SCIENTIFIC OPINION

EFSA Journal

ADOPTED: 28 September 2016

doi: 10.2903/j.efsa.2016.4603

Risk to plant health of Flavescence dorée for the EU territory

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Abstract

Following a request from the European Commission, the EFSA Panel on Plant Health (PLH) performed a quantitative analysis of the risk posed by the Flavescence dorée phytoplasma (FDp) in the EU territory. Three scenarios were analysed, one with current measures in place (scenario A0), one designed to improve grapevine propagation material phytosanitary status (scenario A1) and one with reinforced eradication and containment (scenario A2). The potential for entry is limited, FDp being almost non-existent outside the EU. FDp and its major vector, *Scaphoideus titanus,* have already established over large parts of the EU and have the potential to establish in a large fraction of the currently unaffected EU territory. With the current measures in place (A0), spread of FDp is predicted to continue with a progression of between a few and ca 20 newly infested NUTS 2 regions during the next 10 years, illustrating the limitations of the current control measures against spread. FDp spread is predicted to be roughly similar between scenarios A1 and A2, but more restricted than under scenario A0. However, even with reinforced control scenarios, stabilisation or reduction in the number of infested NUTS 2 regions has only relatively low probability. Under scenario A0, FDp has a 0.5–1% impact on the overall EU grapes and wine production, reflecting the effectiveness of the current control measures against impact. Under both scenarios A1 and A2, FDp impact is predicted to be reduced, by approximately one-third (A1) to two-thirds (A2) as compared to A0, but the associated uncertainties are large. The generalised use of hot water treatment for planting material produced in infected zones has the most important contribution to FDp impact reduction in scenario A1 and has high feasibility. Both increased eradication and containment measures contribute to impact reduction under scenario A2 but the overall feasibility is lower.

Keywords: Flavescence dorée phytoplasma, FDp, European Union, quantitative pest risk assessment, risk reduction scenarios, risk reduction options, grapevine, *Scaphoideus titanus*, *Vitis*

Requestor: European Commission

Question number: EFSA-Q-2015-00271

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Suggested citation: EFSA Panel on Plant Health (PLH), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Jaques Miret JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Urek G, Rossi V, Van Bruggen A, Van Der Werf W, West J, Winter S, Bosco D, Foissac X, Strauss G, Hollo G, Mosbach-Schulz O and Grégoire J-C, 2016. Scientific opinion on the risk to plant health of Flavescence dorée for the EU territory. EFSA Journal 2016;14(12):4603, 83 pp. doi:10.2903/j.efsa.2016.4603

ISSN: 1831-4732

Summary

Following a request from the European Commission, the EFSA Panel on Plant Health (PLH) performed an analysis of the risk to plant health posed by the Flavescence dorée phytoplasma (FDp) in the European Union (EU) territory, with the evaluation of risk reduction options. The temporal scale of this assessment is a 10-year time horizon and three scenarios are analysed, one corresponding to the current situation, with all current official control measures in place (**scenario A0**) and two alternative scenarios, with either a reinforcement of the hot water treatment (HWT) control measure to improve the phytosanitary status of grapevine propagation material (**scenario A1**) or a reinforcement of eradication and containment measures (**scenario A2**).

Concerning *entry*, the Panel did not analyse it in detail because, with the exception of Serbia and Switzerland, the disease does not exist outside of the EU and is, on the other hand, already established in eight of the main grape-growing EU countries (Austria, Croatia, France, Hungary, Italy, Portugal, Slovenia and Spain).

Concerning 'establishment', the Panel determined that both FDp and the *Scaphoideus titanus* vector responsible for epidemic development in grapevine have already established over a large part of the EU territory, but are still spreading and have the potential to establish in at least a large fraction of the EU territory that is currently still unaffected. The Panel also reached the following additional conclusions:

- FDp establishment does not appear to be severely constrained by ecoclimatic conditions and it is likely that the phytoplasma could successfully colonise grapevine wherever this crop is able to develop.
- FDp ability to spread within vineyards, causing an epidemic disease, is limited under most circumstances by the availability of *S. titanus* vectors, which is subject to some ecoclimatic constraints.
- The CLIMEX analysis performed by the Panel strongly suggests that *S. titanus* is likely to be able to establish over most of the EU territory and, in particular, in all northern and central European grapevine-growing areas. Uncertainties exist for the southernmost grapevine-growing areas, in which hot and dry conditions are likely to limit establishment in at least some areas.

Concerning 'spread', the Panel reached the following conclusions:

- With the current measures in place (scenario A0), spread of FDp is likely to continue during the forthcoming period with a progression of between a few and ca 20 newly infested NUTS 2 regions predicted for the 50% uncertainty interval. This analysis clearly illustrates the limitations of the currently deployed control measures, which have not allowed to halt so far the progression of FDp in the EU territory (Appendix A).
- Spread of FDp is expected to be roughly similar between the two strengthened control scenarios (scenarios A1 and A2). The Panel confidently estimates that spread will be more restricted under these scenarios than under the current measures (scenario A0), with a 50% uncertainty interval of between stabilisation in the number of affected NUTS 2 regions and 10–15 newly infested regions. This corresponds roughly to a halving of the spread predicted under scenario A0.
- Overall, a stabilisation or a reduction in the number of infested NUTS 2 regions is only envisioned under the A1 and A2 scenarios of reinforced control measures and then only with a relatively low probability. A combination of the reinforced control measures implemented in scenarios A1 and A2 is expected to have an even higher effectiveness to further limit the spread of FDp.

Concerning impact, the Panel reached the following conclusions:

- Under scenario A0, impact of FDp represents only a very small fraction of the EU table grapes or wine production (in the order of 0.5–1%), a situation which reflects the effectiveness of the currently deployed risk reduction options (RROs) at limiting impact and not the severity and epidemic nature of FDp, which has the potential to inflict major losses if left uncontrolled.
- Under both scenarios A1 and A2, involving the reinforcement of control measures, FDp impact on wine and table grapes production is predicted to be reduced by approximately one-third (A1) and by two-thirds (A2) as compared to scenario A0. The uncertainties associated with

these evaluations are, however, large, as indicated by 50% uncertainty intervals spanning roughly two orders of magnitude.

- Concerning scenario A1, the generalisation of compulsory HWT to not only concern HWT of planting material entering protected zones, but also include any planting material leaving nurseries located in infested NUTS areas has the potential to significantly reduce the probability of FDp infection in traded grapevine plants for planting, and thus the initiation of new outbreaks. In addition, this measure is evaluated by the Panel as having a high feasibility because its implementation is relatively straightforward and does not meet important technical hurdles.
- Concerning scenario A2, the more intense eradication and containment measures are expected to limit the local epidemic development of the disease. Both increased eradication and containment measures, in particular by targeting abandoned vineyards and wild grapevine populations are seen as contributing to the overall effectiveness of this scenario but the reinforced RROs involved will be more difficult to implement than the one included in scenario A1.
- Impact of FDp on the production of nurseries is expected since FDp infestation results in the loss of Plant Passport and in the destruction of all involved production lots. However, in the absence of any precise data, the Panel could not make an uncertainty assessment of this specific impact.
- Impact on grape products quality may in some cases be expected but is difficult to document and even more to quantify. Impact of FDp on environment, if any, is expected to be extremely limited.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

The European Food Safety Authority (EFSA) is requested, pursuant to Article 22(5.b) and Article 29(1) of Regulation (EC) No 178/2002[1], to complete the Pest Risk Assessment (PRA) (step 2) of seven regulated pests, following the analysis and exchange of views with the Member State (MS) of the pest characterisation delivered (Ares(2014)970361). Specifically, EFSA is requested to identify risk reduction options and to provide an assessment of the effectiveness of the current European Union (EU) phytosanitary requirements (step 2) for (1) *Ceratocystis platani* (Walter) Engelbrecht et Harrington, (2) *Cryphonectria parasitica* (Murrill) Barr, (3) *Diaporthe vaccinii* Shaer, (4) *Ditylenchus destructor* Thorne, (5) *Eotetranychus lewisi* McGregor, (6) Grapevine Flavescence dorée and (7) *Radopholus similis* (Cobb) Thorne.

During the preparation of these opinions, EFSA is requested to take into account the recommendations, which have been prepared on the basis of the EFSA pest categorisations and discussed with the MSs in the relevant Standing Committee. In order to gain time and resources, the recommendations highlight, where possible, some elements which require further work during the completion of the PRA process.

<u>Recommendation of the Working Group on the Annexes of the Council Directive 2000/29/EC[2] – Section II – Listing of Harmful Organisms as regards the future listing of Grapevine Flavescence dorée</u>

The current regulatory status of the pest, its identity, distribution, potential for establishment and spread in the PRA area, as well as the potential for consequences in the PRA area have been treated previously by the Panel on Plant Health (hereinafter referred to as Panel) (EFSA PLH Panel, 2014a).

On the basis of this pest categorisation, the Working Group suggests keeping this pest as a Union Quarantine pest, with a specific aim for containment and, only where possible, for eradication.

The Flavescence dorée phytoplasma (FDp) occurs only in Europe. In all the MSs, where FDp occurs, official control measures are obligatory to prevent further spread. They include both the uprooting of symptomatic grapevines and mandatory vector control. These measures aim to keep the disease and its vector at low prevalence and contribute to the aim of containment of FDp in the EU.

Listing FDp as regulated non-quarantine pest (RNQP) will lead to the removal of the compulsory measures which are currently in place. In this situation, the vector will establish in stable population of high abundance in European vine-growing areas; infected vines that remain in a vineyard will serve as a source for infections and will increase the percentage of infested vectors in the population and thereby increase the risk of planting material being infected. As infection in nurseries are often asymptomatic (particularly in rootstock nurseries), listing FDp as RNQP will increase the risk of spreading both disease and vector in plants for planting and thereby threatening European vine production.

Therefore, the PRA initiated by EFSA needs to continue, with the aim to provide further information on potential distribution of the vector and probability of establishment of the pest, as well as risk reduction options for both the vector and the pest on which relevant measures can be taken.

Lastly, the Working Group suggests as well for further analysis and development several control methods which are currently applied in the EU:

- Surveillance of the vector supporting decisions on insecticide application and timing:
  - hanging yellow sticky traps in the vineyards and/or;
  - direct counting of nymphs in the leaf canopy;
  - compulsory insecticide application at least where both vector and FDp are present (which is particularly effective as the vector is monophagous on *Vitis* sp.):
  - applied in commercial vineyards and nurseries;
    - targeting nymphs and adults;
    - numbers vary from one to three per year in commercial vineyards (more numerous in nurseries);
  - control of the vector in amenity plants (vine arbours and hedges).

[1] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1–24.

[2] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ L 169, 10.7.2000, p. 1–112.

- Roguing of symptomatic plants;
- Roguing of the vineyard when infection rate exceed 20–30% of the plants in a plot;
- Removal of abandoned plots and wild *Vitis* spp. rootstock;
- Regular testing in rootstock nurseries;
- Hot water treatment of rootstocks, scions or grafted cuttings is widely applied. This thermotherapy is known to be effective in killing both FDp and vector eggs.

1.2. Interpretation of the Terms of Reference

The Standing Committee on Plants, Animals, Food and Feed (PAFF Committee) decided in February 2015 to request from EFSA a complete PRA before taking a decision about the future regulatory status of this pest in the EU.

The pest categorisation established by EFSA (EFSA PLH Panel 2014a) showed that FDp is present almost exclusively in Europe, where it is already distributed over limited areas in several of the main grape-growing countries (FR, IT, ES, PT, SI, HR, AT, HR and HU) and is still spreading. FDp disease results from the combined presence of the leafhopper *Scaphoideus titanus* Ball (Cicadellidae Deltocephalinae) (hereafter St), introduced from North America, and of phytoplasmas of taxonomic group 16SrV-C and 16SrV-D infecting grapevines, alders (*Alnus* spp.) and wild clematis (*Clematis vitalba*). Phytoplasmas of the taxonomic group 16SrV-C are widespread in alders in south-western France (Malembic et al., 2007) but also all over Europe. Sixty to eighty per cent of the alders are symptomless carriers of phytoplasmas of taxonomic group 16SrV-C. Transmission from alder to alder is achieved by the leafhopper *Oncopsis alni* (Lederer and Seemüller, 1991; Maixner and Reinert, 1999), which may occasionally transmit the phytoplasma to grapevine (Maixner et al., 2000). In Italy and Serbia, phytoplasma strains are present in wild clematis (*C. vitalba*) from which they can be transmitted to grapevine by the planthopper *Dictyophara europaea* (Filippin et al., 2009). The frequency of phytoplasma transmission from alders and clematis to grapevine remains to be determined but phytoplasma transmission cannot provoke an FDp outbreak in the absence of *S. titanus*, which probably arrived in Europe early in the 20th century (Bonfils and Schvester, 1960; Schvester et al., 1962; Vidano, 1964; Bertin et al., 2007; Papura et al., 2012). New entries of *S. titanus* passively carried by host plants imported from third countries are very unlikely, as the introduction into the EU territory of plants of *Vitis* from third countries is prohibited by Directive 2000/29/CE.

Based on these elements, the Panel considers it more appropriate to prepare a conditional assessment, where entry will not be considered because the disease virtually does not exist outside of the EU (with the exception of Serbia and Switzerland). Establishment will not be considered *per se* either, because it already occurred in a large part of the risk assessment area. However, establishment in currently unaffected EU areas is assessed. Spread and impact of FDp are then assessed in the present PRA.

The PRA area is the territory of the EU with 28 MSs (hereafter referred to as EU MSs), restricted to the area of application of Council Directive 2000/29/EC, which excludes Ceuta and Melilla, the Canary Islands and the French overseas departments.

The terms of references also suggest to analyse further 'several control methods which are currently applied in the EU'. A survey among the MSs presently infested by FDp (see Appendix A) revealed that a similar group of risk reduction options (hereafter RROs) is applied in all the surveyed MSs,[3] and that most MSs also implemented the removal of abandoned plots and of wild *Vitis* spp. rootstock and the regular testing in rootstock nurseries. Taking into account the fact that these risk reduction methods are complementary, the Panel examined their global impact, although it also attempted to assess their individual relative weight either for pest control at the vineyard level, or for the prevention of further spread. This latter analysis of individual risk reduction options is presented in Appendix A.

1.3. Specification of the scenarios

The Panel considers three scenarios in the present opinion. This choice of scenarios is motivated by (i) the need to evaluate precisely, as requested in the terms of reference the currently applied control

[3] Namely: general surveillance for the disease; general surveillance for the vector; surveillance of the vector supporting decisions on insecticide application and timing; compulsory insecticide application; control of the vector in amenity plants (vine arbours and hedges); roguing of symptomatic plants; roguing of vineyards when infection rate exceed 20–30% of the plants in a plot; removal of the wild *Vitis* spp. and of abandoned vineyards.

measures and (ii) the decision by the Panel, following exchanges with the European Commission (DG SANTE), to propose scenarios strengthening the current control strategy. The ability to improve FDp control concerns mostly two aspects:

- the quality of the grapevines propagative material, which would directly affect the long distance dispersal of the disease through the commercialisation of infested plants;
- the effectiveness of containment and eradication measures, that currently only partially address some epidemiologically important compartments, with the consequence that local spread and local prevalence of the disease may be difficult to limit under some local situations.

Following exchanges with European Commission, the Panel decided not to evaluate a scenario in which the current control measures would have been lifted.

The evaluated scenarios therefore are:

- **Scenario A0**: Current measures as currently applied by the MSs (see Table 1 for a list of the RROs involved);
- **Scenario A1**: In addition to the current measures, this scenario aims at improving the control of the sanitary status of grapevine propagation materials by generalising compulsory hot water treatment to all planting materials produced in nurseries located in infested areas (Table 1);
- **Scenario A2**: In addition to the current measures, this scenario integrates a strengthening of the containment and eradication programmes (including the targeting of wild *Vitis* spp. and of grapevines in non-agricultural settings (abandoned vineyards, wild vegetation surrounding the vineyards, gardens, etc.)) and an improvement of surveillance (Table 1).

The precise description of the different RROs contributing to the analysed scenarios and of their technical limitations are presented in Table 1 and Appendix A.

Table 1: Risk reduction options associated to the three scenarios

Risk reduction measures	Target	Legislation	Scenarios		
			A0	**A1**	**A2**
Delimitation of buffer zones	FDp	National Decrees	X	X	X
Surveillance of vineyards	FDp + vector	(EU-Survey Program)	X	X	
Improved surveillance of vineyard					**XX**
Surveillance of neighbouring environment	FDp + vector	National Decrees	X	X	
Improved surveillance of neighbouring environment					**XX**
Roguing of individually infected grapevines or vineyards	FDp + vectors	National Decrees	X	X	X
Roguing of abandoned vineyards	FDp + vectors	National Decrees	X	X	
Improved roguing of abandoned vineyards					**XX**
Roguing of wild *Vitis* spp.	FDp + vectors	National Decrees	X	X	
Improved roguing of wild *Vitis* spp.					**XX**
Insecticide treatment in vineyards	Vectors	National Decrees	X	X	X
Surveillance of nurseries	FDp + vector	2000/29/EC Annex IVB (32)	X	X	X
Insecticide treatment in nurseries	Vectors	2000/29/EC Annex IVB (32)	X	X	X
Roguing in nurseries	FDp	2000/29/EC Annex IVB (32)	X	X	X
Hot water treatment	FDp	2000/29/EC Annex IVB (32)	X		X

Risk reduction measures	Target	Legislation	Scenarios		
			A0	A1	A2
Generalised hot water treatment				**XX**	
Certification of propagation material	*Vitis* plants (virus/ viroids/ phytoplasma)	EU Marketing Directive (68/193/EC) for the vegetative propagation of the vine	X	X	X

FDp: Flavescence dorée phytoplasma.
XX: The marking XX in the two last columns indicates increased emphasis regarding specific measures under scenarios A1 or A2.

