ha**	78.4	54.88	70.56	47.04
Production	**t**	117,600	82,320	91,140	60,760
Reduction in production	**t**		-35,280	-26,460	-56,840
Production change	**%**	-	-30%	-23%	-48%
Farm gate price	**€/t**	300	300	300	300
Value of production	**€ million**	35.3	24.7	27.3	18.2
Change in value	**€ million**	-	-10.6	-7.9	17.1
Percent change		-	-30%	-23%	-48%

*based on modelled square plots of 1 ha.

3.5.7 Conclusions (Cabbages)

The white cabbage sector in the Netherlands in 2025 delivered high gross margins and a profitable crop for the grower. White cabbages are both high yielding and high value, with relatively modest costs of production. However, this profitability is highly reliant on good levels of reliable pest and disease control delivered with the support of both insecticides and fungicides, alongside existing IPM practices. A reduction in the total rate of insecticides and fungicides used on white cabbage crops as a result of increased in-field protection of NTAs, could have a negative impact on yields, reducing the total volume of crop produced on the cropped area. Increased buffer size buffer to increase the off-field protection of NTAs could result in only 86% of the available area being planted, assuming average fields size of 1ha.

It is possible to maintain a positive farm gate gross margin on white cabbage crops, with the combination of reduced yields, increased costs and decreasing crop area. However, the combination of increased in-field and off-field NTA protection, the margin would be reduced to 42% relative to current systems, i.e. Scenario 1. At the same time, white cabbage production could almost halve, assuming all producers continue to accept the increased risk associated with production. One option to balance the reduction in yield at the farm level would be to increase farm gate prices, which would have implications across the food supply chain resulting in higher food prices to the consumer.

While this analysis focuses on high-yielding white cabbage varieties, similar impacts would be expected across the wider brassica sector in the Netherlands. It is estimated that in 2024, the Netherlands produced about 357,000 tonnes of brassicas (CBS, 2025). Data from 2018 suggest that about 154,000 tonnes of cabbage are exported by the Netherlands, with an export value of $121 million. The Netherlands is the fourth largest exporter of cabbage globally (WITS, 2026). The reduction in production predicted by this analysis would be sufficient to wipe out the exportable surplus of cabbage in the Netherlands. Key export locations are Germany, Belgium, UK and France, all of which are liable to see similar impacts on their own national cabbage production.

The wider impacts of this reduction in production volume include a reduction in availability of fresh and processed cabbage across Europe, and increased demand for imported cabbage (at risk of being produced to lower environmental standards). Overall, the cost of fresh vegetables is expected to increase for the average consumer.

4 ANALYSIS

4.1 Impact on Ecosystem Services

This Chapter evaluates the impact of the changes in management practices predicted to arise following changes in SPGs for NTAs, on the Ecosystem Services that were prioritised previously in Chapter 2. This exercise was completed for both in-field and off-field ecosystem services for each of the four management scenarios in the context of each case study.

The predicted impacts of the scenarios on the prioritised ESs are summarised in Table 7-2. However, impacts are highly context-dependent (e.g. crop, landscape etc.) and benefits to any specific ES may not offset economic and food security risks without substantial investment in alternative pest management strategies.

Although some ecosystem services were not previously prioritised for assessment, such as spiritual experience and sense of place, these ESs would potentially be significantly impacted as a result of the predicted changes in management practices in some case studies. Hence, these ESs have been included in the following discussion. The impacts assessed in this report are based on expert judgement and best estimates. Due to the complex nature of the interactions identified during this impact analysis, it has not been possible to quantify impact in the term of the metrics identified previously in Table 2-4. Furthermore, there may be further unintended consequences (both positive and negative) that cannot be predicted within the scope of this project.

4.1.1 Food (in-field crop production);

The ecosystem service of food production, for human consumption, is delivered by the in-field area.

The impact on human food production, measured in terms of yield losses and corresponding financial value in each of the case studies are summarised in Table 4-1. Production losses occurred as a result of yield losses from reduced pest or disease control and a reduction in crop area as a result of increased buffer zones.

The impact of in-field protection measures that result in decreases in the use of insecticide or fungicide usage are anticipated to result in significant reductions in yield. These yield reductions may not be uniform across the seasons, or between farms, but will result in increased levels of uncertainty in the industry and higher levels of economic risk. Where there are relatively high levels of economic margins, such as in cabbage, there is the potential to invest in mitigations such as different qualities of net to protect against insect pests. There may also be some resilience in terms of being able to absorb some yield loss.

However, a 50% reduction in rate of insecticide and fungicide use volumes is anticipated to result in yield losses of 11% (wheat) to 36% (apple). This level of yield loss or uncertainty will harm even the most profitable and resilient farming systems. In systems such as Polish apple production, where margins are tight and there is strong competition from imported produce, the impact is expected to be more pronounced as the systems are more sensitive to small yield and quality impacts.

Moreover, Farm Net Income (FNI) and related indicators often show marginal profitability for many specialist EU cereal farms, with net returns frequently in the low single-digit percentages of revenue in average years and dropping to near-zero or negative in challenging seasons (European Commission, 2019). A yield loss of 11% would therefore make cereal production unsustainable for many EU arable farmers.

More stringent off-field protection measures, i.e. an increase in untreated buffer zones, will also impact food production through reductions in area available to grow the crop and/or increased reservoirs for pest or disease. The impact of the increased buffer zones on food production is greatest

in cropping systems that use small fields, e.g. the small-scale apple production in parts of Poland and vineyards in Italy, where fields are often long and thin, meaning an untreated buffer could effectively take up most of the crop area.

Table 4-1. Case study summary – national crop and financial impacts under Scenarios 2-4

Case Study		Wheat (UK)	Apple (Poland)	Vines (Italy)	Cabbage (Netherlands)
Scenario 2 (50% PPP reduction)	Crop loss (t)	1.42 million	1.24 million	1.70 million	35,000
	Percentage	-11%	-36%	-20%	-30%
	Impact (€ million)	**-310**	**-371**	**-3,680**	**-11.6**
Scenario 3 (50% buffer increase)	Crop loss (t)	0.26 million	1.67 million	1.20 million	26,000
	Percentage	-2%	-49%	-11%	-23%
	Impact (€ million)	**-55**	**-500**	**-1,910**	**-8.0**
Scenario 4 (Scenario 2 + Scenario 3)	Crop loss (t)	1.65 million	1.88 million	2.40 million	57,000
	Percentage	-12%	-56%	-28%	-48%
	Impact (€ million)	**-359**	**-565**	**-4,730**	**-17.9**

Adoption of the measures explored in Scenarios 2-4 will necessitate either substantial increases in farm gate prices to balance reduced yields and increased costs. The risk of producers exiting their business's and potentially threatening food security, will be increased. Since the scenarios are based on EU policy objectives including Farm to Fork (European Commission, 2020), it is evident that new SPGs need to be carefully evaluated with respect to their potential impacts across a wide range of cropping systems to ensure that they do not have an damaging impact on food security.

Table 4-2 uses Eurostat (2026) data to project the impacts explored in the national case studies across the EU, and indicates that € billions of crop value will be lost across the EU.

Under the scenarios explored, the region would almost certainly have reductions in exportable surplus, and, in many cases, is likely to become a net importer of cereals, fruit and vegetables, increasing the risks of food insecurity and affordability for consumers. The wine sector could also suffer significant set-backs making European wine uncompetitive on the international market. Some iconic specialist varieties and wines will probably be able to command premium prices and retain a market share, but the more ordinary table wine producers are likely to struggle to compete against imports that are produced in countries with lower environmental protections (Beckman et al., 2020; Boix-Fayos & de Vente, 2023; Schiavo et al., 2023).

Table 4-2. EU-wide projection of crop losses and financial impacts under Scenarios 2-4

Scenario		Wheat	Apple	Vines	Cabbage
Scenario 1 2024 Data (Eurostat, 2026)	EU-26 Total (Mt)	111.6	11.6	20.5	3.8
	Average price €/t	238	1049	500	1010
	Farm Gate Value (€ bn)	26.6	12.2	10.3	3.80
Scenario 2 (50% PPP reduction)	Impact on yield	-11%	-36%	-20%	-30%
	Crop loss (Mt)	12.3	4.2	4.1	1.1
	Impact (€ billion)	**-2.92**	**-4.38**	**-2.05**	**-1.15**
Scenario 3 (50% buffer increase)	Impact on yield	-2%	-49%	-11%	-23%
	Crop loss (Mt)	2.2	5.7	2.3	0.9
	Impact (€ billion)	**-0.53**	**-5.96**	**-1.13**	**-0.88**
Scenario 4 (Scenario 2 + Scenario 3)	Impact on yield	-12%	-56%	-28%	-48%
	Crop loss (Mt)	13.4	6.5	5.7	1.8
	Impact (€ billion)	**-3.19**	**-6.81**	**-2.87**	**-1.84**

It should be noted that these figures represent predictions for only four crops whereas the more stringent SPGs for NTAs are applied at product level and, hence, will impact the availability of PPPs across all crops grown in the EU. Therefore, it will become increasingly difficult for growers to identify and switch to alternative crop production systems that do not experience similar restrictions and issues.

4.1.2 Wild foods

The ecosystem service of wild food provision (i.e. for foraging by humans) is delivered by in-field (weeds and uncropped field buffer zones) and off-field areas.

An increase in untreated buffer zones in scenarios 3 and 4 is anticipated to result in increased levels of plant materials (and, to a lesser extent, edible NTAs) available for foraging, assuming that these buffer zones are maintained as vegetated areas and wild plants are allowed to grow. However, this is less likely to be the case for crops where the ingress of weeds from the vegetative buffer zones into the crop is a concern for profitability (de Snoo, 1999). The reduction in active ingredient applied in scenarios 2 and 4 is not anticipated to impact this ES, as foraged weeds in-crop are unlikely to be affected, and NTAs are of little relevance as wild food in Europe.

4.1.3 Freshwater (groundwater and surface water)

The ecosystem service of fresh water provision is delivered in both the in-field and off-field areas.

The direct impacts of these scenarios on ground and surface water are generally anticipated to be positive, due to a reduction in active ingredient applied in scenarios 2 and 4 and reduction in area treated due to increase in buffer zones used in scenarios 3 and 4.

