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The Impact Indicator for Priority Pests (I2P2): a tool for ranking pests according to Regulation (EU) No 2016/2031

Sánchez, Berta
Barreiro-Hurle, Jesús
Soto Embodas, Iria
Rodriguez-Cerezo, Emilio

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Joint Research Centre

EUR 29793 EN

Contact information
Address: C/ Inca Garcilaso 3. Edificio EXPO. E-41092 Seville (Spain)
Email: jrc-d4-secretariat@ec.europa.eu
Tel.: +34 954 48 8252

JRC Science Hub
https://ec.europa.eu/jrc

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Table of contents

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Abstract

This technical report describes the composite indicator developed by the JRC to rank plant pests, based on their potential economic, social and environmental impact in the EU. This indicator can then be used to inform policymakers implementing the Plant Health Regulation with regards to identification of priority pests. It presents the theoretical framework for the construction of the composite impact indicator for prioritisation of pests (I2P2), and defines and discusses the individual indicators which compose the I2P2, together with the data sources used to calculate them using *T. indica* as an example. Lastly, the I2P2 is applied to a set of 28 Union quarantine pests to show its performance. Using the data for these 28 pests, consistency and robustness checks are applied to test the internal validity of the indicator.

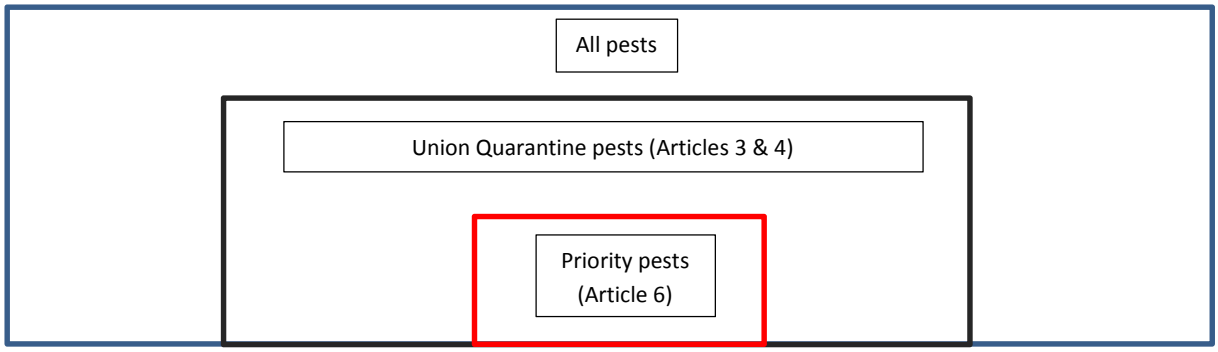
1 Introduction

Globalisation and climate change are shifting the landscape of plant pest distribution (Kriticos et al., 2013). The change in plant pest distribution is recognised as a threat to plant health, which is a key element for plant production, forests, natural and planted areas, natural ecosystems, ecosystem services and biodiversity in the European Union territory. This threat is not only theoretical, as in the last decade the EU has been confronted with several large-scale outbreaks of new plant pests[1] with significant impacts (Pautasso et al., 2015; Roques et al., 2016).

Against this background, EU Plant Health legislation underwent a significant revision in 2016 with the adoption of Regulation (EU) No 2016/2031 (OJEU, 2016), commonly referred to as the Plant Health Law. Among the measures included in this legislation, it is foreseen that pests will be classified according to some specific characteristics. Starting from the broadest group (i.e. the universe of pests), Article 3 of the legislation defines a first subset of pests, known as 'quarantine pests'. Quarantine pests in the framework of the European Union are referred to as 'Union quarantine pests' (Article 4). Such pests shall not be introduced into, moved within, or held, multiplied or released in the Union territory.

Article 6 and Annex I define another subset of pests, those referred to as 'priority pests'. Priority pests are those Union quarantine pests for which the most severe impacts, from an economic, environmental and social perspective, are expected. Annex 1 Section 2 provides an overview of the aspects for which impacts have to be evaluated, in order to select priority pests and include direct and indirect economic losses (i.e. crop losses, costs of control measures, employment, food security and safety, and biodiversity). The Commission will adopt a delegated act to establish a list of priority pests.

Figure 1. Graphical representation of pests according to the classification put forward in Regulation 2016/2031



Note: the figure is not to scale

Inclusion of a specific pest on this list implies that Member States will have to carry out annual surveys (Article 24); draw up and keep up to date a contingency plan (Article 25); carry out simulation exercises concerning implementation of the contingency plans (Article 26); and if presence is confirmed in their territory, adopt an action plan for eradication or containment based

[1] http://ec.europa.eu/food/fvo/news_detail.cfm?id=65

on the contingency plan (Article 27). The hierarchy of pests according to this assessment is summarised in Figure 1. This report focuses on the process to move from Union quarantine pests to priority pests using the Impact Indicator for Priority Pests (I2P2), a composite indicator designed by the JRC specifically for this. This indicator will be calculated for a list of Union quarantine pests put forward by DG SANTE following consultation with the members of the Expert Group on Plant Health Legislation (EGPHL) (Annex I). The indicator could also be used for the assessment of additional pests during the next phases of the Plant Health Regulation implementation.

Based on the information provided by EFSA, the 28 pests can be classified into three groups depending on the type of hosts for which the impacts have been calculated: crops, forestry and combination of the previous two (agroforestry). The classification of the 28 pests using this criterion is presented in Table 1. This classification will be used to form specific rankings (see section 2.4).

Table 1. Classification of pests by type of host for which EFSA has provided impact parameter data.

Pest	Type of host		
	Crops	**Forestry**	**Agroforestry**
Agrilus anxius		**X**	
Agrilus planipennis		**X**	
Anastrepha luden	**X**		
Anoplophora chinensis			**X**
Anoplophora glabripennis		**X**	
Anthonomus eugenii	**X**		
Aromia bungii			**X**
Bactericera cockerelli	**X**		
Bactrocera dorsalis (including B. invadens)	**X**		
Bactrocera zonata	**X**		
Bursaphelenchus xylophilus		**X**	
Candidatus Liberibacter spp.	**X**		
Ceratocystis fagacearum		**X**	
Clavibacter michiganensis subsp. sepedonicus	**X**		
Conotrachelus nenuphar	**X**		
Dendrolimus sibiricus		**X**	
Grapevine flavescence dorée	**X**		
Phyllosticta citricarpa	**X**		
Popillia japonica	**X**		
Ralstonia solanacearum	**X**		
Rhagoletis pomonella (Tephritidae (non-European))	**X**		
Spodoptera frugiperda	**X**		
Synchytrium endobioticum	**X**		
Thaumatotibia leucotreta	**X**		
Thrips palmi	**X**		
Tilletia indica	**X**		
Xanthomonas citri	**X**		
Xylella fastidiosa	**X**		

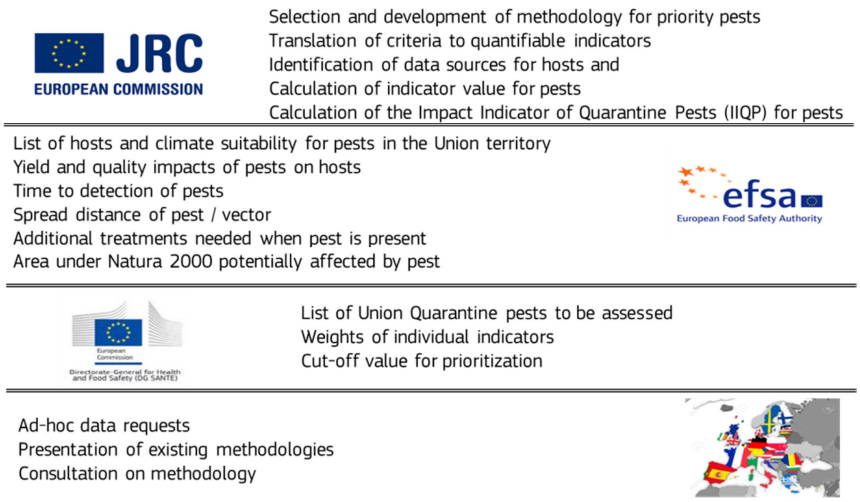
Source: own elaboration based on EFSA input

Prioritising pests based on the criteria set in the Regulation is a complex task. This report provides an overview of the methodology developed by the JRC to assess pests in terms of their impact, and allow a ranking which will support DG SANTE in drawing up the list of priority pests.

As the criteria listed in Annex I Section 1 point 4, and Annex I Section 2, of Regulation (EU) No 2016/2031 cover multiple dimensions (i.e. economic, social and environmental) and each of them is described through multiple impacts (e.g. within the social dimension: employment, food security and safety, and cultural heritage), the methodology should be based on composite indicators and multi-criteria decision analysis (MCDA). Composite indicators and MCDA are advanced fields of operations research and management science, devoted to the development of decision support tools and methodologies to address complex decision-making, involving multiple criteria goals or objectives of conflicting nature. Composite indicators allow comparison between indicators with different scales, dimensions or units of measurement (for example, the sub-indicators needed for measuring each of the criteria put forward in Regulation (EU) No 2016/2031). This decision is further reinforced by the review of similar exercises carried out in different Member States, which have consistently used this approach.

The objective of this Technical Report is to present the methodology developed by the JRC, in collaboration with EFSA and DG SANTE, to rank pests based on the expected impacts. The contributions of each of the three institutions are presented in Figure 2. The JRC designed the methodology, translated the Regulation's criteria into quantifiable indicators and reviewed the available data on economic, environmental and social aspects of the pests' hosts. The EFSA, following a request by DG SANTE for technical assistance pursuant to Article 31 of Regulation (EC) No 178/2002 as regards technical assistance in the field of plant health, conducted Expert Knowledge Elicitation (EKE - EFSA (2014)) exercises for each of the pests, in order to provide the inputs on pest pathology characteristics needed to construct the indicators. DG SANTE mobilised specific expert knowledge within plant health national administrations via the EGPHL, provided the list of Union quarantine pests to be assessed, and set the relative importance of the different criteria to rank pests.

Figure 2. Role of the Commission services, EFSA and Member States in development of the methodology



During development of the methodology, a series of working sessions between the different parties were held in Brussels, Seville, Ispra and Parma. An overview of these meetings can be found in Table 2.

Table 2. Meetings held for development of the methodology

	Location	Dates
Kick-off Meeting JRC-EFSA-SANTE	Videoconference	31/05/2017
JRC-EFSA-SANTE First Working Session	JRC premises - Ispra	06/09/2017
JRC-EFSA-SANTE Second Working Session	Videoconference	08/11/2017
JRC-EFSA-SANTE Third Working Session	EFSA premises - Parma	12/12/2017
1st meeting of the EGPHL	EC premises - Brussels	16/01/2018
JRC-FI EVIRA bilateral videoconference	Videoconference	08/02/2018
JRC-NL NVWA bilateral videoconference	Videoconference	15/02/2018
JRC-EFSA-SANTE Fourth Working Session	JRC premises - Seville	11/04/2018
JRC-EFSA-SANTE Fifth Working Session	EFSA premises - Parma	05/06/2018
2nd meeting of the EGPHL	EC premises - Brussels	09/07/2018
3rd Meeting of the EGPHL	EC premises – Brussels	09/01/2019
JRC-EFSA Sixth Working Session	JRC premises – Seville	18/03/2019
4th Meeting of the EGPHL	EC premises – Brussels	24/04/2019
5th Meeting of the EGPHL	EC premises – Brussels	27/05/2019

Following the introduction presented in this chapter, Chapter 2 presents the methodology developed to prioritise pests. Following a brief review of existing initiatives in different Member States to classify pests, we describe the theoretical framework for construction of the composite Impact Indicator for Priority Pests (I2P2). Chapter 3 describes the case study (*Tilletia indica*) used to provide details on how to calculate the different indicators included in I2P2 and their main characteristics. Chapters 4, 5 and 6 provide details on the individual indicators representing the economic, social and environmental domains, respectively. Chapter 7 provides a summary of the indicator values for each of the pests analysed. Chapter 8 reports the results of sensitivity analysis to assess the robustness of the ranking to different assumptions, and Chapter 9 provides the results of the ranking of pests using I2P2.

2 The Impact Indicator for Priority Pests (I2P2): theoretical background, main assumptions and construction

As shown in Chapter 1, priority pests should be selected from among the list of Union quarantine pests (UQP) based on the magnitude of their impacts on a series of aspects. The classic approach for ranking based on multiple criteria is to develop a composite indicator that summarises the different criteria. Summarising complex or multi-dimensional issues into a single measure is a controversial task with multiple pros and cons (OECD, 2008). However, it is the only way to assure a homogenous analysis of the list of UQP, which supports decision-makers faced with this prioritisation task.

Following Saisana and Trantola (2002), we define indicators as pieces of information that summarise the characteristics of a system, or highlight what is happening within a system. They are often a

compromise between scientific accuracy and the information available at a reasonable cost. A mathematical combination (or aggregation, as it is termed) of a set of indicators is most often called an 'index' or a 'composite indicator'. Composite indicators are based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub-indicators. For each potential impact referred to in the legislation, we have tried to identify a measurable indicator. These indicators are then aggregated in a consistent manner.

The OECD (2008) provides a checklist to follow when building a composite indicator. We have used this checklist as the basis for the construction of the I2P2, following some adaptation to the nature of the task at hand. Table 3 summarises the steps proposed by the OECD, how they have been applied or adapted in the case of the I2P2, and in which chapter of the report this aspect is dealt with.

Table 3. OECD Checklist for building a composite indicator and application to I2P2

Step	Description	Application to I2P2 construction	Report chapter
1. Theoretical Framework	Provides the basis for the selection and combination of variables into a meaningful composite indicator under a fitness-for-purpose principle.	The theoretical framework is based on Regulation (EU) No 2016/2031 and the criteria put forward for selection of priority pests. Individual indicators are grouped into types of impacts using a three-level tree (domain, sub-domain, and indicator).	2.1
2. Data Selection	Should be based on the analytical soundness, measurability, object of analysis coverage, and relevance of the indicators to the phenomenon being measured, and relationship to each other. The use of proxy variables should be considered when data are scarce.	Preference is given to quantitative data. Data sources are chosen based on coverage of EU-28 and pests. When no quantitative data are available, indicators are constructed based on expert input (EFSA).	2.2 Indicator-specific chapters Annex III
3. Imputation of missing data	Is needed in order to provide a complete dataset (e.g. by means of single or multiple imputation).	Not applicable as missing data are avoided in the data selection process.	-
4. Multivariate analysis	Should be used to study the overall structure of the dataset, assess its suitability, and guide subsequent methodological choices (e.g. weighting, aggregation).	Correlation analysis between indicators is undertaken to avoid double counting criteria and adequacy of indicator grouping into types of impacts.	2.3 8
5. Normalisation	Should be carried out to render the variables comparable.	Once the data gathering for each pest and indicator is completed, each indicator is scouted for outliers and its value normalised to allow aggregation.	2.4
6. Weighting and aggregation	Should be done along the lines of the underlying theoretical framework.	Aggregation done following the three-level tree. Weights defined by the legislator.	2.5
7. Uncertainty and sensitivity analysis	Should be undertaken to assess the robustness of the composite indicator in terms of e.g. the mechanism for including or excluding an indicator, the normalisation scheme, the imputation of missing data, the choice of weights, and the aggregation method.	Uncertainty incorporated into the indicator construction by EFSA. Sensitivity analysis of rankings related to weights.	2.6 9
8. Back to the data	Is needed to reveal the main drivers for an overall good or bad performance. Transparency is primordial to good analysis and policymaking.	Identification of driving indicators of the ranking. Comparison of ranking based on individual indicators vs ranking based on composite indicator.	2.6
9. Links to other indicators	Should be made to correlate the composite indicator (or its dimensions) with existing (simple or composite) indicators as well as to identify linkages through regressions.	Comparison of ranking with those resulting from other classification exercises.	2.7
10. Visualisation of the results	Should receive proper attention, given that the visualisation can influence (or help to enhance) interpretability.	Report Excel data sheets Qlik visualisation	

Source: OECD (2008) [first two columns] and own elaboration [third and fourth columns].

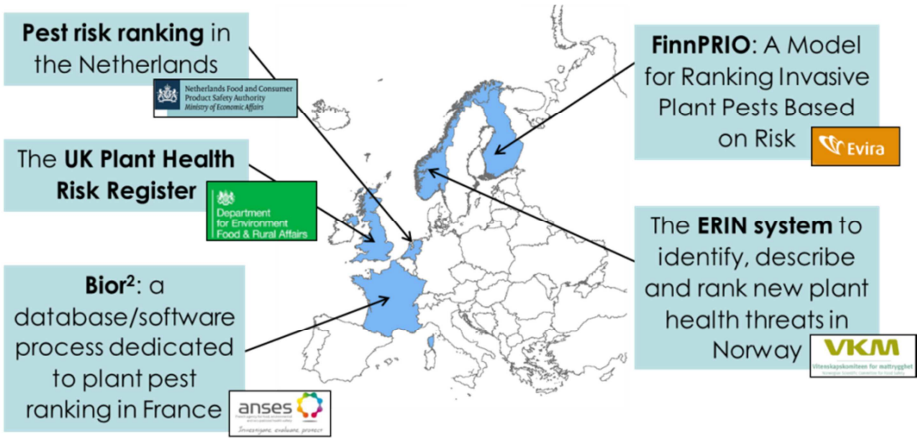
Besides following the state-of-the-art methodology for the construction of composite indicators, the JRC approach has also considered the experience gained by different institutions at national level in Europe to classify[2] pests. Initiatives for classifying pests were found in the Netherlands, UK, France, Finland and Norway (Figure 3). The JRC revised these indexes using both published material and bilateral meetings with the responsible institutions (see Table 2). Moreover, the lead scientists in the development of the UK and Norwegian indexes were part of the expert panel set up by EFSA for this work and discussions were held with them during the JRC-EFSA-DG SANTE working sessions. Our revision highlighted that, while focusing on the same object of analysis (pests), they differ from the I2P2 in three main aspects:

I. All indicators reviewed combine in their assessment the risk of establishment and the relative importance of impacts.

II. Indicators are measured mainly using semi-quantitative expert assessment.

III. Impacts are covered by a very limited number of indicators, mostly of subjective qualitative nature.

Figure 3. Existing initiatives for the identification of priority pests at national level

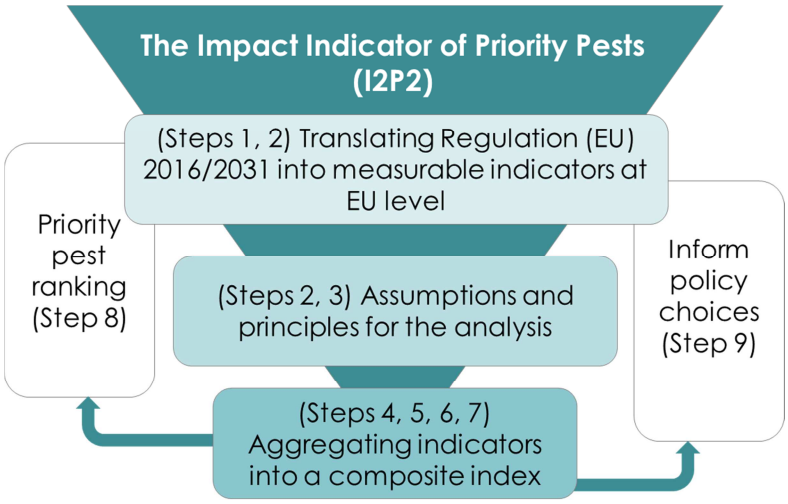


Following this theoretical and applied revision, the JRC proposes a methodological framework which is sketched in Figure 4. The first framework component is to translate the Regulation criteria into measurable indicators; this corresponds to steps 1 and 2 of the checklist presented in Table 3. The second component involves setting the key principles for the analysis and the assumptions needed to calculate the indicators, which also corresponds to step 2 of the aforementioned checklist, along with step 3. Finally, the individual indicators have to be aggregated into the I2P2 composite indicator. This component comprises steps 4, 5, 6 and 7, as the proposed structure of the index has to be validated, indicator-specific values normalised so they are comparable, weights for aggregation decided, and sensitivity analysis undertaken for the impact of different weighting options. Lastly,

[2] We use here the term 'classify' rather than 'prioritise', as the objective of each of the indicators found varies. However, all of them try to identify pests that can be classified as priority.

step 8 will check external validity, comparing results of I2P2 with other related indexes found in the literature, and step 9 will show the results of the prioritisation exercise, using I2P2 to support informed policy choices.

Figure 4. Methodological framework



2.1 Theoretical framework: translating Regulation (EU) No 2016/2031 into measurable indicators at EU level

The objective of the I2P2 is to provide a ranking of pests based on their potential impacts, following the definition provided in Regulation (EU) No 2016/2031. The Regulation states that priority pests should fulfil, among other things, the condition of having the most severe potential impacts in respect of the Union territory (Article 6 point 1 (b)). Therefore, the underlying reasoning for the I2P2 is that it should provide a ranking of pests from most to least severe impacts, and this has been the guiding principle behind the selection of indicators.

Annex I Section 2 further specifies the legal basis for the construction of the index, as in the first paragraph it states that impacts have to fulfil 'one or more of the following points'. The following points include economic, social and environmental impacts (points (a), (b) and (c)), which are then further qualified in indents (for social and environmental impact) or references to other sections of the Annex (for economic impact).

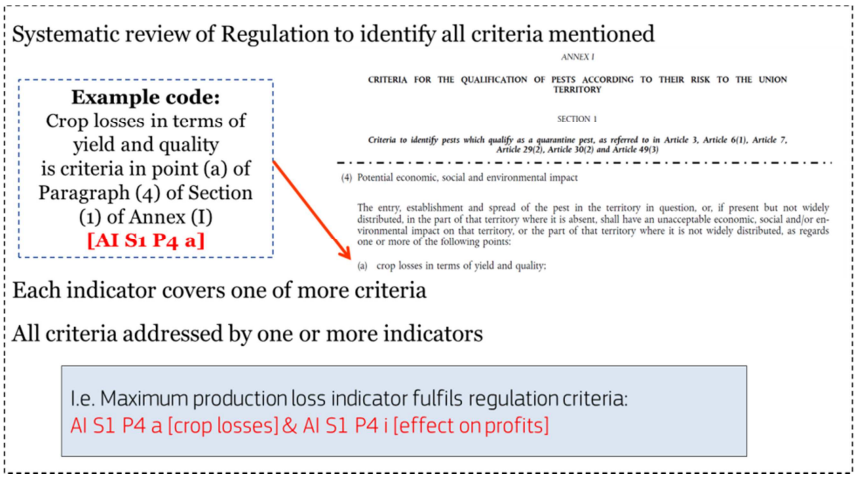
To reflect this structure we propose a three-level indicator structure, where the first level (the I2P2) summarises impacts on economy, society and environment (the domains); each domain (second level) is further split into sub-domains, and each sub-domain (third level) is measured using one or more indicators. Indicators are defined in such a way that the higher the indicator, the higher the impact (see section 2.2).

This wording in Annex 1 Section 2 of the Regulation ('one or more') implies that any single domain can lead to an overall most severe impact; therefore a fully compensatory approach is taken. Under this approach there is no minimum threshold for indicator, sub-domain or domain which needs to be met in order to be designated a priority pest. In practice, this means that, contingent on the weights assigned, one pest could qualify as priority pest even if the impact on one of the domains is not the

most severe. Beyond this, the methodology does not consider decision rules; it provides a ranking of Union quarantine pests with regards to impact. Once the raking is completed, any decision rule suggested by the legislator can be implemented. Examples of decision rules could include a target number of pests or a minimum value threshold for the indicator. It could also include differentiation between pests depending on the nature of their hosts (crops versus forest trees).

The next step has been to revise the criteria listed in Annex I Section 1 point 4 (a) to (s), and in Annex I Section 2 points (a) to (c), of Regulation (EU) No 2016/2031, and to identify indicators that would cover one or more of them. For criteria traceability, each Regulation criterion has been codified with an individual ID (see Annex II of this report). The ID nomenclature matches Regulation criteria with their specific location in the Regulation, following the sequence 'Annex number – Section number – point number – indent letter'. For example, the criterion 'Crop losses in terms of yield and quality' which is mentioned in Annex I Section 1 point 4 indent (a) is coded as [AI S1 P4 a] (Figure 5). Indicators will be measured using the pest-host as unit of analysis. When pests are polyphagous, the analysis will be done considering all the pest-host combinations that reflect the impact of the pest. The identification of hosts for each of the pests has been undertaken by EFSA.

Figure 5. Example of criteria codification



The matching of domains, sub-domains and criteria to indicators results in 25 indicators, which are grouped into 10 sub-domains and 3 domains. The structure of the I2P2 and its respective domains and sub-domains is reflected in Table 4. There is not one-to-one correspondence between criteria and indicators. Some criteria are covered by multiple indicators and some indicators correspond to multiple criteria. For example, the indicator 'maximum production loss' covers the criteria AI S1 P4 a, AI S1 P4 g and AI S1 P4 i. Conversely, the criterion AI S1 P4 j is covered by indicators I.8 and I.9. The methodology ensures that each criterion is covered by at least one indicator.

Table 4. Summary of indicators and the related Regulation criteria for assessing the economic, social and environmental impacts

Domain	Sub-domain	Indicator	Regulation Criteria
Economic Impacts	**1.1 Production impacts**	I.1 Maximum value of production losses	AI S1 P4 a AI S1 P4 g AI S1 P4 i
		I.2 Share of EU production value affected	AI S1 P4 a
		I.3 Difficulty of eradication	AI S1 P4 h AI S1 P4 p
	1.2 Trade impacts	I.4 Number of importing countries expected to impose restrictions on trade	AI S1 P4 k
		I.5 Value of export losses	AI S1 P4 k
		I.6 Share of export losses over total production	AI S1 P4 k
		I.7 Trade dispersion	AI S1 P4 k
	1.3 Price and market impacts	I.8 Change in domestic price	AI S1 P4 j
		I.9 Change in domestic production over imports	AI S1 P4 j
	1.4 Impacts on other agents	I.10 Upstream effects	AI S1 P4 i
		I.11 Downstream effects	AI S1 P4 i
Social impacts	**2.1 Impact on employment**	I.12 Job losses	AI S1 P4 r AI S2 Pb i
	2.2 Impact on food security or food safety	I.13 Share of caloric supply	AI S1 P4q AI S2 Pb ii
		I.14 Share of protein supply	AI S1 P4 q AI S2 Pb ii
		I.15 Share of fat supply	AI S1 P4 q AI S2 Pb ii
		I.16. Ability to produce fungal toxins	AI S1 P4 q AI S2 Pb ii
	2.3 Impact on recreation, landscape or cultural heritage	I.17 Share of holdings with other gainful activities	AI S1 P4 s AI S2 Pb iii
		I.18 Products covered by EU quality labels	AI S1 P4 s AI S2 Pb iii
		I.19 Presence of affected hosts on cultural heritage landmarks	AI S1 P4 s AI S2 Pb iii
Environmental impacts	**3.1 Impact on street trees, parks and natural and planted areas**	I.20 Use of hosts as street trees and in parks	AI S1 P4 e
	3.2 Undesired impacts of control measures	I.21 Undesired effects of control measures	AI S1 P4 b AI S1 P4 d AI S1 P4 h AI S1 P4 m AI S1 P4 p AI S2 Pc ii
	3.3 Impact on biodiversity and ecosystem services	I.22 Soil erosion	AI S1 P4 o AI S2 Pc i
		I.23 Number of protected species and habitats related to hosts	AI S1 P4 o AI S2 Pc i
		I.24 Share of Natura 2000 area and sites affected	AI S1 P4 n AI S1 P4 o AI S1 P4 s AI S2 Pc iii
		I.25 Share under sustainable management practice	AI S1 P4 o AI S1 P4 s

Source: own elaboration

There is not a direct correlation between Regulation criteria and individual indicators, due to data availability limitations. In a perfect setting, each criterion should be covered by at least one indicator; while this was the original goal of the methodology, there are some cases where it has not been possible. Firstly, the process is focused on indicators that are likely to be relevant at the EU level, and quantifiable given the data and information currently available for pest-host combinations. This means that some criteria are not directly addressed by a specific indicator. However, in some cases the information they could add to the I2P2 is embedded into other indicators that can indirectly capture their associated impact.