1.3.1. Definitions

1.3.1.1. Pathways

Because entry is not considered in the present opinion, the Panel did not identify specific pathways for entry. It did, however, identify the following mechanisms for spread of the vector and of the phytoplasma in all assessment scenarios.

Mechanisms for spread of *S. titanus*:

- natural dispersal;
- human-assisted dispersal through the trade of infected plant material;
- hitchiking (passive transportation in vehicles).

Mechanisms for spread of FDp:

- trade of planting material of *Vitis* sp.;
- spread of infectious vector(s) (see above).

Within an area free of Flavescence dorée disease, the Panel also identified the possibility of transfer to grapevine of FDp isolates from non-*Vitis* wild plant reservoirs.

1.3.1.2. Units used

Spatial units: NUTS 2 regions according to EUROSTAT are used as the reference spatial unit throughout the present opinion.

The possibility to use EUROSTAT NUTS 3 regions as the spatial unit has been considered by the Panel; however, information about the presence of the pest or about grapevine production was not available at the NUTS 3 level for all parts of the EU. In addition, surveys and prophylactic control are usually implemented at the NUTS 2 level and the protected zones that have been established in Europe correspond to NUTS 2 or NUTS 1 (the Czech Republic) levels.

Crop production units: Tonnes of grapes per hectare were used to express wine and table grapes production outputs in the spatial units occupied by the pest, using a conversion factor to transform hectolitres of wine into tonnes of grapes.

1.3.1.3. Abundance of the pest

The abundance of FDp in wine and table grapes is expressed throughout the present opinion as the percentage of infected plants in infested NUTS 2 areas.

1.3.1.4. Ecological factors and conditions

The Panel determined that the current distribution of grapevine is the main limiting factor in the risk assessment (RA) area. Climate change is anticipated to alter viticulture and grapevine-growing areas in the future. Suitable growing regions may shift to northern latitudes and higher altitudes in Europe due to the gradually increasing temperatures (Kenny and Harrison, 1993; Fraga et al., 2013). However, the Panel estimated that, within the 10-year time horizon considered, climate change will not significantly contribute to the risks.

1.3.2. Temporal scale

The temporal horizon of the assessment decided upon by the Panel is 10 years. This horizon has been found relevant because (i) in many parts of the RA area it historically corresponds roughly to the time interval between the first observation of the vector and the first reports of FD disease in grapevine and (ii) it allows ample time for symptoms expression and epidemic development of the disease since symptom expression takes 1–2 years and symptomatic plants immediately become sources for further transmission by the vector. Besides, a longer period would have introduced higher uncertainties (climate change; changes in the grapevine-growing area, etc.).

2. Data and methodologies

2.1. Data

An extensive literature search was conducted by EFSA for the pest categorisation of Flavescence dorée (EFSA PLH Panel, 2014a). Further references (including grey literature sources) and information were obtained from experts to describe the history of the spread of FDp and of the vector in the regions of Europe.

A literature search was conducted in CABI (https://www.cabdirect.org/) and Scopus (https://www.scopus.com/) to collect information on disease impact and FDp and *S. titanus* control. The following strings were input for the bibliographic search in both databases: (1) flavescence AND (impact OR damage) (2) (flavescence OR Scaphoideus) AND control.

The bibliographic search in CABI produced 280 records for '(flavescence OR Scaphoideus) AND control' and 58 for 'flavescence AND (impact OR damage)'. The same search in Scopus produced 287 records for '(flavescence OR Scaphoideus) AND control', and 46 for 'flavescence AND (impact OR damage)'. The results from the two databases largely overlap.

To complement the information provided by the literature and online databases on pest distribution, damage and management, the Panel sent a short questionnaire on the current situation at the country level (based on the information available in the European and Mediterranean Plant Protection Organization Plant Quarantine Retrieval (EPPO, 2014) to the National Plant Protection Organization (NPPO) contacts in all the EU MSs (Appendix A).

Information on the trade data and distribution of grapevine was obtained from the EUROSTAT (EUROSTAT, online) database (Appendix D). The EUROPHYT, online database, which collects notifications of interceptions of plants or plant products that do not comply with EU legislation, was consulted searching for pest-specific notifications on interceptions.

2.2. Methodologies

The Panel performed the PRA for FDp following the guiding principles presented in the EFSA Guidance on a harmonised framework for risk assessment (EFSA PLH Panel, 2010) and as defined in the International Standard for Phytosanitary Measures (ISPM) No. 11 (FAO, 2016a,b).

A specific quantitative assessment model was used to perform the pest risk assessment. The specification of the model is described in Appendix D.

When conducting this PRA, the Panel took also into consideration the following EFSA horizontal guidance documents:

- Guidance of the Scientific Committee on Transparency in the Scientific Aspects of risk assessments carried out by EFSA. Part 2: General Principles (EFSA, 2009);
- Guidance on Statistical Reporting (EFSA, 2014a);
- Guidance on the structure and content of EFSA's scientific opinions and statements (EFSA, 2014b).

The assessment follows a quantitative approach, in which the steps of spread and impact are elaborated quantitatively under three RRO scenarios, identified as A0–A2. Entry is not considered in this assessment, because the disease is not known to exist outside of the EU, expect in Serbia and Switzerland. FDp is already established in a number of EU MSs. However, the possibility that FDp could establish in parts of the EU from which it is currently absent was evaluated.

Within each step, substeps are distinguished to quantitatively assess the underlying component processes. An overall summary description of the steps is provided in Appendix C and E which describes the overall risk assessment model without mathematical equations.

Uncertainty involved in estimating spread and impact, is represented using a probability distribution which expresses the best estimates of the variables provided by the experts considering both data (when available) and judgement. The distribution is characterised by a median value and four additional percentiles of the distribution. The median is the value for which the probability of over- or underestimation of the actual true value is judged as equal. Calculations with the model are made by stochastic simulation, whereby values are drawn randomly from the distribution specified for each parameter. The stochastic simulations are repeated at least 20,000 times to generate a probability distribution of outcomes, i.e. the outcome of the impact process in a given time period/year in the future.

In the model calculation, the uncertainty of each component is passed through the model equation, in a way that its contribution to the uncertainty of the final result can be shown. The '**decomposition of uncertainty**' calculates the relative contribution (as a proportion) of each individual input to the overall uncertainty of the result (sum to 1).

Appendix D of the assessment reports the outcomes of scenario calculations. The distributions given in this section characterise the possible range of outcomes at the 10 years time horizon of the opinion under a certain scenario.

The distributions of the uncertain components are characterised by different values and ranges.

The **median** is a central value with equal probability of over- or underestimating the actual value. In the opinion, the median is also referred as 'best estimate'.

The **interquartile range** is an interval around the median, where it is as likely that the actual value is inside as it is likely that the actual value is outside that range. The interquartile range is bounded by the 1st and 3rd quartile (the 25th and 75th percentile) of the distribution. This range expresses the precision of the estimation of interest. The wider the interquartile range, the greater is the uncertainty on the estimate. In this opinion, we refer to the interquartile range by using the term 'uncertainty interval'.

For experimental designs, it is common to report the mean (m) and the standard error ($\pm$ s) for the precision of the estimate of a measured parameter. The interval: m $\pm$ s ([m $-$ s, m $+$ s]) is used to express an interval of likely values. This estimation concept is based on replicated measurements. In the context of uncertainty, it is not reasonable to assume replicated judgements. Therefore, the median and interquartile range is used instead of the mean and the interval m $\pm$ s, but the interpretation as the precision of judgements is similar.

In addition to the median and interquartile range, a second range is reported: the **credibility range**. The credibility range is formally defined as the range between the 1st and 99th percentile of the distribution allowing the interpretation that it is extremely unlikely that the actual value is above the range, and it is extremely unlikely that it is below the range.

Further intervals with different levels of coverage could be calculated from the probability distribution, but these are not reported as standard in this opinion.

Please note that the number of significant figures used to report the characteristics of the distribution does not imply the precision of the estimation. For example, the precision of a variable with a median of 13 could be reported using the associated interquartile range, perhaps 3–38, which means that the actual value is below a few tens. In the opinion, an effort was made to present all results both as a **statement on the model outcome** in numerical expressions (shown in Appendices C and E), and as an **interpretation in verbal terms**, provided in Section 3 of the opinion.

Nevertheless, the distributions of one variable under different scenarios can be compared via the corresponding median values, e.g. consider a variable with a median value of 13 within scenario 1 and the same variable with a median value of 6 within scenario 2. This can be interpreted as the variable in scenario 2 being about half of scenario 1 in terms of its central value. The same principle is also valid for other characteristics of the distribution of a variable under different scenarios, such as comparisons of quartiles or percentiles.

3. Assessment

3.1. Entry

As discussed in Section 1.2, entry is not considered in this assessment, because the disease is not known to exist outside of the EU, except in Serbia (Duduk et al., 2003; Krnjajić et al., 2007), where it most probably originated from the EU, as FDp was widespread in the EU well before being recorded in Serbia.

The vector itself is not likely to enter again, as its main pathway for entry, plants for planting, is closed (Annex III-A of Directive 2000/29 prohibits the import of *Vitis* plants).

3.2. Establishment

As discussed in Section 1.2, FDp is already established in a number of EU MSs. However, the possibility that FDp could establish in parts of the EU from which it is currently absent was evaluated in the present section.

3.2.1. Current distribution of FDp in Europe

According to information from the literature and from NPPOs (EFSA PLH Panel 2014a), FDp is present in eight of the main grape-growing EU countries (Austria, Croatia, France, Hungary, Italy, Portugal, Slovenia and Spain) as well as in Switzerland and in Serbia (Figure 1). In some of these countries (Austria, Croatia, Hungary, Portugal and Spain), FDp is restricted to a few foci or to limited geographical areas. Moreover, FDp is not present in large areas of northern France and southern Italy.

3.2.2. Current distribution of vectors

Scaphoideus titanus is an invasive leafhopper which was introduced from North America to Europe, and was observed first in France in 1958 (Bonfils and Schvester, 1960). It is strictly associated with *Vitis* spp., mainly *Vitis vinifera, Vitis labrusca* and *Vitis riparia*, and requires grapevine for oviposition and completion of its life cycle. The invasion of the European vineyards by *S. titanus* is an ongoing process, and the insect has so far spread to the 11 EU MSs (Austria, Bulgaria, Croatia, France, Hungary, Italy, Portugal, Spain, Romania, Slovenia and Slovakia) and to four European Third Countries (Bosnia-Herzegovina, Montenegro, Switzerland and Serbia) (Tothova et al., 2015) (Figure 1). The distribution range of *S. titanus* in the EU is wider than that of FDp, and even overlaps with some of the EU FDp Protected Zones (Figure 2).

FD phytoplasmas are present in *Alnus* spp. and *Clematis vitalba* and, occasionally, leafhoppers or planthoppers other than *S. titanus* might act as vectors, acquiring FDp from these alternative reservoirs and transmitting it to grapevine. *D. europaea* (Linnaeus) (Auchenorrhyncha, Dictyopharidae) has been shown to transmit FDp from *C. vitalba* to grapevine (Filippin et al., 2009), and the Asian species *Orientus ishidae* (Matsumura) (Cicadellidae, Deltocephalinae), which has recently introduced in Europe (CABI, 2015), has been recently found harbouring FDp in Slovenia, Italy and Switzerland (Mehle et al., 2010; Gaffuri et al., 2011; Trivellone et al., 2016). *D. europaea* is rather widely distributed in the EU according to *Fauna Europaea* (Figure 3). *O. ishidae*, although more limited in distribution, appears to be rapidly spreading (Koczor et al., 2013) and has been recorded so far from the nine EU MSs (CABI, 2015).

The rate of transfer of FDp from the wild compartment to vineyards by these alternative vectors is unknown but likely very low. Evidence for this assessment is provided in Appendix B. Therefore, FDp from *Alnus* and *Clematis* may infrequently represent a source for new epidemic outbreaks of FDp in grapevine (in the presence of *S. titanus*). Once FDp is transferred by such vectors to grapevine it can be further epidemically spread in vineyards by *S. titanus*.

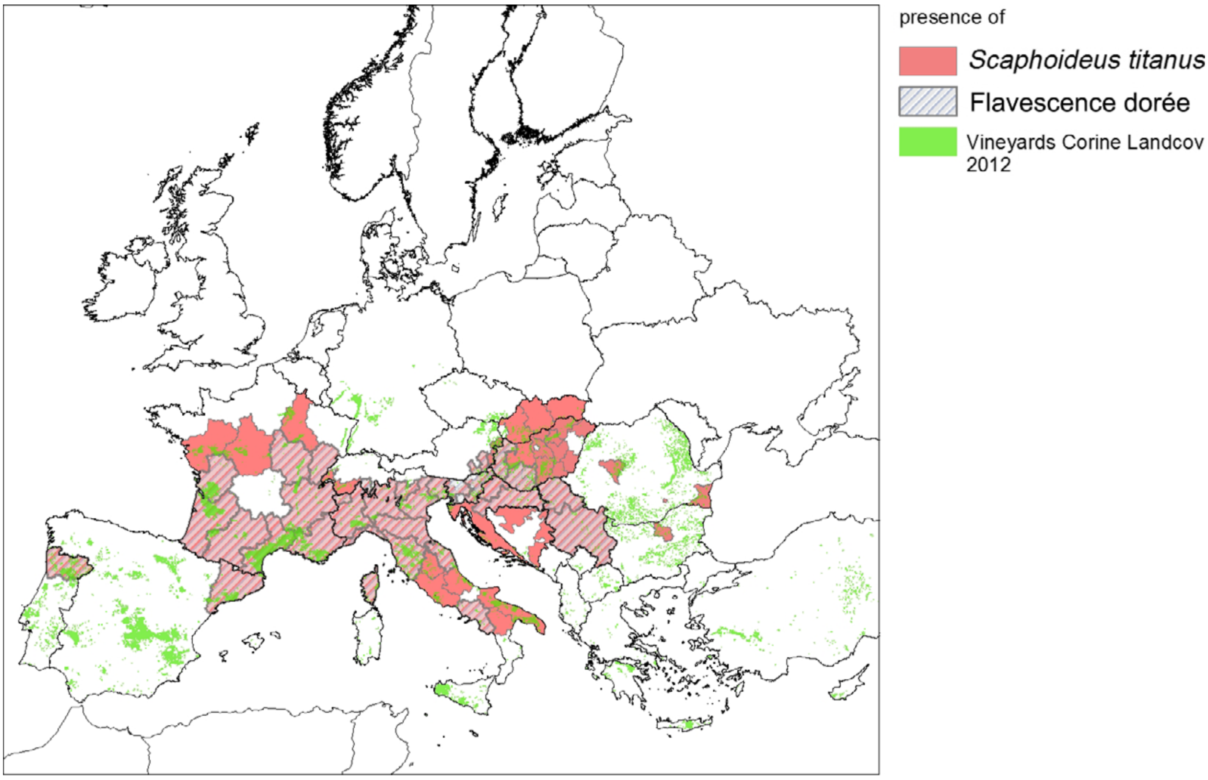

Figure 1: Observed distributions of grapevine cultivation, of FDp infection in grapevine and of *Scaphoideus titanus* in Europe (situation in 2014)

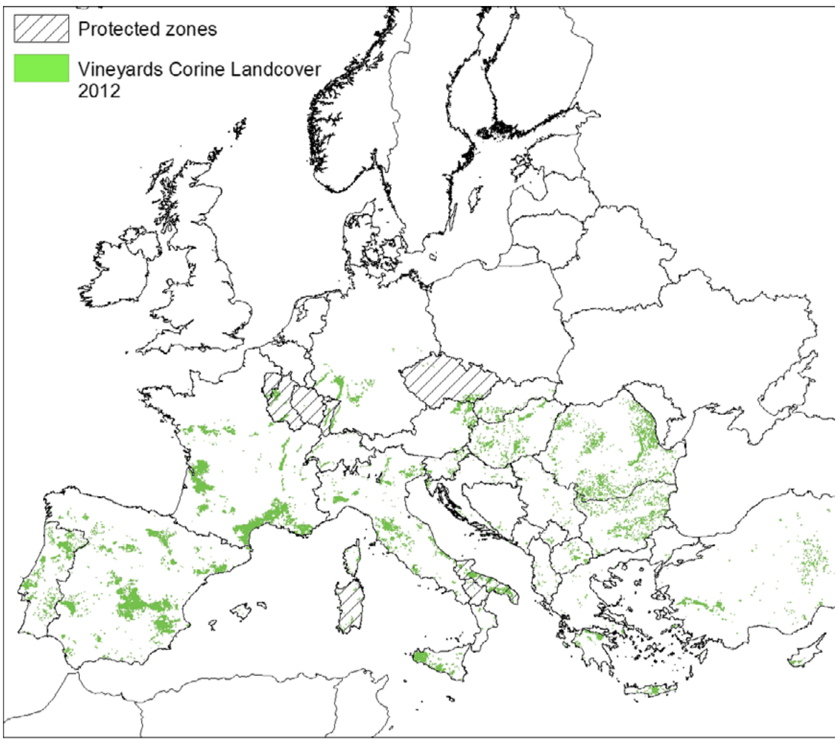

Figure 2: FDp protected zones: the Czech Republic, France (Alsace, Champagne-Ardenne, Picardie (département de l'Aisne), and Lorraine) and Italy (Apulia, Basilicata and Sardinia). In addition, the communes de Citry, Nanteuil-sur-Marne et Saâcy-sur-Marne of Ile de France have the status of PZs (not shown on the map because of scale constraints)