However, there may be unintended consequences as significant reductions in yield and income and the resulting risk of changing land-use could adversely affect water quality. For example, replacement of perennial cropping with annual cropping would result in increased cultivation and risk of soil and nutrient contamination of surface water (with unknown consequences for PPP inputs), whilst loss of vine terraces and associated maintenance on steep slopes in Italy could increase the risk of terrace collapse and associated soil contamination of surface water. Change of land use from agricultural land to building developments increases hard, impermeable surface area and potentially increases the risk of flooding and contaminant run-off into surface waters (Moreno-de-las-Heras et al., 2019; Tarolli et al., 2014).

4.1.4 Erosion prevention, maintenance of soil fertility and carbon sequestration and storage

The soil-related ecosystem services of erosion prevention, maintenance of soil fertility and carbon sequestration and storage is delivered in both the in-field and off-field areas.

The direct impacts of these scenarios on erosion prevention and soil fertility is likely to be minimal in most cases.

Soil fertility could potentially be improved as a result of increased soil arthropod populations due to decreased insecticide and fungicide use in-field and increased buffer zones (Beaumelle et al., 2023; Culliney, 2013). However, this positive effect is likely to need time to build up and could be negated by alternative control measures implemented to compensate for lower PPP use. These factors are also impacted by other agricultural practices unrelated to NTA control, such as tilling and fertilizer applications (Genty et al., 2026).

Meanwhile, increased buffer widths may make vineyard terraces unviable, leading to abandonment, cessation of maintenance, which could lead to increased risk of erosion and terrace collapse.

Similarly, changes in land-use driven by economic factors may potentially impact soil fertility as farmers look to change cropping systems or production practices to enable them to generate income or diversify into other land uses. A potentially positive impact of land abandonment of agricultural fields is the reversion to shrubland and forest, which would stabilise soil and reduce erosion (Weissgerber *et al.* 2023). However, change from perennial cropping to annual cropping could result in increased erosion risk as a result of increased cultivation. Similarly, the potential for land to capture and store carbon may be altered under different cropping regimes, or eliminated if land use is changed to building developments (Fayet et al., 2022; Lasanta et al., 2015). These potential unintended consequences remain complex to assess and predict.

4.1.5 Pollination

The ES of pollination is delivered in both the in-field and off-field areas.

A reduction in insecticide and fungicide use in-field is predicted to have a positive effect on pollination services (Tamburini et al., 2021). Measures are already in place to minimise harm to pollinators to within regulatory acceptable levels, but increased in-field protection is anticipated to support their numbers further. This is particularly relevant in flowering crops such as apples which are attractive food-sources for pollinators. The increase in buffer zones would provide increased refuges and food sources for pollinator species potentially increasing pollination services, dependent on management of these buffers (Gardner et al., 2021; Garratt et al., 2023).

Alternative control methods required to manage pests and diseases due to a reduction in existing PPPs may partially or wholly negate the positive impacts of a reduction in PPP usage. Some alternative methods to traditional PPPs may be highly selective (such as microbial biopesticides, pheromones, and the artificial introduction of predators), though there is likely to be some level of impact on non-target organisms such as pollinators (Cappa & Baracchi, 2024). Other methods such as physical net barriers may be less targeted and limit pollinator access to habitat and pollen and nectar sources.

However, there is an indirect risk that changes in land use, such as a reduction in small scale perennial cropping and a shift to more arable cropping, could result in a reduction in pollen sources for NTAs as well as and a loss of habitat, depending on the choice of cropping. Conversely, if areas of land are abandoned and allowed to naturally regenerate, there may be increased habitat for pollinators, at least during certain periods of regeneration (Fayet et al., 2022).

4.1.6 Biological control

The ES of biological control is delivered in both the in-field and off-field areas.

A reduction in insecticide and fungicide applications should allow populations of predatory species such as carabids and spiders to build up in the cropped area over time and provide greater biological control services (Beaumelle et al., 2023). Likewise, an increase in buffer strip width would provide the potential for greater refugia, to facilitate greater biological control. Evidence for the effectiveness of NTA predator refugia is mixed and likely to be dependent on crop, landscape and the management of the buffer strips.

As discussed for pollinators, a reduction in PPP application in-field is likely to result in an increase in alternative control methods, which may have direct negative effects on predatory species which act as biological controls (Lisi *et al.,* 2025). These methods may be more or less selective than PPPs, and may partially or wholly negate the positive impacts of reducing applications of conventional PPPs.

It is also important to consider the unintended consequences of the changes in crop management practices. For example, if perennial cropping was deemed unviable due to high cost and low margins and there was a conversion to annual cropping, the additional cultivations and reduction in habitat could have a negative impact on biological control species (Estrada-Carmona et al., 2022).

4.1.7 Maintenance of genetic biodiversity

Genetic diversity as an ES is delivered both in-field and off-field.

A reduction in insecticide and fungicide usage as proposed in scenarios 2 and 4, would have positive benefits to genetic diversity of NTAs (Hawki et al., 2019). Specifically, reduced PPP pressure on NTAs would be assumed to enhance the genetic diversity of these species, by allowing populations to build up over time.

Reductions in PPP usage could also increase genetic diversity in pest species, which may have several consequences. The reduction in selection pressure on target pests may, allow a higher proportion of sensitive individuals to survive in pest populations and delay the development of PPP resistance, which is a positive benefit. Conversely, if scenarios 2 and 4 result in a reduced 'toolbox' of active substances available to the grower (which is considered likely) the use of fewer Modes of Action is likely to result in increased occurrence of resistance in pest species. In addition, an increased genetic diversity in pest species may encourage the development of new pest strains.

The inclusion of wider buffers to protect the off-field area should also increase genetic diversity as they increase habitat and refugia for these species (dependent on farmer maintenance of these buffers) (Gardner et al., 2021; Ortego et al., 2024).

However, the inclusion of larger buffers in agricultural fields may lead to unintended negative consequences for genetic biodiversity. This risk is higher in geographic areas and crop markets where the economic impacts of reduced PPP inputs and increased buffers lead to landscape changes. These changes might include the removal of boundary features, such as hedges to create larger fields that can accommodate larger buffers, e.g. amalgamation of apple orchards or vineyards, transitioning to annual cropping or abandonment of some cropping areas that are no-longer economically viable. Removal of perennial crops could result in a decrease of genetic diversity across many taxa as habitats become simpler and able to support less diverse species. Whilst abandonment and allowing areas to naturally regenerate will result in an evolving habitat that might support more genetic diversity across and within species. However, it is noted that later stages of succession will shift the inter-species genetic diversity, as community composition shifts as succession proceeds. It is expected that intra-species genetic variation will be reduced and then eliminated for species which are specialists of open/disturbed habitats (i.e. species that succeed currently in agricultural landscapes). Finally, development of land for building would greatly reduce populations and genetic diversity without the

introduction of adequate compensatory mechanisms (Estrada-Carmona et al., 2022; Fayet et al., 2022).

4.1.8 Habitat for species

Both in-field and off-field areas can provide habitat for wild species of birds, mammals, plants, bees, pollinators and soil organisms.

A necessary part of a habitat is availability of food for the species present. NTAs feed on a range of different food types including pollen, nectar, other arthropods, plant materials and seeds (EFSA, 2015). The changes in crop management in scenario 2 with a reduction in PPP usage could result in increased levels of food for some of the arthropod-eating NTAs, birds, and mammals, as increases in pest species will provide additional foods for those species. Particularly, it is noted that NTAs provide an important food source for insectivorous birds, and for many other bird species when feeding their young. It is not anticipated that there would be direct changes to nectar, pollen, plant materials or seeds in either the in-field or off-field areas from the implementation of this scenario. However, there may be some positive impact on plant habitats in-field if a reduction in insecticide/fungicide application improves soil fertility.

The increase in untreated buffer zones in scenarios 3 and 4 is anticipated to result in increased levels of alternative plant materials being present, assuming that those buffer zones are maintained as vegetative areas. This is expected to increase habitats for certain marginal NTA, bird and mammal species. It is expected that the increase in plant materials and NTAs would provide food sources for some species.

Indirectly, the significant reduction in profitability in these case studies indicates that large areas of agricultural land, particularly that used for orchards and vines, could be taken out of production. Abandonment and natural revegetation of these areas, provide additional habitat for species. However, amalgamation of small fields into larger areas to facilitate productive arable agriculture, could result in a decrease in habitats (Estrada-Carmona et al., 2022; Fayet et al., 2022).

As identified above, the impact of the scenarios on habitats depends in part on how the farmers respond to the increasingly difficult economics of crop production. The direct impact of a reduction in insecticide and fungicide use in crop is anticipated to result in the in-crop habitat becoming more suitable to some species. The introduction of larger untreated buffer areas around fields has the potential to increase habitat area and refuges for certain species. The impacts will be greatest in smaller fields where buffers represent a greater proportion of the total area.

The unintended consequences resulting from changes in crop management are are more difficult to predict. Conversion of perennial crops to arable crops has the potential to reduce habitat areas as perennial crop fields tend to be smaller and, therefore, have a greater proportion of field borders, making the landscape more heterogeneous and thus more diverse. In contrast, large fields of annual crops reduce landscape heterogeneity and increase landscape disturbance. Increase in cultivation and removal of perennial crops will change the features of the habitat and its suitability for specific species (i.e. less suitable for species sensitive to regular disturbance) (Moretti & Benzaquen, 2025; van der Meer et al., 2020). Conversely, abandonment of some areas of land and natural regeneration may create habitat for some species, but could be detrimental to species that are adapted to the changing landscape of an agricultural system. Finally, conversion of land to non-cropped uses (rather than wilding) could result in loss of species habitats at very high levels (Estrada-Carmona et al., 2022; Fayet et al., 2022).

4.1.9 Spiritual experience and sense of place, tourism

These cultural ESs are relevant to both the in- and off-field areas and could be significantly impacted by the changes identified in the scenarios above. Additionally, the impacts already identified on all

other ESs may have indirect effects for this ES. The level of crop management change that is identified in the scenarios to increase NTA protection both in-field and off-field, could have significant implications for the character of a local environment. The reduction of PPP applications could potentially increase the presence of enigmatic species such as butterflies and bees which are attractive to humans using agricultural spaces (assuming these effects are not negated by alternative pest control methods). In addition, the increase in buffer zones would produce a more diverse landscape (assuming no land-use change), which humans are likely to find appealing.