Six Regulation criteria fall under this special condition: three of them are captured in other indicators, while for an additional three we could not identify an implementable indicator to include them. We discuss the six criteria below and summarise the information in Table 5.

Criteria indirectly addressed in other indicators

The indicator that would best reflect the Regulation criterion 'cost of control measures' (A1 S1 P4 b) would require estimating monetary costs that are very site-specific and cannot be easily scaled up or considered without relying on assumptions. These assumptions would increase the uncertainty regarding the pest's impact and therefore the accuracy of the I2P2. As control measures differ by agricultural system, the EFSA could not provide a reliable estimate of the cost. However, this criterion is partly captured in indicator I.21, 'Undesired effects of control measures'. This indicator is constructed as a multi-level variable, taking into account the nature of additional treatments that would be needed to control the pest (see section 6.2.1), and therefore partly captures this criterion.

Regulation criterion 'Effects on existing production practices' (AI S1 P4 d) varies across the different areas where the pest will be capable of spreading, and cannot be accurately measured. In this case, the impact on production practices is also covered by indicator I.21, as the levels of the variable also consider changes in production practices.

Lastly, Regulation criterion 'Costs of environmental restoration and prevention measures' (AI S1 P4 p) is also area specific and not accurately assessable. However, it is also partly captured in indicators I.21 and I.3.

Criteria not captured in the I2P2

Estimating the monetary value related to the criterion *'*Costs of replanting and/or losses due to the necessity of growing substitute plants*'* [AI S1 P4 c] would need assumptions on which alternative or substitute plants would be used, as there are no legal provisions for replacements. A simplified approach would be to assume that replanting costs are irrespective of the species used, and to use an indicator that reflects the total area affected. However, area planted is already used as a key component of many indicators and would not capture the specificity of this criterion. To capture the specificity of the criterion, one could use a dichotomous variable that would favour permanent crops and trees, as the costs associated with removing these are higher than for annual crops. However, the discrimination power of such an approach would be limited. Moreover, the losses due to the necessity of growing substitute plants have been taken into account during the EFSA EKE process to obtain the annualised yield loss estimates for permanent crops.

Two criteria were discarded as lack of pest specific data would lead to a non-discriminatory indicator[3]. Following discussions with the EGPHL and the EFSA, it was concluded that it was not feasible to provide pest specific estimates for the Regulation criterion 'Resources needed for additional research and advice' (AI S1 P4 l). Research and advice would be needed for any new pest entering the Union territory and a priori it is not possible to rank the amount of resources needed, even considering pest groupings (i.e. bacteria versus virus).

The same is true for Regulation criterion 'Effects on native plants' (AI S1 P4 f). There is no official list of native plants. Alternatively, the JRC considered using a reverse index that would check whether any of the hosts susceptible to being affected by a pest were registered in the List of Invasive Alien Species of Union concern, adopted following Regulation (EU) No 1143/2014 on prevention and management of the introduction and spread of invasive alien species[4]. However, none of the identified hosts are included in the list, leading to a non-discriminatory indicator.

Table 5. List of Regulation criteria not directly assessed by specific indicators

Criterion	Reason	Indirectly covered by…
'Cost of control measures' (AI S1 P4 b)	Lack of reliable data	Indicator I.21
'Effects on existing production practices' (AI S1 P4 d)	Lack of reliable data	Indicator I.21
'Costs of environmental restoration and prevention measures' (AI S1 P4 p)	Lack of reliable data	Indicator I.21 Indicator I.3
'Costs of replanting and/or losses due to the necessity of growing substitute plants' (AI S1 P4 c)	Lack of data Fallback not discriminatory across pests	None
'Resources needed for additional research and advice' (AI S1 P4 l)	Not discriminatory across pests	None
'Effects on native plants' (AI S1 P4 f)	Not discriminatory across pests	None

Source: own elaboration

The fact that some criteria are not captured in the I2P2 does not mean it is not fit for purpose. Regulation (EU) No 2016/2031 does not explicitly specify the list of criteria that must be compulsorily met in order to be declared a priority pest, besides being a UQP (see Figure 1). Instead, the wording always refers to '… as regards one or more of the following points'. Despite these limitations, the I2P2 index advances knowledge for plant health policy decision-making by providing better understanding of, and allowing comparison between, economic, social and environmental impacts caused by the different quarantine pests qualifying as priority pests. The methodology developed could be applied on different scales, in different regions and under different scenarios.

[3] Meaning that it would take the same value for all pests.
[4] http://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm

2.2 Data selection: assumptions and principles for the analysis

When searching for indicator-specific data, several assumptions had to be made. The accuracy of I2P2 estimates for the impact of a given quarantine pest will depend on the quality and availability of data. Our approach involves **collection of quantitative or qualitative, measurable components based on existing evidence and available data**. While for some of the proposed indicators quantitative data are harmonised, up-to-date and widely available (e.g. area, yield and prices for annual and perennial crops), for others only anecdotal or non-representative data can be found (e.g. control costs). Moreover, a number of impacts can be subject to ancillary costs or non-monetised effects that are difficult to measure quantitatively, so qualitative measures might be needed (e.g. effects on recreation). This requires a careful consideration of the nature of the data used for each indicator, as the I2P2 aggregates them into a single composite indicator value.

The proposed methodology allows for both quantitative and qualitative measurement of the components outlining each indicator. **Indicators have been constructed using the most representative and reliable official statistical data**, in order to increase replicability and comparability between different pests. As forestry data was obtained from national statistical sources, the data was cross-checked with the EGPHL members. Due to the different units in which the data for the different indicators is reported, indicators have been normalised to avoid distortions in the I2P2 (see section 2.4).

While a quantitative approach using existing official statistical data is the ultimate benchmark, data quality, representativeness or availability does not allow this approach to be applied to all indicators. For such cases, alternative quantitative data based on expert assessment has been sought. This is particularly the case for plant pathology and entomology-related data which have been provided by EFSA. To ensure comparability of data based on expert assessment, EFSA has used the Expert Knowledge Elicitation (EKE) process. This process provides comparable quantitative measures of concepts where statistical data are not available; it is described in EFSA (2014).

Lastly, for some indicators, alternatives to official EU datasets and expert elicitation are explored when EU-wide data are not available. This is the case for indicator I.18 'Products covered by EU quality labels', I.19 'UNESCO World Heritage sites' and I.23 'Effect on biodiversity and wildlife', where ad hoc revisions have been undertaken to create primary data sources (see sections 5.3.2, 5.3.3 and 6.3.2).

Due to the European nature of the assessment, indicators will be calculated at European level (i.e. aggregated impact for the whole EU-28). However, this aggregated impact will be obtained from the sum of impacts calculated at lower spatial scale (i.e. Member State or region), to capture the diversity of pest-host relationships in different areas.

To ensure the index adequately captures severity of impacts, each of the indicators has to be positively correlated with the concept being measured (severity of impact). In the event that the indicator has a negative correlation to this concept, adequate transformations must be made (see section 2.5).

Another guiding principle for data source selection is that of **non-discrimination across pests**. This implies that any data source selected has to be available for all pest-host combinations, to avoid

giving priority to those for which more information is available. This might lead to situations where better alternative data sources could be considered, but their applicability would be limited for some of the pests or MS.

In addition to the selection of data sources, other assumptions are needed regarding how data is used to calculate the potential impact of a pest. A first set of assumptions relates to the time or point of entry and the spread process of the pest used for the estimation of impacts. When measuring yield and quality loss impacts, EFSA has used a scenario corresponding to the point when maximum spread of the pest has occurred and assuming that farmers and foresters maintain current management practice. This means that the time needed to reach the maximum impact is not taken into account when measuring impacts. However, the timescale for maximum spread is part of other indicators, such as indicator I.3 'Difficulty of eradication' which scores higher the higher the maximum distance of spread per year (see section 4.1.3).

When pests can affect multiple hosts (polyphagous pests), indicators will be aggregated for all pest-host pairing when the data are cardinal and in absolute values (i.e. production loss). When that is not the case (i.e. shares or ratios), the maximum value of the indicator from the different pest-host values will be taken. Details on how the polyphagous nature of a pest is taken into account are provided for each indicator in its respective chapter of the report.

EFSA will provide data on five key parameters for the calculation of some indicators. In particular, it will provide information on the list of hosts for each of the Union quarantine pests assessed and expected quality and yield losses following a pest outbreak (see section 4.1.1), the spread rate and time for detection after entry of a given pest (see section 4.1.3), the nature of control measures needed following the outbreak of a pest (see section 6.2.1), the distribution of the pests in the world and the countries where the pests are regulated as a quarantine species (see section 4.2.1), and the number of Natura 2000 sites and their area where hosts are expected to be affected by the pest (see section 6.3.3). The first four parameters are provided as distributions incorporating uncertainty, which will be used for the uncertainty and sensitivity analysis (see section 2.6). More details on the assumptions taken to provide this data can be found in the respective chapters and in EFSA (2018).

2.3 Coherence of index structure: multivariate analysis

Once the values of the indicators have been calculated for all the Union quarantine pests put forward by DG SANTE, a correlation analysis is carried out to confirm that the indicator structure is coherent.

It is true that, in constructing certain indicators, some common parameters (e.g. area) are used. However, this is just a reflection on the concept mentioned in the Regulation. For example, the importance of a pest – in terms of production and in terms of employment – has to be taken into account, and both indicators depend on the area affected. This does not mean that we are double counting any indicator, even where these may be (highly) correlated. The results of the correlation analysis are presented in Chapter 8.

2.4 Normalisation of indicator value

As can be seen in Table 15 and Table 16, the different indicators will have different units (e.g. euros, number of countries, share of production) and scales (e.g. from 0 to infinity, from 0 to 218, from 0 to 1). In order to avoid this affecting the importance an indicator has in the overall index, before aggregating the specific indicators (see below) each one will be normalised to range from zero to 1. For this, the following formula will be applied:

$$I_n = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Where I_n is the normalised value of the indicator, X the original value of the indicator, X_{max} the maximum value the indicator takes for the pests assessed, and X_{min} the minimum value. This normalisation implies that the maximum value of the indicator will be 1 and the minimum 0, with all the rest distributed in the [0,1] space.

When the nature of the impacts differs significantly according to the type of hosts, the normalisation should be carried out taking only the maximum and minimum values across host types. This would be the case for economic impacts for crops and trees, where crop economic impacts are provided on an annual basis (flow) and tree economic impacts on a growing stock basis (stock) (see section 4.1.1); for food security impacts where trees are only considered regarding wood production which is not part of the human diet (see sections 5.2.1, 5.2.2 and 5.2.3); and for the indicator on products covered by EU quality labels (see section 5.3.2). As the I2P2 will be used to generate two separate rankings for pests affecting crops and trees, the normalisation process will be done independently for each type of host. The same applies for pests affecting both crops and trees (*Aromia bungui* and *Conotrachelus nenuphar*). A separate ranking will be made for these two pests, but in addition their relative ranking if considered as crop-only or tree-only pests will be worked out.

2.5 Aggregating multiple indicators into a composite index

The last step to obtain the composite value of the I2P2 is to aggregate the individual indicators. At this stage, two decisions need to be made. Firstly, all indicators should contribute in the same direction to the I2P2, to make sure that the aggregation does not allow compensatory rules between indicators. To this end, all indicators should be constructed in such a way that the higher the value of the indicator, the higher the impact of the pest. For each individual indicator this is tested, and if the relationship is inverse (i.e. the higher the value of the indicator, the lower the impact of the pest) the indicator is reversed using a negative monotonic transformation which reverses the order of the numbers. Details of indicators where this is done are provided in the respective chapters.

Secondly, weights for the aggregation need to be selected. The final decision on weights is outside the scope of the task requested from the JRC and will reflect the relative importance given to each impact by the legislator. However, the JRC must ensure that the construction of the indicator does not assign higher or lower implicit importance to any indicator. Due to the unbalanced number of indicators under each of the three main domains and ten sub-domains (e.g. three sub-domains under social impacts domain and four under economic impacts domain; two indicators under price and market sub-domain and four under food security and food safety sub-domain), a hierarchical

weighting approach is proposed (Figure 6). Under this approach, the full weight (100 %) is split among the three main domains, the weight of the domain is split among the different sub-domains, and the weight of the sub-domain is split among the individual indicators for the sub-domain.

For example, if equal weights are assumed for the three domains, the fact that there are four sub-domains for economic impact and three for social has no impact on the overall importance of the domain. The same applies across sub-domains, where one sub-domain has several indicators and another just one. The final indicator specific weight ($\overline{W}_{Ix}$) is the result of the multiplication of the domain weight, the sub-domain weight and the indicator weight. The results reported here assume equal weights following the feedback received by MS during the EGPHL meetings reported in Table 1. However, this does not preclude the legislator from using alternative weights when drafting the legal text. The legislator could also decide that weights should be equal for all pests, or should differ depending on the nature of their hosts (crops versus trees).

$$\overline{W}_{Ix} = W_{D_i} X\ W_{SD_{ij}} X\ W_{I_{ijx}}$$

s.t.

$$\sum_{i=1}^{i=3} W_{D_i} = 1$$

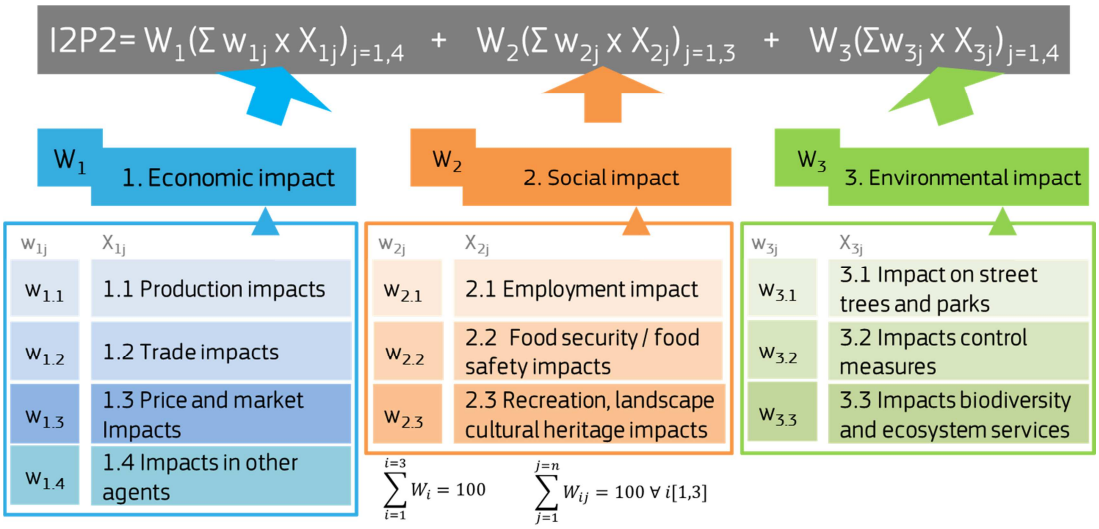
$$\sum_{j=1}^{j=n} W_{SD_{ij}} = 1 \qquad \forall\ i(1,3)$$

$$\sum_{x=1}^{x=n} W_{I_{ijx}} = 1 \qquad \forall\ i(1,3) \& \forall j(1,n)$$

Where W_{Di} is the weight of the domain *i* in the I2P2 for each of the three domains, W_{SDj} is the weight of sub-domain *j* in its respective domain (with j taking the value 3 or 4 depending on the domain); and W_{Ix} is the weight of the indicator in its respective sub-domain (with x ranging from 1 to 4 depending on the sub-domain). For example, the normalised weight of indicator I.2 ($\overline{W}_{I2}$) will be the result of multiplying the weight of the economic impact domain (W_{D_1}) by the weight of the production sub-domain ($W_{SD_{11}}$) by the weight of indicator I.2 ($W_{I_{111}}$). With equal weights across domains, sub-domains and indicators, this would mean that the weight for indicator I.2 would be $^1/_{36}$ (the result of $^1/_3 * {}^1/_4 * {}^1/_3$)[5].

[5] The highest weight for an individual indicator would be $^1/_9$ (indicators #20 and #21) and the lowest would be $^1/_{48}$ (indicators #4, #5, #6 and #7).

Figure 6. Structure of Impact Indicator for Quarantine Pests (I2P2)



2.6 Uncertainty and sensitivity analysis

Uncertainty regarding the indicator is taken into account by the EFSA when providing their input for the indicator calculations (see section 2.2). While the I2P2 will be constructed using the median values (i.e. equally likely to over- or underestimate) for the four parameters provided with uncertainty distribution, the resulting ranking will be compared to the ranking that would result if lower and upper limit of the inter-quartile range (1st and 3rd quartile) for the three parameters were used to calculate the impacts.

An additional source of uncertainty is the potential impact of alternative weighting allocation across domains, sub-domains and indicators. In particular, we have assessed the scenarios reflected in Table 6.

Table 6. Domain specific weights used for the sensitivity analysis.

Pests considered	Reasoning	Weights per domain		
		Economic	Social	Environmental
All	*All indicators have a social dimension and therefore indicators reflecting only social impacts should be given less importance.*	*40*	*20*	*40*
Crops	*Economic losses are the most important for crops, thus they should have more weight.*	*50*	*25*	*25*
Forest	*Social impacts for forests have limited information; economic and environmental domains should drive the assessment.*	*50*	*0*	*50*

The potential impact on rankings of these sensitivity analyses are discussed in Chapter 10.

3 Background information on *Tilletia indica*

To help understanding of how the different indicators are constructed, this report provides detailed information on data sources and a step-by-step calculation based on *Tilletia indica* as a case study.

The first step in calculating the indicator for a pest is to identify the hosts which can be affected by the pest. As part of the EKE process, EFSA first reviewed the hosts mentioned in the available literature (EPPO Global Database, CABI Datasheets and relevant PRAs) and came up with a comprehensive list of all potential hosts of the pest. This list is used for the calculation of indicator I.24 (share of Natura 2000 area and sites). A second, shorter, list identifies the main hosts, in line with the most recent/relevant risk assessments. This second list was used in the consultation with MS regarding forestry, cultural heritage, and street trees and parks (indicators I.19 and I.20). Lastly, the list of hosts for which EFSA conducted an EKE was used to elicit the values of the parameters mentioned in section 2.2. This last list of hosts was defined according to a series of criteria (as provided in the EFSA report) and is the one for which all other indicators are calculated.

The hosts for which EFSA conducted the EKE for *Tilletia indica* are presented in Table 7.

Table 7. Hosts considered for which EFSA conducted an EKE to elicit the parameters for *Tilletia indica*.

Pest	Type of hosts	Hosts
Tilletia indica	Annual crops	*Triticum aestivum*
		Triticum durum
		Triticosecale

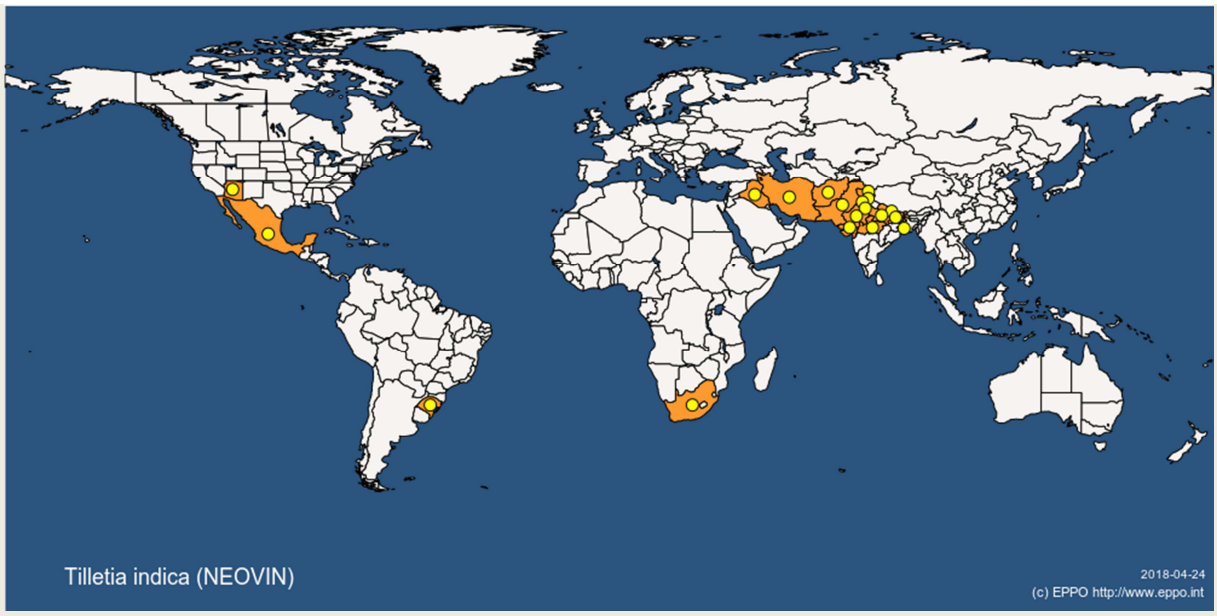
Source: EFSA (hosts)

A brief description of the pest and its impacts on the hosts is included as Box 1.

Box 1. *Tilletia indica* – pest description

Tilletia indica is a floret-infecting smut fungus and the causal agent of Karnal bunt in wheat (*Triticum* spp.) and triticale (× *Triticosecale*).

There is limited knowledge of its long-distance spread capacity: this pathogen can survive long periods as teliospores before germinating and infecting the wheat crop to produce detectable levels of disease, making it difficult to define where it has spread to. The distribution of *Tilletia indica* in the world is captured in the map below.



The main host species identified from literature are *Triticum aestivum* (bread wheat), *Triticum durum* (durum wheat) and *Triticosecale* (triticale). The relative susceptibility of each species is not clear; however, based on Indian evidence triticale is more resistant than durum and bread wheat. In addition, triticale's main use is for animal feed where the effects of Karnal bunt, such as dark colour and a fishy smell on infected kernels, do not result in quality losses as it would in cereals for human consumption. Therefore, the assessment focuses on *T. aestivum* and *T. durum,* assuming zero impact on *Triticosecale*.

Crop damage due to *Tilletia indica* infection usually implies a reduction in the length of ears, as well as in the number of spikelets of bunted ears. There can also be significant effects on seed and grain quality. Yield loss is subject to susceptibility of varieties. *Tilletia indica* is not endemic in EU regions and there is a lack of resistance in current European wheat cultivars.

Quality losses are due to discolouration of grain and grain products, and the presence of trimethylamine. Grain contaminated with *Tilletia indica* is more likely to be rejected and downgraded to animal feed. While there are no adverse health effects, in Europe there is zero tolerance for bunt affected, or for contaminated grain grown under Quality Assurance (QA) schemes.

Source: EFSA Fact Sheet for Expert Knowledge Elicitation for *Tilletia indica*.

4 Economic impact indicators

This chapter provides the rationale for the structure of the economic impact domain of the I2P2, and the selection of the individual indicators. An initial classification of economic impacts from a given Union quarantine pest, following FAO (2011), would divide them between direct and indirect impacts. Direct impacts would reflect changes experienced in the agricultural or forestry sector in terms of revenue and costs. Indirect impacts would reflect changes experienced by other economic agents such as consumers, users of agricultural outputs or producers of agricultural inputs.

Due to the comprehensive list of impacts mentioned in Regulation (EU) No 2016/2031, this simple grouping does not respond to the I2P2 needs so we have grouped impacts into four sub-domains:

i) production impacts; ii) trade impacts; iii) price and market impacts; and iv) impacts on other agents. Each sub-domain has one or more indicators. Production and trade impacts represent the direct impact of a pest, while price and market impacts and impacts on other agents represent the indirect impacts. Table 8 summarises the list of indicators for assessing the economic impact, and the data needed for their calculation.

Table 8. Summary of indicators and data sources under the economic impact domain

Sub-domain	Indicators	Data
Production impacts	I.1 Maximum value of production losses	Host planted area
		Yield
		Price of the commodity with normal quality
		Price of the commodity with reduced quality
		Potential proportion of loss in yield
		Potential proportion of remaining production after yield loss that would result in lower quality
	I.2 Share of EU production value affected	Maximum production loss
		Total production
	I.3 Difficulty of eradication	Duration until detection
		Spread distance
Trade impacts	I.4 Number of importing countries expected to impose restrictions on trade	Number of importing countries
		Number of importing countries not expected to impose restrictions on trade with EU
	I.5 Value of export losses	Quantity of exports to countries banning trade with EU
	I.6 Share of export losses over total production	Quantity of exports to countries banning trade with EU
		Total production
	I.7 Trade dispersion	Quantity of exports to countries banning trade with EU
Price and market impacts	I.8 Change in domestic price	Total production
		Imports and exports
		Maximum production loss
		Quantity of exports to countries banning trade with EU
		Own price elasticity
	I.9 Change in domestic production over imports	Change in domestic supply
		Total imports
Impacts in other agents	I.10 Upstream effects	Output multipliers
		Production loss in value
	I.11 Downstream effects	Intermediate demand
		Total domestic production

The rest of the chapter describes in detail each of the indicators proposed, presenting the theoretical relationship between the indicator and the pest prioritisation process, as well as the data sources used for the calculation. For each indicator, an example is provided of how it is calculated for the three pilot pests.

4.1 Production impacts sub-domain

This sub-domain focuses on the most evident impact of a pest, namely the change in agricultural or forestry income, due to decrease in revenue (due to quantity or quality losses) or to additional costs. Once the pest outbreak occurs, part of the production will be lost, part of the remaining production will have a reduction in quality, and farmers or foresters will have to change their management practices. The production impacts indicators look at both the estimated production losses from the pest and the cost of trying to eradicate the pest and prevent those losses; they are captured in three indicators: I.1 'Maximum value of production losses', I.2 'Share of production affected' and I.3 'Difficulty of eradication'. Each of them provides different insights into the extent of the direct economic impact for the producer. We now proceed with the detailed description of each of the three indicators.

4.1.1 Maximum value of production losses (Indicator I.1)

When there is a pest outbreak, the first visible impact is a reduction in production and/or a reduction in the quality of production. The impact can reduce the crop yield (i.e. lose part of the harvest) and/or reduce the quality of the remaining output. Production impacts can be calculated in quantity or value terms, while quality losses are evaluated in monetary terms considering the price difference between the original and the impacted (lower quality) product. In order to sum both impacts, monetary measures have to be considered. Impacts are compared against current yields and prices.

'Maximum value of production losses' refers to the market value of the production reduction, plus the loss in market value of the production affected by quality loss due to damages caused by the pest during the outbreak in the potential area affected, as calculated in the scenario of maximum spread (see section 2.2). The indicator is calculated as follows, adding across the different MS (*i*) and the different hosts affected by the pest (j):

$$(I.1)\ \ PL = \sum_{j=1}^{j=n} \sum_{i=1}^{i=28} \left[\left(A_{j,i}\ x\ Y_{j,i}\ x\ P_{j\ ,i} x\ r_{loss\ i,j} \right) + \left(A_{j,i}\ x\ Y_{j,i}\ x\ \left(1 - r_{loss\ i,j}\right) x Q_{lossi,j} x (P_{j,i} - P'_{j,i}) \right) \right]$$

Where *PL* is the maximum value of production losses in euros, *A* is the host planted area in hectares, *Y* is the yield of the host in tonnes per hectare, *P* is the average price of the crop in euros per tonne, P' is the average price of the second quality crop in euros per tonne, r_{loss} represents the EFSA provided potential proportion of loss in yield, and Q_{loss} the EFSA provided potential proportion of remaining production after yield loss that would result in lower quality product.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Host planted area (A)

Planted area is the surface of land on which a crop is grown. To calculate this indicator, we need to know the planted area for each of the hosts that can be affected by the pest, measured in hectares. Detailed data on host crop areas can be found in the Eurostat crop

statistics, at national level[6] and NUTS2[7] spatial disaggregation level. Coverage at MS level is comprehensive for annual crops but less so for permanent ones, while there is less availability of further disaggregation at regional level.