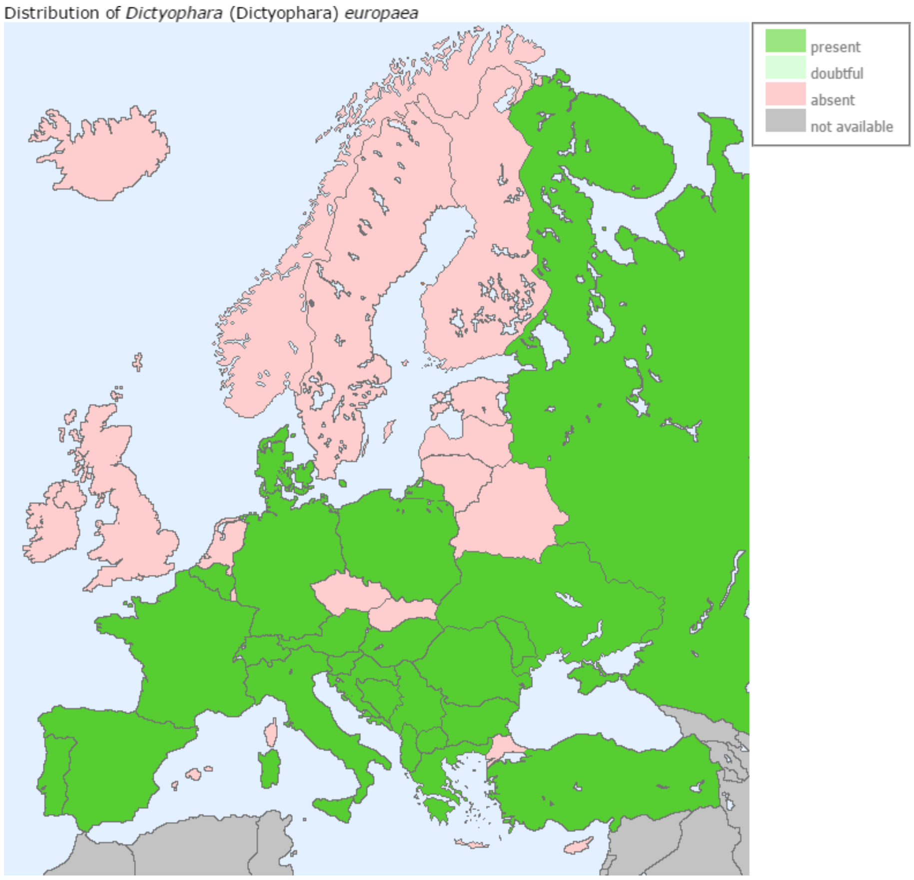

Figure 3: Distribution of *Dictyophara europea* according to *Fauna Europaea* (http://www.faunaeur.org/)

3.2.3. Availability of suitable hosts in yet uncolonised parts of the risk assessment area

Host plants are cultivated and wild species of the genus *Vitis*, including the interspecific hybrids that are used as rootstocks. Wild *Vitis* spp. and hybrids remain symptomless upon infection. Alder (*Alnus* spp.), Ailanthus (*Ailanthus altissima*) and Clematis (*C. vitalba*) are other known natural hosts of FDp. Alders and Ailanthus are known to be symptomless carriers of FDp in Europe, with regular high incidence of infection. Infected clematis may remain symptomless, but sometimes show symptoms (Filippin et al., 2007).

The farm structure survey of EUROSTAT (Table D.3, D.4, D.5 and D.6 in Appendix D) is listing 20 European countries with grape production: Bulgaria (BG), the Czech Republic (CZ), Germany (DE), Greece (EL), Spain (ES), France (FR), Croatia (HR), Italy (IT), Cyprus (CY), Luxembourg (LU), Hungary (HU), Malta (MT), the Netherlands (NL), Austria (AT), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Slovakia (SK) and the United Kingdom (UK) (see also Figure 1).

C. vitalba is present in all European countries, and widespread in France, Germany, Italy, the United Kingdom and former Yugoslavia (CABI 2016). *Alnus glutinosa* is widespread in most of Europe, except in the north of Norway, of Sweden and of Finland, and south-eastern Spain (Houston Durrant et al., 2016); *Alnus cordata* is restricted to Italy, Northern France and Corsica (Houston Durrant et al., 2016); *Alnus incana* is present in most of Central Europe, Scandinavia, eastern France, northern Italy (Houston Durrant et al., 2016).

3.2.4. Ecoclimatic limitations to establishment of *S. titanus* in yet uncolonised EU areas

FDp and its vector *S. titanus* now, respectively, occupy 27 and 52 NUTS 2 regions in the EU, and are still spreading within and beyond these. ACRP (2013) and Maixner (2005) show that they could further establish in vine growing regions in central and northern Europe.

The Panel used the parameters of a published *S. titanus* CLIMEX modelling study (ACRP 2013) to run a simulation for *S. titanus* establishment potential in Europe based on climate data from 1999 until 2010 (JRC). This new study predicts that vine-growing regions in east, central and northern Europe which are not yet invaded, provide good climatic conditions for *S. titanus* establishment. As a consequence, vine-growing areas in Austria, Bulgaria, the Czech Republic, northern France, Germany, Hungary, Romania and Slovakia have a high risk of establishment of *S. titanus* (Ecoclimatic Index EI > 20) (Figure 4). The risk of *S. titanus* establishment in some of the southernmost parts of Europe (Crete, some areas of Southern Spain, Cyprus, etc.) appears lower, due to environmental conditions causing dry and heat stress in the vector. However, uncertainties persist on this assessment because irrigation in these areas might lead to conditions locally more suitable for *S. titanus*.

The CLIMEX® model also shows that the establishment potential of *S. titanus* in northern Europe exceeds the area where there is significant grapevine production (as determined by EUROSTAT and Corine Landcover). Further establishment in the north is therefore limited mostly by host distribution (*Vitis* sp.) rather than by climate. If, due to climate warming, the production area of grapevine in central and northern Europe was to expand to regions where formerly no grapevine was commercially produced, *S. titanus* would likely find suitable climatic conditions for establishment there and then.

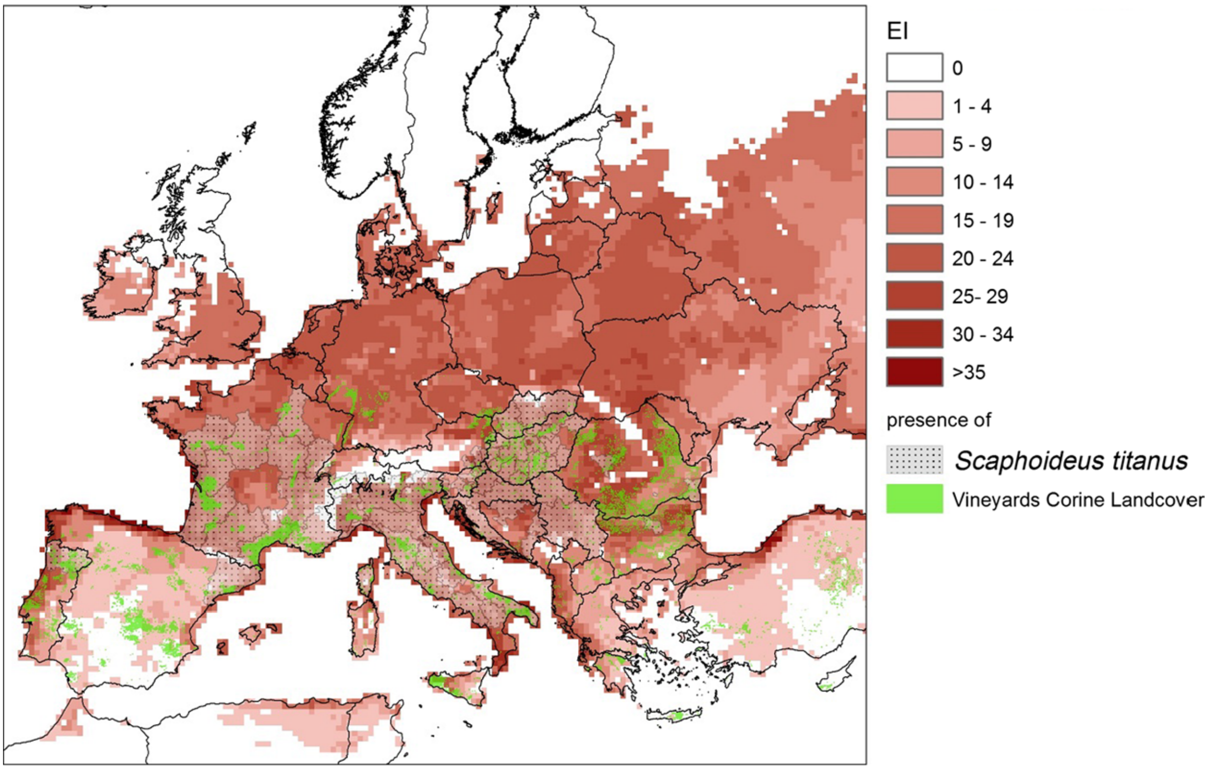

Figure 4: Predicted suitability for establishment of *S. titanus* in Europe based on climate data 1999–2010 (JRC) (AGRI4CAST, online) modelled with the CLIMEX software combined with the vine-growing areas in Europe (CLC 2000, 2006)

3.2.5. Ecoclimatic limitations to establishment of FDp in yet uncolonised EU areas

The development of FDp does not appear to be severely constrained by ecoclimatic conditions and appears unlikely to be affected in the drastic way by an increase in temperatures (Salar et al., 2013). It is therefore likely that FDp could successfully colonise grapevine wherever this crop is able to develop.

3.2.6. Conclusions on Establishment

Both FDp and *S. titanus* have already established over a large part of the risk assessment area, but are still spreading and have the potential to establish in at least a large fraction of the currently still unaffected area.

It is likely that FDp could successfully colonise grapevine wherever this crop is able to grow. However, its ability to spread from grapevine to grapevine, causing an epidemic disease, is limited under most circumstances by the availability of the *S. titanus* vector (the counter example being in nurseries, in which the vegetative multiplication of grapevine and the trade of plants for planting can spread the disease even in the absence of the vector). The availability of the *S. titanus* vector is subject to ecoclimatic constraints. However, the results of the CLIMEX analysis performed by the Panel indicate that *S. titanus* is likely to be able to establish over most of the EU territory and, in particular, in all northern and central European grapevine-growing areas in which this vector has so far not established. Uncertainties exist for the southernmost grapevine-growing areas, in which hot and dry conditions are likely to limit establishment in at least some areas.

3.3. Spread

Because FDp is already established in several MSs, this section assesses the probability of further spread to areas where FDp is not currently present.

Historical data on spread was either available with a spatial resolution of NUTS 3 administrative units or only at the NUTS 2 level for other areas. The Panel adopted the simple approach of a 'patch occupancy model' to address long-distance spread with NUTS 2 regions as 'patches'. The historical data was examined in a retrospective analysis in order to estimate the rate of spread. Logistic, polynomial and linear equations were fitted to the data.

Three mechanisms were identified allowing the spread of FDp: (i) trade and movement of infected propagative material; (ii) infested vectors flying from adjacent spatial units, transported on plants for planting or hitchhiking in vehicles; (iii) transfer from the wild compartment (infected *Alnus* or *Clematis*). The relative contribution of these various mechanisms to the spread of FDp is unknown, although expert judgement tends to attribute only small importance to transfer from the wild compartment (Appendix B).

Based upon expert knowledge, the Panel performed a retrospective analysis of the mechanisms that were involved, when known, in the infestation of EU NUTS 2 regions. This analysis, although very imprecise, suggests that infected planting materials contributed to roughly one-third of the historical spread, while the gradual spread of the disease by the *S. titanus* vector contributed to more than half the spread. The contribution of transfer from the wild compartment (infected *Alnus* or *Clematis*) was very minor in this analysis (see Appendix B). It should, however, be stressed that contrary to vector-mediated spread, the first mechanism is not limited by the connectivity of vineyards between NUTS 2 regions and allows for the long-distance spread of the disease to isolated grape-growing regions and to isolated, yet untouched grapevine patches in already infested spatial units.

3.3.1. Assessment of spread of FDp under the current control measures (scenario A0)

3.3.1.1. General strategy

To evaluate spread under scenario A0, the Panel used existing information in order to reconstruct the historical timeline of gradual *S. titanus* and FDp spread over EU NUTS 2 regions. By taking historical data into consideration, this strategy does not separate the contribution of individual spread mechanisms. However, an effort to separate these contributions can be found in Appendix B.

In a first step, this historical reconstruction was used to determine the current extent of *S. titanus* and FDp colonisation of the EU, expressed as the number of infested NUTS 2 regions. Expert elicitation was then used to estimate the probability distribution of the actual number of infested NUTS 2 regions within the general framework of EFSA guidance on quantitative uncertainty analysis (see Appendix C).

In a second step, the Panel fitted various models to the cumulative sum of infested NUTS 2 areas over time, as inferred from the existing historical data, to make projections of the spread of FDp in the future. Initially, an attempt was made to explore whether the historical spread data could be represented by the concept of logistic growth that potentially could yield parameter estimates with a biological meaning (e.g. intrinsic growth rate and carrying capacity). However, in the case of FDp, there are many factors affecting the rate of spread, including the slowing down of spread rate, due to the implementation of new RROs over time, which could explain why this attempt was not successful. Instead, the Panel resorted to simple curve fitting and extrapolated the various fitted curves over the 10-year time horizon of the present assessment (Figure 5). The models used were:

- Two linear regression models, one taking into account only the early years of the FDp spread (linear 1 model in Figure 5) and the second taking into consideration only later years (linear 2 model in Figure 5). The basis for this strategy is the observation of an actual increase at a given point in time of the slope of the linear function describing FDp spread.
- A polynomial model (polynomial in Figure 5), which was the model showing the best fit with the historical data among all those tested.
- A logistic model (logistic in Figure 5), that also closely matched the historical data.

The outputs of the various models where provided as a basis for an expert elicitation procedure in which the experts expressed their expectations, including their uncertainty of the number of EU NUTS 2 infested regions under scenario A0 in 10 years time from the last year with data (2015; Appendix C).

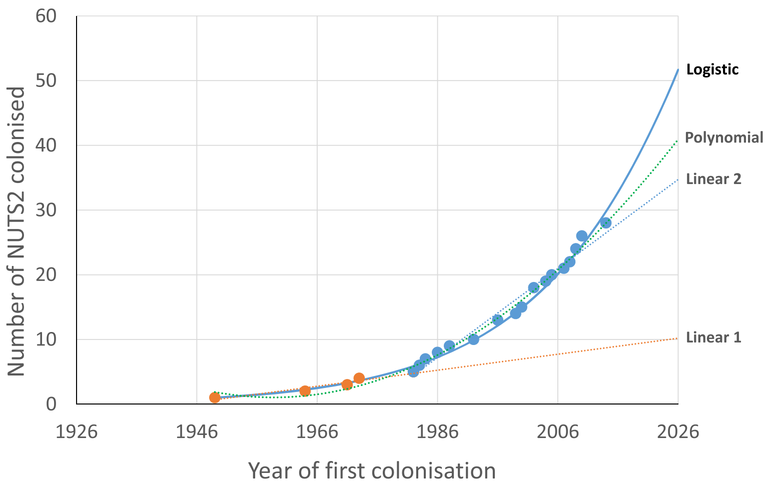

Figure 5: Linear, polynomial and logistic models fitted on the historical values corresponding to the cumulative number of NUTS 2 EU regions infested by FDp

3.3.1.2. Conclusion on the assessment of spread of FDp under the current control measures (scenario A0)

Taking eradication in two NUTS 2 units into account, the currently available data puts at 27 the number of presently infested NUTS 2 regions. This estimation is, however, affected by some uncertainties, because ongoing eradication efforts may already have been successful in some regions while it is also possible that new regions may have been infested without the fact being detected or reported.

An extrapolation of the linear model puts at 37 the number of infested NUTS 2 regions at the 10-year time horizon, which corresponds to a further 10 NUTS 2 being infested over the period. The uncertainty analysis shows the 50% probability interval to correspond to an increase in the number of infested NUTS 2 regions of between a few and 20–30.