However, in contrast, rural communities could see increasing hardship as production of horticultural and viticultural crops becomes increasingly challenging. During the initial transition, there would be risks to mental health as farms look to understand whether they can maintain an economically sustainable business. There is likely to be an increase in labour requirement to perform the additional scouting and crop management practices required to protect the crop. However, without significant increases in farm gate prices for the produce, the risk is that the labour will either be taken on within the family farm without proper payment, or involve high levels of low paid labour. The cost of this labour is likely to be prohibitive for many farms, especially as they look at the increased risk of crop failure (Beckman et al., 2020; Wesseler, 2022).

In the medium term, it is anticipated that a number of smaller family farms will find that it is no-longer viable for them to maintain their farms. This impact is likely to result in either consolidation of farms into larger areas to gain economies of scale, potentially with a switch to annual cropping where the land is suitable, or potentially abandonment of land areas. In both situations, these changes are likely to alter the spiritual essence of a location as small family farms are lost, and even larger commercial farms struggle to maintain profitability. It will change the character of areas, with significant changes expected in the apple orchards of Poland and the vineyards of Italy (Jewell et al., 2025; Quintas-Soriano et al., 2022). In Dutch cabbage production, it may be possible to maintain production, but with far greater reliance on nets, which change the physical appearance of fields. In the UK, although the impacts on wheat crops are not as dramatic as in some of the horticultural crops, the margins are also fairly tight and smaller farms in particular may shift out of agriculture, selling land for redevelopment (e.g. housing or solar power generation) which will change the nature of the local area (Fayet et al., 2022).

These changes all have the potential to affect tourism, where the unique agricultural landscapes that attract tourists to a location are changed beyond recognition.

5 CONCLUSION

Trade-offs are unavoidable: Increasing NTA protection, through reduced PPP use and expanded buffer zones, significantly impacts crop yields and profitability, especially for high-value horticultural crops where quality is as important as yield. The more stringent NTA protection becomes, the greater the likely impact on crop production. There needs to be a balance struck that is able to increase the protection of NTAs, while providing sufficient control over pest species. Time and investment is needed to develop the IPM approaches that facilitate the transition to lower insecticide and fungicide usage.

Context matters: Impacts vary by crop, region and climate. Humid areas and crops highly dependent on fungicides (e.g., apples, vines) face disproportionate risks. Those crops where quality and appearance are important aspects of marketable yield and value are also more sensitive to both pest and disease damage. Changes in specifications and expectations of fresh market consumers, including supermarkets, will be needed to allow a greater proportion of the crop produced to be deemed 'marketable'. In low pest/disease pressure years, production levels may be maintained close to current average levels, but in high pressure years losses are likely to be devastating and may force businesses with insufficient resources to withstand heavy losses, i.e. smaller growers, out of production.

Food security concerns: Each of these scenarios has the potential to significantly reduce food production, especially scenarios increasing protection of in-field NTAs, as the yield impacts from reduced insecticide and fungicide use are high. When combined with increased off-field protection, yield impacts are further increased as the area available for crop production is reduced. Alignment of the outcome of revised SPGs for NTAs with the outcomes proposed in the EU's Farm to Fork Strategy (European Commission, 2020) , is likely to present a substantial threat to European food security and increase dependence on imports of food from other parts of the world to fill the shortfall in domestic production. Combined measures (Scenario 4) could render production economically unviable for many growers, leading to farm exits and reduced national output.

PPP resistance development

Scenarios 2 and 4 are both likely to increase the long-term risk and accelerate the development of pesticide resistance in key crop pests and pathogens, albeit via slightly different mechanisms and with greater severity under Scenario 4.

Under Scenario 2 (50% reduction in in-field insecticide and fungicide use), resistance pressure is anticipated to increase primarily as a result of restricted availability of active substances and modes of action (MoAs). With fewer chemical options and lower total permissible inputs, growers are likely to rely more heavily on a limited number of remaining products, often applied at sub-optimal rates or under higher pest and disease pressure. This increases the likelihood that treatments fail to deliver full control, allowing partially tolerant individuals to survive and reproduce. Over time, repeated use of a reduced set of MoAs increases selection pressure, raising the probability of resistance.. Although greater use of resistant varieties and non-chemical measures could partially mitigate this risk, these measures are often insufficient on their own in high-pressure seasons, particularly for rapidly evolving fungal pathogens.

Under Scenario 4 (combined 50% reduction in PPP use and 50% increase in untreated buffers), resistance risks are likely to be more severe and complex. In addition to the reduced chemical toolbox described for Scenario 2, the expansion of untreated areas creates spatial heterogeneity in exposure, leading to persistent pest and pathogen reservoirs at field edges. Increased buffer area will increase the frequency and intensity of reinfestation events into cropped areas, often necessitating repeated use of the few remaining effective products. While untreated refuges can theoretically dilute resistant populations, in practice, particularly for mobile insect pests and wind- or splash-dispersed pathogens,

the dominant effect is likely to be increased PPP usage within the treated crop area. This effect concentrates selection pressure spatially and temporally, accelerating resistance development in those zones where control remains possible.

Across both scenarios, fungicide resistance risks are especially pronounced, given the already widespread resistance issues in major crop diseases and the reliance on multi-application programmes. Reduced opportunities for rotation, mixture and sequencing of MoAs undermine established resistance-management principles. Insecticide resistance risks are similarly exacerbated in systems where few effective alternatives remain, particularly for pests with high reproductive rates or multiple generations per season.

Environmental gains can be realised, but unevenly: Pollination and biological control services are predicted to improve under more stringent SPGs but the benefits depend on crop type and landscape configuration. Environmental benefits achieved within Europe may be offset by negative impacts elsewhere in the world as European food imports increase from areas of the world with less stringent environmental protections. Increased demand for food imports could risk upsurges in demand for land, which would most likely be met through natural habitat destruction, which has the potential to cause far greater environmental harm than is being balanced by the benefits of improved protection goals in Europe.

Impacts of abandonment of farmland, orchards and vineyards must also be considered. This analysis indicates that permanent plantations are most at risk. Abandonment of vineyards and orchards can lead to biodiversity benefits in the short term through recolonisation by native species, but over the longer term, shrub/forest encroachment often reduces open-habitat specialists and overall diversity (Quintas-Soriano et al., 2022). Ecosystems services can also be impacted. For example, abandoned plantations may benefit soil carbon sequestration and erosion control but may risk hydrogeological instability, e.g. through terrace collapse, as well as cultural service losses such as landscape heritage and tourism (Torquati et al., 2015; Vilumets & Kaasik, 2025).

It is therefore critical that when environmental protection goals are set, the wider consequences to food production and the indirect environmental harm of increased import demands are balanced against the benefits that the specific protection goals provide to NTAs at a local level, otherwise there is a risk of environmental impacts in regions beyond the EU.

This analysis has considered four crop markets in EU Member States. As the changes to SPGs have the potential to affect all crops, and Member States in the EU, it is essential to ensure that the intention to protect NTAs does not lead to unintended consequences that negate this intention and that any changes in SPGs are balanced against the need to maintain food production and food security in the EU.

5.1 Recommendations

More stringent protection of NTAs has been advocated during discussions relating to proposed new Guidance for the effects of PPPs on NTTOs in the EU. However, more stringent protection for NTAs is likely to limit PPP availability and precipitate changes in grower practices that could have wider impacts and unintended socio-economic and environmental consequences beyond the intention to protect NTAs.

The following steps are recommended to ensure that all risks associated with revised SPGs are fully considered:

Strategic and policy assessment

- Conduct national and EU-wide impact assessments to evaluate the implications of new measures prior to the establishment of revised SPGs.

- Develop a comprehensive understanding of the global, direct and indirect consequences of adopting new SPGs, including environmental, economic and social dimensions.

Food security, markets and competitiveness

- Review the implications for food security, recognising that reduced domestic production may deplete strategic reserves, increase vulnerability to supply disruptions and undermine system resilience.
- Evaluate likely changes in EU international competitiveness and import/export balances arising from SPG changes.

Environmental and land-use consequences

- Assess biodiversity impacts resulting from (a) widespread shifts from permanent cropping systems to arable rotations and (b) agricultural land abandonment, including risks of unintended development pressure or reversion to unmanaged scrubland.

Farm viability and rural communities

- Analyse consequences for farmers and rural communities, including (a) loss of skilled labour and long-term implications for sector capability and resilience, and (b) rural poverty limiting the ability to maintain environmental standards.
- Assess the risk of making family-run farming businesses uncompetitive, leading to land consolidation into larger holdings and potentially negating benefits associated with widened buffer zones.

Resistance management and crop protection resilience

- Maintain awareness of the importance of managing pest and disease resistance through ensuring the availability of sufficient modes of action to enable effective rotation of plant protection products.