In order to avoid impacts from exceptional years, the average of the four latest years available is used.

The previous approach is valid for pests that have crops as hosts. When dealing with pests that have forest trees as hosts, an alternative data source is needed. Data on woodland area (sometimes referred to as stocked area) by species is limited in Eurostat[8]. More detailed data by species and region can be found in the National Forest Inventories (NFI) distribution maps developed by JRC-FISE[9], and in the European Forest Institute[10]. As none of these datasets fulfilled the quality requirements for obtaining species or genus specific area, the JRC launched an ad hoc forest data request to MS, using the EGPHL in order to obtain the best data available at MS level. As forestry area does not change much between years, the most recent data will be used without reverting to four-year averages.

***Tilletia indica* - Hosts and host planted area (A)**

Hosts
Triticum aestivum – bread wheat Triticum durum – durum wheat Triticosecale – triticale

EU-28 Host planted area (2013-2016 average; 1000 has)	
Host	**Area**
Bread wheat	24 100
Durum wheat	2 478
Triticale	2 934
TOTAL	29 512

Note: Aggregation of Eurostat data reported at MS level. MS-specific data available in web address in footnote 2.

- Yield (Y)

Crop yield is the amount of agricultural production harvested per unit of land area, under current management practices, in the absence of pest impacts. For crops, yield is usually reported as tonnes per hectare, while for trees it is reported in cubic metres per hectare.

Reported data on crop yields are scarcely available in Eurostat crop statistics, either at national or regional level. However, one can derive implicit yields by dividing total

[6] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpnh1&lang=en
[7] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpnhr&lang=en
[8] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_area&lang=en
[9] http://fise.jrc.ec.europa.eu/data/fisecsw/
[10] http://www.efi.int/portal/virtual_library/databases/efiscen/inventory_database/

production by planted area. As for planted area, data will be calculated at MS level using Eurostat data. In order to avoid impacts from exceptional years, the weighted average by area of the four latest years available is used.

Data on wood extraction, which would be the equivalent of yield for trees, is not systematically available. The concept reported in the statistical sources mentioned above is 'wood growing stock' – also referred to as 'standing volume' – which captures the volume of timber in living trees. This is a stock variable, compared to the annual flow nature of yields for crops. In order to make growing stock and yield comparable, one should divide the stock by the growth cycle of each of the tree species. These data are not accessible, and secondary sources with average growth cycles do not capture the specificities of the different climatic zones. Therefore, yield for forest trees is replaced by growing stock. As mentioned above, to avoid the impact that this difference would make when comparing potential production losses (in general, a stock is always higher than a flow), the I2P2 will be used to provide two ranks: one for pests affecting crops and one for pests affecting trees (see section 2.4).

Wood volume data are available in Eurostat, but only as an aggregated value of forest land which would not allow differentiation of impacts by species[11]. As a starting point to solve this limitation, the JRC team has revised the National Reports included in the 'State of Europe's Forests 2015' report published by Forest Europe[12]. However, the level of detail provided by this source does not match that of the pest-host list. To complement data on growing stock, the JRC ad hoc data request referred to above also included a section on this issue. Here too, as forestry growing stock does not change much between years, the most recent data will be used without reverting to four-year averages.

***Tilletia indica* – Yield (Y)**

EU-28 Yield (2013-2016 weighted average by area; tonnes/ha)	
Host	**Yield**
Bread wheat	5.9
Durum wheat	3.4
Triticale	4.2

Note: Own calculation based on Eurostat data for yields and area at MS level. MS-specific data available in web address in footnote 2.

- Price of the commodity with normal quality (P) and with reduced quality (P')

The prices used in calculation of the indicator refer to producer prices, that is those received by the producers excluding taxes, transport and trade margins[13]. Both prices are measured in euros per tonne (crops) or euros per cubic metre (wood). For crops, price with normal

[11] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_vol&lang=en
[12] foresteurope.org/state-europes-forests-2015-report/#1476295965372-d3bb1dd0-e9a0edited

[13] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aact_uv02&lang=en

quality (P) is reported at MS level in Eurostat. In the event of missing data, we input as MS-specific price the weighted average by area from the MS where the data is available. In order to avoid impacts from exceptional years, when calculating MS-specific prices, the weighted average by area of the four latest years available is used.

Price with reduced quality (P') is pest-host specific. Depending on the information provided by EFSA, an alternative use for reduced quality output is identified. For the pilot pests, EFSA has identified that affected product would need to be sold for animal feed instead of for human consumption (*Tilletia indica*) or that it would need to be sold to a processing industry (e.g. juice) instead of for fresh distribution (*Xanthomonas citri*). As there is no systematic data source for commodity prices by use, the JRC identified case-by-case the alternative use of the reduced quality version of the host, and obtained the best source available for data on its price. In the absence of identified uses for reduced quality products, a zero price will be assumed[14].

Forestry prices are not reported by Eurostat. The Food and Agricultural Organization of the UN (FAO) reports total value and volumes of forestry trade, which would allow calculation of implicit prices, but this relates to transformed products (not the wood standing in the forest). As an alternative, the JRC considered the data available from the UN Economic Commission for Europe (UNECE[15]), which provides data for some species and countries based on country market statements from price market reviews. However, the data coverage is still far from optimal, and therefore additional data has been included in the above mentioned ad hoc data request to the EGPHL.

***Tilletia indica* – Average price (P) and quality reduced price (P') of hosts**

EU-28 Average price (2013-2016 weighted average by production; EUR/tonne)		
	Normal quality price	**Reduced quality price**
Bread wheat	188	169
Durum wheat	258	232
Triticale	144	130

Note: Own calculation based on Eurostat data for prices at MS level. MS-specific data available in web address in footnote 2. Price of reduced quality product assumed as wheat for animal feed based on EFSA input (EFSA, 2018).

- Potential proportion of loss in yield (r_{loss})

Yield loss is provided by EFSA as part of its input to the prioritisation methodology. It takes into account the proportion of area suitable for infection over a long-term time frame, the average proportion of diseased fields and the average proportion of yield loss. The data are

[14] In this extreme case, the valuation of quality losses will be equal to that of production losses, as if P' equals zero (P – P') equals P, thus loss of quality is evaluated at normal quality level commodity prices.
[15] https://www.unece.org/fileadmin/DAM/timber/statsdata/PriceOutputTable.xls
http://www.unece.org/forests/market-statements-2016.html

provided as a probability distribution, fitted using expert elicited raw data (see section A.3 in EFSA, 2014).

***Tilletia indica* – Potential proportion of loss in yield (r_{loss})**

Potential proportion of loss in yield (%)	
Percentile	**Percentage**
1st	0.005
25th	0.025
50th	**0.050**
75th	0.100
99th	0.544

Source: EFSA (2018) – Data presented represent yield loss, without taking into account climate suitability and host distribution. Specific values per MS are used, that take these two factors into account.

- Potential proportion of remaining production after yield loss that would result in lower quality (Q_{loss})

Quality loss is provided by EFSA as part of its input to the prioritisation methodology. It takes into account the proportion of area suitable for infection over a long-term time frame, the average proportion of diseased fields and the average proportion of yield loss. The data are provided as a probability distribution, fitted using expert elicited raw data (see section A.3 in EFSA, 2014).

***Tilletia indica* – Potential proportion of remaining production after yield loss that would result in lower quality (Q_{loss})**

Potential proportion of remaining production after yield loss that would result in lower quality) (%)	
Percentile	**Percentage**
1st	0.1
25th	1.0
50th	**2.1**
75th	3.9
99th	11.7

Source: EFSA (2018) - Data presented represent yield loss without taking into account climate suitability and host distribution. Specific values per MS are used, that take these two factors into account.

Indicator calculation

Following the equation and the data presented above, the value for I.1 'Maximum value of production losses' is **EUR 48.9 million**.

Indicator I.1 'Maximum production loss' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result (EU-28 aggregates)				
	Bread wheat	**Durum wheat**	**Triticale**	**Total**
Host planted area (1 000 has)	24 100	2 478	2 934	29 512
Yield (tonnes/ha)	5.9	3.4	4.2	-
Price of the commodity with normal quality (EUR/tonne)	188	258	144	-
Price of the commodity with reduced quality (EUR/tonne)	169	232	130	-
Potential proportion of loss in yield (%)	0.050	0.050	0	-
Potential proportion of remaining production after yield loss that would result in lower quality (%)	2.1	2.1	0	-
I.1 Maximum value of production losses (million EUR)	**44.9**	**3.9**	**0**	**48.8**

Note: Reported values are EU-28 averages; however, the indicator is calculated aggregating MS-specific values. Therefore, applying the indicator formula to the values reported does not lead to the reported results.

4.1.2 Share of EU production value affected (Indicator I.2)

While indicator I.1 captures the total value of the losses in production and quality, it fails to capture whether this loss has a significant impact on total production of the hosts affected by the pest in the EU-28. Therefore, to capture this we include a second indicator that measures the share of EU production losses due to a pest. The indicator is calculated as follows, adding across the different MS (*i*) and considering the maximum value for the different hosts affected by the pest (j):

$$(I.2)\ PA = max\left(\sum_{i=1}^{i=28} PL_i \Big/ \sum_{i=1}^{i=28} TP_i\right) \qquad \forall\, j\ (1,n)$$

Where *PA* is the share of EU production value affected by the pest, *PL* is the maximum value of production losses, and *TP* is the total production of a specific commodity.

- Maximum value of production losses (PL)

This corresponds to indicator I.1 as described in section 4.1.1.

***Tilletia indica* – Maximum value of production losses (PL)**

Maximum value of production losses (2013-2016 average; million EUR)	
Host	**Value**
Bread wheat	44.9
Durum wheat	3.9
Triticale	0
TOTAL	48.8

Note: Own calculation based on Eurostat data; see section 4.1.1 for details.

- Total production value (TP)

This component represents the total value of production of the hosts identified, for each of the pests analysed. Based on Eurostat data for crops, and data provided by MS in response to the ad hoc data request described above, the indicator is calculated as follows, adding across the different MS (i)[16] and the different hosts affected by the pest (j):

$$TP_j = \sum_{i=1}^{i=28} \left(A_i \; x \; Y_i \; x \; P_{,i}\right)$$

Where A is the area of each host, Y its yield, and P their producer price as defined in section 4.1.1.

***Tilletia indica* – Total production value (TP)**

Total production value (2013-2016 average; million EUR)	
Host	**Value**
Bread wheat	26 851
Durum wheat	2 150
Triticale	1 793
TOTAL	30 794

Note: Own calculation based on Eurostat data; see section 4.1.1 for details.

Indicator calculation

Following the equation and the data presented above, the value for I.2 'Share of EU production value affected' is **0.16 %**.

[16] Where the calculations are made at regional level (NUTS2), *i* will represent the number of regions.

Indicator I.2 'Share of EU production value affected' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result (EU-28 aggregates)		
Hosts	**Production loss (million EUR)**	**Total production (million EUR)**
Bread wheat	44.9	26 851
Durum wheat	3.9	2 150
Triticale	0	1 793
I.2 Share of EU production value affected (%)		**0.16**

4.1.3 Difficulty of eradication (Indicator I.3)

Besides the maximum value of production losses and the share of total production lost, another aspect that needs to be taken into account is whether the pest can be easily eradicated. Two pests with the same level of production losses should not be ranked equally, as if one is easily eradicated and the other not, the impact of the latter would be more severe. As one of the guiding principles is that all indicators should contribute to the I2P2 in the same direction, the indicator is defined as difficulty of eradication, where pests that are more difficult to eradicate should be given more importance than those that are less so, when prioritising pests under Regulation (EU) No 2016/2031.

The best quantitative indicator to reflect this would be the estimated cost of eradication (or control when eradication is not feasible); however, information on eradication costs is very limited and difficult to obtain in a consistent manner. Even if accurate data were available for some pests, the principle of non-discriminatory data sources (see section 2.2) requires a common approach for all pests. Following discussions with EFSA and DG SANTE, an alternative that meets this guidance principle was agreed. Namely, pests are evaluated based on the difficulty of eradication, which is assumed to be positively correlated with potential eradication costs (the more difficult to eradicate a pest, the more costly it would be).

To provide an unbiased measure for difficulty of eradication, two quantitative concepts are combined: (i) time between pest transfer and detection (TDE), and (ii) spread rate (SR), to construct a difficulty of eradication (DE) indicator. The information is provided for the pest, irrespective of the host. The indicator is calculated as follows:

$$(I.3)\ \ DE = TDE\ x\ SR$$

This indicator approximates the expansion of a site-specific outbreak before detection (i.e. the outbreak is only detected after x years and the pest spreads at y metres per year, so the outbreaks when detected will at maximum cover an area of x times y metres). All other factors equal (for which we do not have information), it correlates positively with difficulty of eradication.

As specified in EFSA (2018), the following scenario is considering when estimating the values for the two components:

- The pest can be either one isolated population not known to be established, but expected to survive for the immediate future, or it is already established and has originated one outbreak area.
- There is optimum abundance of host plants.
- There is optimum climate condition for population growth/epidemics and spread of pest.
- Monitoring activity for this pest is conducted according to current practices in the outbreak area.
- The population is present in a focus and adapted to the local environment, and there are no effects due to demographic stochasticity (e.g. Allee effect).
- The spread rate is the outcome of the contribution of natural spread and human-assisted spread. Spread due to post-harvest movement, such as trade in commodities, is not included in the estimation.

In addition, where the pest is a pathogen, spread is considered only when causing successful infection of the host on arrival.

Below we present the data sources available and the selection of the source used for each of the components of this indicator.

➢ Time until detection after entry (TDE)

Time between pest transfer and detection is considered a proxy for difficulty of eradication, as without symptoms the pest can continue spreading and when detected eradication will have to be undertaken in a larger area.

The time gap between entry and detection is a parameter resulting from the EFSA-led EKE process, as a response to the question 'What is the time between the event of pest transfer to a suitable host and its detection?', and is reported in years. The data are provided as a probability distribution, fitted using expert elicited raw data (see section A.3 in EFSA, 2014).

***Tilletia indica* – Time until detection after entry (TDE)**

Time until detection after entry (years)	
Percentile	**Years**
2.5th	4
25th	9
50th	**12**
75th	15
97.5th	22

Source: EFSA (2018)

- Spread rate (SR)

Spread rate is defined as the distance the pest would spread in one year, for an isolated focus under average European conditions. The larger the distance, the wider the spread of the pest given a time for detection after entry and, therefore, the higher the difficulty of eradication.

This parameter is also a result of the EFSA-led EKE process; it is obtained from a response to the question 'What is the spread rate in one year for an isolated focus within this scenario under average European conditions?' and is reported in metres per year. The data are provided as a probability distribution, fitted using expert elicited raw data (see section A.3 in EFSA, 2014).

***Tilletia indica* – Spread rate (SR)**

Spread rate (metres per year)	
Percentile	**m/yr^{-1}**
2.5th	29
25th	467
50th	**1 238**
75th	2 631
97.5th	7 459

Source: EFSA (2018)

Indicator calculation

Following the equation and the data presented above, the value for I.3 'Difficulty of eradication' is **14 856.** While by construction this indicator would have metres as a unit ($yr\ x\ \frac{m}{yr} = m$), the unit does not reflect the concepts and hence the indicator is reported without unit.

Indicator I.3 'Difficulty of eradication' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Time for detection after entry (yr)	12
Spread rate (m/yr^{-1})	1 238
I.3 Difficulty of eradication	**14 856**

4.2 Trade impact sub-domain

This sub-domain focuses on impacts related to the trade of impacted hosts. Besides impacts on production, when a pest outbreak occurs there are disruptions to trade. Third countries may impose

trade bans on the EU. In such cases, EU exports and competitive trade advantage could be lost. The trade impact of a pest is therefore related to the trade flows for the different hosts the pest can affect.

The trade impacts are captured using four indicators. First, we identify the countries which would ban trade with the EU (I.4 Number of importing countries expected to impose restrictions on trade), then we calculate the export losses due to those countries banning imports from the EU (I.5 Export losses) and the share of total production those exports represent (I.6 Share of production exported). Finally, we consider the concentration of trade with the importing countries (I.7 Trade dispersion). Each of these provides different insights into the extent of the trade impacts from the pest outbreak. We now proceed with the detailed description of each of the four indicators.

4.2.1 Number of importing countries expected to impose restrictions on trade (Indicator I.4)

This indicator records the number of third countries banning trade with the EU. Given a total export loss associated with a pest outbreak, the larger the number of trading countries importing a commodity, the higher the impact due to compliance and transaction cost as a result of restrictions imposed on EU exports.

Not all trading countries would ban imports from the EU following an outbreak. We only consider third countries where the pest is not present (or where the pest is present but has quarantine status), since these would be the ones imposing trade restrictions. In addition, we only consider Extra-EU trade, as we assume that the outbreak would affect all of the Union territory. The indicator is calculated as follows, taking into consideration the different hosts affected by the pest (j):

$$(I.4)\ \ NICRT = \sum_{j=1}^{j=n} IC_j - ICnb_j$$

Where *NICRT* is the total number of countries to which the EU exports and which are expected to ban imports from the EU, *IC* is the total number of countries to which the EU exports (i.e. importing countries), and *ICnb* includes those countries to which the EU exports that are not expected to impose restrictions on imports from the EU.

In case of polyphagous pests, simple aggregation of the indicator values for each host would involve overestimating the impact, as the cost would be related to negotiating one agreement for all commodities infected by the pest, not one per host. Therefore, we only consider the number of unique trading countries. For instance, in the case of a pest affecting two commodities, if commodity (a) is traded with Brazil, Argentina and Morocco and commodity (b) is traded with Turkey, Israel and Argentina, the ICnb value will be 5 (Brazil, Argentina, Morocco, Turkey and Israel).

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Number of countries to which the EU exports (IC)

Trade data for individual hosts are reported by Comext, both for crops and forest products. We consulted all the countries importing the host(s) in any given year over the period 2013-2016 and provided a count indicator.

***Tilletia indica* – Number of importing countries (IC)**

Number of countries importing wheat and triticale from the EU: 114
Alphabetical list of countries:
Albania; Algeria; Andorra; Angola; Argentina; Armenia; Australia; Azerbaijan; Bahamas; Bahrain; Bangladesh; Barbados; Belarus; Benin; Bosnia and Herzegovina; Brazil; Burkina Faso; Burundi; Cambodia; Cameroon; Canada; Cape Verde; Chad; Chile; China; Congo; Congo (Democratic Republic of); Costa Rica; Cuba; Djibouti; Egypt; Equatorial Guinea; Eritrea; Ethiopia; Faroe islands; Former Yugoslav Republic of Macedonia; Gabon; Gambia; Georgia; Ghana; Guam; Guinea; Haiti; Hong Kong; Iceland; India; Indonesia; Iran; Iraq; Israel; Côte d'Ivoire; Japan; Jordan; Kazakhstan; Kenya; North Korea; Kosovo; Kuwait; Lebanon; Libya; Madagascar; Malawi; Malaysia; Mali; Mauritania; Mauritius; Mexico; Moldova; Montenegro; Morocco; Mozambique; Myanmar; Namibia; New Caledonia; New Zealand; Niger; Nigeria; Norway; Oman; Pakistan; Panama; Philippines; Qatar; Russia; Rwanda; Saudi Arabia; Senegal; Serbia; Seychelles; Singapore; Somalia; South Africa; Sri Lanka; St Lucia; Sudan; Suriname; Swaziland; Switzerland; Syrian Arab Republic; Taiwan; Tanzania; Thailand; Togo; Trinidad and Tobago; Tunisia, Turkey; Uganda; Ukraine; United Arab Emirates; United States of America; Uruguay; Vietnam; Yemen; Zimbabwe.

Source: Comext data for Extra-EU28

- Number of importing countries not expected to impose restrictions on trade with EU (ICnb)

Not all countries with which the EU trades are expected to impose restrictions on trade with the EU. Countries where the pest is present and is not listed as quarantine are assumed not to restrict trade with the EU for hosts of the pest following an outbreak. Both criteria are needed, as in some cases a country might declare the pest as quarantine despite it being present in its territory. These countries are part of the EFSA input to the JRC.

***Tilletia indica* – Number of importing countries not expected to impose restrictions on trade with EU (ICnb)**

Number of importing countries not expected to impose restrictions on trade with EU for *T.indica: 6*	
Pest is present (10)	***Pest has quarantine status***
South Africa	Argentina
Brazil	Brazil
Mexico	Canada
United States of America	Chile
Afghanistan	Paraguay
India	United States of America
Iran	Uruguay
Iraq	Bahrain
Nepal	China
Pakistan	Israel
	Jordan
	Kazakhstan
	Uzbekistan
	Azerbaijan
	Belarus
	Moldova
	Norway
	Russia
	Turkey
	Ukraine
	New Zealand

Note: The number of countries excludes Brazil and the USA as they have *Tilletia indica* listed as quarantine pests, and Nepal and Afghanistan as they do not import the hosts during the reference period.
Source: EFSA (2018)

Indicator calculation

Following the equation and the data presented above, the number of importing countries banning trade is **108.**

Indicator I.4 'Number of importing countries expected to impose restrictions on trade with EU' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Number of importing countries of wheat and triticale from the EU	114
Number of importing countries not expected to impose restrictions on trade with EU	6
I.4 Number of importing countries expected to	**108**

impose restrictions on trade	

4.2.2 Value of export losses (Indicator I.5)

Even for pests with minor direct impacts on yield or quality, economic impacts on trade can be considerable. Once we have identified the countries expected to impose trade restrictions for the affected hosts, the most evident indicator of trade impact is that of the value of the exports that would be affected. We define this indicator as the sum of the value of exports of each pest host to the countries listed in the previous indicator. The indicator is calculated as follows, adding across the different third countries that are expected to restrict trade (*i*) and the different hosts affected by the pest (*j*):

$$(I.5)\ \ XL = \sum_{j=1}^{j=n} \sum_{i=1}^{i=n} Xb_{ji}$$

Where *XL* is the value of export losses, *Xb* is the value of exports in euros, from EU to each of the importing countries expected to restrict trade with the EU. To avoid impact from changes in export quantities and destinations from year to year, the average for the period 2013-2016 is considered.

***Tilletia indica* – Value of exports to countries banning trade with EU**

Value of exports of wheat and triticale to countries expected to restrict trade with EU (million EUR)	
All countries	**5 413.30**

Source: Comext data for Extra-EU 28 - average of the latest four years available (2013-2016).

Indicator calculation

Following the equation and the data presented above, indicator I.5 'Value of export losses' for *Tilletia indica* takes the value **EUR 5 413.30 million.**

4.2.3 Share of export losses over total production (Indicator I.6)

As in the case of production, the total value of export losses (I.5) fails to capture whether this loss has a significant impact on total exports of the hosts affected by the pest in the EU-28. For this, we include a second indicator which measures the share of lost exports due to the pest outbreak, over EU production. The indicator is defined as the share of EU production exported to countries identified during construction of indicator I.4, over total production of the host in the EU. The indicator is calculated as follows, considering the different trading partners (*i*) and hosts affected by the pest (*j*):

$$(I.6) \qquad SPX = \frac{\sum_{j=1}^{j=n} \sum_{i=1}^{i=n} Xb_{ji}}{\sum_{j=1}^{j=n} TP_j}$$

Where *Xb* is the amount of export losses from the EU in tonnes, and *TP* is total production. This indicator is calculated in quantity rather than in value, to avoid over- or underestimating the share of production due to differences between domestic and export prices. To avoid impact from changes in export quantities and destinations from year to year, the average for the period 2013-2016 is considered.

- Quantity of exports to countries listed in I.4 (Xb)

Similar to value data for exports, data on quantity of exports will be collected from Comext for crops and forestry hosts.

***Tilletia indica* – Quantity of exports to countries listed in I.4 (Xb)**

Quantity of exports of wheat and triticale to countries expected to restrict trade with EU (1 000 t)	
All countries	**27 447**

Source: Comext data for Extra-EU 28 - average of the latest four years available (2013-2016).

- Total production (TP)

This component represents the total quantity of production of the hosts identified for each of the pests analysed. Based on Eurostat data for crops and data provided by MS in response to the ad hoc data request described above, the indicator is calculated as follows, adding across the different MS (*i*)[17] and the different hosts affected by the pest (*j*):

$$TP = \sum_{j=1}^{j=n} \sum_{i=1}^{i=28} \left(A_{j,i} \; x \; Y_{j,i}\right)$$

Where *A* is the area of each host and *Y* its yield as defined in section 4.1.1.

***Tilletia indica* – Total production (TP)**

Total production (1 000 t)			
Bread wheat	Durum wheat	Triticale	Total
143 059	8 328	12 446	**163 833**

Source: Own calculation based on Eurostat data at MS level - average of the latest four years available (2013-2016).

[17] Where the calculations are made at regional level (NUTS2), *i* will represent the number of regions.

Indicator calculation

Following the equation and the data presented above, the value for I.6 'Share of export losses over total production' for *Tilletia indica* is **17 %.**

Indicator I.6 'Share of export losses over total production' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Quantity of exports with countries banning trade to EU (1 000 t)	27 447
Total production of wheat and triticale (1 000 t)	163 833
I.6 Share of export losses over total production (%)	**17 %**

4.2.4 Trade dispersion (Indicator I.7)

Indicator I.4 assesses the number of countries with which the EU trades that are expected to ban imports from the EU, as a proxy for impact due to compliance and transaction cost. However, it fails to capture the concentration of trade with the different countries. If most of the EU's exports go to a limited number of countries, even if limited amounts are exported to a large number of countries, the EU would focus its compliance and negotiation efforts only on that limited number of countries, and the impact would not be as severe as if the EU had to negotiate with a larger number of countries. Therefore, the more disperse EU exports are, the more severe the impact of a pest outbreak.

While there is no index for trade dispersion, the Herfindahl-Hirschman Index (HHI) is a common measure of market concentration. The HHI is calculated by squaring the market share of each firm competing in a market, and then summing the resulting numbers. The maximum value of the indicator tends to 1 (nearly all exports go to one single country; a monopoly situation in competition terms), while its minimum tends to 0 (exports are evenly distributed among an infinite number of countries; a perfect competition situation in competition terms). Thus, the higher the value of the HHI, the less severe the impact of a pest outbreak would be. As mentioned in section 2.2, indicators should be positively correlated with the composite index, therefore indicator I.4 is a transformation of the HHI that reverses its relationship with the severity of the impact. The indicator is calculated as follows, considering the different trading partners (*i*) and hosts affected by the pest (*j*):

$$(I.7)\ \ TD = 1 - \sum_{i=1}^{i=n} \left(\frac{\sum_{j=1}^{j=n} Xb_{ji}}{\sum_{j=1}^{j=n} \sum_{i=1}^{i=j} Xb_{ji}} \right)^2$$

Where *TD* is the trade dispersion, and *Xb* is the quantity of exports from the EU to each of the importing countries expected to impose restrictions on trade with the EU. This indicator is calculated in quantity rather than in value, to avoid over- or underestimating concentration due to differences between export prices to different destinations. To avoid impact from changes in export quantities and destinations from year to year, exports over the period 2013-2016 are considered.

- Quantity of exports to countries expected to impose restrictions on trade with the EU (Xb)

See table reference for *Xb* data in the section above on indicator I.6 'Share of export losses over total production'. For this indicator, we use annual data for each year within the period considered, instead of a sum of annual averages for the full period.