Taking into account the various RROs currently implemented by the EU MSs (and therefore considered under scenario A0), both components of the current control strategy, the eradication and containment measures (see Table 1) and the control of the sanitary status of the propagation material, are seen as contributing to the current limitation of the spread of FDp.

Analysis of infection history suggests that trade of planting material and vector-mediated spread may have contributed, respectively, for one-third and two-thirds to introduction of the FDp in additional NUTS 2 regions (Appendix B).

3.3.1.3. Sources of uncertainty affecting the assessment of spread of FDp under scenario A0

Two major types of uncertainties affect the assessment of spread of FDp under scenario A0. The first uncertainty concerns, as discussed above, the precise number of currently infested NUTS 2 regions, which is then used as a reference to determine the extent of further spread. The second source of uncertainty concerns the spread process itself and its extent over the 10-year time horizon. Although the fit of the cumulated historical data with the various models used is very good, the various models predict different outcomes in the future and it is difficult to determine whether one model should be preferred over another. In addition, it is possible that, for whatever reason(s) the next 10 years could see the emergence of (a) novel trend(s) (e.g. the emergence of insect strains resistant to pesticides, changes in the technical means available for controlling wild plants or resulting from global change) that could alter the dynamic of FDp spread and thus result in a final outcome significantly different from the one predicted by the models.

3.3.2. Assessment of spread of FDp under alternative scenarios

3.3.2.1. General strategy

The Panel used expert judgement in order to evaluate spread under scenarios A1 and A2, i.e. the probability distribution of the actual number of EU NUTS 2 infested regions under these scenarios at the 10-year time horizon. This was performed by trying to describe in which way(s) the spread predicted under scenario A0 would be affected by the implementation of the additional measures characterising scenarios A1 and A2. (see Appendixes A and C).

3.3.2.2. Results of the assessment of spread of FDp under alternative scenarios

Scenario A1 (improvement of the phytosanitary status of the propagation material): The generalised, compulsory use of hot water treatment on all grapevine planting material produced in areas with infected plants has the potential to significantly reduce the probability of FDp infection in traded grapevine propagative material, one of the mechanisms identified for the spread of FDp. In addition, this measure is evaluated by the Panel as having a high feasibility because its implementation is relatively straightforward and does not meet important technical hurdles (see Appendix A).

Scenario A2: The more intense containment and eradication efforts are expected to (i) allow more prompt and effective elimination of FDp infection in some of NUTS 2 regions showing limited FDp prevalence and (ii) limit the second identified spread mechanism, vector-mediated spread between adjoining NUTS 2 regions. Both increased surveillance, even in areas currently free of FDp and increased eradication efforts, in particular by targeting abandoned vineyards and the wild grapevine populations are seen as contributing to the overall effectiveness of this scenario (see Appendix A). On the other hand, overall feasibility is seen as somewhat more difficult than for the RROs involved in scenario A1.

Under both scenarios A1 and A2, FDp is predicted to continue to spread over the next 10 years (see Appendix A), although at a reduced rate as compared to scenario A0. For both scenarios, a progression corresponding to the further infection of roughly half a dozen NUTS 2 regions over the current situation is envisioned, with a 50% uncertainty interval ranging from a slight reduction in the number of infested regions to 10–15 newly infested NUTS 2 regions. In broad terms, these values correspond roughly to a halving of the spread predicted under the A0 scenario.

3.3.2.3. Sources of uncertainty affecting the assessment of spread of FDp under alternative scenarios

Sources of substantial uncertainty affect the assessment of spread of FDp under scenarios A1 and A2. The scenarios contain the implementation of multiple RROs and both their intrinsic effectiveness and the thoroughness with which they would be implemented by individual member states are associated with substantial uncertainty. These uncertainties are, in addition, compounded over the 10-year time horizon. As a consequence, median estimates must be considered in combination with the associated uncertainty intervals when analysing the output of this uncertainty analysis. However, even given these uncertainties, the Panel is of the opinion that implementation of the added or reinforced RROs in scenarios A1 and A2 is likely to substantially reduce the spread of FDp as compared to that predicted under scenario A0.

3.3.3. Overall conclusions on spread

Although carrying very significant uncertainty, the analysis of FDp spread carried out by the Panel reached the following conclusions:

- With the current measures in place (scenario A0), spread of FDp is likely to continue during the forthcoming period with a progression of between a few and ca 20 newly infested NUTS 2 regions predicted for the 50% uncertainty interval. This analysis clearly illustrates the limitations of the currently deployed control measures, which have not allowed to halt so far the progression of FDp in the EU territory (Appendix A).

- Spread of FDp is expected to be roughly similar between the two strengthened control scenarios (scenarios A1 and A2). The Panel confidently estimates that spread will be more restricted under these scenarios than under the current measures (scenario A0), with a 50% uncertainty interval of between stabilisation in the number of affected NUTS 2 regions and 10–15 newly infested regions. This corresponds roughly to a halving of the spread predicted under scenario A0.
- Overall, a stabilisation or a reduction in the number of infested NUTS 2 regions is only envisioned under scenarios A1 and A2 of reinforced control measures and then only with a relatively low probability. A combination of the reinforced control measures implemented in scenarios A1 and A2 is expected to have an even higher effectiveness to further limit the spread of FDp.

3.4. Impact

3.4.1. Assessment of the impact of FDp on wine and table grapes production under the current measures (scenario A0)

3.4.1.1. General strategy for the quantitative uncertainty analysis

The new risk assessment methodology under development by the EFSA PLH Panel performed a quantitative uncertainty analysis of the impact of FDp on wine and table grapes production under scenario A0. This analysis takes into account five parameters:

1) the number of infested NUTS 2 regions at the 10-year time horizon as determined by the spread analysis (see Section 3.3);
2) the average area under grapevine production in NUTS 2 regions, expressed in hectares for table grapes or wine-producing grapes, for EU NUTS 2 regions with grape production;
3) the average abundance of FDp in wine and table grapes production in infested NUTS 2 regions, expressed as the percentage of infected plants at the 10-year time horizon;
4) the average grape production in NUTS 2 regions, expressed in tonnes for table grapes and wine grapes, for EU NUTS 2 regions with grape production;
5) a multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection.

In performing this analysis, the Panel considered that in the absence of *S. titanus*, no epidemic development is expected in grapevine and therefore FDp impact is expected to be minimal. However, it should be considered that from a historical perspective, establishment of *S. titanus* has always preceded the establishment of FDp by a few years, so that the *S. titanus* presence is not expected to be a limiting factor in the NUTS 2 regions corresponding to the output of the spread analysis.

It should be stressed that for the estimation of the multiplication factor providing the estimation of the loss of production as a consequence of FDp infection, the present assessment was made taking into account the current legislation (A0 scenario). The removal of infected plants upon their discovery was therefore considered the rule. As a consequence, the present analysis did not take into account the potential effect of the recovery phenomenon in which, after an initial crisis, grapevines may recover and return to productivity.

In addition, the Panel considered that when plants are uprooted, even if new grapevines are replanted immediately, the new plants will not enter production for 2–3 years. Thus, in a worst-case situation, production would be completely lost for 3 years (loss of 1 year of production of the uprooted plants plus loss of the two-first years of production of the replants) and partially lost during the fourth year (limited production of the replants). The multiplication factor was therefore calculated integrating this multiyear production loss (see Appendix D).

Lastly, currently used control measures involve the complete removal of plots with more than 20% infections, resulting in the additional loss of the production of healthy plants in such plots. This element was also integrated in the calculation of the multiplication factor through an estimation of the proportion of plots in infested NUTS 2 that may reach this 20% threshold (see Appendix E).

The detailed quantitative uncertainty analysis of the impact of FDp on wine and table grapes production under scenario A0 is provided in Appendix E, together with the justifications for the probability distributions used.

3.4.1.2. Conclusion of the assessment of the impact of FDp on wine and table grapes production under the current measures (scenario A0)

The analysis performed by the Panel provides a rough estimation of the impact of FDp on wine and table grapes production under scenario A0. In interpreting the results of this analysis, the Panel also considered the associated uncertainties (see below) which result in a wide 50% uncertainty interval. Indeed, while the consolidated median loss (taking into account all types of grapes production) is estimated at close to 8,000 tonnes of grapes across the whole of the EU, the 50% uncertainty interval spans a range of nearly two orders of magnitude, ranging from about 1,000 tonnes to close to 50,000 tonnes.

It should be stressed that these values represent only a very small fraction of the EU table grapes or wine production, reflecting the effectiveness of the currently deployed RROs. As an illustration of this, the upper impact estimates provided by the 90% uncertainty interval represent around 0.5–1% of the EU production of wine or of table grapes production.

3.4.1.3. Sources of uncertainty affecting the assessment of the impact of FDp on wine and table grapes production under the current measures (scenario A0)

Generally speaking, the parameter that is associated with the largest uncertainties is the estimation of the average abundance of FDp in infested NUTS 2 regions. Indeed, this parameter is shown by the uncertainty analysis to be the single one contributing most significantly to the overall uncertainty (see Appendix D). The estimation of this parameter faces many challenges. Besides the fact that it represents a prediction at a significant time interval (10 years), it should be stressed that there is absolutely no data available at such a high European-wide integration scale, so that the Panel had to rely on expert judgement and on hypotheses whose accuracy is difficult to evaluate. It should also be stressed that the reasoning at the level of an average EU prevalence is largely foreign to the experts, who are used to reason on specific smaller EU territories but not to such a widely integrated average covering highly divergent local situations (NUTS 2 regions with widely different grapevine acreage and infection prevalence). It is therefore difficult, even for the elicited experts, to think in terms of this highly integrated value, which may have severely affected the precision of their estimations. Further discrete sources of uncertainty affecting the estimation of this parameter are described in Appendix E.

The second parameter that contributes significantly to the overall uncertainty is the average area under grapevine production in individual infested NUTS 2 regions. In particular, EU NUTS 2 regions vary widely in their vineyard coverage so that uncertainties on the identity of the individual NUTS 2 regions that will be infested 10 years from now do not allow calculation of precise average acreage values. As a proxy, current acreage values averaged over the currently infested 28 NUTS 2 regions were used but their wide variation is then carried on as an uncertainty factor.

The other three variables (namely: the number of infested NUTS 2 regions at the 10-year time horizon, the average grape production in individual NUTS 2 regions, and the multiplication factor expressing the yield loss in FDp-infected plants) are seen as contributing less to the overall uncertainty. The uncertainties affecting the number of infested NUTS 2 regions under scenario A0 at the 10-year time horizon are described in the Section 3.3 on spread. Uncertainties affecting the grape production itself are those expected from such integrated statistical data, compounded by the variability existing in production between EU NUTS 2 regions.

The main sources of uncertainty affecting the estimation of the probability distribution of the multiplication factor concern:

- The strategy used by the Panel to take into account the multiyear nature of yield loss in a perennial crop which takes several years to reach its productive phase.
- The estimation of the average loss of production on the year of infection. Although some data exist for individual grapevine varieties, the multiplication factor should be viewed as a weighted average taking into consideration all wine or table grape varieties and their respective acreage, an extrapolation and integration of data that is by essence complex and that adds to the uncertainty.
- The estimation of the time needed, on average, for replants to enter their production phase and the reduction in yield observed on their first year of production.
- The impact of the recovery phenomenon on yield losses as not all infected grapevines may be detected and/or pulled out, leaving the possibility that some of these plants may then recover from infection.

3.4.2. Assessment of impact on wine and table grapes production under alternative scenarios

3.4.2.1. General strategy for the quantitative uncertainty analysis

The strategy for the quantitative uncertainty analysis of the impact of FDp on wine and table grapes production under scenarios A1 and A2 is similar to that used to estimate this parameter under scenario A0. It takes into account the number of infested NUTS 2 regions at the 10-year time horizon under these scenarios, as determined by the spread analysis (see Section 3.3).

The values used for the average area under grapevine production and for average grape production in individual NUTS 2 are the same as those used for the analysis under scenario A0 as these values were not considered by the Panel to be affected in a meaningful way by the particular scenario under consideration. Any minor differences that may actually exist in these values under the different scenarios are therefore considered to be part of the uncertainties affecting the analysis (see Section 3.3).

The average abundance of FDp in infested NUTS 2 regions was considered by the Panel to be affected by both scenarios and therefore specific probability distributions of this parameter for the A1 and A2 scenarios were estimated (see Appendix E).

An analysis by the Panel indicated that the multiplication factor providing an estimation of the loss of production of individual grapevines is not, or is only marginally affected by the particular RROs involved in the alternative scenarios. This is because the RROs involved are not expected to affect production loss on the first year of infection of a grapevine and that they do not affect the removal obligation and the ensuing production losses. The only element that can possibly be affected is the proportion of plots reaching > 20% infection, which is expected to be drastically reduced under the reinforced containment and eradication measures implemented in scenario A2.

As a consequence, the multiplication factor is unlikely to be affected under scenario A1, and the same probability distribution was used as for scenario A0. In the case of scenario A2, only the value for the upper 99% probability is likely to be affected under scenario A2, so that a revised probability distribution integrating this minor change was used by the Panel (see Appendix E).

The detailed quantitative uncertainty analysis of the impact of FDp on wine and table grapes production under scenarios A1 and A2 is provided in Appendix D and the justifications for the values used in Appendix E.

3.4.2.2. Conclusion on the assessment of the impact of FDp on wine and table grapes production under alternative scenarios

Scenario A1: The generalisation of compulsory hot water treatment for nurseries located in infested NUTS areas has the potential to significantly reduce the probability of FDp infection in traded grapevine plants for planting, one of the mechanisms identified for the spread of FDp. This would contribute to limit the number of new outbreaks. In addition, this measure is evaluated by the Panel as having a high feasibility because its implementation is relatively straightforward and does not meet important technical hurdles (Table 1 and see Appendix A).

Scenario A2: The more intense eradication and containment measures are expected to limit the epidemic spread of the disease. Both increased surveillance and increased eradication efforts, in particular by targeting abandoned vineyards and the wild grapevine populations are seen as contributing to the overall effectiveness of this scenario (Table 1 and see Appendix A). On the other hand, overall feasibility is seen as somewhat more limited than for the RRO involved in scenario A1.

Under both scenarios A1 and A2, FDp impact is predicted to be reduced as compared to scenario A0. Under scenario A1, median impact is predicted at close to 5,000 tonnes, roughly half of the median impact estimated under scenario A0. The 50% uncertainty interval spans from a few hundred tonnes to close to 30,000 tonnes. Under scenario A2, the median impact is predicted at close to 2,500 tonnes, corresponding to more than a threefold reduction over the impact predicted under scenario A0. The 50% uncertainty interval goes from about a hundred tonnes to 15.000 tonnes. In these two scenarios, the 50% uncertainty interval, which spans roughly two order of magnitude reflects the scale of the uncertainties associated with the estimation of FDp impact.

3.4.2.3. Sources of uncertainty affecting the assessment of the impact of FDp on wine and table grapes production under alternative scenarios

In the present assessment of the impact of FDp under alternative scenarios, some parameters are identical to those used for the assessment under scenario A0. This concerns the average area under grapevine production and average grape yield in infested NUTS 2 regions. In addition, the multiplication factor providing an estimation of the loss of production is only affected in a very minor fashion in scenario A2 and is unchanged in A1. The uncertainties affecting these parameters have been described in detailed in Section 3.4.1.3 and will not be further presented here.

The parameter that is affected by the scenarios is the abundance of FDp, expressed as the average percentage of infected grapevines in infested NUTS 2 regions. As detailed for scenario A0, this is the parameter that affects the most the overall uncertainty on FDp impact and the estimation of this parameter faces many challenges. In addition, the scenarios contain the implementation of multiple RROs and both their effectiveness and the thoroughness with which they would be implemented by the individual member states carry significant uncertainty, which is in turn compounded with the intrinsic difficulty to evaluate the pest abundance parameter. As a consequence, the median predictions and uncertainty intervals should be taken with caution. However, even with these limitations, the Panel sees as highly probable that the implementation of the added or reinforced RROs in scenarios A1 and A2 would significantly reduce the impact of FDp as compared to scenario A0.

3.4.3. Assessment of impact on wine and table grapes quality

Although it is only reported in a limited fashion, FDp infection may sometimes have an impact on grapes or wine quality. In some cases, grapes produced by infected plants may show delayed or uneven ripening, and may see their concentration in sugar or in other compounds affected, resulting ultimately in lower quality. For example, FDp infection has been suggested to negatively impact the quality of wines produced from grapes harvested on infected Merlot plants. The Panel considered these reductions in crop quality as a minor impact as compared to the direct quantitative impact on production and therefore selected not to analyse the impact on crop quality in detail.

3.4.4. Assessment of impact on grapevine nurseries production

Given its current regulatory status, FDp has the potential to have significant impact on grapevine nurseries activities and production. On the one hand, detection of FDp infection in a nursery will result in the loss of the Plant Passport for the complete production lot and will also require increased eradication and containment measures. On the other hand, in affected production areas, nurseries are required to implement significant FDp surveillance and *S. titanus* vector control efforts that may negatively impact their competitiveness. However, specific data on the number of nurseries and of grapevine plants for planting having lost their Plant Passports in recent years as a consequence of FDp infection was generally not available to the Panel. Therefore, due to the lack of data and detailed information on this aspect, the Panel is not in a position to precisely evaluate the impact of FDp on grapevine nurseries production. Anecdotal information obtained from experts indicates, however, that loss of nursery production lots through FDp infection has occurred in some MSs but apparently only on a limited scale.