6 REFERENCES

Agro-Market24. (2026). *Fresh cabbage, average weight 1.2-2 kg*. https://agro-market24.eu/fresh-cabbage-average-weight-1-2-2-kg.75768.html

AHDB. (2024a). *How have wheat net margins fared over the past five years? Grain market daily*. https://ahdb.org.uk/news/how-have-wheat-net-margins-fared-over-the-past-five-years-grain-market-daily

AHDB. (2024b). *Wheat and barley disease management guide*. Agriculture and Horticulture Development Board. https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/AHDB%20Cereals%20&%20Oilseeds/Disease/Wheat%20and%20barley%20disease%20management%20guide%20(2024).pdf

AHDB. (2025a). *Septoria tritici in winter wheat*. https://ahdb.org.uk/knowledge-library/septoria-tritici-in-winter-wheat

AHDB. (2025b). *Supply and Demand—27 November 2025* (No. 202526). https://projectblue.blob.core.windows.net/media/Default/Market%20Intelligence/cereals-oilseeds/supply-demand/uk-supply-demand/202526%20-%20Nov%20update%202.pdf

AHDB. (2025c). *Winter wheat recommended list (2025-26)*. https://projectblue.blob.core.windows.net/media/Default/RL%20harvest%20results/1.%20Winter%20wheat%20recommended%20list%20(2025-26)-3.pdf

AHDB. (2025d). *Yellow rust symptoms and management in wheat*. https://ahdb.org.uk/yellowrust

Albrecht, M., Kleijn, D., Williams, N. M., Tschumi, M., Blaauw, B. R., Bommarco, R., Campbell, A. J., Dainese, M., Drummond, F. A., Entling, M. H., Ganser, D., Arjen de Groot, G., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., … Sutter, L. (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: A quantitative synthesis. *Ecology Letters*, *23*(10), 1488–1498. https://doi.org/10.1111/ele.13576

Andersons. (2011). *Crop Production Technology: The effect of the loss of plant protection products on uk agriculture and horticulture and the wider-economy*. https://www.nfuonline.com/media/toqlcjrh/the-effect-of-the-loss-of-plant-protection-products-on-uk-agriculture-and-horticulture-and-the-wider-economy.pdf

Antal, G., Szabó, S., Szarvas, P., & Holb, I. J. (2024). Yield and cost–benefit analyses for apple scab sanitation practices in integrated and organic apple management systems. *PLANTS, PEOPLE, PLANET*, *6*(2), 470–489. https://doi.org/10.1002/ppp3.10460

Bąkowski, M., Piekarska-Boniecka, H., & Dolańska-Niedbała, E. (2013). Monitoring of the red-belted clearwing moth, Synanthedon myopaeformis, and its parasitoid Liotryphon crassiseta in apple orchards in yellow Moericke traps. *Journal of Insect Science*, *13*(1), 4. https://doi.org/10.1673/031.013.0401

Beaumelle, L., Tison, L., Eisenhauer, N., Hines, J., Malladi, S., Pelosi, C., Thouvenot, L., & Phillips, H. R. P. (2023). Pesticide effects on soil fauna communities—A meta-analysis. *Journal of Applied Ecology*, *60*(7), 1239–1253. https://doi.org/10.1111/1365-2664.14437

Beckman, J., Ivanic, M., Jellife, J., Baquedano, F., & Scott, S. (2020). *Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies | Economic Research Service*. https://www.ers.usda.gov/publications/pub-details?pubid=99740

Bernardi, A. D., Marini, E., Casucci, C., Tiano, L., Marcheggiani, F., Vischetti, C., Bernardi, A. D., Marini, E., Casucci, C., Tiano, L., Marcheggiani, F., & Vischetti, C. (2022). Copper Monitoring in Vineyard Soils of Central Italy Subjected to Three Antifungal Treatments, and Effects of Sub-Lethal Copper Doses on the Earthworm Eisenia fetida. *Toxics*, *10*(6). https://doi.org/10.3390/toxics10060310

Berry, P. M., Kindred, D. R., & Paveley, N. D. (2008). Quantifying the effects of fungicides and disease resistance on greenhouse gas emissions associated with wheat production. *Plant Pathology*, *57*(6), 1000–1008. https://doi.org/10.1111/j.1365-3059.2008.01899.x

Boix-Fayos, C., & de Vente, J. (2023). Challenges and potential pathways towards sustainable agriculture within the European Green Deal. *Agricultural Systems*, *207*, 103634. https://doi.org/10.1016/j.agsy.2023.103634

Bremmer, J., Deacon, S., Alvarez, L., Arts, G., Huiting, H., & Smit, B. (2020). *Impact Assessment Framework with Specific Protection Goals (SPGs) for Non-Target Terrestrial Plants (NTTPs)*. Wageningen Economic Research. https://doi.org/10.18174/532843

Büchele, F., Neuwald, D. A., Scheer, C., Wood, R. M., Vögele, R. T., & Wünsche, J. N. (2022). Assessment of a Postharvest Treatment with Pyrimethanil via Thermo-Nebulization in Controlling Storage Rots of Apples. *Agronomy*, *12*(1), 34. https://doi.org/10.3390/agronomy12010034

Caffini. (2025). *Vine treatments: The complete calendar for every growth stage*. https://www.caffini.com/en/blog/post/vine-treatments-the-complete-calendar-for-every-growth-stage.html

Candolfi, M. P., Barrett, K. L., Campbell, P. J., Forster, R., Grandy, N., Huet, M.-C., Lewis, G., Oomen, P. A., Schmuck, R., & Vogt, H. (2001). Guidance document on regulatory testing and risk assessment procedures for plant pretection products with non-target arthropods. *ESCORT 2 Workshop (European Standard Characteristics Of Non-Target Arthropod Regulatory Testing*.

CBS. (2025). *Vegetables; yield and cultivated area per kind of vegetable* [Webpagina]. Statistics Netherlands. https://www.cbs.nl/en-gb/figures/detail/37738ENG

Chantry, A., Ridley, L., Parrish, G., Richmond, R., Precious, C., Snell, E., MacArthur, R., & Garthwaite, D. (2024). *Pesticide Usage Survey Report 320—Arable Crops in the United Kingdom 2024*. https://pusstats.fera.co.uk/api/report-download/699

CORDIS. (2017). *Combining innovation in vineyard management and genetic diversity for a sustainable European viticulture*. CORDIS. https://cordis.europa.eu/project/id/311775/reporting

Cossentine, J. E., & Kuhlmann, U. (2000). Status of Ageniaspis fuscicollis (Hymenoptera: Encrytidae), an introduced parasitoid of the apple ermine moth (Lepidoptera: Yponomeutidae. *Canadian Entomologist - CAN ENTOMOL*, *132*, 685–689. https://doi.org/10.4039/Ent132685-5

Crop Solutions. (2026). Insect Nets. *Crop Solutions*. https://www.cropsolutions.co.uk/products/insect-nets/

CTGB. (2026). *CTGB Admissions*. https://pesticidesdatabase.ctgb.nl/en/authorisations

Culliney, T. W. (2013). Role of Arthropods in Maintaining Soil Fertility. *Agriculture*, *3*(4), 629–659. https://doi.org/10.3390/agriculture3040629

Danelski, W., Kruczynska, D., BIELICKI, P., & Rozpara, E. (2017). Variation in damage levels by codling moth to ten apple cultivars in an organic orchard in Poland. *TURKISH JOURNAL OF AGRICULTURE AND FORESTRY*, *41*, 121–126. https://doi.org/10.3906/tar-1612-76

de Snoo, G. R. (1999). Unsprayed field margins: Effects on environment, biodiversity and agricultural practice. *Landscape and Urban Planning*, *46*(1), 151–160. https://doi.org/10.1016/S0169-2046(99)00039-0

Defra. (2025a). *Cereal and oilseed areas in England at 1 June 2025*. GOV.UK. https://www.gov.uk/government/statistics/cereal-and-oilseed-rape-areas-in-england/cereal-and-oilseed-areas-in-england-at-1-june-2025

Defra. (2025b). *Farm business income*. GOV.UK. https://www.gov.uk/government/statistics/farm-business-income

Dewar, A., Ferguson, A., Pell, J., Nicholls, C., & Watts, J. (2016). *A review of pest management in cereals and oilseed rape in the UK* (No. RR86). AHDB Cereals & Oilseeds. https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Cereals%20and%20Oilseed/rr86.pdf

Doermann, L. (2025). The Hidden Logic Behind Poland's Stunningly Striped Fields. *SciTechDaily*. https://scitechdaily.com/the-hidden-logic-behind-polands-stunningly-striped-fields/

ECIU. (2025). *Loaves of bread analysis*. https://ca1-eci.edcdn.com/Loaves-of-bread-analysis-ECIU-Oct25.pdf?v=1759824786

EFSA. (2015). Scientific Opinion addressing the state of the science on risk assessment of plant protection products for non-target arthropods. *EFSA Journal*, *13*(2), 3996. https://doi.org/10.2903/j.efsa.2015.3996

EFSA, E. F. S., Adriaanse, P., Arts, G., Lassen, S. B., Chaton, P.-F., Fuerst, M., Ingels, B., Pieper, S., Rundlof, M., Sousa, J. P., Van Eekelen, R., Arena, M., Fait, G., Ippolito, A., Padovani, L., Sharp, R., & Auteri, D. (2025). Analysis of the evidence to support the definition of specific protection goals for terrestrial organisms—Part 1: Proposed strategy. *EFSA Journal*, *23*(6), e9501. https://doi.org/10.2903/j.efsa.2025.9501

Estrada-Carmona, N., Sánchez, A. C., Remans, R., & Jones, S. K. (2022). Complex agricultural landscapes host more biodiversity than simple ones: A global meta-analysis. *Proceedings of the National Academy of Sciences*, *119*(38), e2203385119. https://doi.org/10.1073/pnas.2203385119

EU CAP. (2016). *EIP-AGRI Focus Group on IPM Brassica: Final Report | EU CAP Network*. https://eu-cap-network.ec.europa.eu/publications/eip-agri-focus-group-ipm-brassica-final-report_en#section--resources

European Commission. (2019). *EU Cereal Farms Report 2017*. https://agriculture.ec.europa.eu/system/files/2020-01/fadn-cereal-report-2017_en_0.pdf

European Commission. (2020). *Farm to Fork Strategy*. https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

European Commission. (2021). *Better regulation: Guidelines and toolbox*. https://commission.europa.eu/law/law-making-process/better-regulation/better-regulation-guidelines-and-toolbox_en

European Commission. (2025). *Biodiversity strategy for 2030—Environment*. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

European Council. (2024). *The apple: Pride of Polish orchards and the official fruit of the Polish presidency*. The Apple: Pride of Polish Orchards and the Official Fruit of the Polish Presidency. https://polish-presidency.consilium.europa.eu/en/news/the-apple-pride-of-polish-orchards-and-the-official-fruit-of-the-polish-presidency/

European Parliament. (2009). Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. *Official Journal of the European Union*, *309/1*(24.11.2009).