Indicator calculation

Following the equation and the data presented above, the value for I.7 'Trade dispersion' is **0.92**. EU exports are distributed evenly among the different trading partners, and compliance and transaction costs would be high, thus the impact would be severe.

4.3 Price and market impacts sub-domain

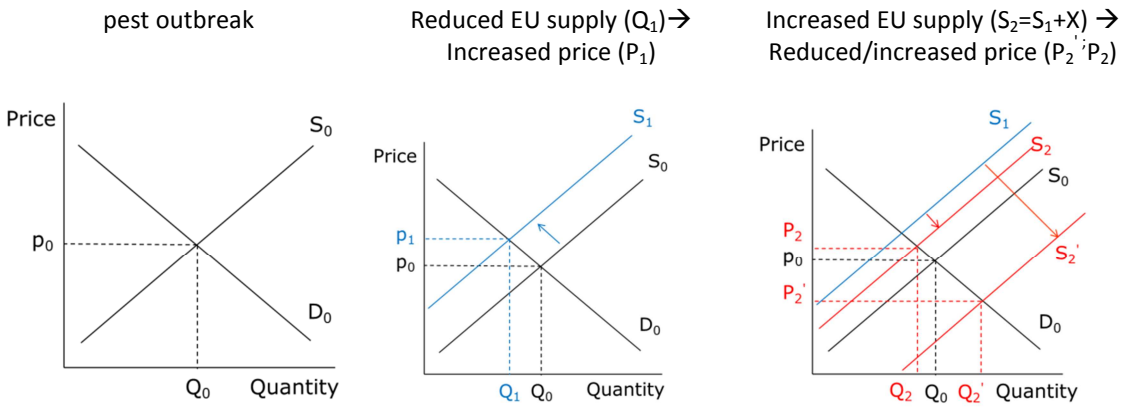
A third aspect to consider when assessing the severity of pest impacts from an economic perspective is that of the impact that changes in production and exports have on market prices, and in turn on consumer welfare due to changes in demand and supply for agricultural, horticultural or forestry products. This sub-domain groups indicators that capture how these changes will affect prices and markets for the affected hosts.

From a comparatively static viewpoint, as a general rule decreased supply would trigger higher prices, which would negatively affect consumers (panel b in Figure 7). If the reduction in supply is small in relation to world production, and the commodity is widely traded, this reduced production could be easily replaced by imports and the impact in prices will be insignificant. However, production available in the domestic market is affected not only by the reduction in production; changes in access to international markets also change domestic supply. If the EU is a net exporter of the affected commodity and trading partners restrict exchanges with the EU, domestic supply of the commodity will be supplemented by the exported quantity that is no longer traded and now has to be sold within the EU. Depending on the relative size of both components, after a pest outbreak prices could fall in the EU due to increased domestic supply. The final price (P_2) will depend on the relative size of production and export losses. If export losses are higher than production losses, the final price will be lower (see S_2' in panel c of Figure 7), and if they are lower than production losses, the final price will be higher (see S_2 in panel c of Figure 7).

When considering the severity of the impacts for the production and trade sub-domains above, the severity of impacts has been evaluated from a producer perspective: the higher the losses, the more severe the impacts. For price impacts, higher prices mean higher incomes for producers, thus the impact would be less severe; however, for consumers higher prices imply a reduction in their welfare and the impact on them would be higher. To avoid this dichotomy of impacts, when considering severity we will focus on absolute values, thus considering the effect on prices without taking into account who (producers or consumers) benefits from the change.

Figure 7. Price impacts due to changes in domestic production and supply following a pest outbreak in EU

a) Market equilibrium before b) Reduced yield → c) Export ban →



The price and markets impacts are captured using two indicators. First, we estimate the change in domestic price due to changes in domestic supply (I.8 'Change in domestic price'), and second we consider how easy it would be to substitute lost domestic supply with imports (I.9 'Ratio of domestic production over imports'). Each of the two indicators provides different insights into the extent of the price and market impacts of the pest outbreak. We now proceed with the detailed description of each of the two indicators.

4.3.1 Change in domestic price (Indicator I.8)

Price effects are complex and difficult to measure quantitatively without an economic model capable of capturing the different price response scenarios reflecting changes in the domestic production and trade of a product due to the pest. Here, we follow a short-term static comparative analysis using quantity-price elasticities and changes in quantity. This approach is reductionist, as it does not consider second order effects related to changes in production due to reallocation of areas where impacted hosts were grown, or changes in trade patterns.

Change in domestic price is expressed as a percentage of price change related to the change in domestic supply of a specific commodity in the EU market after the outbreak, and the commodity price elasticities. The indicator is calculated as follows, considering the different hosts affected by the pest (*j*):

$$(I.8)\ \ \Delta P\ = \max_{\forall j} \left| (\Delta Q_j\ x\ \frac{1}{E_j}) \right|$$

Where *ΔP* is the change in domestic price in percentage terms, *ΔQ* is the percentage change in domestic supply, and *E* is the price demand elasticity for the commodity affected. Domestic supply is defined as production plus imports minus exports. Elasticity is introduced as its inverse, as lower elasticity values imply higher changes in price; the indicator should be positively correlated with the impact and higher reductions in price would imply higher impacts (for producers). In the case of polyphagous pests, we consider the maximum value of the indicator for the different host-commodities affected.

Where the hosts affected are close substitutes (e.g. different types of vegetables) and different elasticities for each are available, we run a risk of overstating the impact of prices as we are missing

the possibility of consumers just shifting from one product to the other. In such cases (clearly identified in the individual data sheets), the calculation will be made by calculating the percentage change for all products together and the average elasticity for the products considered.

Data for this indicator are taken in quantity, as the elasticity refers to changes in prices following changes in quantities. To avoid the impact of changes in export quantities and destinations from year to year, or changes in production, data is taken as the average for the period 2013-2016.

Below we present the data sources available and the selection of the source used for each of the components of this indicator.

- Change in domestic supply in percentage terms (ΔQ)

Change in domestic supply is the result of reductions due to production loss, and increases due to exports that can no longer be sold on foreign markets. Data for both components have been described above in sections 4.1.1 and 4.2.2 respectively. Import data is also taken from the Comext database, considering only Extra-EU imports.

$$\Delta Q = \frac{-PL + Xb}{TP + M - X}$$

In the case of pests affecting trees, and because the production affected is the stock of biomass and the trade reflects the flow of biomass, if Xb is greater than (TP – PL) then the value of Xb will be truncated to the value of (TP – PL) to avoid the value of this component of the indicator being greater than 1.

***Tilletia indica* – Change in domestic supply for wheat and triticale (ΔQ)**

Change in domestic supply (%)	
TOTAL	**20**

Note: Eurostat data at MS level - average of the latest four years available (2013-2016).

- Own price elasticities of demand (E)

Price demand elasticities represent the percentage change in the price of a commodity in response to a quantity percentage change in supply. There is no official data source for elasticities as they have to be empirically estimated. For corps, we use those used in the CAPRI model[18]. As there are no data on price elasticities for all commodities, we take the commodity group in which the host is included[19]. As CAPRI does not report elasticities for

[18] www.capri-model.org

[19] Price elasticity is higher the more substitutes there are for a product (Varian, 2010); for example price elasticity of oranges will be higher than that of citrus. Due to the structure of our indicator, this means that we are underestimating the value of the change in domestic price. However, as this is the case for all hosts, we assume that the ranking will not be affected.

trees, in this case we use the elasticities of demand for end products reported in Table 3 in Buongiorno (2015).

***Tilletia indica* – Own price elasticity of demand (E)**

Wheat and triticale	**-0.22**

Source: CAPRI – average of MS-specific elasticities

Indicator calculation

Following the equation and the data presented above, the value for I.8 'Change In domestic price' is **90 %**.

Indicator I.8 'Change in domestic price' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Total production (1 000 t)	163 833
Quantity of imports (1 000 t)	5 068
Quantity of exports (1 000 t)	30 241
Maximum value of production losses (1 000 t)	48
Quantity of exports to countries banning trade with EU (1 000 t)	27 447
Change in domestic supply (%)	20
Own price elasticity if demand	-0.22
I.8 Change in domestic price (%)	**90**

4.3.2 Change in domestic production over imports (Indicator I.9)

In addition to the price change due to changes in domestic supply, the impact of a pest outbreak will be more severe the higher the ratio of domestic supply over imports, as it will be more difficult to substitute the lost production with imports. The indicator is calculated as follows, considering the different hosts affected by the pest (*j*):

$$(I.9)\ \ RDP = \begin{cases} 0, & if\ \Delta Q_j > 0 \\ \max\limits_{1<j<n}\left(\left|\frac{-PL_j + Xb_j}{M_j}\right|\right), & if\ \Delta Q_j < 0 \end{cases}$$

Where *RDP* is the ratio of domestic production over imports, *Q* is the domestic supply in absolute terms (-PL + Xb) and *M* is the total amount of Extra-EU imports. In the case of polyphagous pests, we consider the maximum value of the indicator for the different host-commodities affected.

The indicator is left censored as zero for positive changes in domestic supply, as there will be no impact if no additional imports are needed to fulfil domestic consumption.

Data for this indicator are taken in quantity, to avoid the impact of differing domestic, export and import prices. To avoid the impact of changes in export quantities and destinations from year to year, or changes in production, data is taken as the average for the period 2013-2016.

- Change in domestic supply (ΔQ)

See definition of the numerator in section 4.3.1.

- Total imports (M)

Data on quantity of exports will be collected from Comext for crops and forestry hosts.

***Tilletia indica* – Quantity of imports (M)**

Quantity of imports (1 000 t)	
Wheat and triticale	**5 068**

Note: Comext data at EU-28 level - average of the latest four years available (2013-2016)

Indicator calculation

Following the equation and the data presented above, the value for I.9 'Ratio of domestic production over imports' is **0** (change in domestic supply is greater than zero).

Indicator I.9 'Ratio of domestic production over imports' (for wheat) applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Change in domestic supply (1 000 t)	27 399
Quantity of imports (1 000 t)	5 068
I.9 Ratio of domestic production over import (%)	**0**

4.4 Impacts in other agents sub-domain

This sub-domain focuses on the impacts of a pest outbreak beyond the agricultural sector. This is another category of indirect effects that tries to capture the impacts on other economic sectors. Impact in other agents is captured using one indicator: the share of production that is used in other economic sectors. Downstream sectors include those sectors that use the products derived from the affected hosts (e.g. use of grain and by-products by processing industry). Upstream sectors include those that provide inputs to the affected hosts (e.g. nurseries). In both cases, a pest outbreak would limit the supply or demand for those sectors, due to the reduced activity in the farming or forestry sector.

The actual measurement of indirect impacts is difficult to calculate without relying on assumptions, since most data are aggregated and not related to specific crops or forestry species. The standard approach for measuring inter-sector relationships is that of input-output tables (Eurostat, 2008). To measure this indicator, we use the EU28 BioSAMs Social Accounting Matrix (SAM) for 2010, which contains 171 accounts, including 80 activity/commodity accounts for the EU developed at the JRC (Mainar-Causapé and Philippidis, 2018). The BioSAM covers 41 agricultural and forestry-related activities and provides a harmonised dataset built as an extension of traditional input-output tables, which integrates all relationships among institutional sectors, productive activities, goods and services, and production factors. For each activity, the BioSAM provides the distribution of total activity output as input for other activities (receipts) and the contribution of other activities' output as input to the activity production (payments). The latter can be considered proxies for upstream relationships and the former for downstream relationships. We now proceed with the detailed description of each of the two indicators.

4.4.1 Upstream effect (Indicator I.10)

If the outbreak of a pest implies a reduction in production of the commodity associated with the hosts, there will be a reduction in demand by producers of the host for outputs from other sectors in the economy. The reduction in demand is assumed to be proportional to the reduction in production. Thus, the upstream effect is measured using the accounting multiplier matrix, taking into account the coefficients that represent the 'pull' effect of a specific commodity on all other economic activities. The indicator is calculated as follows, adding across the different hosts affected by the pest (*j*) and considering all economic activities covered in the BioSAM (*k*):

$$(I.10)\ UE = \sum_{j=1}^{j=n} \left(PL_j x \sum_{k=1}^{k=n} OM_{jk} \right)$$

Where *PL* is the production loss in value associated with pest outbreak, and *OM* are the output multipliers of the commodity (host) to other economic activities. Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Maximum value of production losses (PL)

This corresponds to the first addend in indicator I.1, which represents the value of production lost due to yield loss.

***Tilletia indica* – Maximum value of production losses**

Maximum value of production losses (million EUR)	
Wheat (yield loss only)	**9.4**

Source: see section 4.1.1

- Output multipliers (OM)

Output multipliers represent the impact that one additional (less) unit of production of an activity would have on other sectors.

***Tilletia indica* – Output multipliers (OM)**

Sum of multipliers effect (ratio)	
All sectors vs wheat	**1.8**

Source: Data from EU-28 BioSAMs for 2010 (Mainar-Causapé and Philippidis, 2018)

Indicator calculation

Following the equation and the data presented above, the upstream effect related to production losses of hosts affected by *Tilletia indica* is **EUR 17 million**.

Indicator I.10 'Upstream effect' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Maximum value of production losses (million EUR)	9.4
Sum of multiplier effects	1.8
I.10. Upstream effect (million EUR)	**17**

Source: Eurostat, EFSA and EU-28 BioSAMs for 2010 (Mainar-Causapé and Philippidis, 2018).
Note: The value is calculated assuming wheat as a combined activity comprising bread and durum wheat.

4.4.2 Downstream effect (Indicator I.11)

If the outbreak of a pest implies a reduction in production of the commodity associated with the hosts, there will be a reduction in the output available as an input for other sectors. While for upstream effects we use absolute values for the indicator, which are affected by the relative size of the different host activities, for downstream effects we use the percentage of host-related output that is used as an input for other activities. The indicator is calculated as follows, considering the different hosts affected by the pest (*j*) and all economic activities covered in the BioSAM (*k*):

$$(I.11)\ DE = \max_{\forall j} \frac{\sum_{k=1}^{k=n} ID_{jk}}{TP_j}$$

Where *ID* is intermediate demand for the host by other economic activities, and *TP* is total production value of the host. Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Intermediate demand (ID)

The value of the commodity affected that is used for development of other sectors in total domestic production is collected from the EU-28 BioSAMs for 2010 (Mainar-Causapé and Philippidis, 2018).

***Tilletia indica* – Intermediate demand (ID)**

Intermediate demand (million EUR)	
Wheat vs all sectors	**8 241**

Source: Data from EU-28 BioSAMs for 2010 (Mainar-Causapé and Philippidis, 2018)

- Total production value BioSAM (TPB)

Value of total production for wheat, as reported in the BioSAM 2010.

***Tilletia indica* – Total production value BioSAM (TPB)**

Total production value BioSAM (million EUR)	
Wheat	**43 331**

Source: Data from EU-28 BioSAMs for 2010 (Mainar-Causapé and Philippidis, 2018)

Indicator calculation

Following the equation and the data presented above, the downstream effect related to production losses for hosts affected by *Tilletia indica* is **19 %**.

Indicator I.11 'Downstream effects' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Intermediate demand (million EUR)	8 241
Total production value BioSAM (million EUR)	43 331
I.11. Downstream effect (%)	**19**

Source: EU-28 BioSAM
Note: The value is calculated assuming wheat as a combined activity comprising bread and durum wheat.

5 Social impact indicators

This chapter provides the rationale for the structure of the social impact domain in the I2P2 and the selection of the individual indicators. Pest outbreaks do not only have economic impacts. Regulation (EU) No 2016/2031 refers to considering social and environmental impacts when assessing the

severity of quarantine pests for priority listing (see Annex I Section 1 point 4; Annex I Section 2 points (b) and (c)).

Following the structure of Annex I Section 2 point (b), the domain has been split into three sub-domains, captured by one or more indicators: impact on employment, impact on food security or food safety, and impact on recreation, landscape and cultural heritage. Table 9 summarises the list of indicators for assessing social impact, with their components.

The rest of the chapter describes in detail each of the indicators proposed, presenting the theoretical relationship between the indicator and the pest prioritisation process, as well as the data sources used for the calculation. For each indicator, an example is provided on how it is calculated for the *Tilletia indica* pilot pest.

Table 9. Summary of indicators and components for social impacts

Sub-domain	Indicators	Data
Impact on employment	I.12 Job losses	Host planted area
		Production loss in quantity
		Total production
		Labour needs for the production
Impact on food security or food safety	I.13 Share of caloric supply	Host-specific caloric supply
		Total caloric supply
	I.14 Share of protein supply	Host-specific protein supply
		Total protein supply
	I.15 Share of fat supply	Host-specific fat supply
		Total fat supply
	I.16. Capacity to produce fungal toxins	Capacity to produce fungal toxins
Impact on recreation, landscape or cultural heritage	I.17 Share of holdings with other gainful activities	Holdings with other gainful activities
		Total number of holdings
	I.18 Products covered by EU quality labels	Number of Protected Designation of Origin, Protected Geographical Indication or Traditional Speciality Guaranteed
	I.19 Presence of affected hosts on cultural heritage landmarks	Number of UNESCO World Heritage Sites Number of coats of arms Number of anthems Number of works of arts

5.1 Impact on employment sub-domain

The economic impacts of the outbreak of a pest are captured as described in section 4.1.1. However, crop or forest production loss due to a pest outbreak will lead to reductions in labour needs, which translates into a reduction in employment levels associated with the hosts. Here, impact on employment refers to the reduction in number of jobs directly related to crop, horticultural or forestry production which would result if the production levels of the host were reduced due to the pest outbreak. We propose a single quantifiable measure of employment related to the affected activity to cover this sub-domain.

5.1.1 Jobs losses (Indicator I.12)

Employment requirements differ depending on the farming or forestry activities and systems affected. The effect on employment is estimated in terms of reduced labour use per activity, for each individual host affected by a pest, which is linked to the extent of the impact of the pest on production. When measuring employment effects, only the primary production or activity is taken into account. Other indirect employment losses from host-related sectors are already indirectly captured in indicators I.10 'Upstream effect' and I.11 'Downstream effect'. Also, we only consider employment losses and not potential additional labour needs related to control and eradication measures, as these are defensive costs (UN, 1997); they can be considered proxies for the benefits of prevention, but not for reducing impacts of negative events (Lipert and Pulselli, 2008). The indicator is calculated as follows, adding across the different MS (*i*) and the different hosts affected by the pest (*j*)[20]:

$$(I.12)\ JL = \sum_{j=i}^{j=n} \sum_{i=1}^{i=28} \left(A_{ji}\ x\ \frac{PL_{ji}}{TP_{ji}} x L_{ji} \right)$$

Where *JL* is the effect on employment loss in number of annual working units (AWU), *A* is the host planted area in hectares, *PL* is the production loss in quantity due to the pest outbreak, *TP* is the total production and *L* is the labour requirement per hectare in AWU for production of the host.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Host planted area (A)

See description in section 4.1.1: Maximum production loss.

[20] Depending on data availability regarding labour needs, individual host impacts will be aggregated. For the example of *Tilletia indica*, the relevant aggregation level is 'cereals' and therefore areas, production loss and total production will be aggregated for the three hosts.

***Tilletia indica* - Host planted area (A)**

EU-28 Host planted area (2013-2016 average; 1 000 has)	
Host	**Area**
Bread wheat	24 100
Durum wheat	2 478
Triticale	2 934
TOTAL	29 512

Source: Aggregation of Eurostat data reported at MS level

- Production loss in quantity (PL)

We measure the production loss indicator in quantity. This means that we assume that losses in quality will have no impact on labour demand, as the crops will still be harvested even if they are sold at a lower price. For this, we take indicator I.1, exclude losses due to quality and exclude the price component of the yield losses.

$$\sum_{j=1}^{j=n} \sum_{i=1}^{i=28} \left(A_{j,i} \; x \; Y_{j,i} \; x \; r_{loss\ i,j} \right)$$

***Tilletia indica* – Production loss in quantity (PL)**

Maximum production loss (2013-2016 average; 1 000 t)	
Host	**Value**
Bread wheat	45.2
Durum wheat	2.8
Triticale	0
TOTAL	48

Note: Own calculation based on Eurostat data; see section 4.1.1 for details.

- Total production (TP)

As defined in section 4.2.3.

***Tilletia indica* – Total production (TP)**

As the production loss indicator for the host Triticale is zero, total production is not reported.

Total production (1 000 t)		
Bread wheat	Durum wheat	Total
143 059	8 328	**151 387**

Note: Eurostat data at MS level - average of the latest four years available (2013-2016)

- Labour need for production (L)

The labour need for production is determined by the average number of working hours associated with host production, including both paid and un-paid (i.e. family) labour. It is expressed as the number of full-time workers, per hectare and per year, for specific crops or forest species.

For crops, as part of the farm structure surveys (FSS)[21] Eurostat collects data on labour force directly or indirectly employed by the holding, by type of crop. Data is reported on an annual basis, in annual work units per hectare (AWU per ha). Data are available at MS or NUTS2 level for the total agricultural area and for different farm types (i.e. specialist cereals, oilseed and protein crops; general field cropping; specialist horticulture indoor and outdoor; specialist vineyard; specialist fruit and citrus fruit). As no host-specific data are available, we identify the farm type which corresponds with the affected hosts and take that value as a proxy for the crop-specific value.

Data on forest employment are also available in annual work units as part of Eurostat's forestry statistics[22]. However, data are only provided at MS level and are not differentiated by species, thus providing little variance to the indicator beyond that related to production loss. To avoid this lack of discriminatory power for this indicator, species or genus-specific data have been included in the MS ad hoc data request mentioned above, and will be used if available.

***Tilletia indica* – Labour need for production (L)**

Among the different farm types for which data are available, specialist cereals best represent the labour needs for wheat.

Labour need for wheat and triticale production (AWU per ha)	
Specialist cereals	**0.03**

Note: Eurostat data at MS level - latest year available (2013)

[21] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_kvftreg&lang=en
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_olfreg&lang=en
[22] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_awu&lang=en
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_emp_lfs1&lang=en

Indicator calculation

Following the equation and the data presented above, the value for I.12 'Job losses' is **217 AWU**.

Indicator I.12 'Job losses' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Wheat planted area in EU (1 000 has)	26 578
Maximum production loss for wheat and triticale (1 000 t)	48
Total production of wheat (1 000 t)	151 387
Labour need for the production (AWU per ha)	0.03
I.12. Job losses (AWU)	**217**

Note: reported values are EU-28 averages; however, the indicator is calculated aggregating MS-specific values. Therefore, applying the indicator formula to the values reported does not lead to the reported results.

5.2 Impact on food security or food safety

Food security is a multidimensional concept which relates to the availability of, and access at all times to, sufficient and nutritious food to maintain a healthy and active life. Due to scarcity of data, the selection of indicators to cover this concept only focuses on one of these dimensions, that of food availability (FAO, 2017). The selected indicators capture the change in availability of the three macronutrients that provide dietary energy (carbohydrates, protein and fats), among all commodities (including fruits and vegetables), due to a reduction in the supply of crops affected by the pest outbreak. The caloric supply (measured in kilocalories per person per day) and the protein and fat available for human consumption (measured in grams per person per day) are key indicators in terms of food consumption patterns and trends (WHO, 2009; Vasileska and Rechkoska, 2012). Therefore, in order to illustrate the size of impact on food consumption patterns of the host-commodities that can be affected by a pest, we include the following indicators: I.13 'Caloric supply', I.14 'Protein supply' and I.15 'Fat supply'. The higher the contribution of the affected commodities to EU average diets, the higher the social impact will be.

Food safety aims to ensure a high level of protection of human health and consumer interests, but it is also a very complex issue with multiple components (e.g. safe and nutritious food and feed; animal health, welfare and plant protection; adequate and transparent information about the origin, content/labelling and use of food)[23]. The European Commission actively takes part in setting international phytosanitary and quality standards for plants and plant products[24] and only authorised products are allowed into the EU. Understanding this, we estimate the food safety measurement by means of the ability of the pest to produce aflatoxins: indicator I.16 'Ability to produce fungal toxins'. We now proceed with the detailed description of each of the four indicators.

[23] http://europa.eu/pol/index_en.htm
[24] https://ec.europa.eu/food/plant

5.2.1 Share of caloric supply (Indicator I.13)

The caloric supply indicator is estimated as the share of EU food supply of a commodity or processed commodities for human consumption that is affected by a pest. The indicator is calculated as follows, adding across the different hosts affected by the pest (*j*):

$$(I.13)\ SCS = \sum_{j=1}^{j=n} \frac{CS_j * r_{loss}}{TCS}$$

Where *SCS* is the share of EU caloric supply of the commodities or related processed commodities that can be affected by the pest, *FS* is the caloric supply quantity of the commodity, r_{loss} is the yield loss as described in section 4.1.1, and *TCS* is the total caloric supply including all commodities available for human consumption. The indicator is calculated for the EU-28 as whole.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Caloric supply of affected hosts (CS)

The FAO Food Balance Sheets[25] provide data per capita values for the supply of all food commodities, and the calories, protein and fat content. The caloric supply quantity is expressed, by primary commodity and related processed commodities, as the daily supply of calories in kilocalories (kcal) per capita per day in the EU-28. The per capita caloric supply of each primary and processed commodity available for human consumption can be found in the FAO Food Balance Sheets.

***Tilletia indica* – Caloric supply of affected host (CS)**

Wheat and wheat products caloric supply quantity in EU (kcal/capita/day)	
Wheat and wheat products	**786**

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

- Potential proportion of loss in yield (r_{loss})

Yield loss is provided by EFSA as part of its input to the prioritisation methodology as described in section 4.1.1.

***Tilletia indica* – Potential proportion of loss in yield (r_{loss})**

Potential proportion of loss in yield (%)	
Percentile	**Percentage**
1st	0.005

[25] http://www.fao.org/economic/ess/fbs/en/

25th	0.025
50th	**0.050**
75th	0.100
99th	0.544

Source: EFSA (2018) – Data presented reflects yield loss without taking into account climate suitability and host distribution. Specific values per MS are used, that take these two factors into account.

- Total caloric supply quantity (TCS)

The total caloric supply quantity is the aggregation, across all the commodities available for human consumption, of calories in kilocalories (kcal) per capita per day.

***Tilletia indica* – Total caloric supply quantity (TCS)**

Total food supply quantity including all commodities in EU (kcal/capita/day)	
All commodities for food consumption	**3 409**

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

Indicator calculation

Following the equation and the data presented above, the share of caloric supply in the EU coming from hosts (wheat and wheat products) affected by *Tilletia indica* is **0.007 %**.

Indicator I.13 'Share of caloric supply' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Wheat and wheat products food supply quantity in EU (kcal/capita/day)	786
Potential proportion of loss in yield (%)	0.032
Total food supply quantity including all commodities in EU (kcal/capita/day)	3 409
I.13. Share of caloric supply (%)	**0.007**

5.2.2 Share of protein supply (Indicator I.14)

Following the same approach used in the share of caloric supply indicator, the share of protein supply provided by the affected hosts is calculated. The indicator is calculated as follows, adding across the different hosts affected by the pest (*j*):

$$(I.14)\ \ SPS = \sum_{j=1}^{j=n} \frac{PS_j * r_{loss}}{TPS}$$

Where *SPS* is the share of protein supply of the commodity or related processed commodities that can be affected by the pest, *PS* is the protein supply quantity of the commodity, and *TPS* is the total protein supply including all commodities available for human consumption.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Protein supply quantity (PS)

Data on protein supply quantities were taken from the FAO Food Balance Sheets described above.[26] The protein supply quantity is expressed, by primary commodity and related processed commodities, as the EU daily protein supply in grams (g) per capita per day.

***Tilletia indica* – Protein supply quantity (PS)**

Wheat and wheat products protein supply quantity in EU (g/capita/day)	
Wheat and wheat products	**25**

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

- Total protein supply quantity (TPS)

The total protein supply quantity is expressed, for all the commodities available for human consumption as the EU daily supply of grams (g) per capita per day.