Overall, the Panel concludes that although it is significant in terms of the necessity to implement additional control measures to protect nurseries in affected areas, the impact on nurseries production is likely to be limited within the PRA time scale but cannot be adequately quantified at this stage. For the same reasons, evaluation of this impact under scenarios A1 and A2 cannot be precisely quantified.

3.4.5. Assessment of impact on the environment

FDp is a phytoplasma with a narrow host range. Besides grapevine (and wild *Vitis* spp.) it may naturally infect a few other hosts, such as *C. vitalba* (Filippin et al., 2009) and *Alnus* spp. (Malembic et al., 2007). However, it is not known to cause any significant damage in these alternative hosts, which it largely infects symptomlessly. As a consequence the Panel considered that FDp impact on changes in ecosystem services provision levels, if any, would be extremely limited and therefore decided not to assess it in detail.

For the same reasons (limited host range, asymptomatic infection in non-grapevine hosts, etc.), the Panel estimated that FDp is unlikely to cause significant changes in biodiversity and therefore decided not to analyse this potential impact on the environment in detail.

It should be noted, however, that some control strategies may involve the removal of wild *Vitis* spp. reservoirs, resulting in losses in the biodiversity of the relatively rare ancestral undomesticated *Vitis sylvestris* populations. In addition, other control strategies call for the use of insecticides in order to control *S. titanus* vector populations, with potential detrimental impact on non-target insect populations.

Overall, the Panel concludes that the impact of FDp on the environment, if any, is expected to be extremely limited in nature and extent.

3.4.6. Conclusions on impact

Although the analysis of FDp impact on grapevine production should be seen as carrying very significant uncertainty, the Panel reached the following conclusions:

- Under scenario A0, impact of FDp represents only a very small fraction of the EU table grapes or wine production (in the order of 0.5–1%), a situation which reflects the effectiveness of the currently deployed RROs at limiting impact and not the severity and epidemic nature of FDp, which has the potential to inflict major losses if left uncontrolled.
- Under both scenarios A1 and A2, involving the reinforcement of control measures, FDp impact on wine and table grapes production is predicted to be reduced by approximately one-third (A1) and by two-thirds (A2) as compared to scenario A0. The uncertainties associated with these evaluations are, however, large, as indicated by 50% uncertainty intervals spanning roughly two orders of magnitude.
- Concerning scenario A1, the generalisation of compulsory HWT to not only concern HWT of planting material entering protected zones, but also include any planting material leaving nurseries located in infested NUTS areas has the potential to significantly reduce the probability of FDp infection in traded grapevine plants for planting, and thus the initiation of new outbreaks. In addition, this measure is evaluated by the Panel as having a high feasibility because its implementation is relatively straightforward and does not meet important technical hurdles.
- Concerning scenario A2, the more intense eradication and containment measures are expected to limit the local epidemic development of the disease. Both increased eradication and containment measures, in particular by targeting abandoned vineyards and wild grapevine populations are seen as contributing to the overall effectiveness of this scenario but the reinforced RROs involved will be more difficult to implement than the one included in scenario A1.
- Impact of FDp on the production of nurseries is expected since FDp infestation results in the loss of Plant Passport and in the destruction of all involved production lots. However, in the absence of any precise data, the Panel could not conduct an uncertainty assessment of this specific impact.
- Impact on grape products quality may in some cases be expected but is difficult to document and even more to quantify. Impact of FDp on environment, if any, is expected to be extremely limited.

4. Conclusions

Following a request from the European Commission, the PLH Panel performed an analysis of the risk to plant health posed by the FDp in the EU territory, with the evaluation of RROs. The temporal scale of this assessment is a 10-year time horizon and three scenarios are analysed, one corresponding to the current situation, with all current official control measures in place (scenario A0) and two alternative scenarios, with either a reinforcement of the hot water treatment control measure to improve the phytosanitary status of grapevine propagation material (scenario A1) or a reinforcement of eradication and containment measures (scenario A2).

Concerning entry, the Panel did not analyse it in detail because, with the exception of Serbia and Switzerland, the disease does not exist outside of the EU and is, on the other hand, already established in eight of the main grape-growing EU countries (Austria, Croatia, France, Hungary, Italy, Portugal, Slovenia and Spain).

Concerning establishment, the Panel determined that both FDp and the *S. titanus* vector responsible for epidemic development in grapevine have already established over a large part of the EU territory, but are still spreading and have the potential to establish in at least a large fraction of the EU territory that is currently still unaffected. The Panel also reached the following additional conclusions:

- FDp establishment does not appear to be severely constrained by ecoclimatic conditions and it is likely that the phytoplasma could successfully colonise grapevine wherever this crop is able to develop.

- FDp ability to spread within vineyards, causing an epidemic disease, is limited under most circumstances by the availability of *S. titanus* vectors, which is subject to some ecoclimatic constraints.
- The CLIMEX analysis performed by the Panel strongly suggests that *S. titanus* is likely to be able to establish over most of the EU territory and, in particular, in all northern and central European grapevine-growing areas. Uncertainties exist for the southernmost grapevine-growing areas, in which hot and dry conditions are likely to limit establishment in at least some areas.

Concerning **spread**, the Panel reached the following conclusions:

- With the current measures in place (**Scenario A0**), spread of FDp is likely to continue during the forthcoming period with a progression of between a few and ca 20 newly infested NUTS 2 regions predicted for the 50% uncertainty interval. This analysis clearly illustrates the limitations of the currently deployed control measures, which have not allowed to halt so far the progression of FDp in the EU territory (Appendix A).
- Spread of FDp is expected to be roughly similar between the two strengthened control scenarios (scenarios A1 and A2). The Panel confidently estimates that spread will be more restricted under these scenarios than under the current measures (scenario A0), with a 50% uncertainty interval of between stabilisation in the number of affected NUTS 2 regions and 10–15 newly infested regions. This corresponds roughly to a halving of the spread predicted under scenario A0.
- Overall, a stabilisation or a reduction in the number of infested NUTS 2 regions is only envisioned under the A1 and A2 scenarios of reinforced control measures and then only with a relatively low probability. A combination of the reinforced control measures implemented in scenarios A1 and A2 is expected to have an even higher effectiveness to further limit the spread of FDp.

Concerning **impact**, the Panel reached the following conclusions:

- Under scenario A0, impact of FDp represents only a very small fraction of the EU table grapes or wine production (in the order of 0.5–1%), a situation which reflects the effectiveness of the currently deployed RROs at limiting impact and not the severity and epidemic nature of FDp, which has the potential to inflict major losses if left uncontrolled.
- Under both scenarios A1 and A2, involving the reinforcement of control measures, FDp impact on wine and table grapes production is predicted to be reduced by approximately one-third (A1) and by two-thirds (A2) as compared to scenario A0. The uncertainties associated with these evaluations are, however, large, as indicated by 50% uncertainty intervals spanning roughly two orders of magnitude.
- Concerning scenario A1, the generalisation of compulsory HWT to not only concern HWT of planting material entering protected zones, but also include any planting material leaving nurseries located in infested NUTS areas has the potential to significantly reduce the probability of FDp infection in traded grapevine plants for planting, and thus the initiation of new outbreaks. In addition, this measure is evaluated by the Panel as having a high feasibility because its implementation is relatively straightforward and does not meet important technical hurdles.
- Concerning scenario A2, the more intense eradication and containment measures are expected to limit the local epidemic development of the disease. Both increased eradication and containment measures, in particular by targeting abandoned vineyards and wild grapevine populations are seen as contributing to the overall effectiveness of this scenario but the reinforced RROs involved will be more difficult to implement than the one included in scenario A1.
- Impact of FDp on the production of nurseries is expected since FDp infestation results in the loss of Plant Passport and in the destruction of all involved production lots. However, in the absence of any precise data, the Panel could not give priority to make an uncertainty assessment of this specific impact.
- Impact on grape products quality may in some cases be expected but is difficult to document and even more to quantify. Impact of FDp on environment, if any, is expected to be extremely limited.

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Abbreviations

CLC	Copernicus Land Monitoring Services
EPPO	European and Mediterranean Plant Protection Organization
FDp	Flavescence dorée phytoplasma
HWT	hot water treatment
ISPM	International Standard for Phytosanitary Measures

JRC	Joint Research Centre
MS	Member State
NPPO	National Plant Protection Organization
PAFF Committee	Standing Committee on Plants, Animals, Food and Feed
PLH	Plant Health
PRA	pest risk assessment
PQR	Plant Quarantine Retrieval
RA	risk assessment
RNQP	Regulated Non-Quarantine Pest
RRO	risk reduction option

Appendix A – Description of the various RROs available for FDp control

Context: the three scenarios considered in this assessment (see Section 1.3)

- **Scenario A0**: Current measures as currently applied by the member states (see Table A.2).
- **Scenario A1**: In addition to the current measures, this scenario aims at improving the control of the sanitary status of grapevine propagation materials by generalising compulsory hot water treatment in all nurseries located in infested areas.
- **Scenario A2**: In addition to the current measures, this scenario integrates a strengthening of the containment and eradication programmes (including the targeting of wild *Vitis* spp. and of grapevines in non-agricultural settings (abandoned vineyards, wild vegetation surrounding the vineyards, gardens, etc.) and an improvement of surveillance.

Overview of the contents of this appendix

- A1. Selection of FDp relevant control measures based on expert judgement.
- A2. Review of FDp relevant control measures.
  - A2.1 Overview of measures as applied by the Member States.
  - A2.2 Description and current application of measures for FDp control.
- A3. Evaluation of limitations and feasibility of current measures (scenario A0).
  - A3.1 Limitations and feasibility of current measures for propagative material.
  - A3.2 Limitations and feasibility of current measures for eradication and containment.
  - A3.3 Rating the feasibility and relative effectiveness of the RROs in the scenarios.
- A4. Evaluation of scenario A1: improvement of phytosanitary status of propagation material.
- A5. Evaluation of scenario A2: improvement of eradication and containment.

A.1. Selection of FDp relevant control measures based on expert judgement

The Panel reviewed the list of potential risk reduction options (Table A.1) and, based on expert judgements, determined those that could be applied to FDp or its vector.

Table A.1: Potential risk reduction options

	Checklist RROs	Relevance for FDp	Comment if the answer is NO
Control measures			–
C1	Chemical treatments on consignments or during processing	N	Not relevant for FDp as there is no effective chemical treatment available for phytoplasma
C2	Chemical treatments on crops including reproductive material	Y	–
C3	Cleaning and disinfection of facilities, tools, machinery and packaging	N	Not regarded as an important control measure as FDp does not propagate through mechanical contact
C4	Controlled atmosphere	N	Not relevant for FDp as there are no evidences of efficacy of controlled atmosphere in sanitising infected plants
C5	Growing plants in isolation	Y	–
C6	Physical treatments on consignments or during processing	N	Not relevant for FDp as there are no evidences of efficacy of physical treatments
C7	Soil treatment	N	FDp is not a soil-borne organism
C8	Timing of planting or harvesting	N	Not relevant control measure for FDp
C9	Waste disposal	N	The discarded plant material is not source of inoculum
C10	Use of resistant and tolerant plant species	Y	–
C11	Quarantine and other restrictions of movement	Y	–

	Checklist RROs	Relevance for FDp	Comment if the answer is NO
C12	Heat and cold treatments	Y	–
C13	Roguing	Y	–
C14	Biological control and behavioural manipulation	N	Not efficient agent or method known so far
C15	(other) Cultural control	N	Not regarded as an important control measure for FDp
C16	Use of non-infested water	N	Water does not transport FDp
C17	Conditions of transport	N	Not relevant for FDp
C17	Pest-free plants for planting	Y	–
Supporting measures			
S1	Certified and approved premises	Y	–
S2	Inspection (visual examination and trapping)	Y	–
S3	Laboratory testing	Y	–
S4	Phytosanitary certificate	Y	–
S5	Delimitation of buffer zones	Y	–
S6	Sampling scheme	Y	–
S7	Certification of plant reproductive material	Y	–
S8	Surveillance	Y	–

A.2. Review of FDp relevant control measures

A.2.1. Overview of measures as applied by member states where presence of FDp has been declared

The answers to a questionnaire sent on October 2015 to the relevant NPPOs are summarised in the table below.

Table A.2: Answers received from relevant member states regarding the RROs implemented

Measures	Member States								
	Austria	Croatia	France	Germany*	Hungary	Italy	Portugal	Slovenia	Spain
Implementation of Buffer Zones		5,000 m	500–2,000 m		3,000 m	–	2,000 m	X	
General surveillance for the FDp disease	X	X	X	X*	X	X	X	X	X
General surveillance for the vector *S. titanus*	X	X	X	?	X	X	X	X	X
Surveillance of the vector supporting decisions on insecticide application and timing									
Hanging yellow sticky traps in the vineyards	X	X	X	No	X	X	X	X	X
Direct counting of nymphs in the leaf canopy	X	No	X	No	X	X	X	X	X
Compulsory insecticide application at least where both vector and FDp are present									
Applied in commercial vineyards and nurseries	X	X	X	No	X	X	X	X	X
Targeting nymphs and adults	X	X	X	No	X	X	X	X	X

Measures	Member States								
	Austria	**Croatia**	**France**	**Germany***	**Hungary**	**Italy**	**Portugal**	**Slovenia**	**Spain**
Variable numbers of treatments, from one to three per year in commercial vineyards (more numerous in nurseries)	X	X	X	No	X	X	X	X	X
Control of the vector in amenity plants (vine arbours and hedges)	X	No		No		X	X	X	
Roguing of symptomatic plants	X	X	X	No	X	X	X	X	X
Roguing of the vineyard when infection rate exceed 20–30% of the plants in a plot	X	X	X	No	X	X	X	X	X
Removal of abandoned plots and wild *Vitis* spp. rootstocks	X	(X)	X	No	X	X		X	?
Regular testing in rootstock nurseries	X	No	?	(X)	No	X	No		X
Hot water treatment of rootstocks, scions or grafted cuttings	X	No	X	No	(X)	X	(X)	(X)	
Hot water treatments inside the buffer zone			X						

(x) In some cases; * one report and successful eradication, DE therefore considered as 'pest free area'; ? Not clearly stated.

A.2.2. Description and current application of measures for FDp control

A.2.2.1. Delimitation of buffer zones

The delimitation of a buffer zone aims to prevent immigration of the vector to the nurseries or vineyards neighbouring outbreak areas. Therefore, the effectiveness of the buffer zone is primarily affected by the dispersal behaviour of the vector (see discussion of vector mobility in the 'Roguing' Section below). In the absence of any natural barrier (wood, hedges, wild *Vitis* spp.), a maximum dispersal radius of 600 m was recorded by Riolo et al. (2014). The crepuscular flight activity of *S. titanus* adults suggests that their dispersal is more likely to be active than passively related to the wind (Lessio and Alma, 2004), although in some cases wind may enhance spread up to several km (Steffek et al., 2007; Chuche and Thiéry, 2014). Large scale passive dissemination is mainly attributed to human activities (Weintraub and Beanland, 2006).

Application by the MSs (Scenario A0)

At present, all the MSs where FDp is present indicated that they implement a buffer zone of 500–2,000 m (or corresponding to the area of the municipality) in outbreak areas to guarantee pest-free places of production for FDp. Within the buffer zone, specific measures are applied according to national and regional decrees including: surveillance, roguing of infected grapevines, abandoned vineyards and wild *Vitis* spp., and insecticide treatments (EFSA questionnaire 2015).

A.2.2.2. Surveillance

Surveillance, the official visual examination or inspection of plants, to determine if the respective pest is present and/or to determine compliance with phytosanitary regulations (ISPM No.5, FAO, 2016a,b) is applied by the Phytosanitary Services of all the MS for FDp.

Application by MSs (Scenario A0)

Surveillance is applied more intensively in buffer zones.

- *Surveillance for FDp-infected grapevines.* For FDp, regular inspection is applied usually in a number of the production vineyards but in all nurseries, aiming primarily to detect infected grapevines before large outbreaks develop. Grapevines exhibiting FDp symptoms are identified and subsequently processed for molecular diagnosis (PCR for FDp). The number of molecular tests depends on local situations. It should be noted that rootstocks do not develop symptoms and therefore, when infected, are very difficult to identify visually, as only molecular detection can reveal the presence of FDp.
- *Surveillance for the S. titanus presence.* In nurseries, the presence of *S. titanus* is always monitored. Surveillance also implies the monitoring of insect populations in selected vineyards using yellow sticky traps and direct observation/counting of nymphs in May–June (mostly on June) in the leaf canopy to support decisions regarding the number (ranging from 1 to 4) and the timing of insecticide applications. The intensity of the inspections depends on the country and area under surveillance.
- *Surveillance for the hosts' presence outside vineyards.* Surveillance also aims at locating abandoned vineyards and wild *Vitis* spp. plants. Other host plants (*Alnus, Clematis* and *Ailanthus*) of some FDp strains are not included in the surveillances as there is not enough scientific data to support their role as disease reservoirs (see the Section on roguing, below).