Eurostat. (2026). *Eurostat Database*. https://ec.europa.eu/eurostat/web/main/home

Fayet, C. M. J., Reilly, K. H., Van Ham, C., & Verburg, P. H. (2022). What is the future of abandoned agricultural lands? A systematic review of alternative trajectories in Europe. *Land Use Policy*, *112*, 105833. https://doi.org/10.1016/j.landusepol.2021.105833

Fera. (2026). *Pesticides usage statistics—Data*. https://pusstats.fera.co.uk/data/times-treated

Fones, H., & Gurr, S. (2015). The impact of Septoria tritici Blotch disease on wheat: An EU perspective. *Fungal Genetics and Biology, Septoria Tritici Blotch Disease of Wheat: Tools and Techniques to Study the Pathogen Zymoseptoria Tritici*, *79*, 3–7. https://doi.org/10.1016/j.fgb.2015.04.004

Food & Wine. (2023). *You'll Be Surprised by How Many Grapes it Takes to Make One Bottle of Wine*. Food & Wine. https://www.foodandwine.com/how-many-grapes-in-wine-8406875

Gardner, E., Breeze, T. D., Clough, Y., Smith, H. G., Baldock, K. C. R., Campbell, A., Garratt, M. P. D., Gillespie, M. A. K., Kunin, W. E., McKerchar, M., Potts, S. G., Senapathi, D., Stone, G. N., Wäckers, F., Westbury, D. B., Wilby, A., & Oliver, T. H. (2021). Field boundary features can stabilise bee populations and the pollination of mass-flowering crops in rotational systems. *Journal of Applied Ecology*, *58*(10), 2287–2304. https://doi.org/10.1111/1365-2664.13948

Garinie, T., Nusillard, W., Lelièvre, Y., Taranu, Z. E., Goubault, M., Thiéry, D., Moreau, J., & Louâpre, P. (2024). Adverse effects of the Bordeaux mixture copper-based fungicide on the non-target vineyard pest *LOBESIA BOTRANA* . *Pest Management Science*, *80*(9), 4790–4799. https://doi.org/10.1002/ps.8195

Garratt, M. P. D., O'Connor, R. S., Carvell, C., Fountain, M. T., Breeze, T. D., Pywell, R., Redhead, J. W., Kinneen, L., Mitschunas, N., Truslove, L., Xavier e Silva, C., Jenner, N., Ashdown, C., Brittain, C., McKerchar, M., Butcher, C., Edwards, M., Nowakowski, M., Sutton, P., & Potts, S. G. (2023). Addressing pollination deficits in orchard crops through habitat management for wild pollinators. *Ecological Applications*, *33*(1), e2743. https://doi.org/10.1002/eap.2743

Genty, L., Meynard, C. N., Bopp, M.-C., Henckel, L., Chayre, A., Gibert, C., & Fried, G. (2026). Intensive management negatively impacts field margin ecosystem service indicators at both field and landscape levels. *Ecological Applications*, *36*(1), e70161. https://doi.org/10.1002/eap.70161

Gianessi, L., & Williams, A. (2011). *Europe's Wheat Yields are the World's Highest Due to Fungicide Use* (International Pesticide Benefits Case Study No. 43). CropLife International. https://croplife.org/case-study/europes-wheat-yields-are-the-worlds-highest-due-to-fungicide-use/

Gorlach, K., Nowak, P., Jastrzębiec-Witowska, A., & Dąbrowski, A. (2018). *Apple production in Malopolska voivodeship*.

Grabowski, M. (2020). Incidence of postharvest fungal diseases of apples in integrated fruit production. *Acta Sci. Pol. Hortorum Cultus*, *20*(1), 123–129. https://doi.org/10.24326/asphc.2021.1.12

Hatt, S., & Döring, T. F. (2023). Designing pest suppressive agroecosystems: Principles for an integrative diversification science. *Journal of Cleaner Production*, *432*, 139701. https://doi.org/10.1016/j.jclepro.2023.139701

Hawkins, N. J., Bass, C., Dixon, A., & Neve, P. (2019). The evolutionary origins of pesticide resistance. *Biological Reviews*, *94*(1), 135–155. https://doi.org/10.1111/brv.12440

Hayes, M. (2025). Wheat's Defenses Breached: New Strain of Yellow Rust Overcomes Key Resistance Gene Across Europe. *BGRI - Borlaug Global Rust Initiative*. https://bgri.cornell.edu/wheats-defenses-breached-new-strain-of-yellow-rust-overcomes-key-resistance-gene-across-europe/

Holland, J., Bown, B., Clarke, J., & McHugh N. (2019). Patterns of cereal aphid infestation in autumn and implications for Barley Yellow Dwarf Virus control. *IOBC-WPRS Bulletin*, *143*. https://iobc-wprs.org/product/patterns-of-cereal-aphid-infestation-in-autumn-and-implications-for-barley-yellow-dwarf-virus-control/

Hossard, L., Philibert, A., Bertrand, M., Colnenne-David, C., Debaeke, P., Munier-Jolain, N., Jeuffroy, M. H., Richard, G., & Makowski, D. (2014). Effects of halving pesticide use on wheat production. *Scientific Reports*, *4*(1), 4405. https://doi.org/10.1038/srep04405

Index Mundi. (2019). *Poland—Arable land (% of land area)*. https://www.indexmundi.com/facts/poland/indicator/AG.LND.ARBL.ZS

IPBES. (2016). *The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production*. https://zenodo.org/records/3402857

IPBES. (2021). *IPBES Core Glossary*. https://www.ipbes.net/glossary-tag/ecosystem-service

Jewell, K., Soriano, B., Fleskens, L., Quaranta, G., Salvia, R., & Iglesias, A. (2025). Exploring the relationship between land abandonment and landscape identity in traditional cultural landscapes: The case of Castelsaraceno, Italy. *Journal of Rural Studies*, *119*, 103802. https://doi.org/10.1016/j.jrurstud.2025.103802

Kenfaoui, J., Radouane, N., Mennani, M., Tahiri, A., Ghadraoui, L. E., Belabess, Z., Fontaine, F., Hamss, H. E., Amiri, S., Lahlali, R., & Barka, E. A. (2022). A Panoramic View on Grapevine Trunk Diseases Threats: Case of Eutypa Dieback, Botryosphaeria Dieback, and Esca Disease. *Journal of Fungi*, *8*(6). https://doi.org/10.3390/jof8060595

Kumar, P. (Ed.). (2011). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Routledge. https://doi.org/10.4324/9781849775489

Lasanta, T., Nadal-Romero, E., & Arnáez, J. (2015). Managing abandoned farmland to control the impact of re-vegetation on the environment. The state of the art in Europe. *Environmental Science & Policy*, *52*, 99–109. https://doi.org/10.1016/j.envsci.2015.05.012

MA. (2005). *Millennium Ecosystem Assessment*. https://www.millenniumassessment.org/en/index.html

Masny, S. (2017). Occurrence of Venturia inaequalis races in Poland able to overcome specific apple scab resistance genes. *European Journal of Plant Pathology*, *147*(2), 313–323. https://doi.org/10.1007/s10658-016-1003-x

McKirdy, A. (2018). AHDB to invest in BYDV management in cereal crops. *Crop Production Magazine*. https://www.cpm-magazine.co.uk/news/ahdb-invest-bydv-management-cereal-crops/

Moreno-de-las-Heras, M., Lindenberger, F., Latron, J., Lana-Renault, N., Llorens, P., Arnáez, J., Romero-Díaz, A., & Gallart, F. (2019). Hydro-geomorphological consequences of the abandonment of agricultural terraces in the Mediterranean region: Key controlling factors and landscape stability patterns. *Geomorphology*, *333*, 73–91. https://doi.org/10.1016/j.geomorph.2019.02.014

Moretti, E., & Benzaquen, M. (2025). Mitigating farmland biodiversity loss: A bio-economic model of land consolidation and pesticide use. *Royal Society Open Science*, *12*(12), 251000. https://doi.org/10.1098/rsos.251000

OIV. (2025a). *OIV 2025 World Wine Production Outlook—First estimates 2025*. International Organisation of Vine and Wine. https://www.oiv.int/sites/default/files/documents/OIV_2025_World_Wine_Production_Outlook.pdf

OIV. (2025b). *State of the World Vine and Wine Sector in 2024*. International Organisation of Vine and Wine. https://www.oiv.int/sites/default/files/documents/OIV-State_of_the_World_Vine-and-Wine-Sector-in-2024.pdf

Ortego, J., Albrecht, M., Báldi, A., Bilde, T., Craig, S. B. B., Herrera, J. M., Hood, A. S. C., Kleijn, D., Maurer, C., Molina, F. P., Öckinger, E., Potts, S. G., Settepani, V., Thomsen, P. F., Trillo, M., Vajna, F., Velado-Alonso, E., & Bartomeus, I. (2024). Seminatural areas act as reservoirs of genetic diversity for

crop pollinators and natural enemies across Europe. *Conservation Science and Practice*, *6*(5), e13080. https://doi.org/10.1111/csp2.13080

PwC. (2024). *Economic social and environmental importance-of the wine sector in the EU*. https://www.ceev.eu/medias/5983/March-2024-Report-PwC-Economic-social-and-environmental-importance-of-the-wine-sector-in-the-EU-compressed.pdf

Quintas-Soriano, C., Buerkert, A., & Plieninger, T. (2022). Effects of land abandonment on nature contributions to people and good quality of life components in the Mediterranean region: A review. *Land Use Policy*, *116*, 106053. https://doi.org/10.1016/j.landusepol.2022.106053

Redman, G. (2024). *Nix Farm Management Pocketbook 2025 Edition*. Agro Business Consultants Ltd. https://theandersonscentre.co.uk/store/nix-farm-management-pocketbook-56th-edition/

Ridley, L., Parrish, G., Chantry, A., Richmond, R., MacArthur, R., & Garthwaite, D. (2022). *Pesticide Usage Survey Report 309—Arable Crops in the United Kingdom 2022*. https://pusstats.fera.co.uk/api/report-download/699

Schiavo, M., Le Mouël, C., Poux, X., & Aubert, P.-M. (2023). The land use, trade, and global food security impacts of an agroecological transition in the EU. *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1189952

Sobiczewski, P., Pulawska, J., Berczynski, S., & Konicka, M. (1999). Fire blight detection and control in Poland. *Acta Horticulturae*, (489), 115–120. https://doi.org/10.17660/ActaHortic.1999.489.16