***Tilletia indica* – Total protein supply quantity (TPS)**

Total protein supply quantity including all commodities in EU (g/capita/day)	
All commodities for food consumption	**104**

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

Indicator calculation

Following the equation and the data presented above, the share of protein supply in the EU coming from hosts (wheat and wheat products) affected by *Tilletia indica* is **0.008 %**.

Indicator I.14 'Share of protein supply' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Wheat and wheat products protein supply quantity in EU (g/capita/day)	25
Potential proportion of loss in yield (%)	0.032
Total protein supply quantity including all commodities in EU (g/capita/day)	104

[26] http://www.fao.org/economic/ess/fbs/en/

I.14. Share of protein supply (%)	0.008

5.2.3 Share of fat supply (Indicator I.15)

Following the same approach used in the share of caloric and protein supply indicator, the share of fat supply provided by the affected hosts is calculated. The indicator is calculated as follows, adding across the different hosts affected by the pest (*j*):

$$(I.15)\ SFS = \sum_{j=1}^{j=n} \frac{FS_{j*r_{loss}}}{TFS}$$

Where *SFS* is the share of fat supply of the commodity or related processed commodities that can be affected by the pest, *FS* is the fat supply quantity of the commodity, and *TFS* is the total fat supply including all commodities available for human consumption.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Fat supply quantity (FT)

Data on fat supply quantities were taken from the FAO Food Balance Sheets described above.[27] The fat supply quantity is expressed, by primary commodity and related processed commodities, as the EU daily fat supply in grams (g) per capita per day.

***Tilletia indica* – Fat supply quantity (FS)**

Wheat and wheat products fat supply quantity in EU (g/capita/day)	
Wheat and wheat products	**4**

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

- Total fat supply quantity (TFS)

The total fat supply quantity is expressed, for all the commodities available for human consumption, as the EU daily supply of grams (g) per capita per day.

***Tilletia indica* – Total fat supply quantity (FTS)**

Total fat supply quantity including all commodities in EU (g/capita/day)	
All commodities for food consumption	**140**

[27] http://www.fao.org/economic/ess/fbs/en/

Note: FAO Food Balance Sheet data at EU level - latest year available (2013)

Indicator calculation

Following the equation and the data presented above, the share of fat supply in the EU coming from hosts (wheat and wheat products) affected by *Tilletia indica* is **0.001 %**.

Indicator I.15 'Share of fat supply' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Wheat and wheat products fat supply quantity in EU (g/capita/day)	4
Potential proportion of loss in yield (%)	0.032
Total fat supply quantity including all commodities in EU (g/capita/day)	140
I.15. Share of fat supply (%)	**0.001**

5.2.4 Ability to produce fungal toxins (Indicator I.16)

Fungal toxins (or mycotoxins) are known to be genotoxic and carcinogenic, and exposure through food should be kept as low as possible. Fungal toxins can occur in foods such as groundnuts, tree nuts, maize, rice, figs and other dried foods, spices, crude vegetable oils and cocoa beans, as a result of fungal contamination before or after harvest. Maximum levels for fungal toxins and certain other contaminants in food are set in Regulation (EC) 1881/2006 and subsequent amendments[28].

This indicator captures whether the pest has the ability to produce fungal toxins, or indirectly increase the risk of fungal toxins (e.g. through damage to grains).

$$(I.16)\ \ APA = \begin{cases} 1 & if\ Yes \\ 0 & if\ No \end{cases}$$

Where *APA* is the ability of the pest to produce fungal toxins in any of its hosts. Where the pest has the ability to produce fungal toxins or indirectly increase the risk of them, it will be assigned the value 1; where the pest does not have this ability, it will be assigned the value 0.

The data on the capacity to produce fungal toxins will be provided by EFSA in their EKE reports.

Indicator calculation

According to the EKE report on *Tilletia indica* (EFSA, 2018), this pest does **not** have the capacity to produce fungal toxins.

[28] https://www.efsa.europa.eu/en/topics/topic/aflatoxins-food

Indicator I.16 'Ability to produce fungal toxins' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Tilletia indica ability to produce fungal toxins	No
I.16. Ability to produce fungal toxins (1 / 0)	**0**

5.3 Impact on recreation, landscape or cultural heritage

Agricultural and forestry production are multifunctional activities, as they jointly produce multiple commodity and non-commodity outputs. Some of these non-commodity outputs exhibit the characteristics of positive externalities or public goods, with the result that markets for these goods do not exist or are functioning poorly (OECD, 2001). This sub-domain captures indirect effects of a pest on society, focusing on the capacity to disrupt some of these multifunctional activities, in particular those related to recreation and culture. Ecosystems where the hosts are potentially affected by a pest can be key to recreational activities, and/or hosts can be part of the cultural heritage of a specific area of the EU. A pest outbreak can interrupt the proper development of these activities or sites and have a negative impact on the society.

The impacts on recreation, landscape or cultural heritage are captured in three indicators: I.17 'Share of holdings with other gainful activities', I.18 'Products covered by EU quality labels', and I.19 'UNESCO World Heritage Sites'. Each of these is independent from the others and provides different insights into the extent of these indirect impacts on society. We now proceed with the detailed description of each of the three indicators.

5.3.1 Share of holdings with other gainful activities (Indicator I.17)

Farm and forest holdings can undertake other gainful activities in addition to their crop and wood production. When the main activity is disrupted, we can assume that the other gainful activities will also be disrupted. Available data on other gainful activities are provided as an aggregate that captures tourism, handicraft, aquaculture, wood processing in farms, contractual work using equipment of the holding, and processing of products other than primary farm or forest ones[29]. The higher the share of farms growing a specific crop or group of crops, the more severe the impact on these activities. While not all of these are related to recreation, we consider it the best proxy that can be found in the official statistics domain for this concept.

[29] Activities are not taken into account if only the farm labour force (family and non-family) and no other resources of the holding are used, the workers are seen as working under two separate arrangements, and these other gainful activities are thus not seen as being directly related to the holding. For example, if the farmer rents agricultural machinery that he does not use in the farm, he will not be counted as having other gainful activities. By contrast, if he uses the machinery in his farm, he will.

The indicator is calculated as follows, adding across the different MS affected by the pest (*n*) and the different hosts affected by the pest (*j*):

$$(I.17)\ \ SHOGA = \max\left(\frac{\sum_{i=1}^{i=n} HOGA_{ij}}{\sum_{i=1}^{i=n} H_{ij}}\right)\forall j$$

Where *SHOGA* is the share of farm or forest holdings with other gainful activities associated with the host affected by a pest, *HOGA* is the number of holdings with other gainful activities by each country that is affected by the pest, and *H* is the total number of holdings by country that is affected by the pest.

Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

- Holdings with other gainful activities (HOGA)

As part of the Farm Structure Survey, data are available in Eurostat[30] on the number of holdings undertaking other gainful activities in each of the EU-28 MS, by farming type (i.e. specialist field crops; specialist horticulture; specialist permanent crops). Gainful activities of the farm comprise all activities other than farm work, directly related to the holding and having an economic impact on the holding.

Data are only available for farm types, and these farm types do not correspond one-to-one with the pest-hosts subject to the analysis; therefore, the value for the farm type that covers the pest-host under analysis is chosen.

These data are only available for farm types that do not include forestry activities. In order to capture the fact that forests have a higher recreational and landscape value, hosts that are trees will be assigned the maximum value for this indicator.

***Tilletia indica* – Holdings with other gainful activities (HOGA)**

Among the different farm types for which data are available, specialist cereals best represent the holdings producing wheat and triticale.

Holdings with other gainful activities (number, EU-28)	
Holdings with other gainful activities (*specialist field crops*)	**1 363 740**

Source: Aggregated using Eurostat data at MS level - latest year available (2013)

[30] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_ogaft&lang=en

- Number of holdings (H)

Data on number of holdings are used by aggregated farming types by EU-28 MS, in order to make them comparable with HOGA units. These can be found in Eurostat[31].

***Tilletia indica* – Number of holdings (H)**

Number of holdings for wheat production (number of holdings)	
Total number of holdings for specialist field crops	**3 194 870**

Source: Aggregated using Eurostat data at MS level - latest year available (2013)

Indicator calculation

Following the equation and the data presented above, the value for I.17 'Share of holdings with other gainful activities' is **43 %**.

Indicator I.17 'Share of holdings with other gainful activities' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Other gainful activities for specialist field crops (number of holdings)	1 363 740
Total number of holdings for specialist field crops (number of holdings)	3 194 870
I.17. Share of holdings with other gainful activities (%)	**43 %**

5.3.2 Products covered by EU quality labels (Indicator I.18)

Another aspect to the agricultural and forestry sector's multifunctionality is that related to EU protected agricultural and food products. To measure the potential impact on these services, we propose an indicator that captures the relationship between the hosts affected by the pests and products covered by EU quality schemes for agricultural products.

The proposed indicator is a count variable that reflects the number of Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG) associated with the host. Below, we present the data sources available and the selection of the source used for each of the components of this indicator.

As EU quality labels do not apply to wood products, this indicator takes a value of 0 for the six pests affecting forestry species.

[31] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_kvftreg&lang=en

- EU quality schemes for agricultural products

The World Trade Organisation (WTO) agreement on intellectual property rights (TRIPs) provides an international baseline for protecting and promoting agricultural and food products in the domestic and the international market, through quality schemes for agricultural products (GIs)[32]. To date, over 3 330 quality schemes are registered in the EU. EU agricultural and food products are registered with the status of Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), or Traditional Speciality Guaranteed (TSG).

Data on the number of quality schemes are collected from the EU dataset DOOR[33] (Database of Origin and Registration), including all PDO, PGI and TSG products registered. The JRC team has reviewed the list to identify those related to the host-commodity that can be affected by the pest, by MS.

Indicator I.18 'Products covered by EU quality labels' applied to pilot pest *Tilletia indica*

Quality schemes related to wheat and wheat products in EU
1. Farine de blé noir de Bretagne/ Gwinizh du Breizh (FR) 2. Farine de Petit Épeautre de Haute Provence (FR) 3. Petit Épeautre de Haute Provence (FR) 4. Fränkischer Grünkern (DE) 5. Gofio Canario (ES)

Source: Expert assessment based on DOOR (Database of Origin and Registration).

Indicator calculation

Following the data presented above, the value for I.18 'Products covered by EU quality labels' is **5.**

5.3.3 Presence of affected hosts on cultural heritage landmarks (Indicator I.19)

Another dimension of the agricultural and forestry sector's multifunctionality is that related to cultural heritage (CH). To measure this dimension of the potential impact on these services, we propose an indicator that captures the relationship between the hosts affected by the pests and a selection of aspects related to the cultural heritage of each of the Member States.

Out of the multiple aspects that relate to the cultural heritage of a country, we have selected five:

(a) Presence of the host in any of the country's UNESCO World Heritage sites[34].

[32] https://ec.europa.eu/agriculture/quality_en
[33] http://ec.europa.eu/agriculture/quality/door/list.html;jsessionid=pL0hLqqLXhNmFQyFl1b24mY3t9dJQPflg3xbL2YphGT4k6zdWn34%21-370879141
[34] http://whc.unesco.org/en/criteria/

(b) Presence of the host in the coat of arms of the country or any of its regions.

(c) Reference to the host in the anthem of the country or any of its regions.

(d) Presence of the host in major national or regional works of art.

(e) Any other reason why the host would be considered of importance for the cultural heritage of the country (e.g. national tree).

The JRC team consulted the MS representatives at the EGPHL, asking them to provide input for these aspects. In particular, the JRC provided MS with the list of UNESCO World Heritage sites included in the UNESCO World Heritage List (WHL)[35] and asked them to identify those related to hosts that can be affected by the pest. A particular World Heritage Site is assumed to have a direct relationship with the host if two conditions are fulfilled: (i) the agricultural or natural site contains a host or commodity that could potentially be affected by the pest, and (ii) damage or disappearance of the host or commodity is a limiting factor for the correct functioning or existence of the system. In addition, four open-ended questions were included in the request, covering items (b), (c), (d) and (e). Information was provided by 26 Member States.

Based on the responses provided, the JRC constructed five count indicators. The first one is a count variable reflecting the number of WHL sites related to each host, as identified by MS. The other four reflect the number of MS for which the host is mentioned in any of the other questions. The first indicator ranges from 0 to the total number of WHL sites identified, taking into account the number of hosts for which the analysis has been done; the other four range from 0 (e.g. no MS has mentioned the host as being present in the coat of arms of the country or any of its regions) to 28 (e.g. all MS have mentioned the host as being present in the coat of arms of the country or any of its regions), also taking into account the number of hosts for which the analysis has been done.

$$CH_k = \sum_{j=1}^{j=n} \sum_{i=1}^{i=28} X_i \qquad \forall k[1,5]$$

Where X_i takes the value of sites identified for the first indicator (see (a) above) and the value of host mentioned by MS in their responses to the other four questions (see (b), (c), (d) and (e) above), and *j* represents the different hosts affected by the pest.

Indicator I.19 is then constructed as a composite of the five indicators, giving equal weights to the WHL component and the average of the other four.

$$CH = (0.5\, xCH_1) + \left(0.5x\left(\frac{CH_2 + CH_3 + CH_4 + CH_5}{4}\right)\right)$$

[35] This list provides an international baseline for protection and maintenance of agricultural or natural landscape sites representative of the different regions of the world. Moreover, the list has started to include sites from the World Heritage Forest Programme, which safeguards forest conservation at a global level. http://whc.unesco.org/en/list/

The Plant Health Regulation distinguishes between crops and trees when referring to impacts on heritage. Reference to landscape is mentioned both in Annex I Section 1 point 4, ident (s) ('effects on water quality, recreation, tourism, **landscape heritage**, animal grazing, hunting, fishing') and in Annex I Section 2 points (b) and (c), ident (iii) ('the disappearance of, or long-term large-scale damage to, important tree species growing or cultivated in the Union territory or tree species of high importance in terms of **landscape** as well as cultural or historical heritage for the Union'). Therefore, the impact on landscape should be calculated where the pest affects either crops or trees. However, cultural and historical heritage is only mentioned in Annex I Section 2 points (b) and (c), ident (iii) which explicitly mention the 'disappearance of, or long-term large-scale damage to, **important tree species**'. Therefore, CH is calculated differently when dealing with these two types of hosts. For trees, the formula above applies, while for crops items (b) to (e) which refer to cultural and historical heritage are disregarded and CH is calculated as follows:

$$CH = (0.5\, xCH_1)$$

Indicator I.19 'Presence of affected hosts on cultural heritage landmarks' applied to pilot pest *Tilletia indica*

Wheat and wheat products affected on cultural heritage landmarks in EU
3.50

Source: Expert assessment based on World Heritage List by MS.

6 Environmental impact indicators

This chapter provides the rationale for the structure of the environmental impact domain of the I2P2 and the selection of the individual indicators. The environmental impacts from the introduction and spread of a Union quarantine pest can be classified into three sub-domains: impacts on street trees, parks and natural and planted areas; undesired impacts of control measures on the environment; and impacts on biodiversity and ecosystem services that can be provided by the host affected. Each sub-domain has one or more indicators. Table 10 summarises the list of indicators for assessing the environmental impacts and their components.

The rest of the chapter describes in detail each of the indicators proposed, presenting the theoretical relationship between the indicator and the pest prioritisation process, as well as the data sources used for the calculation. For each indicator, an example is provided of how it is calculated for the *Tilletia indica* pilot pest.

Table 10. Summary of indicators and components for environmental impacts

Sub-domain	Indicators	Data
Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	Qualitative responses by MS representatives to ad hoc data request
Undesired impacts of control measures	I.21 Undesired effects of control measures	Type of control measures needed
Impact on biodiversity and ecosystem services	I.22 Soil erosion	C-factor per host
	I.23 Number of protected species and habitats related to hosts	Number of habitats and species listed under Council Directive 92/43/EEC and Directive 2009/147/EC associated with hosts
	I.24 Share of Natura 2000 area and sites affected	Share of Nature 2000 sites affected
		Share of total area of Natura 2000 affected
	I.25 Share under sustainable management practice	Share under sustainable management practices area

6.1 Impact on street trees, parks and natural and planted areas sub-domain

Annex I Section 1 point 4 (e) explicitly mentioned this sub-domain as an area for which the severity of impacts should be assessed. This sub-domain tries to capture the use of hosts affected by the pest as street and park trees, and their role in natural and planted areas. It is assumed that the indicator will only play a role for pests with forest tree species, as the impact on natural areas is captured in indicator I.24 'Share of Natura 2000 area and sites' affected. This sub-domain consists of a single indicator: the use of host as street trees and in parks. We now proceed with the detailed description of this indicator.

6.1.1 Use of hosts as street trees and in parks (Indicator I.20)

This indicator measures the relative extent of the host trees that can be affected by a pest, used in streets and parks in the MS. As there is no official dataset with the specific tree species used in

streets and parks, the JRC has included a specific question on this as part of the ad hoc data requested mentioned in Chapter 2. By definition, this indicator will only take non-zero value for tree and ornamental hosts.

Following the data request, 15 MS[36] submitted data. These MS represent 60 % of total EU territory and 59 % of total forestry area.

For each tree species or genus, MS are requested to respond whether it is used in streets and parks, and to rate the relative extent using a four-level scale. The scale of impact is 1 to 4; however, when there is no use at all (as in the case of wheat), we provide the value of 0. The correspondence between the levels of the scale and their abundance is shown in Table 11.

Table 11. Correspondence between abundance scale used in the measurement of the indicator and share of presence

Share of presence	Abundance scale
Not used	0
Less than 1 %	1
Between 1 % and 20 %	2
Between 21 % and 50 %	3
More than 50 %	4

The indicator is calculated as follows, adding across the different MS (*i*) and the different hosts affected by the pest (*j*):

$$(I.20)\ \ USTP = \sum_{i=1}^{i=28} \sum_{j=1}^{j=n} QPS_{i,j}$$

Where *QPS* is the rating value for abundance of use of hosts as street and park trees, provided by MS in response to the ad hoc consultation. Hosts are considered at genus level, so if information is provided for more than one species, the maximum value of QPS across the different species is taken.

Indicator calculation

Following the equation and the data presented above, the value for I.20 'Use of hosts as street trees and in parks' is **0**.

[36] BE, BG, DE, DK, EE, FI, FR, HU, LH, LT, NL, PT, SE, SI and UK.

Indicator I.20 'Use of hosts as street trees and in parks' applied to pilot pest *Tilletia indica*

Abundance scale of use of hosts (0-4)	
Host	
Bread wheat	**0**
Durum wheat	**0**
Triticale	**0**
Sum	**0**

Note: Own calculations for EU-28, using indicator formula based on MS responses to ad hoc consultation

6.2 Environmental and other undesired impacts of control measures

6.2.1 Undesired effects of control measures (Indicator I.21)

Annex I Section 1 point 4 (m) explicitly mentioned this sub-domain as an area for which the severity of impacts should be assessed. This sub-domain tries to capture the risk of undesired effects associated with the need for additional treatments with Plant Protection Products (PPP) at field level to control the pest. These treatments are dedicated to controlling the pest or to maintaining production at the same efficiency level as it was before the outbreak. The indicator is calculated as follows, considering the different hosts affected by the pest (*j*):

$$(I.21)\ UECM = \max_{\forall j} CM_j$$

Where *UECM* is the rating value for undesired effects provided by the EFSA EKE process. The EKE process provides an assessment of the undesired effects of control measures, based on the nature of the additional treatments, on forest and cropping production, for the control of each pest. The assessment considers four categories as described in Table 12. The different cases have increasing probability of undesired effects, and are thus positively correlated with the severity of the impact.

Table 12. Categories used in the EFSA EKE process for expected changes in the use of Plant Protection Products (PPPs) following establishment of a pest in the EU.

Expected change in the use of PPPs	**Case**	**CM value**
PPPs effective against the pest are not available/feasible in the EU	A	0
PPPs applied against other pests in the risk assessment area are also effective against the pest, without increasing the amount/number of treatments	B	0
PPPs applied against other pests in the risk assessment area are also effective against the pest, but only if the amount/number of treatments is increased	C	1
A significant increase in the use of PPPs is not sufficient to control the pest; only new integrated strategies combining different tactics are likely to be effective	D	2

Indicator calculation

Following the equation and the data presented above, the value for I.21 'Undesired effects of control measures' is **0**.

Indicator I.21 'Undesired effects of control measures' applied to pilot pest *Tilletia indica*

Additional treatments for *T. indica*	
PPPs applied against other pests in the risk assessment area are also effective against the given pest, with no need to increase the amount of treatments	**0**

Note: EFSA (2018)

6.3 Impacts on biodiversity and ecosystem services

Annex I Section 1 point 4 (f) explicitly mentioned this sub-domain as an area for which the severity of impacts should be assessed. This sub-domain provides four indicators, one specific to ecosystem services (I.22) and three that relate to biodiversity (I.23, I.24 and I.25). Each of them is independent from the others and provides different insights into the extent of the direct economic impact for the producer. We now proceed with the detailed description of each of the four indicators.

6.3.1 Soil erosion (Indicator I.22)

The cover-management factor, known as C-factor, is a measure commonly used to estimate the soil erosion risk. It accounts for how land cover, crops and crop management practices cause soil loss (Kinnell, 2010). Panagos et al. (2015) provided estimations of the C-factor at EU level, by weighting literature C-factor values according to specific parameters for arable lands (percentage of land per crop and soil management) and non-arable lands (fractional vegetation cover based on remote sensing dataset). In Table 13, we have collected those mean C-factor values per land cover type, together with the land cover type description, that can be applicable to construction of the I2P2 soil erosion indicator (i.e. Broad-leaved forest; Coniferous forest; Pastures; Fruit trees and berry plantations; Olive groves; Vineyards). With this data, it is possible to obtain a measurement of the severity of the impact on erosion which captures the additional erosion that each hectare affected would generate.

Table 13. Soil erosion indicator, built on soil water erosion rates per land cover group

Land cover type	Land cover type description	Mean C-factor values per land cover type (E)	Soil erosion indicator (SE)
Maximum erosion value area	No vegetation area	1	1
Coniferous forest	Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate	0.0011	0.9989
Broad-leaved forest	Vegetation formation composed principally of trees, including shrub and bush understories, where broad-leaved species predominate	0.0013	0.9987
Pastures	Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system; mainly used for grazing	0.0903	0.9097
Fruit trees and berry plantations	Parcels planted with fruit trees or shrubs: single/mixed fruit species, fruit trees associated with permanently grassed surfaces	0.2188	0.7812
Olive groves	Areas planted with olive trees	0.2273	0.7727
Wheat and spelt	Common and durum wheat, spelt, rye	0.2000	0.8000
Barley	Barley	0.2100	0.7900
Maize	Green maize, corn	0.3800	0.6200
Rice	Rice	0.1500	0.8500
Protein crops	Dried pulses and protein crops	0.3200	0.6800
Tubers	Potatoes, sugar beet	0.3400	0.6600
Oilseeds	Oilseed	0.2800	0.7200
Rape	Rape and turnip rape	0.3000	0.7000
Sunflower seed	Sunflower seed	0.3200	0.6800
Linseed	Linseed	0.2500	0.7500
Soya		0.2800	0.7200
Cotton seed		0.5000	0.5000
Tobacco		0.4900	0.5100
Vineyards	Areas planted with vines	0.3527	0.6473
Tomatoes		0.3200	0.6800
Other vegetables		0.3200	0.6800

Source: JRC, based on Panagos et al. (2015)

To obtain a proxy of the impact on erosion of the different pests, we consider the alternative land use to that of the hosts as being no vegetation cover. This use corresponds to the category 'maximum erosion or no vegetation rate' in Table 13 and takes a value of 1. All other land uses have C-factors below 1, showing that the presence of vegetation reduces erosion. The additional erosion caused by the pest can be proxied as the difference between the C-factor values associated with the different hosts affected by the pest and this maximum erosion land use, as follows:

$$(I.22)\ SE = E_{os} - E_i$$

Where *SE* is the soil erosion indicator, E_{os} is the C-factor for the land use 'maximum erosion rate' and E_i is the C-factor value for host *i*. SE values ranges between 0 and 1.

For the case of polyphagous pests, the indicator is calculated as maximum additional erosion for the different hosts:

$$(I.22)\ \max_{\forall j} SE_j$$

While we acknowledge that this indicator is far from a perfect measure of additional erosion expected following a pest outbreak, the proxy captures the severity of the impact. The construction of a better indicator is constrained by data availability. Firstly, we do not have the exact area of each host that will be affected by the pest. Secondly, we do not have information as to whether the pest impact will imply disappearance or removal of the host, and therefore we cannot calculate the total additional erosion generated by the pest. However, as the area affected by the pest is already captured in the production loss indicator (see above), not taking the affected area into account does not invalidate this measurement.

Indicator calculation

Indicator I.22 'Soil erosion' applied to pilot pest *Tilletia indica*

Soil erosion for *T. indica*	
C-factor for wheat (wheat)	**0.2000**
Soil erosion indicator	**0.8000**

Note: Panos et al (2018)

6.3.2 Number of protected species and habitats related to hosts (Indicator I.23)

The impact of a pest on a host also impacts wildlife and biodiversity associated with the specific host. We propose an indicator that captures this impact by identifying the relationship between hosts affected, and species and habitats listed under Council Directive 92/43/EEC and Directive 2009/147/EC of the European Parliament and of the Council. These two pieces of legislation are explicitly mentioned in Annex I Section 2 point C (i) of Regulation (EU) No 2016/2031.

The JRC reviewed whether the list of plant hosts that can be affected by the Union quarantine pests selected by DG SANTE are related to the habitat types listed in Annex I; animal and plant species listed in Annex II, IV and V of Council Directive 92/43/EEC; and bird species in Annex I and II of Directive 2009/147/EC.

For each host, the JRC constructs a quantitative measure of the number of species and habitats related to it. To do this, we have cross-checked the EU habitat interpretation manual (EC, 2013) for Annex I of Directive 92/43/EEC, and the European reference databases on linkages between species/habitat types and broad ecosystems (EEA, 2018), for references to different ways to refer to the hosts, as shown in

Table 14.

Table 14. Triticum species related to habitat types and species listed in the Habitats Directive and the Birds Directive

	Habitats Directive							Birds Directive				TOTAL HABITATS	TOTAL SPECIES HD	TOTAL SPECIES BD	TOTAL
	A I	P	A II	R	A IV	R	A V	A I	R	A II	R				
Cereal	0	0	4	3	4	3	0	8	4	14	2	0	14	28	42
Wheat	0	0	1	1	1	1	0	2	1	2	0	0	4	5	9
Triticosecale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum aestivum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum durum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Results for Annex I based on EC (2013); rest of Annexes based on EEA (2018c).
Priority (P) - Number of 'priority' habitats where the host species is mentioned in the habitat description (counted twice in TOTAL HABITATS); Risk (R) - Number of Annex II, IV species under risk for which the host species is mentioned in their habitat description ('risk': IUNC categories CR, EN, NT, VU) (counted twice in TOTAL SPECIES HD).

Indicator calculation

From the different options considered, we have chosen to keep that using 'cereal or wheat' as the most representative and differentiating for the hosts considered. Following the approach described above in relation to bread wheat, durum wheat and triticale, the value of indicator I.23 'Number of protected species and habitats related to hosts' is **9**.

Indicator I.23 'Number of protected species and habitats related to hosts' applied to pilot pest *Tilletia indica*

Summary of data used for calculation of the indicator and final result	
Number of habitats and species listed under Council Directive 92/43/EEC and Directive 2009/147/EC related to bread wheat, durum wheat and triticale	9
I.23 Number of protected species and habitats related to hosts	**9**

Source: expert assessment

6.3.3 Share of Natura 2000 area and sites affected (Indicator I.24)

Another indicator that can measure the severity of the impact of a pest outbreak on biodiversity and ecosystem services is whether host production loss following the outbreak will happen inside

protected areas. The disappearance of a host in a protected area can affect the proper functioning of the system.