A.2.2.3. Roguing

Infected plants represent sources of inoculum, therefore their removal (*roguing*) is a major component of disease control strategies. In the case of perennial hosts, their replacement with healthy ones also decrease yield losses (Sisterson and Stenger, 2013).

Roguing of infected grapevines. For FDp, the replacement of symptomatic/infected grapevines within productive vineyards or a complete removal of abandoned vineyards eliminates disease sources of infected *S. titanus,* and thus the risk of FDp local spread. As the density of *S. titanus* greatly affects disease spread (Bressan et al., 2006), roguing is always combined with insecticide treatments (Chuche and Thiéry, 2014).

Roguing of hosts outside vineyards. The surrounding environment significantly affects FDp spread in the vineyards due to the movement of infested vectors. High vector populations develop on wild *Vitis* spp. and migrates to the neighbouring grapevines (Forte et al., 2009; Pavan et al., 2012a). Therefore, the roguing of wild *Vitis* spp. is also required in order to prevent re-immigration of infectious vector population to neighbouring vineyards.

S. titanus is a grapevine specialist and, in Europe, lives on cultivated grapevines and wild American *Vitis* sp. (wild grapevine, henceforth WGV, mainly from overgrown rootstocks), with a preference for WGV over *V. vinifera* (Lessio et al., 2007). On the other hand, wild American and European *Vitis* spp., such as *V. riparia, V. labrusca, V. longii, V. simpsonii, V. doaniana, V. champinii, V. armurensis, V. rubra, V. rupestris, V. pentagona, V. sylvestris*, are susceptible to FDp (Moutous, 1977; Eveillard et al., 2012). They remain symptomless upon infection (Caudwell et al., 1994), and may increase up to 6 m above the ground level, sometimes offering a very dense and shaded habitat that is very attractive for *S. titanus* (Cravedi et al., 1993). Abandoned vineyards or hedgerows and groves colonised by WGV are considered potentials sources of infested *S. titanus*, which can then recolonise the cultivated vineyards (Pavan et al., 2012a; Lessio et al., 2014) especially late in the season.

A border effect, e.g. decreasing gradient of disease incidence and of *S. titanus* adult captures from vineyards borders towards the centre (Pavan et al., 2012a; Lessio et al., 2014), supports the role of infested WGV at the edges of woodlands bordering vineyards and of abandoned vineyards neighbouring cultivated ones as external sources of FD-infested *S. titanus* adults. Exploiting the role of WGV as FDp and vector sources, Lessio et al. (2014) using a mark-capture technique showed that introduction to the cultivated grapes from the wild decreases with the distance. Up to 80% of the *S. titanus* adults covered short distances of up to 30 m, while a long-distance spread of up to 200 m was also recorded. Avoidance of new plantations in the close proximity of WGV may thus be advised (Lessio et al., 2014). A distance of at least 40 m between uncultivated grapevines and cultivated vineyards, or using the less susceptible grape varieties near woodland vegetation has been suggested (Pavan et al., 2012a).

Although hedgerows or groves represent potential sources of FDp and its vector, the use of insecticides is not permitted as they represent natural areas. Complete removal in the near vicinity of vineyards is advisable, but difficult to achieve. It has to be noted that removing this wild vegetation that also harbours beneficial organisms (natural enemies, pollinators) (Pavan et al., 2012a), may impact biodiversity. As WGV are generally excluded from insecticide treatments, the movement of *S. titanus* to treated vineyards may also indirectly result in a lower recorded effectiveness of the insecticides applied in these vineyards.

In Italy, growers are advised to mechanically destroy the creeper wild vegetation within at least 10 m surrounding the vineyard (Bosco and Mori, 2013). However, roguing should be done at times when *S. titanus* adults are absent in order to prevent increased movement to the neighbouring cultivated grapevines (Lessio et al., 2014).

Application by the MSs (Scenario A0)

Roguing of infected grapevines. At present, FDp is a quarantine pathogen, and therefore removal of diseased grapevines is implemented by all the MSs (**A0 scenario**). It is performed mechanically by the growers and officially inspected by the national phytosanitary services. Any FDp-infected grapevine is removed from the vineyards and the nurseries. In vineyards where infection rate exceeds 20–30% of the grapevines, the whole vineyard is removed. The suggested procedure includes elimination of the above-ground part of the infected grapevine immediately after its identification and complete uprooting before April in the year following detection.

Roguing of hosts outside vineyards. Under the current situation (**A0 scenario**), removal of abandoned vineyards is also mandatory in all viticultural areas while, in some MSs, roguing of wild *Vitis* spp. is also included in the applied measures. The effectiveness of roguing highly depends on the effectiveness of surveillance.

Some uncertainty is linked to the recovery phenomenon, e.g. the remission of disease symptoms, which is suggested to affect both the effectiveness and the feasibility of the replacement of grapevines affected by FDp. Recovery highly depends on the variety (see resistant or tolerant varieties) (Bellomo et al., 2007; Pavan et al., 2012b).

A.2.2.4. Insecticide treatments

Given the bacterial and intracellular nature of FDp, the only known molecules that have possible effects are antibiotics the use of which is prohibited in agriculture. Therefore the only chemicals that can be applied to control FDp are those targeting its vector.

In the absence of control measures, *S. titanus* can reach high population sizes, triggering epidemics of FDp with a 10-fold increase in infected grapevines per year (EPPO/CABI, 1997). Pueyo et al. (2008, in Chuche and Thiéry, 2014) mention that, in the Pyrénées-Orientales (southwestern France), FDp expanded from 60 ha in 1991–20,000 ha in 1993. Applications in vineyards target the vector populations within the vineyard and any re-immigration from surrounding areas (wild *Vitis* spp.).

According to Chuche and Thiéry (2014), several chemical classes are used against *S. titanus* (nymphs and adults): pyrethrins, neonicotinoids, organophosphates, pyrethroids, growth regulators (thiadiazin, buprofezin), as well as various blends (COSVIR XI 2013; E-phy 2013; OFAG 2013 in Chuche and Thiéry (2014). Organic growers have to use pyrethrins, which appear insufficiently effective and persistent (Gusberti et al., 2008; Sivčev et al., 2010 in Chuche and Thiéry, 2014).

Application by MSs (Scenario A0)

Under the present regime (**A0 scenario** evaluated by the panel), insecticide applications against *S. titanus* are compulsory in all the EU MSs where both the vector and FDp are present (EFSA 2014a, EFSA questionnaire 2015, Table A.2) and they are triggered by surveillance (existence of FDp foci, counting of vectors in traps or on the plants). The frequency of vineyard treatments varies between countries: one to three per year in Italy (Belli et al., 2010 in Chuche and Thiéry, 2014), two in Switzerland (Jermini et al., 2007 in Chuche and Thiéry, 2014), two or three in France (Trespaille-Barrau and Grosman, 2011 in Chuche and Thiéry, 2014). In nurseries, the number of treatments can be higher, on a calendar basis (Chuche and Thiéry, 2014; EFSA questionnaire 2015, Table A.2).

The effectiveness of insecticide applications strongly depends upon the prevention of any re-colonisation from the wild compartment (see roguing of all wild host plants in the natural environment in A2 scenario).

A.2.2.5. Growing plants in isolation

This measure is applied only for the production of propagation material in nurseries located in pest and pathogen-free areas or at a minimal distance from infested areas (*isolation*). However, it is difficult to guarantee and maintain pest freedom of production sites. In the current situation, the production in greenhouses/screen houses is sometimes used for the rooting last growing stage after grafting while the grafting material is usually coming from the field.

In an area where the vector and the pathogen are present, the whole cycle of production of propagation material in greenhouses or screen house can fully protect the material against the vector and the disease. Important parameters affecting the effectiveness of the measure are the source of the propagation material *(scions and rootstock; for specific terms of propagation material see EFSA opinion on Dactulospaira,* (EFSA PLH Panel, 2014b)*)* and the duration of the production process that is under exclusion conditions.

Application by the MSs (Scenario A0)

There is variation in how the measure is applied in different countries. In the current situation, the production in greenhouses is sometimes used for the last growing stage after grafting while the grafting material is usually coming from the field.

A.2.2.6. Hot water treatments (HWT)

The phytosanitary standard detailing the 'long-duration HWT' conditions of 50°C for 45 min against FDp is provided by EPPO (2012). This thermotherapy is applied to dormant wood of both scions and rootstocks separately or unrooted grafted vines of *V. vinifera* for planting.

Hot water treatment (HWT) of the dormant canes is highly effective (100%) in eliminating FDp (Caudwell et al., 1997; Bianco et al., 2000; Mannini and Marzachì, 2007). HWT may additionally eliminate *S. titanus* eggs in on 1-year-old grapevine propagation material and significantly reduce their number in older cuttings (Linder et al., 2010). *S. titanus* is a univoltine species that overwinters as egg in the bark of 2-year-old (or older) wood (Vidano, 1964; Bagnoli and Gargani, 2011). Therefore, HWT may improve also the sanitary status of the cuttings concerning the presence of *S. titanus*. Trade of infected/infested propagation planting material play a major role in long-distance spread of the FDp and its vector (Weintraub and Beanland, 2006). The original introduction of *S. titanus* in Europe is thought to have accidentally occurred via imported grapevine canes carrying eggs (Bertin et al., 2007).

Legislation

In the Council Directive 2000/29/EC,[4] Annex IVB (32), hot water treatment is (only) an optional requirement for the elimination of the FDp (referred as 'Grapevine Flavescence dorée MLO') from *Vitis* planting material destined for the Protected Zones (PZs) of the Czech Republic, France (Alsace, Champagne-Ardenne, Picardie (département de l'Aisne), Ile de France (communes de Citry, Nanteuil-sur-Marne et Saâcy-sur-Marne) and Lorraine) and Italy (Apulia, Basilicata and Sardinia). According to these requirements in 2000/29/EC, when no symptoms of FDp have been observed on the mother-stock plants since the beginning of the last two complete cycles of vegetation, nurseries that are situated in areas where FDp is present and where FDp symptoms are present in the nursery can only trade plants for planting to PZs if the plant material is hot water treated.

<u>According to the Council Directive 2000/29/EC, the requirements for protected zones (PZ) are:</u>

(a) the plants originate and have been grown in a place of production in a country where Grapevine Flavescence dorée MLO is not known to occur; or
(b) the plants originate and have been grown in a place of production in an area free from Grapevine Flavescence dorée MLO established by the National Plant Protection Organisation in accordance with the relevant international standards; or
(c) the plants originate and have been grown in either the Czech Republic, France (Alsace, Champagne-Ardenne, Picardie (département de l'Aisne), Ile de France (communes de Citry, Nanteuil-sur-Marne et Saâcy-sur-Marne) and Lorraine) or Italy (Apulia, Basilicata and Sardinia); or

[4] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Official Journal of the European Communities L 169/1, consolidated version of 30.6.2014, p. 1–181.

(cc) the plants originate and have been grown in Switzerland (except the Canton of Ticino and the Misox Valley); or

(d) the plants originate and have been grown in a place of production where:

(aa) no symptoms of Grapevine Flavescence dorée MLO have been observed on the mother-stock plants since the beginning of the last two complete cycles of vegetation; and

(bb) either

(i) no symptoms of Grapevine Flavescence dorée MLO have been found on the plants in the place of production; or

(ii) the plants have undergone hot water treatment of at least 50°C for 45 min in order to eliminate the presence of Grapevine Flavescence dorée MLO.

Beside the EU Directive 2000/29/EC, HWT is recognised as a phytosanitary treatment in EPPO Standard PM 4/8, as well as by other organisations (Frison and Ikin, 1991; ICA-37, 2007). Outside the EU, similar HWTs are in use, e.g. in Australia, where a HWT of 50°C for 30 min is mandatory for imported dormant grapevine cuttings, against both FDp and Pierce's disease (DAFF, 2013).

Application by the MSs (Scenario A0)

In the current regime, HWT is only applied as an optional measure for plant propagation material entering the protected zones as specified by 2000/29/EC. Additionally, two MSs (EFSA questionnaire, Table A.2) indicate that HWT is obligatory for nurseries situated in an outbreak area within a buffer zone, irrespective of the destination of the plant material (PZ or not), or of the presence of FDp symptoms in the nursery. Some MSs prescribe compulsory HWT of all basic propagation material, or of the material deposited in germplasm repositories.

A.2.2.7. Certification

The risk assessment area has a compulsory certification scheme for the vegetative propagated grapevine material marketed within the EU, described by Council Directive 68/193/EEC.

This Directive specifies phytosanitary requirements in general terms, i.e. 'Harmful organisms which reduce the usefulness of the propagation material shall be at the lowest possible level' either in the production crop (Annex I.4), or in the propagation material itself (Annex II.1.4.). Annex I.5 explicitly mentions for growing crops of propagating material only the following viruses: GFLV, ArMV, GLRaV-1, GLRaV-3 and GFkV (the last one for rootstocks only). Nevertheless, 2000/29/EC requirements set up in Annex IVAII point 17 regarding FDp shall be satisfied by plants for planting of *Vitis* produced in EU under the certification scheme.

EPPO (2008) published a certification scheme including tests for FDp in the minimum sanitary requirements for the production of pathogen-tested material of grapevine varieties and rootstocks.

Application by the MSs (Scenario A0)

Certification of grapevine propagation material for FDp is currently not applied in the EU because the pest is not included in the list of organisms covered by Council Directive 68/193/EEC. However, phytosanitary requirements related to FDp established in point 17 of Annex IVAII of the Council Directive 2000/29/EC shall be satisfied by certified plants.

A.2.2.8. Resistant and tolerant or less susceptible species and varieties

Grapevine exhibits a high intraspecific (*V. vinifera* cultivars) and interspecific (*Vitis* spp. other than *V. vinifera*, hybrids and rootstocks) variability in its susceptibility to FDp. Although all *V. vinifera* varieties are susceptible, they differ in the expression and intensity of symptoms, while some rootstocks bred from American *Vitis* species may remain symptomless (Schvester et al., 1967; Caudwell et al., 1994; Eveillard et al., 2012). Eveillard et al. (2012) showed that some rootstocks (e.g. Kober 5BB) may show either a low FDp multiplication, or cannot be infected with FDp (e.g. the *Muscadinia rotundifolia*-derived intergenic hybrid Nemadex Alain Bouquet), therefore representing potential sources of resistance. The low *S. titanus* survival rate recorded on *M. rotundifolia*-derived intergenic hybrids may represent a source for vector resistance (Eveillard et al., 2012).

The susceptibility of the grapevine varieties primarily affects severity of the symptoms. When infected, the most susceptible varieties may exhibit an irregular sprouting, early in the spring (Morone et al., 2001; Roggia et al., 2014). For most varieties, the main symptoms develop later in the season, in all or in selected branches, including downward curling and discoloration (reddening or yellowing on red or white cultivars, respectively) of the leaves, death of inflorescences and berries, stunting, and lack of lignification of new shoots (Caudwell, 1964, 1990). Eventually, decline results in the death of the affected grapevines (Morone et al., 2007). In some varieties, following the first year of symptom expression, a spontaneous and cultivar-dependent remission of symptoms, known as 'recovery', is observed (Caudwell, 1961; Belli et al., 1978). Recovered plants usually do not contain detectable FDp, but they may continue to be less productive (Morone et al., 2007). In the recovered plants, biochemical changes such as accumulation of hydrogen peroxide (H_2O_2) occur in the phloem (Musetti et al., 2007; Gambino et al., 2013; Margaria et al., 2013).

The susceptibility of several genotypes was measured based on symptoms recording, the percentage of infected plants and the FDp titre as measured by quantitative real-time polymerase chain reaction (PCR) (Eveillard et al., 2012; Jarausch et al., 2013). This susceptibility affects the observed disease incidence in the field (e.g. Kuzmanović et al., 2008; Boudon Padieu, 1996). It also affects acquisition and further spread of the disease by *S. titanus* by influencing the FDp titre in infected grapevines (Galetto et al., 2014). Bressan et al. (2005) showed that the highly FDp-susceptible Pinot blanc variety was a better source for FDp acquisition by *S. titanus* than the tolerant Merlot variety.

Application by the MSs (Scenario A0)

In many areas, grapevine is cultivated for the production of local wines; varieties are adapted to specific ecoclimatic conditions and determine the quality of wine, therefore changing varieties is not widely applicable.

A.3. Evaluation of limitations and feasibility of current measures (scenario A0)

A.3.1. Limitations and feasibility of the current measures in nurseries

Although the feasibility of the compulsory **EU certification scheme** is high, it has low effectiveness because FDp is not explicitly listed, while certified planting material can be produced in areas where the disease is present.

The main limitation of **surveillance** for the detection of all infected plants in nurseries is the absence of symptoms on infected rootstocks, affecting both feasibility and effectiveness (both rated as medium).

The feasibility of **roguing** in the nurseries is high because of the reduced size of the plants and the lots. Once identified, infected grapevines are very effectively removed from the nurseries (the whole lot is immediately removed or hot water treated).