Stearns, S. (2021). *Perimeter Trap Cropping Works! | Integrated Pest Management*. https://ipm.cahnr.uconn.edu/perimeter-trap-cropping-works/

Steele, T. N., Schürch, R., Ohlinger, B. D., & Couvillon, M. J. (2022). Apple orchards feed honey bees during, but even more so after, bloom. *Ecosphere*, *13*(9), e4228. https://doi.org/10.1002/ecs2.4228

Strutt & Parker. (2023). Attention to detail key to improving arable profit margins. *Strutt & Parker - Rural Hub*. https://rural.struttandparker.com/article/attention-to-detail-key-to-improving-arable-profit-margins/

Südtirol Apfel. (2026). *All About Apples – Nutrition, Storage & Facts*. Consisto GmbH. https://www.southtyroleanapple.com/en/info/all-about-apples.html

Tamburini, G., Pereira-Peixoto, M.-H., Borth, J., Lotz, S., Wintermantel, D., Allan, M. J., Dean, R., Schwarz, J. M., Knauer, A., Albrecht, M., & Klein, A. (2021). Fungicide and insecticide exposure adversely impacts bumblebees and pollination services under semi-field conditions. *Environment International*, *157*, 106813. https://doi.org/10.1016/j.envint.2021.106813

Tarolli, P., Preti, F., & Romano, N. (2014). Terraced landscapes: From an old best practice to a potential hazard for soil degradation due to land abandonment. *Anthropocene, Landscapes in the Anthropocene*, *6*, 10–25. https://doi.org/10.1016/j.ancene.2014.03.002

Torquati, B., Giacchè, G., & Venanzi, S. (2015). Economic analysis of the traditional cultural vineyard landscapes in Italy. *Journal of Rural Studies*, *39*, 122–132. https://doi.org/10.1016/j.jrurstud.2015.03.013

van der Meer, M., Kay, S., Lüscher, G., & Jeanneret, P. (2020). What evidence exists on the impact of agricultural practices in fruit orchards on biodiversity? A systematic map. *Environmental Evidence*, *9*(1), 2. https://doi.org/10.1186/s13750-020-0185-z

Vilumets, S., & Kaasik, R. (2025). *Report on the effect of land abandonment on agrobiodiversity and Ecosystem Services* (Framework D4.4). https://ec.europa.eu/research/participants/documents/downloadPublic?appId=PPGMS&documentIds=080166e51ac6712f

Vincent, C., & Lasnier, J. (2024). Hoplocampa testudinea Klug, European Apple Sawfly / Hoplocampe des pommes (Hymenoptera: Tenthredinidae). In *Biological Control Programmes in Canada, 2013-2023* (pp. 251–256). https://doi.org/10.1079/9781800623279.0026

Vinetur. (2026). *The ultimate wine magazine*. https://www.vinetur.com/en/home/

Vinitaly. (2024). *Wine & Vinitaly: Without wine Italy would lose 1.1% of gdp and annual revenue for the country of 45.2 billion euros*. Vinitaly. https://www.vinitaly.com/en/press/press-releases/wine-vinitaly-without-wine-italy-would-lose-11-of-gdp-and-annual-revenue-for-the-country-of-452-billion-euros/

Warabieda, W. (2015). Effect of two-spotted spider mite population (Tetranychus urticae Koch) on growth parameters and yield of the summer apple cv. Katja. *Horticultural Science*, *42*(4), 167–175. https://doi.org/10.17221/259/2014-HORTSCI

Wesseler, J. (2022). The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics. *Applied Economic Perspectives and Policy*, *44*(4), 1826–1843. https://doi.org/10.1002/aepp.13239

White, S., Telling, S., Griffiths, H., Skirvin, D., Williamson, M., Ellis, S., Schaare, T., Granger, R., & Potter, O. (2023). *Management of aphid and BYDV risk in winter cereals* (Project Report No. 646). AHDB Cereals & Oilseeds. https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Cereals%20and%20Oilseed/2023/PR646%20final%20project%20report.pdf

WHO. (2015). *Sustainable Development Goals*. https://www.who.int/europe/about-us/our-work/sustainable-development-goals

Wilson, H., & Daane, K. M. (2017). Review of Ecologically-Based Pest Management in California Vineyards. *Insects*, *8*(4). https://doi.org/10.3390/insects8040108

WITS. (2026). *Netherlands White and red cabbages, kohlrabi, kale...etc, f exports by country 2018*. https://wits.worldbank.org/trade/comtrade/en/country/NLD/year/2018/tradeflow/Exports/partner/ALL/product/070490

7 APPENDIX 1 – ECOSYSTEM SERVICE EVALUATION

Key for Table 7-1, 6-2, and 6-3:

	In-field: material change in service provision and potential for change across scenarios
	Off-field: material change in service provision and potential for change across scenarios
	In-field and off-field: material change in service provision and potential for change across scenarios
	Not prioritised: only non-material change anticipated OR considered as part of another ecosystem service to avoid double counting across services

7.1 Relevance of Ecosystem services to NTAs

Table 7-1 Anticipated presence or absence of ecosystem services in-field and off-field and relevance to NTAs

				In-field			Off-field			ES Relevance to NTAs
Code	**Ecosystem Service (ES)**	**Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)**	**SPU (agro-ecosystems)**	**Presence (Y/N)**	**Baseline service provision (low/ moderate /high)**	**Beneficiaries**	**Presence (Y/N)**	**Baseline service provision (low/ moderate/ high)**	**Beneficiaries**	**Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.**
Provisioning Services (ES that describe the material or energy outputs from ecosystems, including food, water and other resources)										
ES1a	**Food (in-field crop production)**	Ecosystems provide the conditions for growing food. Food comes principally from managed agro ecosystems but marine and freshwater systems	Crop	Y	High	Farmer, consumers	N	n/a	n/a	**None**: NTAs do not directly provide food for humans. They have minor contributions through harvested insect products,

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
		or forests also provide food for human consumption.								but in an arable SPG context, this is irrelevant.
ES1b	**Raw materials (in-field)**	Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels, fodder and plant oils that are directly derived from wild and cultivated plant species.	Crop	Y	High	Farmer, consumers	N	n/a	n/a	**None**: Not provided by NTAs in arable fields.
ES2	**Wild foods**	Ecosystems provide the conditions for growing food. Wild foods from forests are often underestimated.	Wild species foraged for food (or medicine)	Y	n/a	n/a	Y	Low to high (context dependent)	Collectors (local community, recreational users and consumers)	**Low**: NTAs may directly provide food for humans, especially in some societies with traditions of consuming invertebrates, though less likely to be relevant in Europe. They also have minor contributions through harvested insect products.
ES3	**Freshwater (groundwater)**	Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally.	Plants and soil organisms supporting them	Y	Potentially high	Farmers, local community	Y	Low to high (context dependent)	Local community	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
ES4	**Freshwater (surface water)**	Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally.	Plants	Y	Low to high (context dependent)	Local community, recreational users	Y	Low to high (context dependent)	Local community, recreational users	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.
ES5	**Medicinal resources (off field)**	Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing the raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.	Wild species foraged for medicinal uses	N	n/a	n/a	Y	Low to moderate (context dependent)	n/a	**Low**: Some arthropods are sources of medicinal compounds, but it is negligible in this context.
Regulating Services (services that ecosystems provide by acting as regulators, such as, regulating the quality of air and soil or by providing flood and disease control)										
ES6	**Local climate and air quality**	Trees provide shade whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.	Plants	Y	Low to moderate	Local and regional population	Y	Low to high (context dependent)	Local and regional population	**Low**: NTAs have a negligible role compared to plants and soils.
ES7	**Erosion prevention and maintenance of soil fertility. Carbon sequestration**	Soil erosion is a key factor in the process of land degradation and desertification. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and	Soil organisms (surface active detritovores, soil arthropods, microorganisms, macroorganisms such as	Y	Low to moderate	Farmer	Y	Low to high (context dependent)	Other farmers/landowners, local communities	**Low**: Surface-active detritivores and soil arthropods contribute to litter breakdown, soil structure, and fertility. These are considered in-soil organisms and not

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
	and storage	agriculture and healthy functioning ecosystems supply the soil with nutrients required to support plant growth. Ecosystems regulate the global climate by storing and sequestering greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. In this way, forest ecosystems are carbon stores. Biodiversity also plays an important role by improving the capacity of ecosystems to adapt to the effects of climate change.	earthworms) and rooted plants							NTAs with PPPs applied not directly to soil. Therefore, NTAs do not have a role here. However, when PPPs are applied directly to soil, these arthropods are considered NTAs. There is not typically a litter layer in an agricultural setting (perhaps minorly in-field borders or orchards, for example), thus their influence is minor.
ES8	**Moderation of extreme events**	Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. For example, wetlands can soak up flood water whilst trees can stabilize slopes. Coral reefs and mangroves help protect coastlines from storm damage.	Rooted plants in flood plains	Y	Low to moderate	Local communities	Y	Low to high (context dependent)	Local communities	**None**: No direct role for NTAs.

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
ES9	**Waste-water treatment**	Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.	Plants, fauna, macrofauna, bacteria and fungi	Y	Low to moderate	Farmer	Y	Low to high (context dependent)	Other farmers/landowners, local communities	**Low**: Dung beetles, for example, aid in waste removal, reducing pathogens, and improving nutrient cycling. Other arthropods that do this are considered in-soil organisms, not NTAs. However, this is negligible compared to microbes, plants, and soils.
ES10	**Pollination**	Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats. Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee (Klein et al, 2007).	NTA pollinators include bees, hoverflies, butterflies and other species. Plants provide habitat and food that supports pollinators	Y	Low to moderate (context-dependent)	Farmer, local communities, consumers	Y	Low to high (context dependent)	Other farmers/landowners, local communities	**None-High (context dependent)**: NTA pollinators **(**flies, beetles, butterflies, moths, wild bees etc.**)** provide pollination services to some crops and wild plants. Relevance in-field is crop dependant **(**e.g. monocots are wind-pollinated, so no relevance**)**. Without insect pollination 12% of global crops would not or hardly produce, 28% would see a substantial reduction in quantity or quality and for 52% of the crops, pollinators only provide limited or no contribution **(**remaining 8% unknown**)**.