To measure this, EFSA will provide two quantitative indicators, based on the overlap of the host area suitable for infection and the Natura 2000 areas. The indicator will be measured in terms of both number of sites and total area. The indicator is calculated as follows, considering the different hosts affected by the pest (*j*):

$$(I.24)\ SN2Ka = \max_{\forall j}(NSR_j; NAR_j)$$

Where *NSR* is the share of Natura 2000 sites and *NAR* is the share of Natura 2000 area potentially affected by an outbreak. As mentioned in Chapter 3, for calculating this indicator EFSA has considered the full list of hosts reported in publicly available databases.

The value reported by EFSA for this indicator is **0**.

6.3.4 Share of area under sustainable management practices (Indicator I.25)

The environmental quality associated with a crop or trees goes beyond whether the species are related to protected habitats or species (as captured by indicator I.23) or are grown in a protected area (as captured by indicator I.24). The different management practices under which the crop is grown are also connected with the environmental impact associated with loss of production. There is quasi-unanimous agreement that environmental performance is higher for organic farming (for crops) and certified forest management (for trees) than for their alternatives. Therefore, as an additional proxy for environmental impact, we propose an indicator that quantifies the area of each host that is certified under those schemes.

Organic farming is a way of producing food that respects natural life cycles. It minimises human impact on the environment and operates as naturally as possible. It is regulated by Council Regulation (EC) No. 834/2007 and data is available, by crop, in Eurostat[37]. The indicator is calculated as follows, considering the different hosts (*j*) affected by the pest:

$$(I.25)\ SASMP = \max_{\forall j}(SASMP_j)$$

Where *SASMP* is the indicator as reported by Eurostat for the different crops.

As far as tree hosts are concerned, the two most well-known forest certifications that provide an international baseline for protecting and promoting sustainable forest management and use are: Forest Stewardship Council (FSC)[38] and Programme for the Endorsement of Forest Certification (PEFC)[39]. These two certifications help to preserve forest biodiversity and longevity, and maintain foresters' employment rights and proper status for recreational purposes.

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[37] http://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics
[38] www.fsc.org
[39] www.pefc.org

Total area of FSC certified area was obtained from FAO (2015)[40] (cross-checked during the MS data request process), while shares of FSC area per host, at genus level, were calculated using the data available on the FSC project certificate webpage[41]. Applying the FSC rate, calculated using the latter, to the total area under FSC from the former, we obtained an estimate of the FSC area per genus. Dividing this area by the total area for the genus, we obtain the share of total area under FSC.

As individual certificate data is not available for PEFC, this approach cannot be used to calculate PEFC shares. In this case, we use the share of each genus, in total area at MS level, and multiply if by total PEFC area as reported by FAO (2015) (cross-checked during the MS data request process). This provides the genus-specific PEFC area, which is then divided by the total area for the genus to obtain the share of total area under PEFC.

This indicator is calculated as follows, considering the different hosts affected by the pest (*j*):

$$(I.25)\ SASMP = \max_{\forall ji}\left(\frac{FSC_j}{TOT_j};\ \frac{PEFC_j}{TOT_{j;}}\right)$$

Where *FSC* is the total host area under FSC (ha); *PEFC* is the total host area under PEFC (ha) and *TOT* is the total forest area.

As the FSC certificates do not distinguish the area for each species, when reporting multiple species under the same certificate, shares for rare species calculated using the approach described above overshoot 100 %. Therefore, single genus or species that represent less than 1 % of the total area of all the hosts are discarded when calculating the maximum value.

Indicator calculation

Following the data presented above for the case of crops, the value for I.25 'Share of area under sustainable management practices' for the case of *Tilletia indica* is **0.41 %.**

Indicator I.25 'Share of area under sustainable management practices' applied to pilot pest *Tilletia indica*

Share of total area fully converted or under conversion to organic farming	
Crop	Share under organic farming (%)
Wheat and spelt	0.41

[40] www.fao.org/3/a-i4808e.pdf
[41] www.info.fsc.org/certificate.php

7 Summary of results for impact indicators of assessed pests

Table 15. Summary of impact indicators for the evaluated pests affecting crops

Domain	Sub-domain	Indicators	*T. i.*	*X.c.*	*P.c.*	*S.e.*	*C.m.*	*C.l.*	*G.f.d.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (million EUR)	48.8	470.8	340.7	118.9	331.0	2 562.6	887.3
		I.2 Share of EU production value affected (%)	0.16 %	12.46 %	9.06 %	1.00 %	2.78 %	67.80 %	4.30 %
		I.3 Difficulty of eradication	14 856	163	2 244	2 434	3 917	42 598	187
	Trade impacts	I.4. Number of importing countries expected to impose restrictions on trade	108	95	106	140	138	96	139
		I.5 Value of export losses (million EUR)	5 413.3	479.5	494.4	478.4	498.7	509.1	133.4
		I.6 Share of export losses over total production (%)	17 %	6 %	7 %	2 %	2 %	7 %	0 %
		I.7 Trade dispersion	0.92	0.91	0.91	0.95	0.95	0.92	0.91
	Price and market impacts	I.8 Change in domestic price (%)	90 %	1 %	9 %	3 %	1 %	119 %	8 %
		I.9 Change in domestic production over imports (%)	0 %	0 %	0 %	0 %	78 %	316 %	109 %
	Impacts in other agents	I.10 Upstream effect (million EUR)	17	237	74	244	679	2 527	566
		I.11 Downstream effect (%)	19 %	5 %	5 %	21 %	21 %	5 %	92 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	217	4 874	1 628	885	2 465	55 600	20 312
	Impact on food security or food safety	I.13 Share of caloric supply	0.01 %	0.04 %	0.01 %	0.04 %	0.10 %	0.48 %	0.02 %
		I.14 Share of protein supply	0.01 %	0.02 %	0.01 %	0.03 %	0.08 %	0.27 %	0.01 %
		I.15 Share of fat supply quantity	0.00 %	0.01 %	0.00 %	0.00 %	0.00 %	0.05 %	0.00 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43 %	38 %	38 %	43 %	43 %	38 %	39 %
		I.18 Products covered by EU quality labels	5	21	21	25	25	21	13
		I.19 Presence of affected hosts on cultural heritage landmarks	3.5	12.6	9.1	4.0	4.0	12.6	19.0
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	7	4	0	0	7	2
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0	1	1	0	0	2	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.800	0.781	0.781	0.660	0.660	0.781	0.647
		I.23 Number of protected species and habitats related to hosts	9	1	1	4	4	1	3
		I.24 Share of Natura 2000 area and sites affected (%)	0 %	0 %	0 %	50 %	50 %	0 %	50 %
		I.25 Share under sustainable management practices (%)	0.41 %	0.03 %	0.03 %	0.01 %	0.01 %	0.03 %	0.17 %

Table 15 (cont.) Summary of impact indicators for the evaluated pests affecting crops

Domain	Sub-domain	Indicators	*S.f.*	*R.s.*	*A.l.*	*R.p.*	*P.j.*	*B.d.*	*B.z.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (million EUR)	659.9	2 820.1	295.4	1 588.3	2 420.3	639.1	530.4
		I.2 Share of EU production value affected (%)	11.67 %	17.28 %	5.13 %	30.44 %	14.69 %	17.15 %	9.55 %
		I.3 Difficulty of eradication	242 320	1 398	18 017	1 092	11 122	13 125	14 813
	Trade impacts	I.4. Number of importing countries expected to impose restrictions on trade	103	93	127	133	158	94	119
		I.5 Value of export losses (million EUR)	1 936.9	790.1	809.3	832.1	2 225.9	837.8	826.4
		I.6 Share of export losses over total production (%)	2 %	1 %	7 %	13 %	4 %	7 %	7 %
		I.7 Trade dispersion	0.91	0.94	0.91	0.87	0.93	0.90	0.90
	Price and market impacts	I.8 Change in domestic price (%)	0 %	15 %	9 %	41 %	2 %	3 %	8 %
		I.9 Change in domestic production over imports (%)	0 %	0 %	0 %	417 %	0 %	3 %	0 %
	Impacts in other agents	I.10 Upstream effect (million EUR)	1 217	999	291	1 566	2 183	630	523
		I.11 Downstream effect (%)	52 %	21 %	5 %	5 %	92 %	5 %	5 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	14 261	59 206	5 760	34 523	86 306	11 092	10 225
	Impact on food security or food safety	I.13 Share of caloric supply	0.12 %	0.18 %	0.07 %	0.19 %	0.16 %	0.15 %	0.14 %
		I.14 Share of protein supply	0.08 %	0.28 %	0.04 %	0.04 %	0.09 %	0.08 %	0.07 %
		I.15 Share of fat supply quantity	0.01 %	0.04 %	0.01 %	0.03 %	0.03 %	0.03 %	0.03 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	1	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	41 %	43 %	40 %	39 %	45 %	40 %	40 %
		I.18 Products covered by EU quality labels	10	47	29	26	80	30	29
		I.19 Presence of affected hosts on cultural heritage landmarks	2.0	6.5	28.9	9.9	90.5	28.9	22.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	22	9	51	24	20
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	0	1	1	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.850	0.680	0.781	0.781	0.910	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	20	4	1	0	195	1	1
		I.24 Share of Natura 2000 area and sites affected (%)	50 %	52 %	50 %	51 %	54 %	27 %	24 %
		I.25 Share under sustainable management practices (%)	0.01 %	0.10 %	0.21 %	0.06 %	3.01 %	0.21 %	0.21 %

Table 15 (cont.) Summary of impact indicators for the evaluated pests affecting crops

Domain	Sub-domain	Indicators	*B.c.*	*A.e.*	*X.f.*	*T.l.*	*T.p.*	*C.n*
Economic impacts	Production impacts	I.1 Maximum value of production losses (million EUR)	1 458.9	739.8	5 496.1	1 185.2	662.6	1 924.2
		I.2 Share of EU production value affected (%)	7.76 %	36.74 %	69.10 %	23.22 %	12.69 %	19.10 %
		I.3 Difficulty of eradication	794 475	3 283	14 849	2 665	1 707	536
	Trade impacts	I.4. Number of importing countries expected to impose restrictions on trade	145	76	147	127	79	149
		I.5 Value of export losses (million EUR)	1 016.8	188.0	741.0	1 885.3	431.1	1 468.7
		I.6 Share of export losses over total production (%)	2 %	4 %	2 %	5 %	2 %	11 %
		I.7 Trade dispersion	0.96	0.86	0.91	0.94	0.80	0.86
	Price and market impacts	I.8 Change in domestic price (%)	15 %	70 %	107 %	21 %	3 %	13 %
		I.9 Change in domestic production over imports (%)	0 %	405 %	13 %	0 %	19 %	119 %
	Impacts in other agents	I.10 Upstream effect (million EUR)	1 919	1 089	9 870	1 375	441	1 897
		I.11 Downstream effect (%)	21 %	21 %	92 %	52 %	10 %	5 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	52 674	23 006	297 186	26 841	22 802	43 699
	Impact on food security or food safety	I.13 Share of caloric supply	0.35 %	0.01 %	0.27 %	0.25 %	0.08 %	0.28 %
		I.14 Share of protein supply	0.34 %	0.01 %	0.18 %	0.21 %	0.13 %	0.10 %
		I.15 Share of fat supply quantity	0.03 %	0.00 %	0.45 %	0.04 %	0.02 %	0.07 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	1	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43 %	35 %	100 %	100 %	43 %	39 %
		I.18 Products covered by EU quality labels	47	47	70	52	79	58
		I.19 Presence of affected hosts on cultural heritage landmarks	6.5	19.0	137.3	75.4	21.6	44.5
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	65	47	4	43
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2	2	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.680	0.680	0.999	0.999	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	4	4	103	67	16	0
		I.24 Share of Natura 2000 area and sites affected (%)	47 %	23 %	60 %	15 %	12 %	52 %
		I.25 Share under sustainable management practices (%)	0.10 %	0.10 %	46.76 %	26.97 %	0.10 %	0.06 %

Table 16. Summary of impact indicators for the evaluated pests affecting forests

Domain	Sub-domain	Indicators	*A.a*	*A.p.*	*C.f.*	*A.g..*	*B.x..*	*D.s.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (million EUR)	63 006.0	23 467.1	7 903.0	23 997.9	32 499.0	4 850.3
		I.2 Share of EU production value affected (%)	77 %	75.00 %	2.10 %	7.12 %	7.34 %	0.48 %
		I.3 Difficulty of eradication	13 884.0	17 246	497	1 566	45 059	156 750
	Trade impacts	I.4. Number of importing countries expected to impose restrictions on trade	34.0	51	123	99	109	140
		I.5 Value of export losses (million EUR)	25.6	10.3	251.0	372.2	159.4	3 301.0
		I.6 Share of export losses over total production (%)	0 %	0 %	0 %	0 %	0 %	0 %
		I.7 Trade dispersion	0.6	0.88	0.81	0.82	0.90	0.89
	Price and market impacts	I.8 Change in domestic price (%)	442 %	432 %	12 %	31 %	42 %	2 %
		I.9 Change in domestic production over imports (%)	12914 %	135794 %	7091 %	3181 %	6190 %	196 %
	Impacts in other agents	I.10 Upstream effect (million EUR)	131 847.0	49 117	16 537	50 218	68 007	10 137
		I.11 Downstream effect (%)	61 %	61 %	61 %	61 %	61 %	61 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	18 003.0	5 314	1 256	5 286	7 407	832
	Impact on food security or food safety	I.13 Share of caloric supply	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
		I.14 Share of protein supply	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
		I.15 Share of fat supply quantity	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	0.0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100 %	100 %	100 %	100 %	100 %	100 %
		I.18 Products covered by EU quality labels	0	0	0	0	0	0
		I.19 Presence of affected hosts on cultural heritage landmarks	17.0	20.6	31.0	197.8	23.0	67.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	30.0	28	16	224	23	110
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0.0	0	0	0	0	0
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987	0.9987	0.9987	0.9989	0.9989
		I.23 Number of protected species and habitats related to hosts	95.0	47	234	676	114	104
		I.24 Share of Natura 2000 area and sites affected (%)	50 %	50 %	51 %	52 %	51 %	23 %
		I.25 Share under sustainable management practices (%)	52 %	42.62 %	27 %	66 %	52 %	51 %

Table 17. Summary of impact indicators for the evaluated pests affecting agroforestry

Domain	Sub-domain	Indicators	*A.c.*	*A.b.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (million EUR)	18 971.5	345.0
		I.2 Share of EU production value affected (%)	8.30 %	6.70 %
		I.3 Difficulty of eradication	1 630	1 268
	Trade impacts	I.4. Number of importing countries expected to impose restrictions on trade	156	140
		I.5 Value of export losses (million EUR)	2 650.6	362.8
		I.6 Share of export losses over total production (%)	0 %	2 %
		I.7 Trade dispersion	0.92	0.86
	Price and market impacts	I.8 Change in domestic price (%)	12 %	39 %
		I.9 Change in domestic production over imports (%)	0 %	1 %
	Impacts in other agents	I.10 Upstream effect (million EUR)	38 468	465
		I.11 Downstream effect (%)	61 %	61 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	206 531	9 552
	Impact on food security or food safety	I.13 Share of caloric supply	0.2 %	0.0 %
		I.14 Share of protein supply	0.1 %	0.0 %
		I.15 Share of fat supply quantity	0.1 %	0.0 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100 %	100 %
		I.18 Products covered by EU quality labels	89	30
		I.19 Presence of affected hosts on cultural heritage landmarks	330.1	56.9
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	360	49
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987
		I.23 Number of protected species and habitats related to hosts	960	45
		I.24 Share of Natura 2000 area and sites affected (%)	54 %	53 %
		I.25 Share under sustainable management practices (%)	66.28 %	68.76 %

8 Correlation analysis

Following the calculation of the 25 indicators for the sample of pests selected, correlation analysis is done to study the overall structure of the dataset, assess its suitability, and guide subsequent methodological choices (OECD, 2015).

A correlation analysis between the different indicators was undertaken for the two groupings of pests. Correlations within indicators of the same domain are shaded in blue, orange and green respectively. Within each domain, correlations between indicators in each of the sub-domains are bordered by a thick line. High correlations are defined as those above 0.5.

As a general rule, highly collinear indicators within a given sub-domain ($r > 0.92$ approximately) need to be treated, either by eliminating one of the two (weight of 0), or by counting them as a single indicator (adjusting their relative weights); otherwise they will influence the results of principal component analysis and dominate the pest scores in the respective sub-domain.

A second issue to be considered is that of negative correlations. Negative correlations indicate that either the direction of effects is wrong or that there are implicit trade-offs between indicators, a feature of the phenomenon being measured.

8.1 Correlation analysis for pests affecting crops

Table 18 shows the correlation analysis for the 20 pests affecting crops. For our dataset, there is no sub-domain-specific correlation above the threshold; therefore, we maintain the full set of indicators to calculate I2P2 for pests affecting crops.

As far as negative correlations are concerned, these come from indicators that try to capture a different feature within each sub-domain. For example, I.1 and I.2 are negatively correlated with I.3. While the former two measure the absolute and relative impact of the pest, indicator I.3 relates to the difficulty of eradication, which has no a priori theoretical relationship with the impact. It is generally desirable not to have high negative correlations, at least within the sub-domains (OECD, 2015); as the maximum negative correlation value, in absolute terms, is below 0.50, no change is made to the indicator.

Moving up the indicator structure, correlation between the individual sub-domain scores (Table 19) and domain scores (

Table 20) also shows no high correlation among them, validating our indicator structure for pests affecting crops.

Table 18. Correlation of individual indicator values for pests affecting crops

	I.01	I.02	I.03	I.04	I.05	I.06	I.07	I.08	I.09	I.10	I.11	I.12	I.13	I.14	I.15	I.16	I.17	I.18	I.19	I.20	I.21	I.22	I.23	I.24	I.25
I.01	1.00																								
I.02	0.77	1.00																							
I.03	0.02	-0.12	1.00																						
I.04	0.29	-0.10	0.19	1.00																					
I.05	-0.10	-0.22	0.04	0.10	1.00																				
I.06	-0.22	-0.04	-0.22	-0.05	0.59	1.00																			
I.07	0.07	-0.16	0.31	0.45	0.17	-0.24	1.00																		
I.08	0.51	0.77	-0.09	-0.13	0.24	0.30	-0.07	1.00																	
I.09	0.10	0.50	-0.15	-0.18	-0.26	0.25	-0.39	0.48	1.00																
I.10	0.90	0.75	0.06	0.35	-0.08	-0.21	0.06	0.56	0.05	1.00															
I.11	0.49	0.17	-0.00	0.47	0.11	-0.47	0.27	0.09	-0.19	0.53	1.00														
I.12	0.93	0.70	0.04	0.34	-0.06	-0.25	0.05	0.51	-0.02	0.98	0.57	1.00													
I.13	0.63	0.63	0.37	0.24	-0.07	-0.03	0.17	0.40	0.19	0.50	0.02	0.45	1.00												
I.14	0.55	0.40	0.54	0.06	-0.08	-0.33	0.30	0.22	-0.08	0.37	0.05	0.38	0.82	1.00											
I.15	0.85	0.68	-0.04	0.30	-0.07	-0.16	0.01	0.51	-0.07	0.97	0.45	0.96	0.38	0.27	1.00										
I.16	-0.15	0.10	0.12	-0.40	-0.01	-0.18	-0.20	0.07	0.32	-0.04	0.10	-0.10	-0.23	-0.19	-0.13	1.00									
I.17	0.55	0.43	-0.07	0.30	0.11	-0.21	0.22	0.30	-0.24	0.67	0.52	0.65	0.31	0.34	0.70	-0.15	1.00								
I.18	0.55	0.30	0.02	0.19	-0.14	-0.30	-0.28	-0.02	-0.09	0.46	0.30	0.54	0.30	0.39	0.43	-0.13	0.41	1.00							
I.19	0.72	0.51	-0.19	0.44	0.05	-0.16	0.03	0.26	-0.17	0.79	0.64	0.81	0.31	0.18	0.78	-0.17	0.78	0.67	1.00						
I.20	0.61	0.41	-0.21	0.50	0.11	0.03	0.03	0.14	-0.19	0.65	0.46	0.65	0.38	0.15	0.66	-0.26	0.69	0.61	0.94	1.00					
I.21	0.46	0.68	-0.00	0.02	-0.18	-0.12	-0.20	0.37	0.32	0.49	0.38	0.46	0.43	0.21	0.38	0.22	0.42	0.45	0.64	0.58	1.00				
I.22	0.47	0.43	-0.17	0.17	0.35	0.14	-0.01	0.26	-0.23	0.55	0.41	0.53	0.30	0.14	0.55	-0.05	0.75	0.39	0.78	0.79	0.60	1.00			
I.23	0.52	0.24	-0.08	0.44	0.25	-0.20	0.20	0.07	-0.22	0.50	0.73	0.56	0.16	0.12	0.41	-0.07	0.50	0.62	0.79	0.71	0.52	0.66	1.00		
I.24	0.37	-0.05	0.18	0.65	-0.18	-0.37	0.22	-0.25	-0.04	0.36	0.45	0.37	0.12	0.10	0.31	0.05	0.11	0.26	0.27	0.26	-0.11	-0.08	0.27	1.00	
I.25	0.69	0.57	-0.09	0.30	0.03	-0.21	0.15	0.42	-0.17	0.84	0.56	0.82	0.31	0.28	0.86	-0.11	0.96	0.42	0.84	0.72	0.47	0.73	0.51	0.16	1.00

Note: I.XX Refers to the numbering of indicators presented in Table 4.

Table 19. Correlation of sub-domain values for pests affecting crops

	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3
1.1	1.00									
1.2	-0.03	1.00								
1.3	0.50	-0.07	1.00							
1.4	0.58	0.16	0.11	1.00						
2.1	0.81	0.06	0.28	0.82	1.00					
2.2	0.90	-0.09	0.37	0.45	0.63	1.00				
2.3	0.53	0.06	0.86	0.71	0.77	0.47	1.00			
3.1	0.41	0.31	-0.03	0.61	0.65	0.32	0.86	1.00		
3.2	0.57	-0.18	0.40	0.48	0.46	0.50	0.58	0.58	1.00	
3.3	0.50	0.31	-0.05	0.85	0.78	0.44	0.85	0.83	0.46	1.00

Note: X.X refers to the numbering of sub-domains presented in Table 4

Table 20. Correlation of domain values for pests affecting crops

	Economic	Social	Environmental
Economic	1.00		
Social	0.73	1.00	
Environmental	0.61	0.81	1.00

Following this analysis, the I2P2 structure for crops is defined as follows:

$$I2P2_{crops}=0.3*\left[0.25*\left((0.3*I_{01}+0.3*I_{02}+0.3*I_{03})+(0.25*I_{04}+0.25*I_{05}+0.25*I_{06}+0.25*I_{07})+(0.5*I_{0.8}+0.5*I_{09})+(0.5*I_{10}+0.5*I_{11})\right)\right] + 0.3*\left[\left((I_{12})+(0.25*I_{13}+0.25*I_{14}+0.25*I_{15}+0.25*I_{16})+(0.3*I_{17}+0.3*I_{18}+0.3*I_{19})\right)\right] + 0.3\left[(I_{20})+(I_{21})+(0.25*I_{22}+0.25*I_{23}+0.25*I_{24}+0.25*I_{25})\right]$$

This results in the indicator, sub-domain and domain-specific weights reflected in Table 21. As can be seen, the application of a hierarchical weighting approach ensures that weights are equal across domains and sub-domains.

Table 21. Indicator, sub-domain and domain weights used for the I2P2 application to crops

Indicator	Indicator weight	Sub-domain weight	Domain weight
I.1 Maximum value of production losses	0.03	0.08	0.33
I.2 Share of EU production value affected	0.03		
I.3 Difficulty of eradication	0.03		
I.4 Number of importing countries expected to impose restrictions on trade	0.02	0.08	
I.5 Value of export losses	0.02		
I.6 Share of export losses over total production	0.02		
I.7 Trade dispersion	0.02		
I.8 Change in domestic price	0.04	0.08	
I.9 Change in domestic production over imports	0.04		
I.10 Upstream effects	0.04	0.08	
I.11 Downstream effects	0.04		
I.12 Job losses	0.11	0.11	0.33
I.13 Share of caloric supply	0.03	0.11	
I.14 Share of protein supply	0.03		
I.15 Share of fat supply	0.03		
I.16. Ability to produce fungal toxins	0.03		
I.17 Share of holdings with other gainful activities	0.04	0.11	
I.18 Products covered by EU quality labels	0.04		
I.19 Presence of affected hosts on cultural heritage landmarks	0.04		
I.20 Use of hosts as street trees and in parks	0.11	0.11	0.33
I.21 Undesired effects of control measures	0.11	0.11	
I.22 Soil erosion	0.03	0.11	
I.23 Number of protected species and habitats related to hosts	0.03		
I.24 Share of Natura 2000 area and sites affected	0.03		
I.25 Share under sustainable management practice	0.03		

Note – figures do not add up due to rounding.

8.2 Correlation analysis for pests affecting forestry

A first distinguishing feature of the datasets for pests affecting forestry, already made evident in Table 16, is the fact that there are four indicators for which there are no data available (I.13, I.14 and I.15 reflecting the share of calories, proteins and fats affected, and I.18 reflecting the number of food products covered by EU quality labels) and four indicators for which there is no variability between the six pests assessed (I.11 downstream effects, I.16 ability to produce fungal toxins, I.17 share of holdings with other gainful activities and I.21 undesired effects of control measures).

This means that these indicators are not capable of impacting the ranking of pests[42]; setting their weight to 0 will allow for a better ranking of impacts, based on indicators where there are differences.

Table 22 shows the correlation analysis for the six pests affecting forestry. For our dataset, there is no sub-domain-specific correlation around the threshold mentioned above, so we maintain the full set of indicators to calculate I2P2 for pests affecting forestry.

As far as negative correlations are concerned, these come from indicators that try to capture a different feature within each sub-domain. As for crops, I.1 and I.2 are negatively correlated with I.3. While the former two measure the absolute and relative impact of the pest, indicator I.3 relates to the difficulty of eradication, which has no a priori theoretical relationship with the impact. It is generally desirable not to have high negative correlations, at least within the sub-domains (OECD, 2015); as the maximum negative correlation value, in absolute terms, is below 0.50, no change is made to the indicator.

Moving up the indicator structure, correlation between the individual sub-domain scores (Table 23) and domain scores (Table 24) also shows no high correlation among them, validating our indicator structure for pests affecting forestry.

[42] While for indicators I.13, I.14, I.15, I.17 and I.18 this situation will not change no matter how many pests affecting forestry are evaluated, for indicators I.16 and I.21 it could do. If this is the case when additional quarantine pests are evaluated, the relative weights will be revised.