The number and the timing of **insecticide treatments** in nurseries meet no limitations therefore their feasibility and effectiveness are high and cannot be further improved.

The most important limitation of **hot water treatment** (HWT) is that it is not obligatory for all grapevine propagation material but only for plant material destined for protected zones. However, some MSs already require hot water treatment for nurseries located in the buffer zones. A minor limitation is the timing of the hot water treatment. In general, HWT is applied to scions and rootstocks before grafting. After grafting the propagation material remains for one growing season in the nursery. During this period, the possibility of infection cannot be excluded, as protected cultivation (screen house) is not applied for grapevine propagation material. HWT can also be applied to grafted cuttings just before they are traded. This latter option provides the highest possible safeguard. However, some negative effect on the viability of the propagating material is observed (Burr et al., 1996; Waite et al., 2013). Tolerance of propagation material to HWT could be possibly affected by the grapevine variety or the growth conditions of the cuttings (Tassart-Subirats et al., 2003; Waite and Morton, 2007). However, EPPO (2012) attributed the observed negative effect of HWT on the vitality of propagation material largely to inappropriate material, or to the non-respect of the pre-, post- and treatment conditions. The feasibility of HWT is high due to the availability of properly designed equipment and standardised procedures for its general application (ICA-37, 2007; Waite and Morton, 2007; USDA, 2016).

A.3.2. Limitations and feasibility of the current measures in buffer zones

Delimitation of buffer zones. Given the dispersal capacity of *S. titanus*, the implementation of a 500–2,000 m buffer zone is adequate to prevent re-immigration to neighbouring nurseries and vineyards, assuming that appropriate control measures are taken in the buffer zone. As this administrative procedure is already applied for several plant pathogens including FDp, its feasibility is high.

For surveillance in vineyards, a major constraint is the fact that not all vineyards and plants are inspected. If surveillance does not cover at least 25% of the vineyards every year, it has poor chances to detect early outbreaks and therefore to prevent the development of large outbreaks. On the other hand, symptoms are sometimes difficult to be identified by non-skilled inspectors (especially on varieties that show mild symptoms) as they vary according to the grapevine variety. Additionally, a high local incidence of Bois Noir has a masking effect on early FDp outbreak. Finally, latently infected plants escape visual inspection therefore the identification and roguing, decreasing the effectiveness of the measure. The feasibility of surveillance is high when properly scheduled at the optimal period for symptom expression.

Surveillance in the natural environment, aimed at detecting all wild *Vitis* spp., is very challenging due to the size of the buffer zone and the heterogeneity of the environment, even when limiting the search to the surroundings of vineyards. These factors negatively affect both effectiveness and feasibility of the measure.

Due to late symptom appearance, **roguing of infected individual grapevines or complete vineyards** effectively takes place at the end of the vegetation cycle. Also, incomplete grapevine roguing may result in the regrowth of symptomless infected rootstocks. The long administrative procedures for **removing abandoned vineyards** may cause a delay in the elimination of uncontrolled inoculum sources. The **removal of wild *Vitis* spp**. often meets with major obstacles due to their difficult access (e.g. escarpments, along rivers) and their high density. In addition, regrowth is common and removal has to be repeated. Wild *Vitis* spp. can be mulched and, when they regrow, sprayed with herbicides, however, such applications outside cultivated areas raise major environmental concerns. As accessibility is the major factor affecting feasibility of roguing, it is rated as high for vineyards, medium for abandoned vineyards, affected the necessary by administrative procedures, and low for the wild *Vitis* spp.

Several **insecticides** are registered for use and routinely applied in the vineyards (high feasibility). However, they cannot be applied all over the season in the productive vineyards. Depending on the chemical used, applications stop well before harvest to avoid pesticide residues in the grapes. Therefore, vineyards are unprotected to late infections by incoming vectors from the wild vegetation. The activity and/or persistence of insecticides registered and used for organic vineyards is limited, therefore their effectiveness is lower. The possibility that *S. titanus* adults may transmit FDp with short feedings sequences, before acquiring the lethal dose of insecticides, may also decrease the effectiveness of applied insecticides.

A.3.3. Rating the feasibility and relative effectiveness of the RROs in the scenarios

In Table A.3, on the next page, an overview is given of the feasibility and the relative effectiveness of the single RROs in the scenarios. For each scenario, an expert judgement was made of the control effect of the RRO and in particular if there were limiting factors constraining the optimal control effect of the RRO. The effectiveness was rated as ‘high’ if there was no or very few limiting factors on the control effectiveness of the RRO. If there were significant limiting factors acting on the effectiveness of the RRO, these were rated between low and medium. Thus, RRO’s with a low rating are not fully effective in controlling FDp and the vector and are candidates for improvement. The same rating is applied to the feasibility of the RROs taking into account the limitations described in the table and in Sections 3.1 and 3.2.

A.4. Proposed strengthened measures for propagative material (scenario A1)

The single measure separating scenario A1 from scenario A0 is the compulsory application of HWT for all grapevine propagation material originated from NUTS 2 regions where FDp is present and irrespectively of its destination. Due to the theoretical 100% effectiveness of HWT, the Panel does not consider any increase in surveillance intensity and laboratory testing (nurseries are surveyed every year).

If HWT is applied according to the accepted protocol (50°C for 45 min), it fully eliminates FDp in the treated plant material (Caudwell et al., 1997; Mannini and Marzachì, 2007). While the systematic adoption of HWT is proposed, timing of application can be pre- or post-grafting. When applied after grafting, the highest safeguard is achieved but some negative effects on the vigour of the propagated material can be observed in the production vineyards. When applied before grafting, cuttings are kept in nursery for 1 year after HWT and protected by repeated insecticide applications against vector. This measure will control the long-distance spread of the disease and reduce its impact.

Table A.3: List of RROs and their individual contribution limiting the overall effectiveness (without separating the effectiveness on spread and impact) of the various scenarios (A0, A1 and A2)

RRO	Description of limitation	Contribution of individual measures limiting the overall effectiveness of the scenarios		
		A0 (current measures)	**A1 (improved propagation material)**	**A2 (strengthened eradication/ containment)**
Delimitation of buffer zones	Current situation appropriate	Low	Low	Low
Surveillance of vineyard	Percentage vineyards inspected	High	High	Low
Surveillance of neighbouring environment	Detection abandoned vineyards, wild *Vitis* spp. vegetation	High	High	Medium
Roguing of individually infected grapevines or vineyards	Incomplete or delayed roguing	Low	Low	Low
Roguing of abandoned vineyards	Delay in roguing (administrative process)	Medium	Medium	Low
Roguing of wild *Vitis* spp.	Feasibility/regrowth	High	High	Medium
Insecticide treatment in vineyard	Availability of a.i.*, number of applications	Medium*/ high	Medium*/high	Medium*/high
Surveillance in nursery	Detectability non-symptomatic rootstock; intensity	Medium	Medium	Medium
Insecticide treatment in nursery	Calendar treatments	Low	Low	Low
Roguing in nursery	None	Low	Low	Low
Hot water treatment	Limited implementation	High	Low	High
Certification of propagation material	FDp is not included in the EU certification scheme	High	High	High

*: Limited availability of active ingredients for organic viticulture.

The application of HWT to all propagation material produced in FDp infested regions, instead of that destined to PZ, will increase the effectiveness from low to high.

A.5. Proposed strengthened measures for eradication and containment (scenario A2)

The measures strengthened in scenario A2 in comparison to scenario A0 are:

- surveillance in vineyards;
- surveillance in neighbouring environment;
- roguing of individually infected grapevines or vineyards;
- roguing of abandoned vineyards;
- roguing of wild *Vitis* spp.

The intensity of the **surveillance in vineyards** can be increased in order to prevent the development of large outbreaks. A minimal surveillance should be kept in all NUTS 2 regions free of *S. titanus.* Based on the fast rate of the increase of the disease (10-fold increase in the absence of any control measures; EPPO/CABI 1997), a minimum of 3 years is necessary for the development of large outbreaks (more than 20% of the vineyard). Therefore, in NUTS 2 regions where the vector is present, the Panel proposes that one-third of vineyards should be surveyed on a yearly basis (so all vineyards will be surveyed every 3 years), in addition to the already surveyed buffer zones. As a result the suggested intensity of surveillance will substantially improve the effectiveness of surveillance and roguing.

Administrative processes in place for **abandoned vineyards** should be simplified to achieve a faster removal of these inoculation sources and this will increase the effectiveness of the measure.

Improvement of the removal of inoculation sources in the natural environment of the buffer zones could include: **increased surveillance** and mapping of major spots of the gone **wild *Vitis*** spp. vegetation, **effective removal** of gone wild *Vitis* spp. in the surrounding of the vineyards and, as a preventive measure, before establishing new plantations. This measure is currently poorly applied and its increased implementation will result in a higher effectiveness.

Altogether the proposed measures allow the early identification of new foci, improving eradication effectiveness and decreasing local spread.

Appendix B – Proportion of the spread associated with propagative material vs. infective insects based on historical evidence

Table B.1: Proportion of the spread associated with propagative material vs infective insects based on historical evidence (NUTS 2 units) (from expert elicitation)

NUTS 2 areas	Propagative material	Local spread by vector	Emergence from wild reservoir	Justifications
Midi-Pyrénées/FR 62			X	Emergence from *Alnus glutinosa*
Aquitaine/FR 61		X		Came from Gers, 10 km away
Corse/FR 83	X			Geographical barrier, initial outbreak around Bastia Harbour
Lombardia/ITC4	X			The first identification of FDp in Italy, no other area infested since then in IT
Languedoc Roussillon/ FR 81		X		The location of the outbreak, Castelnaudary, makes probable a passive movement of vectors by the tramontane wind from the initial outbreak area
Veneto/ITD3	X			First finding in eastern Italy. New varieties introduced from France (e.g. chardonnay)
Emilia-Romagna/ITD5		X		FDp was first identified in the Piacenza province, neighbouring the infested area of Oltrepò Pavese (Lombardia Region)
Friuli-Venezia Giulia/ ITD4		X		This region has been colonised few years after Veneto, so it could have been infested from Veneto, but no information are available on the origin of infected plants
Piemonte/ITC1			X	Neighbouring area in Lombardia, but no true continuity. A different genotype (FD-C) compared to the one in Lombardia was responsible for the initial outbreak (infection from the wild compartment cannot be excluded). When the phytoplasma was identified many plots were already infested, and this hampered the eventual identification of infected propagation material
Centre-Val de Loire/FR 24	X			Original case nearby Chinon was in a young planting. No FDp outbreaks in surrounding regions
Poitou-Charentes/ FR 53		X		Certainly spread from neighbouring Aquitaine. Old vineyards
Catalunya/ES51[(a)]		X		Local spread from French border enhanced by dominant wind 'Tramontane' coming from France
Liguria/ITC3		X		–
Rhône-Alpes/FR 71	X			First cases in nurseries in Beaujolais far away from any Flavescence dorée outbreak
Provence-Alpes-Côte d'Azur		X		Initial case located close to an outbreak in the Rhones-Alpes neighbouring region (Drôme department)
Toscana/ITE1		X		FDp is present in the area neighbouring eastern Liguria which is infested too
Trentino-Alto Adige/ ITD1+D2		X		Continuity of vineyards with the infested areas of Lombardia and Veneto Regions
Champagne Ardenne[(a)]	X			A single plant was found and an infected rootstock was claimed
Bourgogne/FR 26	X			Cases in 2004–2009 in young plants due to infected-rootstocks
Zahodna Slovenija/SI04		X		–
Norte/PT11	X			No outbreak in Portugal or in bordering region of Spain
Vzhodna Slovenija/SI03		X		–
Steiermark/AT22		X		–

NUTS 2 areas	Propagative material	Local spread by vector	Emergence from wild reservoir	Justifications
Sjeverozapadna Hrvatska		X		–
Marche/ITE3	X			In one of the two epidemics *S. titanus* was not present, therefore infected propagation material thought to have started the small outbreak
Campania/ITF3	X			Geographical isolation (Ischia island) suggests that infected propagation material originated the epidemics, although infected vineyards are of different ages and therefore the presence of FDp has been likely identified some years after the introduction
Nyugat-Dunántúl/HU22		X		–
Dél-Dunántúl/HU23		X		–
Germany RheinHessen Pflaz[(b)]	X			–
Valle d'Aoste		X		Probable local spread from neighbouring Piemonte Region. Continuity of vineyards
Total	**11** (37%)	**17** (57%)	**2** (6%)	

(a): Present status regarding FDp: eradicated.
(b): A nursery found infested, but vector absent from Germany. Present status of FDp: eradicated. This NUTS 2 area was not included in the spread analysis as the vector is absent and no vineyards were infested.

Appendix C – Detailed explanations for the ratings describing the probability distributions of spread of FDp under the different scenarios

C.1. Initial conditions for the spread

Within the framework of this opinion, the initial condition for the 10-year future projection coincides with the situation in the year 2015, the latest year for which complete data were available. The five values estimated for these initial conditions are justified as follows:

- Median: **27** NUTS 2, corresponding to the number of NUTS 2 region that are currently declared as infested (29 NUTS 2 that declared presence of the disease until 2016), minus the two regions that have recently declared a successful eradication in 2016 (Champagne-Ardennes in France and Cataluña in Spain).
- Lower quartile Q1: corresponds to the median value minus the Centre Val de Loire in France that has some chance to achieve eradication during 2016 (it reported in 2014 only a single small outbreak and will possibly achieve eradication upon the completion of the 2016 surveys), giving a value of **26**.
- Lower 1% probability bound: corresponds to Q1 minus an arbitrary further two regions, giving a value of **24**.
- Upper quartile Q3: estimated by supposing that all countries that declared one NUTS 2 region infested could have at least one additional infested NUTS 2 region that has escaped the surveys. As 9 countries have declared FDp infested regions, Q3 correspond to 27 + 9 = **36**.
- Upper 99% probability bound: **52**, corresponding to the number of NUTS 2 regions where the presence of the vector *S. titanus* is confirmed, assuming that FDp infection is present in all of these NUTS 2 regions but has so far escaped detection by surveys.

C.1.1. Sources of uncertainty

- Presence of the disease in new NUTS 2 units may not be always confirmed rapidly;
- Similarly, official notification of eradication, which depends on the intensity of surveys, may not always be justified

C.2. Future spread under scenario A0 – current control measures in place

The spread of FDp with all current control measures in place was analysed using the historical data from the literature. Different models were fitted to the cumulative distribution of infested NUTS 2 spatial areas. The projection of the different models at the end of the 10-year horizon were used to derive the ratings describing spread under scenario A0.

The five estimated values characterising the uncertainty distribution for the number of NUTS 2 regions in the EU to be infested by FDp for scenario A0 are justified as follows

- Median: **37**, corresponding to the value given by the polynomial model at the 10-year horizon (40) minus the two declared eradications (Cataluña + Champagne-Ardennes) and one highly probable eradication (Centre Val de Loire in France).
- Lower quartile Q1: **34**, corresponding to the value given by the linear model of the second phase;
- Lower 1% probability bound: **27**, corresponding to the current situation with no further spread
- Upper quartile Q3: **52**, estimated by the logistic model for disease progression;
- Upper 99% probability bound: **65**, corresponding to the total number of NUTS 2 occupied by insect vectors as predicted by the logistic model.

Scenario A1 – strengthened measures for propagative material

The five estimated values characterising the uncertainty distribution for the number of NUTS 2 regions in the EU to be infested by FDp estimated for scenario A1 are justified as follows:

- Median: **33**, corresponding to a 40% reduction in the numbers of newly infested NUTS 2 regions as compared to scenario A0 as a consequence of the improvement of the sanitary status in grapevine propagation materials linked to the additional control measures implemented in this scenario;

- Lower quartile Q1: **30**, corresponding to a situation intermediate between the median and the lower 1% probability bound because of lack of precise information and therefore of high uncertainty;
- Lower 1% probability bound: **27**, corresponding to the current situation with no further spread;
- Upper quartile Q3: **40**, corresponding to a situation intermediate between the median and the upper 99% probability bound, because of lack of precise information and therefore of high uncertainty;
- Upper 99% probability bound: **48**, estimated by counting all the NUTS 2 with vineyards in continuity with, or contiguous to, vineyards already infested in another NUTS 2. In this worst-case scenario, these 21 NUTS 2 could be infested by local, vector-mediated spread, even in the absence of any contribution of infested planting material to disease spread.

Scenario A2 – strengthened measures for eradication and containment

The five estimated values characterising the uncertainty distribution for the number of NUTS 2 regions in the EU to be infested by FDp for scenario A2 are justified as follows:

- Median: **32**, corresponding to the progression of the disease seen in the A0 scenario from which is removed an estimated five NUTS 2 regions as a consequence of the increased eradication ability resulting from the strengthening of surveillance and control RROs in this scenario;
- Lower quartile Q1: **26**, corresponding to a situation intermediate between the median and the lower 1% probability bound because of lack of precise information and therefore of high uncertainty;
- Lower 1% probability bound: **20**, corresponding to the lower 1% probability bound in the A0 scenario minus the successful eradication of FDp in an estimated seven NUTS 2 regions;
- Upper quartile Q3: **39**, corresponding to a situation intermediate between the median and the lower 1% probability bound because of lack of precise information and therefore of high uncertainty;
- Upper 99% probability bound: **46**, corresponding to halving of the worst-case progression of FDp observed in scenario A0 as a consequence of the additional or reinforced control measures implemented in scenario A2.