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
										In terms of global production volumes, 60% of production comes from crops that do not depend on animal pollination **(**e.g., cereals and root crops**)**, 35% of production comes from crops that depend at least in part on animal pollination and 5% have not been evaluated **(**established but incomplete**)**. If this is translated to agricultural productivity 5-8% of global crop production depends on pollinators (IPBES, 2016).
ES11	**Biological control**	Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.	Beneficial NTAs (natural enemies such as ladybirds, ground beetles, lacewings, spiders, parasitic wasps), vertebrate predators, and fungal species. Plants provide habitat and food that supports these	Y	Low to moderate (crop-dependant)	Farmer, consumers	Y	Low to high (context dependent)	Other farmers/landowner, local community	**Low-Moderate**: Predatory and parasitic NTAs regulate pest populations, but relevance in-field is crop-dependant. For example, flower strips can enhance pest control services in adjacent fields by 16% on average. However, effects yield may be variable (Albrecht et al., 2020).

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
Cultural Services (non-material benefits people obtain from contact with ecosystems, including aesthetic, spiritual and psychological benefits)										
ES12	**Spiritual experience and sense of place (off-field)**	In many parts of the world natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.	Particular NTAs and plant species (crop and NTTPs), trees, patches of vegetation and ecosystems as landscape features, landscape elements/habitats	Y	Moderate to high	Farmers, local community	Y	Low to high (context dependent)	Local community, recreational users, wild food consumers	**Low**: Certain NTAs used to feature in cultural symbolism and traditional practices. This can include scarab beetles in Egypt, bees in many religions like Hinduism and Islam, and dragonflies in Japan. However, the reverence for these NTAs is largely not practiced today in EU, thus the influence of NTAs on this ES is minor.
ES13	**Tourism**	Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008 global earnings from tourism summed up to US$ 944 billion. Cultural and eco-tourism can also educate people about the importance of biological diversity.	Attractive plants and vegetation, plant species that provide habitat to vertebrates (e.g. bird watching) and attractive NTAs (e.g., butterflies, dragonflies)	Y	Low to high (context dependent)	Tourists, farmers, local communities	Y	Low to high (context dependent)	Tourists, local communities	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance ecotourism. NTAs could also have negative impacts on tourism e.g. presence of biting insects or those attracted to waste.
ES14	**Aesthetic appreciation and inspiration for**	Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural	Particular plant species such as flowering plants (also attractive NTAs and	Y	Low to high (context dependent)	Local populations, recreational users	Y	Low to high (context dependent)	Local populations, recreational users	**Low-High (context dependent):** Attractive NTAs provide aesthetic

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
	culture, art, design	landscapes have been the source of inspiration for much of our art, culture and increasingly for science.	vertebrates attracted by the habitat provided by plant species), structures constructed and/or modified by their typical biota.							value and cultural inspiration.
ES15	**Recreation and mental and physical health**	Walking and playing sports in green space is not only a good form of physical exercise but also lets people relax. The role that green space plays in maintaining mental and physical health is increasingly being recognized, despite difficulties of measurement.	Attractive NTAs and appreciated agricultural landscapes (e.g. fields bordered by hedgerows) and semi-natural habitats, wild foods providing foraging opportunities for local population and recreational users (crop and NTTPs)	Y	Low to high (context dependent)	Local populations, recreational users	Y	Low to high (context dependent)	Local populations, recreational users, wild food consumers	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance recreation and mental health. NTAs could also have negative impacts e.g. presence of biting insects or those attracted to waste, which may also spread disease.
Habitat or supporting services (underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals)										
ES16	**Maintenance of genetic biodiversity**	Genetic diversity is the variety of genes between and within species populations. Genetic diversity distinguishes different breeds or races from each other thus providing the basis for locally well adapted	Habitats large enough to contain a sufficient number of effectively mating and reproducing species to prevent	Y	Low	Farmer (e.g., greater resilience in crop production such as maintaining	Y	Low to high (context dependent)	Local communities	**Low-High (context dependent):** NTA species richness and functional diversity provide resilience, redundancy, and future options for ecosystems and

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
		cultivars and a gene pool for further developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as 'biodiversity hotspots'.	reduction of genetic biodiversity and maintain evolutionary processes to safeguard their potential for continuous adaptation. Genetic biodiversity of crop plants is acknowledged but is not considered relevant for this assessment as it is not affected by the choice of weed control methods and remains unchanged across scenarios.			predator-prey relationships), local community				agriculture. Pollinators can ensure gene flow between plant populations. Plant pollination by NTAs can ensure diverse plant populations reproduce.
ES17	**Habitat for species (functioning of ecological components of the agro ecosystem)**	Habitats provide everything that an individual plant or animal needs to survive: forage; water; and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon	Habitats large enough to support organisms or communities of organisms. Includes ecosystem engineers (e.g. earthworms,	Y	Low to moderate (note: in-field, the crop defines the habitat during the cropping season,	Farmer, local community	Y	Low to high (context dependent)	Local communities	**Low-High (context dependent):** NTAs form part of farmland biodiversity, creating prey and microhabitats for higher trophic levels and sustaining ecosystem function.

Code	Ecosystem Service (ES)	Definitions adapted from Bremmer *et al.* 2020 (which used The Economics of Ecosystems and Biodiversity [TEEB] approach, 2010)	SPU (agro-ecosystems)	In-field			Off-field			ES Relevance to NTAs
				Presence (Y/N)	Baseline service provision (low/ moderate /high)	Beneficiaries	Presence (Y/N)	Baseline service provision (low/ moderate/ high)	Beneficiaries	Relevance of NTAs to ES (None, Low, Moderate, High) and explanation.
		different ecosystems during their movements.	plants) and large plants and animals that provide surfaces for periphytic organisms, hedgerows.		NTTPs provide habitat and food for herbivores after harvest)					

7.2 Changes in Ecosystem services across scenarios

Table 7-2. Anticipated changes in ecosystem service delivery across scenarios. Scenario 1 = Current practice in 2025, Scenario 2 = Prioritising in-field NTA protection over ES food production. Scenario 3 = Balancing ES food production but with increased focus on off-field NTA protection and Scenario 4 - Prioritising NTA protection over ES food production and increased focus on off-field environmental protection

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
Provisioning Services (ES that describe the material or energy outputs from ecosystems, including food, water and other resources)													

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES1a	**Food (in-field crop production)**	**None**: NTAs do not directly provide food for humans. They have minor contributions through harvested insect products, but in an arable SPG context, this is irrelevant.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements. Insecticides protect against crop damage from pests, and fungicides protect against disease, in-field. 'Typical' management practices which balance crop yield with non-target arthropod protection, but may utilise aspects of e.g. IPM alongside the use of PPPs. Off-field conforms with current legal requirements.	Y	Predict loss of broad-spectrum active substances and/or reduction in application rates; increased use of more targeted active substances; increased use of precision application; increased use of alternative protections e.g. insect mesh; increased use of resistant crop varieties. Yield loss anticipated due to increased pest and disease pressure where alternative methods are not sufficient to bridge PPP gap.	Y	Predict increased buffer zones to protect off-field NTAs - results in decreased cropped area; increased use of drift-reducing technologies to reduce off-field drift; possible reduction in application rates where former are not sufficient to protect off-field. Yield loss anticipated due to decreased cropped area and possible increased pest and disease pressure with reduced application rates.	Y	Yield loss anticipated due to increased pest and disease pressure where alternative methods are not sufficient to bridge PPP gap; decreased cropped area due to increased buffer zones; possible creation of in-field compensation areas; possible creation of off-field habitat to facilitate recovery; possible changes in timing/cropping depending on economic impact.	Published and grey literature; agronomy expert input	Y	N (ES not present)
ES1b	**Raw materials (in-field)**	**None**: Not provided by NTAs in arable fields.	Y	See Food above	Y	See Food above	Y	See Food above	Y	See Food above	See Food above	Y	N (ES not present)
ES2	**Wild foods**	**Low**: NTAs may directly provide food for humans, especially in some societies with traditions of	Y	Insecticide / fungicide applied according to label and conforms with	N	Increase protections for NTAs in-field, but NTAs do not significantly	Y	Increased protection of NTAs off-field anticipated with potential beneficial effects for wild food NTAs	Y	Increased protection of NTAs off-field anticipated with potential beneficial effects for wild food NTAs (though likely to	Published and grey literature, national statistical offices and databases.	N	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
		consuming invertebrates. They also have minor contributions through harvested insect products.		current legal requirements.		contribute to wild food in Europe.		(though likely to be minimal). Increased buffer zones potentially increase non-cropped area which could be used for foraging wild foods.		be minimal). Increased buffer zones potentially increase non-cropped area which could be used for foraging wild foods.			
ES3	**Freshwater (groundwater)**	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Reduced insecticide / fungicide use anticipated leading to lower impacts to this ES.	Y	Increased use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones, enforcing drift reducing technologies) may lead to lower impacts to this ES.	Y	Reduced insecticide / fungicide use in-field and increased use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones, enforcing drift reducing technologies) would lead to lower impacts to this ES.	EU and country level statistics (for WFD water bodies); Ecotoxicity test and environmental fate data from dossier	Y	Y
ES4	**Freshwater (surface water)**	**Low**: NTAs are not direct providers. They have an indirect role which is negligible compared to plants/soils.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Reduced insecticide / fungicide use anticipated leading to lower impacts to this ES.	Y	Increased use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones, enforcing drift reducing technologies) may lead to lower impacts to this ES.	Y	Reduced insecticide / fungicide use in-field and increased use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones, enforcing drift reducing technologies) would lead to lower impacts to this ES.	EU and country level statistics (for WFD water bodies); Ecotoxicity test and environmental fate data from dossier	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES5	**Medicinal resources (off-field)**	**Low**: Some arthropods are sources of medicinal compounds, but it is negligible in this context.	Y	Any potential impacts are considered alongside 'wild food'.	N	Any potential impacts are considered alongside 'wild food'. Not considered relevant for in-field.	Y	Any potential beneficial effects are considered alongside 'wild food'. Likely to be minimal.	Y	Any potential impacts are considered alongside 'wild food'. Not considered relevant for in-field. Likely to be minimal	-	N	N (considered alongside 'wild food')
Regulating Services (services that ecosystems provide by acting as regulators, such as, regulating the quality of air and soil or by providing flood and disease control)													
ES6	**Local climate and air quality**	**Low**: NTAs have a negligible role compared to plants and soils.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y (negligible change)	Reduced insecticide / fungicide use anticipated - possible negligible positive impact on emissions due to reduced tractor use (though may be off-set by alternative control methods).	Y (negligible change)	Reduced area covered (increased buffer zones) - possible negligible positive impact on emissions due to reduced tractor use.	Y (negligible change)	Reduced insecticide / fungicide use anticipated - possible negligible positive impact on emissions due to reduced tractor use (though may be off-set by alternative control methods).	Scientific literature on deposition and dispersion rates per type of habitat/vegetation.	N (change is negligible)	N (change is negligible)