Table 22. Correlation of individual indicator values for pests affecting forestry

	I.01	I.02	I.03	I.04	I.05	I.06	I.07	I.08	I.09	I.10	I.11	I.12	I.13	I.14	I.15	I.16	I.17	I.18	I.19	I.20	I.21	I.22	I.23	I.24	I.25
I.01	1.00																								
I.02	0.68	1.00																							
I.03	-0.41	-0.35	1.00																						
I.04	-0.81	-0.96	0.53	1.00																					
I.05	-0.54	-0.45	0.95	0.62	1.00																				
I.06	-0.50	-0.37	0.96	0.56	1.00	1.00																			
I.07	-0.77	-0.56	0.40	0.64	0.36	0.33	1.00																		
I.08	0.68	1.00	-0.34	-0.95	-0.45	-0.37	-0.55	1.00																	
I.09	0.01	0.67	-0.23	-0.55	-0.31	-0.26	0.19	0.67	1.00																
I.10	1.00	0.68	-0.41	-0.81	-0.54	-0.50	-0.77	0.68	0.01	1.00															
I.11																									
I.12	0.99	0.69	-0.36	-0.80	-0.48	-0.44	-0.82	0.69	-0.01	0.99		1.00													
I.13																									
I.14																									
I.15																									
I.16																									
I.17																									
I.18																									
I.19	-0.22	-0.42	-0.07	0.27	0.14	0.08	0.14	-0.44	-0.31	-0.22		-0.25							1.00						
I.20	-0.22	-0.39	0.11	0.27	0.30	0.25	0.14	-0.40	-0.31	-0.22		-0.23							0.98	1.00					
I.21																									
I.22	-0.27	-0.51	0.80	0.59	0.63	0.63	0.55	-0.50	-0.35	-0.27		-0.28							-0.16	-0.05		1.00			
I.23	-0.15	-0.43	-0.35	0.22	-0.13	-0.20	0.01	-0.44	-0.36	-0.15		-0.18							0.94	0.85		-0.34	1.00		
I.24	-0.34	-0.63	-0.24	0.44	-0.07	-0.15	0.34	-0.64	-0.35	-0.34		-0.40							0.89	0.79		-0.09	0.93	1.00	
I.25	0.34	-0.02	0.14	-0.12	0.13	0.12	-0.06	-0.03	-0.24	0.34		0.31							0.67	0.74		0.17	0.51	0.45	1.00

Notes: i) Empty cells refer to indicators that have been discarded for pests affecting forestry (see section 8.2). ii) I.XX refers to the numbering of indicators presented in Table 4.

Table 23. Correlation of sub-domain values for pests affecting forestry

	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3
1.1	1.00									
1.2	-0.51	1.00								
1.3	0.67	-0.63	1.00							
1.4	0.75	-0.83	0.41	1.00						
2.1	0.78	-0.80	0.41	0.99	1.00					
2.2										
2.3	-0.44	0.21	0.98	-0.22	-0.25		1.00			
3.1	-0.31	0.29	-0.39	-0.22	-0.23		0.98	1.00		
3.2										
3.3	-0.25	0.05	-0.47	0.14	0.07		0.68	0.65		1.00

Note: X.X refers to the numbering of sub-domains presented in Table 4.

Table 24. Correlation of domain values for pests affecting forestry

	Economic	Social	Environmental
Economic	1.00		
Social	0.02	1.00	
Environmental	- 0.39	0.69	1.00

Following this analysis, the I2P2 structure for forestry is defined as follows:

$$I2P2_{forestry}=0.3*[0.25*((0.3*I_{01}+0.3*I_{02}+0.3*I_{03})+(0.25*I_{04}+0.25*I_{05}+0.25*I_{06}+0.25*I_{07})+(0.5*I_{0.8}+0.5*I_{09})+(I_{10}))] + 0.3*[0.5*(I_{12}+I_{19})] + 0.3[0.5*(I_{20})+0.5*(0.25*I_{22}+0.25*I_{23}+0.25*I_{24}+0.25*I_{25})]$$

This results in the indicator, sub-domain and domain-specific weights reflected in Table 25. As can be seen, the application of a hierarchical weighting approach ensures that weights are equal across domains and sub-domains.

Table 25. Indicator, sub-domain and domain weights used for the I2P2 application to forestry

Indicator	Indicator weight	Sub-domain weight	Domain weight
I.1 Maximum value of production losses	0.03	0.08	0.33
I.2 Share of EU production value affected	0.03		
I.3 Difficulty of eradication	0.03		
I.4 Number of importing countries expected to impose restrictions on trade	0.02	0.08	
I.5 Value of export losses	0.02		
I.6 Share of export losses over total production	0.02		
I.7 Trade dispersion	0.02		
I.8 Change in domestic price	0.04	0.08	
I.9 Change in domestic production over imports	0.04		
I.10 Upstream effects	0.08	0.08	
I.11 Downstream effects			
I.12 Job losses	0.17	0.17	0.33
I.13 Share of caloric supply			
I.14 Share of protein supply			
I.15 Share of fat supply			
I.16. Ability to produce fungal toxins			
I.17 Share of holdings with other gainful activities		0.17	
I.18 Products covered by EU quality labels			
I.19 Presence of affected hosts on cultural heritage landmarks	0.17		
I.20 Use of hosts as street trees and in parks	0.17	0.17	0.33
I.21 Undesired effects of control measures			
I.22 Soil erosion	0.04	0.17	
I.23 Number of protected species and habitats related to hosts	0.04		
I.24 Share of Natura 2000 area and sites affected	0.04		
I.25 Share under sustainable management practice	0.04		

Note – figures do not add up due to rounding.

8.3 Correlation analysis for pests affecting agroforestry

The correlation analysis for the two pests affecting both crops and forestry cannot be undertaken due to the limited number of observations. However, as can be seen in Table 17, there are a number of indicators for which there is no variability in scores. This is the case for I.11, I.16, I.17 and I.22. Therefore, as in the case of pests affecting trees, the weights of those indicators is set to 0 and the weight distributed equally among the rest of the indicators in the relative sub-domain.

Following this analysis, the I2P2 structure for agroforestry is defined as follows:

$$I2P2_{agroforestry}=0.3*\left[0.25*\left((0.3*I_{01}+0.3*I_{02}+0.3*I_{03})+(0.25*I_{04}+0.25*I_{05}+0.25*I_{06}+0.25*I_{07})+(I_{0.8})+(0.5*I_{10}+0.5*I_{11})\right)\right]$$
$$+$$
$$0.3*\left[\left((I_{12})+(0.3*I_{13}+0.3*I_{14}+0.3*I_{15})+(0.5*I_{18}+0.5*I_{19})\right)\right]$$
$$+$$
$$0.3\left[(I_{20})+(I_{21})+(0.3*I_{23}+0.3*I_{24}+0.3*I_{25})\right]$$

This results in the indicator, sub-domain and domain-specific weights reflected in Table 26. As can be seen, the application of a hierarchical weighting approach ensures that weights are equal across domains and sub-domains.

Table 26. Indicator, sub-domain and domain weights used for the I2P2 application to agroforestry

Indicator	Indicator weight	Sub-domain weight	Domain weight
I.1 Maximum value of production losses	0.03	0.08	0.33
I.2 Share of EU production value affected	0.03		
I.3 Difficulty of eradication	0.03		
I.4 Number of importing countries expected to impose restrictions on trade	0.02	0.08	
I.5 Value of export losses	0.02		
I.6 Share of export losses over total production	0.02		
I.7 Trade dispersion	0.02		
I.8 Change in domestic price	0.08	0.08	
I.9 Change in domestic production over imports	-		
I.10 Upstream effects	0.04	0.08	
I.11 Downstream effects	0.04		
I.12 Job losses	0.11	0.11	0.33
I.13 Share of caloric supply	0.04	0.11	
I.14 Share of protein supply	0.04		
I.15 Share of fat supply	0.04		
I.16. Ability to produce fungal toxins	-		
I.17 Share of holdings with other gainful activities	-	0.11	
I.18 Products covered by EU quality labels	0.06		
I.19 Presence of affected hosts on cultural heritage landmarks	0.06		
I.20 Use of hosts as street trees and in parks	0.11	0.11	0.33
I.21 Undesired effects of control measures	0.11	0.11	
I.22 Soil erosion	-	0.11	
I.23 Number of protected species and habitats related to hosts	0.04		
I.24 Share of Natura 2000 area and sites affected	0.04		
I.25 Share under sustainable management practice	0.04		

Note – figures do not add up due to rounding

9 Ranking of pests using I2P2

Based on the indicator-specific values reported in Chapter 7, and using the hierarchical weights reported in Table 21 and Table 25, the I2P2 has been calculated for the 28 pests assessed. The rankings of pests according to their economic, social and environmental impacts are reported in Table 27, Table 28 and Table 29.

Table 27. Ranking of pests affecting crops, using the I2P2 as an indicator for economic, social and environmental impact.

Pest	I2P2		Ranking by domains		
	Rank	Value	Economic	Social	Environmental
Xylella fastidiosa (Pierce's disease)	1	0.8104	1	1	1
Popillia japonica (Japanese beetle)	2	0.5117	4	3	2
Thaumatotibia leucotreta (Citrus codling moth)	3	0.4714	8	2	3
Candidatus liberibacter (Citrus greening)	4	0.3750	2	5	5
Conotrachelus nenuphar	5	0.3349	10	6	4
Anthonomus eugenii	6	0.2960	5	9	7
Bactericera cockerelli	7	0.2792	7	4	14
Rhagoletis pomonella (Apple maggot fly)	8	0.2728	3	12	10
Spodoptera frugiperda (Fall armyworm)	9	0.2246	11	10	11
Bactrocera dorsalis (Oriental fruit fly)	10	0.2068	17	11	8
Anastrepha ludens (Mexican fruit fly)	11	0.2051	16	14	6
Bactrocera zonata (Peach fruit fly)	12	0.1983	15	13	9
Grapevine flavescence doree (Flavescence doree of grapevine)	13	0.1958	9	16	12
Ralstonia solanacearum (Bacterial wilt; Brown rot)	14	0.1747	12	7	17
Thrips palmi	15	0.1707	20	8	13
Xanthomonas citri (Citrus canker)	16	0.1321	19	18	15
Phyllosticta citricarpa (Black spot of citrus)	17	0.1262	18	19	16
Tilletia indica (Karnal bunt of wheat)	18	0.1220	6	20	20
Clavibacter michiganensis ssp. Sepedonicus (Bacterial ring rot of potato)	19	0.1126	13	15	19
Synchytrium endobioticum (Wart disease of potato)	20	0.0930	14	17	18

Table 28. Ranking of pests affecting trees, using the I2P2 as an indicator for economic, social and environmental impact.

Pest	I2P2		Ranking by domains		
	Rank	Value	Economic	Social	Environmental
Anaplophora glabripennis	1	0.5659	6	1	1
AgrilusAnxius (Bronze birch borer)	2	0.3925	2	2	4
Dendrolimus sibiricus	3	0.3037	4	5	2
Bursaphelenchus xylophilus (Pine wood nematode)	4	0.2752	5	3	3
Agrilus planipennis (Emerald ash borer)	5	0.2690	1	4	5
Ceratocystis fagacearum (Oak wilt)	6	0.1185	7	6	6

Table 29. Ranking of pests affecting agroforestry, using the I2P2 as an indicator for economic, social and environmental impact.

Pest	I2P2		Ranking by domains		
	Rank	Value	Economic	Social	Environmental
Anoplophora chinensis (Citrus long-horned beetle)	1	0.7477	1	1	1
Aromia bungii (Redneck long-horned beetle)	2	0.2731	2	2	2

10 Sensitivity analysis to incorporate uncertainty

As mentioned in section 2.6, the results need to be assessed for robustness against two dimensions: the weights assigned to the different domains of the indicator, and the uncertainty underlying some of the parameters used to construct the indicators. In this chapter, we undertake the two sensitivity analyses and discuss their impacts on the rankings presented in Chapter 9. The sensitivity analysis is only carried out for pests affecting crops and pests affecting trees. Due to the limited number of pests assessed, for pests affecting agroforestry an alternative sensitivity analysis was carried out. For these pests, we analyse their ranking if they were analysed together with pests affecting crops or with pests affecting forestry.

10.1 Alternative weights

The first sensitivity analysis we undertake aims to identify whether our results (i.e. the ranking of pests) are affected by the choice of weights for each of the domains[43]. As shown in Table 6, the I2P2 has been calculated using two alternative sets of weights. The results for the ranking of pests based on the alternative weights are reported in Table 30 and Table 31 for pests affecting crops and forestry respectively. As can be seen for pests affecting crops (Table 30), the ranking is consistent for the first six pests under any of the weightings chosen. The first nine pests are also equal, even when there is a change in the ranking of two pests under the 40-20-40 scenario. In this scenario, less importance is given to the social dimension and there is a rank swap between *Bactericera c.* and *R. pomonella* for position 7 and 8. This change is driven by the fact that the latter had a very low ranking for the social sub-domain (Table 27).

[43] Sensitivity of results to changes of weights in the sub-domains and individual indicators has not been analysed, as no sound theoretical reasoning was found to change those weights.

Table 30. Sensitivity of ranking to alternative weights (pests affecting crops)

Pest	Equal weights	40-20-40		50-25-25	
	Ranking	Ranking	Change	Ranking	Change
Xylella fastidiosa (Pierce's disease)	1	1	=	1	=
Popillia japonica (Japanese beetle)	2	2	=	2	=
Thaumatotibia leucotreta (Citrus codling moth)	3	3	=	3	=
Candidatus liberibacter (Citrus greening)	4	4	=	4	=
Conotrachelus nenuphar	5	5	=	5	=
Anthonomus eugenii	6	6	=	6	=
Bactericera cockerelli	7	8	-1	7	=
Rhagoletis pomonella (Apple maggot fly)	8	7	1	8	=
Spodoptera frugiperda (Fall armyworm)	9	9	=	9	=
Bactrocera dorsalis (Oriental fruit fly)	10	12	-2	13	-3
Anastrepha ludens (Mexican fruit fly)	11	11	=	12	-1
Bactrocera zonata (Peach fruit fly)	12	13	-1	14	-2
Grapevine flavescence doree (Flavescence doree of grapevine)	13	10	3	10	3
Ralstonia solanacearum (Bacterial wilt; Brown rot)	14	14	=	11	3
Thrips palmi	15	16	-1	15	=
Xanthomonas citri (Citrus canker)	16	18	-2	18	-2
Phyllosticta citricarpa (Black spot of citrus)	17	19	-2	19	-2
Tilletia indica (Karnal bunt of wheat)	18	15	3	16	2
Clavibacter michiganensis ssp. Sepedonicus (bacterial ring rot of potato)	19	17	2	17	2
Synchytrium endobioticum (Wart disease of potato)	20	20	=	20	=

Note: Negative changes in rank imply that the ranking with the alternative weights is lower than with the reference case of equal weights, and vice versa for positive changes.

Table 31. Sensitivity of ranking to alternative weights (pests affecting forestry)

Pest	Equal weights	40-20-40		50-0-50	
	Ranking	Ranking	Change	Ranking	Change
Anaplophora glabripennis	1	1	=	1	=
Agrilus Anxius (Bronze birch borer)	2	2	=	3	-1
Dendrolimus sibiricus	3	3	=	2	1
Bursaphelenchus xylophilus (Pine wood nematode)	4	5	-1	5	-1
Agrilus planipennis (Emerald ash borer)	5	4	1	4	1
Ceratocystis fagacearum (Oak wilt)	6	6	=	6	=

Note: Negative changes in rank imply that the ranking with the alternative weights is lower than with the reference case of equal weights, and vice versa for positive changes.

For the pests affecting forestry (Table 31), the ranking is less consistent; however the pest for which the aggregated impact is least severe (that ranked in last position) remains the same (*Ceratocystis f.*). When the weight given to social impact is halved (40-20-40 scenario), the ranking of *Agrilus a.* and *Dendrolimus s.* swaps, as the former has a high impact for the social sub-domain (Table 28). If the weight given to the social sub-domain is further reduced (50-0-50 scenario), the relative importance of impacts for pests scoring high in that sub-domain is reduced: *Agrilus a.* and *Bursaphelencus x.* are outranked by pests with more severe impacts in the economic (*Agrilus p.*) and environmental (*Dendrolimus s.*) sub-domains.

Overall, based on the results of this sensitivity analysisly, we can conclude that the ranking obtained using the I2P2 is consistent enough, providing a robust ranking for the first nine pests in the case of pests affecting crops, and the first five in the case of pests affecting trees.

10.2 Uncertainty of parameters

Secondly, we need to investigate some of the parameters provided by EFSA calculated as probability distributions. In particular, estimates for yield loss, quality loss, spread rate and time until detection are reported in this manner. The I2P2 results reported above are based on the median values for these impacts. However, some median estimates might be very certain (i.e. the spread of the distribution is narrow), but others very uncertain (i.e. the spread of the distribution is wide). Moreover, the uncertainty might be biased upwards (i.e. wide spread between median and Q75), downwards (i.e. wide spread between median and Q25) or both (i.e. wide spread between median and Q75 and between median and Q25).

The parameters provided by EFSA are used directly or indirectly for 10 indicators. This directly impacts calculation of maximum value of production losses (I.1) via yield and quality loss parameters, calculation of difficulty of eradication (I.3) via time to detection and spread rate, and calculation of share of caloric, protein and fat supply (I.13, I.14, I.15) via the yield loss parameter. Indirectly, it affects the calculation of share of EU production value affected (I.2), change in domestic price (I.8), change in domestic production over imports (I.9), upstream effects (I.10) and job losses (I.12), which use I.1 as an input.

To incorporate this uncertainty, indicators using the four parameters have been calculated using the Q25 and Q75 values and two new versions of the I2P2 constructed: I2P2-Q25 and I2P2-Q75. The results of the individual indicators are reported in Annex IV. The rankings of pests using these versions of the I2P2 are summarised in Table 32 and Table 33 for pests affecting crops and forestry respectively.

For pests affecting crops, the impact of uncertainty does not change the ranking of the first seven pests when considering the low level of impacts scenario (Q25), or of the first three pests when considering the high level of impacts scenario (Q75). If one considers the first 10 pests under any of the approaches, the only change in the first 10 pests under the low impact scenario would be that *A. ludens* would rank 9th and *B. dorsalis* would fall to 11th position. Under the high impact scenario, even though the individual ranking of some pests would change, the first 10 pests would remain invariant.

Table 32. Sensitivity of ranking to alternative values of the parameters with probability distribution (pests affecting crops)

Pest	Median	Q25		Q75	
	Ranking	Ranking	Change	Ranking	Change
Xylella fastidiosa (Pierce's disease)	1	1	=	1	=
Popillia japonica (Japanese beetle)	2	2	=	2	=
Thaumatotibia leucotreta (Citrus codling moth)	3	3	=	3	=
Candidatus liberibacter (Citrus greening)	4	4	=	5	-1
Conotrachelus nenuphar	5	5	=	4	1
Anthonomus eugenii	6	6	=	8	-2
Bactericera cockerelli	7	7	=	7	=
Rhagoletis pomonella (Apple maggot fly)	8	10	-2	6	2
Spodoptera frugiperda (Fall armyworm)	9	8	1	9	=
Bactrocera dorsalis (Oriental fruit fly)	10	11	-1	10	=
Anastrepha ludens (Mexican fruit fly)	11	9	2	11	=
Bactrocera zonata (Peach fruit fly)	12	12	=	12	=
Grapevine flavescence doree (Flavescence doree of grapevine)	13	13	=	13	=
Ralstonia solanacearum (Bacterial wilt; Brown rot)	14	15	-1	14	=
Thrips palmi	15	14	1	15	=
Xanthomonas citri (Citrus canker)	16	17	-1	16	=
Phyllosticta citricarpa (Black spot of citrus)	17	18	-1	17	=
Tilletia indica (Karnal bunt of wheat)	18	16	2	18	=
Clavibacter michiganensis ssp. Sepedonicus (Bacterial ring rot of potato)	19	19	=	19	=
Synchytrium endobioticum (Wart disease of potato)	20	20	=	20	=

In the case of pests affecting forestry, there is no impact on the ranking for the first five pests when considering the uncertainty of the parameters provided by EFSA. Under the low impact scenario, *B. xylophilus* and *A. planipennis* would swap ranks for 4th and 5th place, while under the high impact scenario the swap would be between *D. sibiricus* and *B. Xylophilus* for 3rd and 4th place.

Table 33. Sensitivity of ranking to alternative values of the parameters with probability distribution (pests affecting forestry)

Pest	Median	Q25		Q75	
	Ranking	Ranking	Change	Ranking	Change
Anaplophora glabripennis	1	1	=	1	=
AgrilusAnxius (Bronze birch borer)	2	2	=	2	=
Dendrolimus sibiricus	3	3	=	4	-1
Bursaphelenchus xylophilus (Pine wood nematode)	4	5	-1	3	1
Agrilus planipennis (Emerald ash borer)	5	4	1	5	=
Ceratocystis fagacearum (Oak wilt)	6	6	=	6	=

10.3 Sensitivity analysis for pests affecting agroforestry

The sensitivity analysis for pests affecting agroforestry is done using an alternative approach. Both pests have been analysed together with the pests affecting crops and with the pests affecting forestry. When the two pests are included with the pests affecting crops, *A. chinensis* ranks 1st and *A. bungii* 6th (Table 34). This is driven by the high relative impact that these pests have in the

environmental and social sub-domains[44] (Table 35); more so for *A. bungii* which only ranks 12th in terms of the economic sub-domain, while *A. chinensis* ranks 2nd, only after *X. fastidiosa*.

When analysed with the pests affecting forestry, again *A. chinensis* is ranked 1st, while *A. bungii* has a lower aggregated impact. However, when looking at the individual sub-domains, *A. bungii* is ranked 4th for economic impacts.

Table 34. Ranking of agroforestry pests if considered with the other two groups for I2P2

Pest	Analysed with pests affecting…	
	Crops	Trees
Anoplophora chinensis (Citrus long-horned beetle)	1	1
Aromia bungii (Redneck long-horned beetle)	6	7

Table 35. Ranking of agroforestry pests if considered with the other two groups for the different sub-domains of I2P2

Pest	Analysed with pests affecting…					
	Crops (n=22)			Trees (n=8)		
	ECO	SOC	ENV	ECO	SOC	ENV
Anoplophora chinensis (citrus long-horned beetle)	2	2	1	1	1	7
Aromia bungii (Redneck longhorned beetle)	12	10	3	4	8	7

Based on this analysis, there is evidence to justify inclusion of these two pests as priority pests when considering the overall sample of pests.

11 Using these rankings to inform establishment of a list of priority pests

These rankings can be used to identify any number of priority pests. Based on the analysis of the ranking, the relative changes in the I2P2 values, the sensitivity analysis and the feedback received from EGPHL members, the Commission Proposal for a delegated act includes the first 12 pests affecting crops, the first five pests affecting forestry and both pests affecting agroforestry. Below, we provide the rationale for this selection.

The decision to include the first 12 pests affecting crops is justified by the significant jump in the I2P2 values between rankings 12 and 13[45]. While changes in the I2P2 value up to position 12 are around 1-2 %, the jump from rank 12 to 13 is above 10 %. Moreover, these 12 pests are ranked in a stable manner across all sensitivity analyses undertaken. The ranking of the first 12 pests is invariant in the Q25 and Q75 scenarios. Moreover, the only change with regards to these pests in the ranking is the following:

[44] *A. chinensis* ranks 2nd and 1st for the social and environmental sub-domains respectively, while *A. bungii* ranks 9th and 3rd.

[45] The actual jump is between pests ranked 13th and 14th; however, during the meetings held with MS representatives in the framework of the EGPHL, a majority view was expressed against the inclusion of *F. doree* as a priority pest.

a) *F. doree* above *B. zonata* under the 40-20-40 scenario.

b) *F. doree* and *R. solanacerarum* above *B. zonata* and *B. dorsalis* under the 50-25-25 scenario.

During the meetings held with MS representatives in the framework of the EGPHL, a majority view was expressed against inclusion of *F. doree* as a priority pest. With regards to *R. solanacearum,* the domain for which it has the highest impact (enters the top 12 pests) is social, and in general this domain was considered to be less important.

The decision to include the first five pests affecting forestry is also based on the stability of the ranking in the sensitivity analysis undertaken, and to the fact that *C. fagacearum* consistently ranks last for all domains.

Lastly, the decision to include in the proposal the two pests affecting agroforestry is supported by the fact that, as shown in section 10.3, no matter where one decides to include them they rank among the pests affecting crops and forestry previously included in the list.

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LIST OF ACRONYMS

DG SANTE	Directorate General for Health and Food Safety
EFSA	European Food Safety Agency
EGPHL	Expert Group on Plant Health Legislation
FSC	Forest Stewardship Program
I2P2	Impact Indicator for Quarantine Pests
JRC	Joint Research Centre
MCDA	multi-criteria decision analysis
MS	Member State
PEFC	Programme for the Endorsement of Forest Certification
UQP	Union Quarantine pests

LIST OF FIGURES

LIST OF TABLES

ANNEX I - List of Union Quarantine Pests put forward for analysis by DG SANTE

INSECTS

1. *Agrilus anxius*
2. *Agrilus planipennis*
3. *Anastrepha ludens*
4. *Anoplophora chinensis*
5. *Anoplophora glabripennis*
6. *Anthonomus eugenii*
7. *Aromia bungii*
8. *Bactericera cockerelli*
9. *Bactrocera dorsalis (including Bactrocera invadens)*
10. *Bactrocera zonata*
11. *Conotrachelus nenuphar*
12. *Dendrolimus sibiricus*
13. *Popillia japonica*
14. *Rhagoletis pomonella (Tephritidae (non-European))*
15. *Spodoptera frugiperda*
16. *Thaumatotibia leucotreta*
17. *Thrips palmi*

BACTERIA

18. *Candidatus Liberibacter spp. (citrus greening)*
19. *Clavibacter michiganensis subsp. sepedonicus*
20. *Ralstonia solanacearum*
21. *Xylella fastidiosa*
22. *Xanthomonas citri*
23. *Grapevine flavescence dorée*

NEMATODES

24. *Bursaphelenchus xylophilus*

FUNGI

25. *Ceratocystis fagacearum*
26. *Phyllosticta citricarpa*
27. *Synchytrium endobioticum*
28. *Tilletia indica*

ANNEX II - Regulation (EU) 2016/2031 criteria to identify Union quarantine pests which qualify as a priority pest

Section 1 of Annex I of Regulation (EU) 2016/2031	**ID code***
Point (4) Potential economic, social and environmental impact - The entry, establishment and spread of the pest in the territory in question, or, if present but not widely distributed, in the part of that territory where it is absent, shall have an unacceptable economic, social and/or environmental impact on that territory, or the part of that territory where it is not widely distributed, as regards one or more of the following points.	
(a) Crop losses in terms of yield and quality	AI S1 P4 a
(b) Costs of control measures	AI S1 P4 b
(c) Costs of replanting and/or losses due to the necessity of growing substitute plants	AI S1 P4 c
(d) Effects on existing production practices	AI S1 P4 d
(e) Effects on street trees, parks and natural and planted areas;	AI S1 P4 e
(f) Effects on native plants, biodiversity and ecosystem services	AI S1 P4 f
(g) Effects on the establishment, spread and impact of other pests, for example due to the capacity of the pest concerned to act as a vector for other pests	AI S1 P4 g
(h) Changes to producer costs or input demands, including control costs and costs of eradication and containment	AI S1 P4 h
(i) Effects on producer profits that result from changes in quality, production costs, yields or price levels	AI S1 P4 i
(j) Changes to domestic or foreign consumer demand for a product resulting from quality changes	AI S1 P4 j
(k) Effects on domestic and export markets and prices paid, including effects on export market access and likelihood of phytosanitary restrictions imposed by trading partners	AI S1 P4 k
(l) Resources needed for additional research and advice	AI S1 P4 l
(m) Environmental and other undesired effects of control measures	AI S1 P4 m
(n) Effects on Natura 2000 or other protected areas	AI S1 P4 n
(o) Changes in ecological processes and the structure, stability or processes of an ecosystem, including further effects on plant species, erosion, water table changes, fire hazards, nutrient cycling	AI S1 P4 o
(p) Costs of environmental restoration and prevention measures	AI S1 P4 p
(q) Effects on food security and food safety	AI S1 P4 q
(r) Effects on employment	AI S1 P4 r
(s) Effects on water quality, recreation, tourism, landscape heritage, animal grazing, hunting, fishing	AI S1 P4 s
Section 2 of Annex I of Regulation (EU) 2016/2031	
(a) Economic impact - the pest has the potential to cause major losses in terms of the direct and indirect effects referred to in point (4) of Section 1 for plants with a significant economic value in the Union territory (may be trees that are not in production).	AI S1 P4 a to AI S1 P4 s
(b) Social impact - the pest has the potential to cause one or more of the following effects.	AI S2 Pb i to AI S2 Pb iii
(i) A significant employment decrease in the agriculture, horticulture or forestry sector concerned or industries related to those sectors, including tourism and recreation	AI S2 Pb i
(ii) Significant risks to food security or food safety	AI S2 Pb ii
(iii) The disappearance of, or long-term large-scale damage to, important tree species growing or cultivated in the Union territory or tree species of high importance in terms of landscape as well as cultural or historical heritage for the Union.	AI S2 Pb iii
(c) Environmental impact - the pest has the potential to cause one or more of the following effects.	AI S2 Pc i to AI S2 Pc iii
(i) Significant effects on biodiversity and ecosystems services, including effects on species and habitats listed under Council Directive 92/43/EEC (1) and Directive	AI S2 Pc i

2009/147/EC of the European Parliament and of the Council (2)	
(ii) Significant and long-term increases of the use of plant protection products on the plants concerned;	AI S2 Pc ii
(iii) The disappearance of, or long-term large-scale damage to, important tree species growing or cultivated in the Union territory or tree species of high importance in terms of landscape as well as cultural or historical heritage for the Union	AI S2 Pc iii

* Annex number - Section number - Letter and subscript if necessary

ANNEX III – Summary of data sources and availability

As described in the report, different quantitative or qualitative data have been used to measure the indicators for each pest. Table 36 summarises the data sources used for each of the indicators.