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES7	**Erosion prevention and maintenance of soil fertility. Carbon sequestration and storage**	**Low**: Surface-active detritivores and soil arthropods contribute to litter breakdown, soil structure, and fertility. These are considered in-soil organisms and not NTAs with PPPs applied not directly to soil. Therefore, NTAs do not have a role here. However, when PPPs are applied directly to soil, these arthropods are considered NTAs. There is not typically a litter layer in an agricultural setting (perhaps minorly in-field borders or orchards, for example), thus their influence is minor.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements. Current level of protection for soil-dwelling arthropods.	Y	Reduced insecticide / fungicide use anticipated also for soil-directed applications. Possible positive impact on soil fertility by increased populations of soil arthropods	Y	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones) may lead to lower impacts on soil-dwelling arthropods and therefore positive impacts on soil fertility.	Y	Reduced rate of soil-directed insecticides / fungicides and increased buffer zones may lead to lower impacts on soil-dwelling arthropods and therefore positive impacts on soil fertility.	Soil monitoring data (Government databases/maps, research, etc.)	Y	Y
ES8	**Moderation of extreme events**	**None**: No direct role for NTAs.	N/A	Insecticide / fungicide applied according to label and conforms with current legal requirements.	N/A	No anticipated changes	N/A	No anticipated changes	N/A	No anticipated changes	N/A	N/A	N/A

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES9	**Waste-water treatment**	**Low**: Dung beetles, for example, aid in waste removal, reducing pathogens, and improving nutrient cycling. Other arthropods that do this are considered in-soil organisms, not NTAs. However, this is negligible compared to microbes, plants, and soils.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements. Current level of protection for small number of NTAs providing this service (e.g. dung beetles).	Y (negligible change)	Reduced insecticide / fungicide use anticipated. Possible positive impact on the small number of NTAs providing this service (e.g. dung beetles).	Y (negligible change)	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible positive impact on the small number of NTAs providing this service (e.g. dung beetles).	Y (negligible change)	Reduced insecticide / fungicide use and increased buffer zones anticipated. Possible positive impact on the small number of NTAs providing this service (e.g. dung beetles).	Soil monitoring data (Government databases/maps, research, etc.). Ecotoxicity data from activated sludge tests in dossier.	N (change is negligible)	N (change is negligible)
ES10	**Pollination**	**None-High (context dependent)**: NTA pollinators **(**flies, beetles, butterflies, moths, wild bees etc.**)** provide pollination services to some crops and wild plants. Relevance in-field is crop dependant **(**e.g. monocots are wind-pollinated, so no relevance**)**. Without pollination 12% of global crops would not or hardly produce, 28% would see a substantial reduction in quantity or quality	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements. Current level of protection for NTA pollinators.	Y	Reduced insecticide / fungicide use anticipated. Possible positive impact on invertebrate pollinators - particularly where applied to pollinator-attractive crops.	Y	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible increased protection of invertebrate pollinators off-field.	Y	Reduced insecticide / fungicide use and increased buffer zones anticipated. Possible positive impact on invertebrate pollinators in-field and off-field.	Data on distribution and abundance of pollinator species (country level, e.g. via voluntary recording societies)	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
		and for 52% of the crops, pollinators only provide limited or no contribution **(**remaining 8% unknown**)**.											
ES11	**Biological control**	**Low-Moderate**: Predatory and parasitic NTAs regulate pest populations, but relevance in-field is crop-dependant. For example, flower strips can enhance pest control services in adjacent fields by 16% on average. However, effects yield may be variable (Albrecht et al. 2020).	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Possible increase in NTAs relevant to biological control due to reduced use of broad-spectrum insecticides and increased use of alternative control methods e.g. in-field compensation areas, and creation of off-field habitat to facilitate recovery	Y	Possible increase in NTAs relevant to biological control due to use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones).	Y	Possible increase in NTAs relevant to biological control in- and off-field due to reduced use of broad-spectrum insecticides and increased use of alternative control methods e.g. in-field compensation areas, and creation of off-field habitat to facilitate recovery; and use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones).	Farm business surveys, national statistics	Y	Y
Cultural Services (non-material benefits people obtain from contact with ecosystems, including aesthetic, spiritual and psychological benefits)													
ES12	**Spiritual experience and sense of place (off-field)**	**Low**: Certain NTAs used to feature in cultural symbolism and traditional practices. This can include scarab beetles in Egypt, bees in many religions like Hinduism and Islam,	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Change of landscapes due to lack of economic viability could have negative effects on community sense of place. Knock-on effects of other ESs.	↗	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible minor positive impact NTAs off-field.	↗	Change of landscapes due to lack of economic viability could have negative effects on community sense of place. Knock-on effects of other ESs.Use of certain agricultural practices to protect off-field	Context specific - published and grey literature	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
		and dragonflies in Japan. However, the reverence for these NTAs is largely not practiced today in EU, thus the influence of NTAs on this ES is minor.								NTAs (e.g. increasing buffer zones). Possible minor positive impact NTAs off-field.			
ES13	Tourism	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance ecotourism. NTAs could also have negative impacts on tourism e.g. presence of biting insects or those attracted to waste.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Reduced insecticide / fungicide use anticipated. Possible increase in attractive NTAs in-field, which may enhance ecotourism. However, also possible increase in negative-impact NTAs such as biting insects. Knock-on effects of other ESs.	Y	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible minor increase in attractive NTAs off-field, which may enhance ecotourism. However, also possible minor increase in negative-impact NTAs such as biting insects. Knock-on effects of other ESs.	Y	Reduced insecticide / fungicide use anticipated. Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible minor increase in attractive NTAs on- and off-field, which may enhance ecotourism. However, also possible minor increase in negative-impact NTAs such as biting insects. Knock-on effects of other ESs.	Tourism statistics at EU and country level, published and grey literature	Y	Y
ES14	**Aesthetic appreciation and inspiration for culture, art, design**	**Low-High (context dependent):** Attractive NTAs provide aesthetic value and cultural inspiration.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Similar impacts to 'tourism'.	Y	Similar impacts to 'tourism'.	Y	Similar impacts to 'tourism'.	Published and grey literature, local cultural data	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES15	**Recreation and mental and physical health**	**Low-High (context dependent)**: Attractive NTAs (e.g., butterflies, dragonflies) enhance recreation and mental health. NTAs could also have negative impacts e.g. presence of biting insects or those attracted to waste, which may also spread disease.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Similar impacts to 'tourism'.	Y	Similar impacts to 'tourism'.	Y	Similar impacts to 'tourism'.	Published and grey literature, local recreation and visitor surveys.	Y	Y
Habitat or supporting services (underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals)													
ES16	**Maintenance of genetic biodiversity**	**Low-High (context dependent):** NTA species richness and functional diversity provide resilience, redundancy, and future options for ecosystems and agriculture. Pollinators can ensure gene flow between plant populations. Plant pollination by NTAs can ensure diverse plant populations reproduce.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements. Current levels of protection for NTA populations.	Y	Reduced insecticide / fungicide use anticipated. Possible increase in numbers of individuals and diversity of species in-field. Greater numbers of NTAs can lead to increased genetic biodiversity and improve genetic resilience.	Y	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible increase in numbers of individuals and diversity of species off-field. Greater numbers of NTAs can lead to increased genetic biodiversity and improve genetic resilience.	Y	Reduced insecticide / fungicide use anticipated. Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible increase in numbers of individuals and diversity of species in- and off-field. Greater numbers of NTAs can lead to increased genetic biodiversity and improve genetic resilience.	Published and grey literature	Y	Y

ES code	Ecosystem service (ES)	Relevance of NTAs to ES (none, low, moderate, high) and explanation.	Scenario 1: status quo		Scenario 2: increased in-field protection, status quo off-field		Scenario 3: increased off-field protection, status quo in-field		Scenario 4: increased in-field and off-field protection		Ecosystem data availability	Prioritised for assessment IN-FIELD (Y / N)	Prioritised for assessment OFF-FIELD (Y / N)
			Presence Y/N	Impacts / effects	Change Y/N	Impacts / effects (Off-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field remains as Scenario 1.)	Change Y/N	Impacts / effects (In-field impacts as Scenario 2; off-field impacts as Scenario 3.)			
ES17	**Habitat for species (functioning of ecological components of the agro ecosystem)**	**Low-High (context dependent):** NTAs form part of farmland biodiversity, creating prey and microhabitats for higher trophic levels and sustaining ecosystem function.	Y	Insecticide / fungicide applied according to label and conforms with current legal requirements.	Y	Reduced insecticide / fungicide use anticipated. Possible increase in numbers of individuals and diversity of species in-field. Greater number of species of NTAs can lead to increased habitat value.	Y	Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible increase in numbers of individuals and diversity of species in-field. Greater number of species of NTAs can lead to increased habitat value.	Y	Reduced insecticide / fungicide use anticipated. Use of certain agricultural practices to protect off-field NTAs (e.g. increasing buffer zones). Possible increase in numbers of individuals and diversity of species in- and off-field. Greater number of species of NTAs can lead to increased habitat value.	Published and grey literature, land cover data	Y	Y

8 APPENDIX 2 – QUESTIONNAIRE

1030541_Wheat UK Questionnaire.xlsx