Table 36. Summary of data needs by pest and main host at risk to estimate indicators

Data needs	Unit	Data sources	Spatial resolution	Quality /comments
Host planted area (A)	1000 hectares	Eurostat	MS	For forest tree hosts data source is National forestry inventories and EGPHL input
Yield (Y)	Tonnes ha^{-1}	Eurostat	MS	For forest tree hosts 'wood growing stock' or 'standing volume' data source is National forestry inventories and EGPHL input
Average price (P)	Euro $tonne^{-1}$	Eurostat	MS	For forest tree hosts data source is FAO and UNECE and EGPHL input
Potential proportion of loss in yield (r_{loss})	%	EFSA EKE	MS	Fitted probabilistic distribution
Potential proportion of remaining production after yield loss that would result in lower quality (Q_{loss})	%	EFSA EKE	MS	Fitted probabilistic distribution
Time for detection after entry (TD)	Years	EFSA EKE	EU	Fitted probabilistic distribution
Spread rate (SR)	Meters $year^{-1}$	EFSA EKE	EU	Fitted probabilistic distribution
Importing countries (IC)	Number	Comext	EU28	
Countries no expecting to ban trade (ICnb)	Number	EFSA EKE	EU28	Countries where the pest is present and is not listed as Quarantine
Quantity of exports (Xb, X)	Tonnes and EUR	Comext	EU 28	
Quantity of imports (M)	Tonnes and EUR	Comext	EU 28	
Own Price elasticities of demand	number	CAPRI	MS EU 28	
Output multipliers (OM)	Number	BIOSAM	EU28	
Intermediate demand (ID)	EUR	BIOSAM	EU28	
Labour need for the production (L)	AWU ha^{-1}	Eurostat	MS	Per Farm type
Caloric supply of affected hosts (CS)	Kcal $capita^{-1}$ day^{-1}	FAO	EU 28	
Total caloric supply quantity (TCS)	Kcal $capita^{-1}$ day^{-1}	FAO	EU 28	
Protein supply of affected hosts (PS)	gr $capita^{-1}$ day^{-1}	FAO	EU 28	
Total protein supply quantity (TPS)	gr $capita^{-1}$ day^{-1}	FAO	EU 28	
Fat supply of affected hosts (FS)	gr $capita^{-1}$ day^{-1}	FAO	EU 28	
Total fat supply quantity (TFS)	gr $capita^{-1}$ day^{-1}	FAO	EU 28	

Capacity to produce aflatoxins	Yes/no	EFSA EKE	EU28	Pest specific
Holdings with other gainful activities (HOGA)	Number	Eurostat	MS EU 28	Farm type specialist cereals
Number of holdings (H)	Number	Eurostat	MS EU 28	Per farm type
EU quality schemes for agricultural products	Number	DOOR	EU 28	
Presence of affected hosts on cultural heritage landmarks	Number	UNESCO and MS request	EU 28	
Abundance of use hosts as street and park trees (QPS)	Rating	MS ad-hoc request	MS	Not applicable for crops
Undesired effects of control measures (CM)	Rating	EFSA EKE	EU28	
Soil erosion	index	JRC	Per ha	Based on c-factor methodology (Panos et al. 2018)
Habitat types listed in Annex I; animal and plant species listed in Annex II, Annex IV and Annex V, of Council Directive 92/43/EEC; and bird species in Annex I and II of Directive 2009/147/EC	Number	Ad-hoc outsourced support	EU28	
Share of Natura 2000 sites (NSR)	%	EFSA EKE	EU28	
Share of Natura 2000 area (NAR)	%	EFSA EKE	EU28	
Share of total area fully converted or under conversion to organic farming	%	Eurostat	EU28	
Share of area under sustainable forestry management practices	%	FAO PEFC FSC	EU28	

ANNEX IV – Indicator values using Q25 and Q75 estimates for parameters reported as probability distributions

Table 37. Summary of impact indicators for the evaluated pests affecting crops (Q25)

Domain	Sub-domain	Indicators	*T. i.*	*X.c.*	*P.c.*	*S.e.*	*C.m.*	*C.l.*	*G.f.d.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	23.5	303.8	150.5	71.3	293.4	1,965.4	515.9
		I.2 Share of EU production value affected (%)	0.08 %	8.04 %	4.00 %	0.60 %	2.47 %	52.00 %	2.50 %
		I.3 Difficulty of eradication	4,203	61	782	665	1,611	16,981	46
	Trade impacts	I.4. Number of importing countries banning trade	108	95	106	140	138	96	139
		I.5 Value of export losses (Million EUR)	5,413.3	479.5	494.4	478.4	498.7	509.1	133.4
		I.6 Share of export losses over total production (%)	17 %	6 %	7 %	2 %	2 %	7 %	0 %
		I.7 Trade dispersion	0.92	0.91	0.91	0.95	0.95	0.92	0.91
	Price and market impacts	I.8 Change in domestic price (%)	90 %	5 %	11 %	3 %	0 %	89 %	4 %
		I.9 Change in domestic production over imports (%)	0 %	0 %	0 %	0 %	29 %	234 %	59 %
	Impacts in other agents	I.10 Upstream effect (Million EUR)	9	141	37	146	602	1,938	329
		I.11 Downstream effect (%)	19 %	5 %	5 %	21 %	21 %	5 %	92 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	109	2,902	814	531	2,184	42,643	11,810
	Impact on food security or food safety	I.13 Share of caloric supply	0.00 %	0.02 %	0.01 %	0.02 %	0.09 %	0.37 %	0.01 %
		I.14 Share of protein supply	0.00 %	0.01 %	0.00 %	0.02 %	0.07 %	0.21 %	0.00 %
		I.15 Share of fat supply quantity	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.04 %	0.00 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43 %	38 %	38 %	43 %	43 %	38 %	39 %
		I.18 Products covered by EU quality labels	5	21	21	25	25	21	13
		I.19 Presence of affected hosts on cultural heritage landmarks	3.5	12.6	9.1	4.0	4.0	12.6	19.0
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	7	4	0	0	7	2
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0	1	1	0	0	2	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.800	0.781	0.781	0.660	0.660	0.781	0.647
		I.23 Number of protected species and habitats related to hosts	9	1	1	4	4	1	3
		I.24 Share of Natura 2000 area and sites affected (%)	0 %	0 %	0 %	50 %	50 %	0 %	50 %
		I.25 Share under sustainable management practices (%)	0.41 %	0.03 %	0.03 %	0.01 %	0.01 %	0.03 %	0.17 %

Table 37 (cont.) Summary of impact indicators for the evaluated pests affecting crops (Q25)

Domain	Sub-domain	Indicators	*S.f.*	*R.s.*	*A.l.*	*R.p.*	*P.j.*	*B.d.*	*B.z.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	335.4	1,371.0	225.5	775.9	1,350.0	372.0	315.8
		I.2 Share of EU production value affected (%)	6.07 %	8.01 %	5.13 %	14.87 %	9.10 %	11.75 %	6.75 %
		I.3 Difficulty of eradication	105,188	461	8,525	339	5,079	4,833	6,163
	Trade impacts	I.4. Number of importing countries banning trade	103	93	127	133	158	94	119
		I.5 Value of export losses (Million EUR)	1,936.9	790.1	809.3	832.1	2,225.9	837.8	826.4
		I.6 Share of export losses over total production (%)	2 %	1 %	7 %	13 %	4 %	7 %	7 %
		I.7 Trade dispersion	0.91	0.94	0.91	0.87	0.93	0.90	0.90
	Price and market impacts	I.8 Change in domestic price (%)	2 %	6 %	9 %	4 %	4 %	7 %	12 %
		I.9 Change in domestic production over imports (%)	0 %	0 %	0 %	46 %	0 %	0 %	0 %
	Impacts in other agents	I.10 Upstream effect (Million EUR)	619	552	222	765	1,201	367	311
		I.11 Downstream effect (%)	52 %	21 %	5 %	5 %	92 %	5 %	5 %
Social impacts	Impact on employment	I.12 Job losses (jobs)	7,209	32,378	4,183	16,865	49,875	6,189	5,912
	Impact on food security or food safety	I.13 Share of caloric supply	0.06 %	0.10 %	0.06 %	0.09 %	0.09 %	0.09 %	0.09 %
		I.14 Share of protein supply	0.04 %	0.15 %	0.03 %	0.02 %	0.05 %	0.04 %	0.04 %
		I.15 Share of fat supply quantity	0.00 %	0.02 %	0.01 %	0.02 %	0.02 %	0.02 %	0.02 %
		I.16 Ability to produce fungal toxins (y=1/n=0)	1	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	41 %	43 %	40 %	39 %	45 %	40 %	40 %
		I.18 Products covered by EU quality labels	10	47	29	26	80	30	29
		I.19 Presence of affected hosts on cultural heritage landmarks	2.0	6.5	28.9	9.9	90.5	28.9	22.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	22	9	51	24	20
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	0	1	1	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.850	0.680	0.781	0.781	0.910	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	20	4	1	0	195	1	1
		I.24 Share of Natura 2000 area and sites affected (%)	50 %	52 %	50 %	51 %	54 %	27 %	24 %
		I.25 Share under sustainable management practices (%)	0.01 %	0.10 %	0.21 %	0.06 %	3.01 %	0.21 %	0.21 %

Table 37 (cont.) Summary of impact indicators for the evaluated pests affecting crops (Q25)

Domain	Sub-domain	Indicators	*B.c.*	*A.e.*	*X.f.*	*T.l.*	*T.p.*	*C.n*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	875.8	474.6	4,160.0	817.9	403.1	1,044.0
		I.2 Share of EU production value affected (%)	4.65 %	23.56 %	55.80 %	17.10 %	7.86 %	10.50 %
		I.3 Difficulty of eradication	363,483	897	5,910	1,094	590	190
	Trade impacts	I.4. Number of importing countries banning trade	145	76	147	127	79	149
		I.5 Value of export losses (Million EUR)	1,016.8	188.0	741.0	1,885.3	431.1	1,468.7
		I.6 Share of export losses over total production (%)	2 %	4 %	2 %	5 %	2 %	11 %
		I.7 Trade dispersion	0.96	0.86	0.91	0.94	0.80	0.86
	Price and market impacts	I.8 Change in domestic price (%)	9%	41%	85%	10%	0%	5%
		I.9 Change in domestic production over imports (%)	0%	240%	0%	0%	2%	0%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	1,151	699	7,613	931	309	1,029
		I.11 Downstream effect (%)	21%	21%	92%	52%	10%	5%
Social impacts	Impact on employment	I.12 Job losses (jobs)	31,398	14,949	228,596	18,347	16,026	23,752
	Impact on food security or food safety	I.13 Share of caloric supply	0.21%	0.01%	0.17%	0.18%	0.06%	0.15%
		I.14 Share of protein supply	0.21%	0.01%	0.11%	0.14%	0.09%	0.05%
		I.15 Share of fat supply quantity	0.02%	0.00%	0.32%	0.02%	0.01%	0.04%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	1	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43%	35%	100%	100%	43%	39%
		I.18 Products covered by EU quality labels	47	47	70	52	79	58
		I.19 Presence of affected hosts on cultural heritage landmarks	6.5	19.0	137.3	75.4	21.6	44.5
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	65	47	4	43
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2	2	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.680	0.680	0.999	0.999	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	4	4	103	67	16	0
		I.24 Share of Natura 2000 area and sites affected (%)	47%	23%	60%	15%	12%	52%
		I.25 Share under sustainable management practices (%)	0.10%	0.10%	46.76%	26.97%	0.10%	0.06%

Table 38. Summary of impact indicators for the evaluated pests affecting forestry (Q25)

Domain	Sub-domain	Indicators	*A.a*	*A.p.*	*C.f.*	*A.g..*	*B.x..*	*D.s.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	54,823.0	20,338.2	4,516.0	11,984.8	21,514.0	2,428.1
		I.2 Share of EU production value affected (%)	67%	65.00%	1.20%	3.56%	4.86%	0.24%
		I.3 Difficulty of eradication	3,787.0	6,138	136	736	15,493	52,470
	Trade impacts	I.4. Number of importing countries banning trade	34.0	51	123	99	109	140
		I.5 Value of export losses (Million EUR)	25.6	10.3	251.0	372.2	159.4	3,301.0
		I.6 Share of export losses over total production (%)	0%	0%	0%	0%	0%	0%
		I.7 Trade dispersion	0.6	0.88	0.81	0.82	0.90	0.89
	Price and market impacts	I.8 Change in domestic price (%)	384%	375%	7%	15%	28%	0%
		I.9 Change in domestic production over imports (%)	11237%	117686%	3955%	1576%	4093%	51%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	114,724.0	42,568	9,450	25,079	45,019	5,075
		I.11 Downstream effect (%)	61%	61%	61%	61%	61%	61%
Social impacts	Impact on employment	I.12 Job losses (jobs)	15,665.0	4,605	718	2,642	4,929	417
	Impact on food security or food safety	I.13 Share of caloric supply	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.14 Share of protein supply	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.15 Share of fat supply quantity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0.0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100%	100%	100%	100%	100%	100%
		I.18 Products covered by EU quality labels	0	0	0	0	0	0
		I.19 Presence of affected hosts on cultural heritage landmarks	17.0	20.6	31.0	197.8	23.0	67.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	30.0	28	16	224	23	110
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0.0	0	0	0	0	0
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987	0.9987	0.9987	0.9989	0.9989
		I.23 Number of protected species and habitats related to hosts	95.0	47	234	676	114	104
		I.24 Share of Natura 2000 area and sites affected (%)	50%	50%	51%	52%	51%	23%
		I.25 Share under sustainable management practices (%)	52%	42.62%	27%	66%	52%	51%

Table 39. Summary of impact indicators for the evaluated pests affecting agroforestry (Q25)

Domain	Sub-domain	Indicators	*A.c.*	*A.b.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	12,296.0	196.5
		I.2 Share of EU production value affected (%)	6.57%	3.40%
		I.3 Difficulty of eradication	812	478
	Trade impacts	I.4. Number of importing countries banning trade	156	140
		I.5 Value of export losses (Million EUR)	2,650.6	362.8
		I.6 Share of export losses over total production (%)	0%	2%
		I.7 Trade dispersion	0.92	0.86
	Price and market impacts	I.8 Change in domestic price (%)	11%	20%
		I.9 Change in domestic production over imports (%)	0%	0%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	24,935	257
		I.11 Downstream effect (%)	61%	61%
Social impacts	Impact on employment	I.12 Job losses (jobs)	193,620	5,729
	Impact on food security or food safety	I.13 Share of caloric supply	0.1%	0.0%
		I.14 Share of protein supply	0.1%	0.0%
		I.15 Share of fat supply quantity	0.1%	0.0%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100%	100%
		I.18 Products covered by EU quality labels	89	30
		I.19 Presence of affected hosts on cultural heritage landmarks	330.1	56.9
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	360	49
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987
		I.23 Number of protected species and habitats related to hosts	960	45
		I.24 Share of Natura 2000 area and sites affected (%)	54%	53%
		I.25 Share under sustainable management practices (%)	66.28%	68.76%

Table 40. Summary of impact indicators for the evaluated pests affecting crops (Q75)

Domain	Sub-domain	Indicators	*T. i.*	*X.c.*	*P.c.*	*S.e.*	*C.m.*	*C.l.*	*G.f.d.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	92.0	736.0	629.6	178.3	374.0	3,065.3	1,547.7
		I.2 Share of EU production value affected (%)	0.30%	19.47%	16.75%	1.50%	3.15%	81.10%	7.50%
		I.3 Difficulty of eradication	39,465	368	5,074	6,808	8,163	86,130	775
	Trade impacts	I.4. Number of importing countries banning trade	108	95	106	140	138	96	139
		I.5 Value of export losses (Million EUR)	5,413.3	479.5	494.4	478.4	498.7	509.1	133.4
		I.6 Share of export losses over total production (%)	17%	6%	7%	2%	2%	7%	0%
		I.7 Trade dispersion	0.92	0.91	0.91	0.95	0.95	0.92	0.91
	Price and market impacts	I.8 Change in domestic price (%)	90%	7%	5%	1%	2%	145%	14%
		I.9 Change in domestic production over imports (%)	0%	18%	0%	0%	134%	384%	197%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	34	392	148	366	768	3,023	987
		I.11 Downstream effect (%)	19%	5%	5%	21%	21%	5%	92%
Social impacts	Impact on employment	I.12 Job losses (jobs)	435	7,997	3,256	1,328	2,785	66,506	35,429
	Impact on food security or food safety	I.13 Share of caloric supply	0.01%	0.06%	0.03%	0.05%	0.11%	0.57%	0.04%
		I.14 Share of protein supply	0.02%	0.04%	0.02%	0.04%	0.09%	0.33%	0.01%
		I.15 Share of fat supply quantity	0.00%	0.01%	0.00%	0.00%	0.00%	0.06%	0.00%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43%	38%	38%	43%	43%	38%	39%
		I.18 Products covered by EU quality labels	5	21	21	25	25	21	13
		I.19 Presence of affected hosts on cultural heritage landmarks	3.5	12.6	9.1	4.0	4.0	12.6	19.0
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	7	4	0	0	7	2
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0	1	1	0	0	2	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.800	0.781	0.781	0.660	0.660	0.781	0.647
		I.23 Number of protected species and habitats related to hosts	9	1	1	4	4	1	3
		I.24 Share of Natura 2000 area and sites affected (%)	0%	0%	0%	50%	50%	0%	50%
		I.25 Share under sustainable management practices (%)	0.41%	0.03%	0.03%	0.01%	0.01%	0.03%	0.17%

Table 40 (cont.) Summary of impact indicators for the evaluated pests affecting crops (Q75)

Domain	Sub-domain	Indicators	*S.f.*	*R.s.*	*A.l.*	*R.p.*	*P.j.*	*B.d.*	*B.z.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	1,129.5	4,579.2	482.4	2,577.8	3,830.4	1,013.5	816.8
		I.2 Share of EU production value affected (%)	19.26%	27.88%	8.09%	49.41%	22.29%	24.08%	13.05%
		I.3 Difficulty of eradication	461,775	3,395	35,133	3,194	21,131	34,700	35,278
	Trade impacts	I.4. Number of importing countries banning trade	103	93	127	133	158	94	119
		I.5 Value of export losses (Million EUR)	1,936.9	790.1	809.3	832.1	2,225.9	837.8	826.4
		I.6 Share of export losses over total production (%)	2%	1%	7%	13%	4%	7%	7%
		I.7 Trade dispersion	0.91	0.94	0.91	0.87	0.93	0.90	0.90
	Price and market impacts	I.8 Change in domestic price (%)	3%	27%	5%	85%	7%	14%	15%
		I.9 Change in domestic production over imports (%)	0%	0%	0%	870%	0%	14%	0%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	2,083	1,641	476	2,542	3,473	999	805
		I.11 Downstream effect (%)	52%	21%	5%	5%	92%	5%	5%
Social impacts	Impact on employment	I.12 Job losses (jobs)	24,518	97,727	9,490	56,029	134,756	18,063	16,013
	Impact on food security or food safety	I.13 Share of caloric supply	0.19%	0.30%	0.12%	0.30%	0.26%	0.25%	0.22%
		I.14 Share of protein supply	0.13%	0.46%	0.06%	0.06%	0.14%	0.12%	0.11%
		I.15 Share of fat supply quantity	0.01%	0.06%	0.02%	0.05%	0.05%	0.05%	0.05%
		I.16 Ability to produce fungal toxins (y=1/n=0)	1	0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	41%	43%	40%	39%	45%	40%	40%
		I.18 Products covered by EU quality labels	10	47	29	26	80	30	29
		I.19 Presence of affected hosts on cultural heritage landmarks	2.0	6.5	28.9	9.9	90.5	28.9	22.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	22	9	51	24	20
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	0	1	1	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.850	0.680	0.781	0.781	0.910	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	20	4	1	0	195	1	1
		I.24 Share of Natura 2000 area and sites affected (%)	50%	52%	50%	51%	54%	27%	24%
		I.25 Share under sustainable management practices (%)	0.01%	0.10%	0.21%	0.06%	3.01%	0.21%	0.21%

Table 40 (cont.) Summary of impact indicators for the evaluated pests affecting crops (Q75)

Domain	Sub-domain	Indicators	*B.c.*	*A.e.*	*X.f.*	*T.l.*	*T.p.*	*C.n*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	2,238.5	1,000.8	6,861.1	1,616.6	1,026.7	3,106.0
		I.2 Share of EU production value affected (%)	11.80%	49.70%	80.50%	29.96%	19.22%	30.50%
		I.3 Difficulty of eradication	1,468,933	7,720	31,801	5,740	4,294	1,196
	Trade impacts	I.4. Number of importing countries banning trade	145	76	147	127	79	149
		I.5 Value of export losses (Million EUR)	1,016.8	188.0	741.0	1,885.3	431.1	1,468.7
		I.6 Share of export losses over total production (%)	2%	4%	2%	5%	2%	11%
		I.7 Trade dispersion	0.96	0.86	0.91	0.94	0.80	0.86
	Price and market impacts	I.8 Change in domestic price (%)	23%	98%	129%	35%	6%	36%
		I.9 Change in domestic production over imports (%)	19%	567%	42%	0%	43%	338%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	2,961	1,474	12,098	1,906	629	3,063
		I.11 Downstream effect (%)	21%	21%	92%	52%	10%	5%
Social impacts	Impact on employment	I.12 Job losses (jobs)	79,001	31,077	364,872	36,874	32,479	70,437
	Impact on food security or food safety	I.13 Share of caloric supply	0.53%	0.01%	0.39%	0.34%	0.11%	0.45%
		I.14 Share of protein supply	0.52%	0.02%	0.25%	0.30%	0.18%	0.16%
		I.15 Share of fat supply quantity	0.04%	0.00%	0.58%	0.05%	0.02%	0.11%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	1	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	43%	35%	100%	100%	43%	39%
		I.18 Products covered by EU quality labels	47	47	70	52	79	58
		I.19 Presence of affected hosts on cultural heritage landmarks	6.5	19.0	137.3	75.4	21.6	44.5
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	0	0	65	47	4	43
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2	2	2	1	1
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.680	0.680	0.999	0.999	0.781	0.781
		I.23 Number of protected species and habitats related to hosts	4	4	103	67	16	0
		I.24 Share of Natura 2000 area and sites affected (%)	47%	23%	60%	15%	12%	52%
		I.25 Share under sustainable management practices (%)	0.10%	0.10%	46.76%	26.97%	0.10%	0.06%

Table 41. Summary of impact indicators for the evaluated pests affecting forestry (Q75)

Domain	Sub-domain	Indicators	*A.a*	*A.p.*	*C.f.*	*A.g..*	*B.x..*	*D.s.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	70,370.0	26,596.1	14,300.0	41,127.5	45,931.0	9,699.0
		I.2 Share of EU production value affected (%)	86%	85.00%	3.80%	12.66%	10.38%	0.97%
		I.3 Difficulty of eradication	37,730.0	41,552	1,759	3,160	104,376	234,650
	Trade impacts	I.4. Number of importing countries banning trade	34.0	51	123	99	109	140
		I.5 Value of export losses (Million EUR)	25.6	10.3	251.0	372.2	159.4	3,301.0
		I.6 Share of export losses over total production (%)	0%	0%	0%	0%	0%	0%
		I.7 Trade dispersion	0.6	0.88	0.81	0.82	0.90	0.89
	Price and market impacts	I.8 Change in domestic price (%)	493%	490%	22%	51%	60%	5%
		I.9 Change in domestic production over imports (%)	14424%	153903%	13015%	5362%	8760%	486%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	147,257.0	55,666	29,924	86,064	96,115	20,271
		I.11 Downstream effect (%)	61%	61%	61%	61%	61%	61%
Social impacts	Impact on employment	I.12 Job losses (jobs)	20,108.0	6,022	2,273	9,175	10,452	1,664
	Impact on food security or food safety	I.13 Share of caloric supply	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.14 Share of protein supply	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.15 Share of fat supply quantity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0.0	0	0	0	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100%	100%	100%	100%	100%	100%
		I.18 Products covered by EU quality labels	0	0	0	0	0	0
		I.19 Presence of affected hosts on cultural heritage landmarks	17.0	20.6	31.0	197.8	23.0	67.8
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	30.0	28	16	224	23	110
	Undesired impacts of control measures	I.21 Undesired effects of control measures	0.0	0	0	0	0	0
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987	0.9987	0.9987	0.9989	0.9989
		I.23 Number of protected species and habitats related to hosts	95.0	47	234	676	114	104
		I.24 Share of Natura 2000 area and sites affected (%)	50%	50%	51%	52%	51%	23%
		I.25 Share under sustainable management practices (%)	52%	42.62%	27%	66%	52%	51%

Table 42. Summary of impact indicators for the evaluated pests affecting agroforestry (Q75)

Domain	Sub-domain	Indicators	*A.c.*	*A.b.*
Economic impacts	Production impacts	I.1 Maximum value of production losses (Million EUR)	32,277.5	582.1
		I.2 Share of EU production value affected (%)	12.00%	11.90%
		I.3 Difficulty of eradication	3,049	3,112
	Trade impacts	I.4. Number of importing countries banning trade	156	140
		I.5 Value of export losses (Million EUR)	2,650.6	362.8
		I.6 Share of export losses over total production (%)	0%	2%
		I.7 Trade dispersion	0.92	0.86
	Price and market impacts	I.8 Change in domestic price (%)	19%	69%
		I.9 Change in domestic production over imports (%)	16%	5%
	Impacts in other agents	I.10 Upstream effect (Million EUR)	65,577	795
		I.11 Downstream effect (%)	61%	61%
Social impacts	Impact on employment	I.12 Job losses (jobs)	227,404	15,710
	Impact on food security or food safety	I.13 Share of caloric supply	0.3%	0.1%
		I.14 Share of protein supply	0.2%	0.0%
		I.15 Share of fat supply quantity	0.2%	0.0%
		I.16 Ability to produce fungal toxins (y=1/n=0)	0	0
	Impact on recreation, landscape or cultural heritage	I.17. Share of holdings with other gainful activities (%)	100%	100%
		I.18 Products covered by EU quality labels	89	30
		I.19 Presence of affected hosts on cultural heritage landmarks	330.1	56.9
Environmental impacts	Impact on street trees, parks and natural and planted areas	I.20 Use of hosts as street trees and in parks	360	49
	Undesired impacts of control measures	I.21 Undesired effects of control measures	1	2
	Impacts on biodiversity and ecosystem services	I.22 Soil erosion	0.9987	0.9987
		I.23 Number of protected species and habitats related to hosts	960	45
		I.24 Share of Natura 2000 area and sites affected (%)	54%	53%
		I.25 Share under sustainable management practices (%)	66.28%	68.76%

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