Table C.1: Synthesis of the ratings for spread under the different scenarios

Number of NUTS 2 regions with infected grapevines at the 10-year time horizon					
Overall assessment Percentile	**Low (1%)**	**1st Quartile (25%)**	**Median (50%)**	**3rd Quartile (75%)**	**High (99%)**
Current values	24	26	27	36	52
Scenario A0 – current control measures in place	27	34	37	52	65
Scenario A1 – current control measures, with increased control of the propagative material	27	30	33	40	48
Scenario A2 – current control measures, with increased local control aiming at containment or eradication	20	26	32	39	46

Appendix D – Data and model specifications as used in the opinion

D.1. General data

The farm structure survey of EUROSTAT (Regional, permanent crops: table ef_pompereg) lists 20 European countries with grape production: Bulgaria (BG), the Czech Republic (CZ), Germany (DE), Greece (EL), Spain (ES), France (FR), Croatia (HR), Italy (IT), Cyprus (CY), Luxembourg (LU), Hungary (HU), Malta (MT), the Netherlands (NL), Austria (AT), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Slovakia (SK) and the United Kingdom (UK).

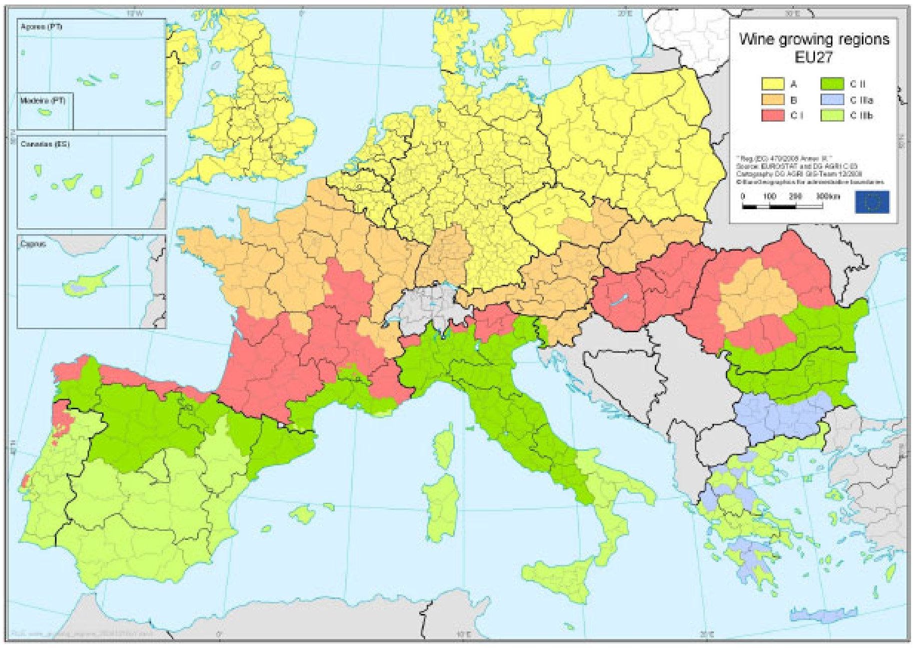

Figure D.1: EU wine growing classes according to EC 479/2008 (DG Agri, 2008)

EC regulation 479/2008 Annex IX proposes a classification in six wine growing zones. According to these following levels of for regional stratification are defined:

Table D.1: Regional stratification of different wine-producing countries

Reginal stratification	Countries
NUTS 0: Country level	LU, NL, PL, UK
NUTS 1: State level (groups of regions)	DE
NUTS 2: Regional level	BG, CY[(a)], CZ, EL, ES, FR, HR, IT, HU, MT[1], AT, RO, PT, SI, SK
No wine production	BE, DK, EE, IE, LV, LT, FI, SE

(a): NUTS 2 level is equal to the NUTS 0 level.

The division of the EU reflects the importance for wine production, the level of information available from EUROSTAT, and a harmonised approach between the countries. In total, 134 regions are selected in 20 countries to retrieve information on the wine production.

Table D.2 shows the selection of regions of wine production considered in the model.

For 28 of the selected 134 regions, the presence of FDp was reported in the past.

Table D.2: Selected regions of wine productions and the coverage by data from EUROSTAT

BE – Belgium	No wine growing regions
BG – Bulgaria	**NUTS 2 – level (6 regions)** BG31 – Severozapaden; BG32 - Severen tsentralen; BG33 – Severoiztochen; BG34 – Yugoiztochen; BG41 – Yugozapaden; BG42 – Yuzhen tsentralen

BE – Belgium	**No wine growing regions**
CZ – Czech Republic	**NUTS 2 – level (5 regions):** CZ01 – Praha; CZ02 - Strední Cechy; CZ04 – Severozápad; CZ06 – Jihovýchod; CZ07 – Strední Morava
DK – Denmark	**No wine growing regions**
DE – Germany	**NUTS 1 – level (10 regions):** DE1 – Baden-Württemberg; DE2 – Bayern; DE4 – Brandenburg; DE7 – Hessen; DEA – Nordrhein-Westfalen; DEB – Rheinland-Pfalz; DEC – Saarland; DED – Sachsen; DEE – Sachsen-Anhalt; DEG – Thüringen
EE – Estonia	**No wine growing regions**
IE – Ireland	**No wine growing regions**
EL – Greece	**NUTS 2 – level (13 regions):** EL11 – Anatoliki Makedonia, Thraki; EL12 – Kentriki Makedonia; EL13 – Dytiki Makedonia; EL14 – Thessalia; EL21 – Ipeiros; EL22 – Ionia Nisia; EL23 – Dytiki Ellada; EL24 – Sterea Ellada; EL25 – Peloponnisos; EL30 – Attiki; EL41 – Voreio Aigaio; EL42 – Notio Aigaio; EL43 – Kriti
ES – Spain	**NUTS 2 – level (16 regions):** ES11 – Galicia; ES12 – Principado de Asturias; ES13 – Cantabria; ES21 – País Vasco; ES22 – Comunidad Foral de Navarra; ES23 – La Rioja; ES24 – Aragón; ES30 – Comunidad de Madrid; ES41 – Castilla y León; ES42 – Castilla-la Mancha; ES43 – Extremadura; **ES51 – Cataluña**; ES52 – Comunidad Valenciana; ES53 – Illes Balears; ES61 – Andalucía; ES62 – Región de Murcia
FR – France	**NUTS 2 – level (19 regions)** FR10 – Île de France; FR21 – Champagne-Ardenne; FR22 – Picardie; **FR24 – Centre (FR); FR26 – Bourgogne**; FR30 – Nord-Pas-de-Calais; FR41 – Lorraine; FR42 – Alsace; FR43 – Franche-Comté; FR51 – Pays de la Loire; **FR53 – Poitou-Charentes; FR61 – Aquitaine;** **FR62 – Midi-Pyrénées**; FR63 – Limousin; **FR71 – Rhône-Alpes**; FR72 – Auvergne; **FR81 – Languedoc-Roussillon; FR82 – Provence-Alpes-Côte d'Azur;** **FR83 – Corse**
HR – Croatia	**NUTS 2 – level (2 regions):** HR03 – Jadranska Hrvatska; **HR04 – Kontinentalna Hrvatska**
IT – Italy	**NUTS 2 – level (21 regions):** **ITC1 – Piemonte**; ITC2 – Valle d'Aosta/Vallée d'Aoste; **ITC3 – Liguria;** **ITC4 – Lombardia; TD1/H1 – Bolzano/Bozen; ITD2/H2 –Trento;** **ITD3/H3 – Veneto; ITD4/H4 – Friuli-Venezia Giulia; ITD5/H5 – Emilia-Romagna;** **ITE1/I1 – Toscana**; ITE2 – Umbria; **ITE3/I3 – Marche**; ITE4 – Lazio; ITF1 – Abruzzo; ITF2 – Molise; **ITF3 – Campania**; ITF4 – Puglia; ITF5 – Basilicata; ITF6 – Calabria; ITG1 – Sicilia; ITG2 – Sardegna
CY – Cyprus	**NUTS 0/2 – level (1 region):** CY00 – Kypros
LV – Latvia	**No wine growing regions**
LT – Lithuania	**No wine growing regions**
LU – Luxembourg	**NUTS 0/2 – level (1 region):** LU00 – Luxembourg
HU – Hungary	**NUTS 2 – level (7 regions):** HU10 – Közép-Magyarország; HU21 – Közép-Dunántúl; **HU22 – Nyugat-Dunántúl;** **HU23 – Dél-Dunántúl**; HU31 – Észak-Magyarország; HU32 – Észak-Alföld; HU33 – Dél-Alföld
MT – Malta	**NUTS 0/2 – level (1 region):** MT00 – Malta

BE – Belgium	**No wine growing regions**
NL – Netherlands	**NUTS 0 – level (1 region):** NL – Netherlands
AT – Austria	**NUTS 2 – level (8 regions):** AT11 – Burgenland (AT); AT12 – Niederösterreich; AT13 – Wien; AT21 – Kärnten; **AT22 – Steiermark**; AT31 – Oberösterreich; AT33 – Tirol; AT34 – Vorarlberg
PL – Poland	**NUTS 0 – level (1 region):** PL – Poland
PT – Portugal	**NUTS 2 – level (7 regions):** **PT11 – Norte**; PT15 – Algarve; PT16 – Centro (PT); PT17 – Área Metropolitana de Lisboa; PT18 – Alentejo; PT20 – Região Autónoma dos Açores (PT); PT30 – Região Autónoma da Madeira (PT)
RO – Romania	**NUTS 2 – level (8 regions):** RO11 – Nord-Vest; RO12 – Centru; RO21 – Nord-Est; RO22 – Sud-Est; RO31 – Sud – Muntenia; RO32 – Bucuresti – Ilfov; RO41 – Sud-Vest Oltenia; RO42 – Vest
SI – Slovenia	**NUTS 2 – level (2 regions):** **SI01 – Vzhodna Slovenija; SI02 – Zahodna Slovenija**
SK – Slovakia	**NUTS 2 – level (4 regions):** SK01 – Bratislavský kraj; SK02 – Západné Slovensko; SK03 – Stredné Slovensko; SK04 – Východné Slovensko
FI – Finland	**No wine growing regions**
SE – Sweden	**No wine growing regions**
UK – United Kingdom	**NUTS 0 – level (1 region):** UK – United Kingdom

In bold and underlined = reported infection in the past.
Weblink: http://ec.europa.eu/eurostat/data/database

D.2. Wine production data

To describe the wine production, several sources of EUROSTAT were used:

D.2.1. Farm Structure Survey (EUROSTAT: apro_acs_a)

In the Farm Structure Survey, EUROSTAT is collecting information on agricultural production (harvest/harvested area) of:

- Grapes for wine production
- Grapes for table use
- Grapes for raisins
- Grapes for other purposes

On a country level, the yield per area was calculated from harvested production and production area. The values are provided yearly. The following tables show the values for the years 2005–2014 and the 20 grape-producing countries.

Table D.3: Acreage, total production and yield of 20 countries as average from 2005 to 2014

Country	Grapes			Grapes for wine			Grapes for table use			Grapes for raisins		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
	1,000 ha	1,000 tonnes	tonnes/ha	1,000 ha	1,000 tonnes	tonnes/ha	1,000 ha	1,000 tonnes	tonnes/ha	1,000 ha	1,000 tonnes	tonnes/ha
BG	79.50	284.04	4.05	79.89	255.19	3.72	4.34	15.42	4.17			
CZ	15.88	74.66	4.68	16.12	78.30	4.84						
DE	99.68	1,302.95	13.07	99.72	1,225.31	12.29						
EL	103.53	979.37	9.45	62.28	547.92	8.80	12.98	196.56	15.01	28.26	234.89	7.94
ES	1,028.94	6,224.91	6.10	1,009.99	5,927.69	5.91	16.87	265.65	15.89	1.83	2.14	1.18
FR	789.49	5,397.08	6.81	798.65	5,393.14	6.73	6.57	51.44	7.96	0.46	4.17	9.07
HR	31.03	186.28	6.00	31.07	186.28	5.99	0.30	2.60	8.67			
IT	752.81	7,707.61	10.24	685.70	6,355.66	9.27	62.51	1,301.34	21.00			
CY	8.09	30.19	3.67	7.49	25.35	3.36	0.58	4.77	7.75	0.02	0.06	3.27
LU	1.23	17.02	13.84	1.23	17.01	13.83						
HU	77.90	461.74	5.90	74.38	444.46	5.95	2.70	13.51	5.02			
MT	0.61	4.51	7.39	0.64	4.90	7.66	0.05	0.41	8.10			
NL	0.16	0.00	0.00	0.16	0.00	0.00						
AT	44.63	314.72	7.05	44.63	314.72	7.05						
PL	0.48	1.31	2.24									
PT	186.43	850.53	4.56	183.64	829.12	4.51	2.80	21.40	7.61			
RO	177.19	833.70	4.69	168.99	781.32	4.61	8.21	52.39	6.36			
SI	16.23	108.43	6.68	16.23	108.41	6.68	0.01	0.07	7.00			
SK	10.56	46.31	4.38	10.42	45.93	4.40	0.13	0.30	2.45			
UK	1.65	3.60	2.41	1.50	1.35	0.68						

Grey cells = Values used for modelling//(Weblink: http://ec.europa.eu/eurostat/data/database)
Source: EUROSTAT, table apro_acs_a, Yield/ha calculated, weighted average (of complete data).

Table D.4: Productivity of grape production as average of 20 countries from 2005 to 2014

Year	Grapes			Grapes for wine			Grapes for table use			Grapes for raisins		
	Area	Production	Yield/ha	Area	Production	Yield/ha	Area	Production	Yield/ha	Area	Production	Yield/ha
	1000 ha	1000 tonnes	tonnes/ha	1000 ha	1000 tonnes	tonnes/ha	1000 ha	1000 tonnes	tonnes/ha	1000 ha	1000 tonnes	tonnes/ha
2005	3,513	25,257	7.2	3,449	22,749	6.6	140	2,285	16.4	37	421	11.5
2006	3,720	27,492	7.4	3,532	24,812	7.0	135	2,158	16.0	36	461	12.7
2007	2,821	19,142	6.8	3,517	22,876	6.5	128	1,928	15.0	42	313	7.4
2008	1,669	13,558	8.1	2,385	17,206	7.2	103	1,629	15.8	33	320	9.8
2009	1,673	13,716	8.2	822	5,048	6.1	98	1,669	17.0	21	135	6.5
2010	3,273	22,302	6.8	3,225	21,148	6.6	123	1,980	16.1	22	149	6.9
2011	3,152	22,084	7.0	3,113	20,876	6.7	110	1,783	16.2	27	155	5.9
2012	3,118	20,550	6.6	3,089	19,690	6.4	105	1,717	16.4	22	122	5.6
2013	3,120	24,186	7.8	3,090	23,350	7.6	99	1,839	18.6	29	135	4.6
2014	3,075	23,180	7.5	3,050	22,611	7.4	96	1,658	17.3	30	159	5.3

Weblink: http://ec.europa.eu/eurostat/data/database
Source: EUROSTAT, table apro_acs_a, Yield/ha calculated, weighted average (of complete data).

D.2.2. Farm Structure Survey (EUROSTAT: popermreg)

Finally, the Farm Structure Survey also reports production areas on NUTS 2 level for:

- Vineyards for wine production
  - Quality wines
  - Other wines
- Table grape production
- Production of raisins

Values are reported for the years 2005, 2007, 2010 and 2013.

Table D.5: Acreage in hectare for grapes of different uses for 20 countries

Harvested area [ha] **Average of the years 2005, 2007, 2010, 2013**					
Country	**All grapes**	**Quality wines**	**Other wines**	**Table grapes**	**Raisins**
BG	50,547.5	9,167.5	38,417.5	2,955.0	0.0
CZ	14,530.0	13,517.5	847.5	162.5	0.0
DE	97,567.5	97,467.5	0.0	100.0	0.0
EL	95,400.0	13,180.0	43,415.0	12,905.0	25,900.0
ES	926,732.5	588,990.0	313,950.0	21,980.0	1,812.5
FR	820,567.5	600,952.5	213,185.0	6,425.0	0.0
HR	24,853.3	12,450.0	10,560.0	375.0	0.0
IT	687,635.0	322,282.5	321,855.0	43,497.5	0.0
CY	9,132.5	450.0	7,835.0	832.5	15.0
LU	1,280.0	1,280.0	0.0	0.0	0.0
HU	62,802.5	38,827.5	21,927.5	2,050.0	0.0
MT	675.0	380.0	212.5	85.0	0.0
NL	80.0	0.0	80.0	0.0	0.0
AT	47,970.0	47,970.0	0.0	0.0	0.0
PL	113.3	0.0	113.3	0.0	0.0
PT	177,547.5	127,392.5	47,722.5	2,435.0	0.0
RO	168,610.0	60,525.0	100,437.5	7,647.5	0.0
SI	16,275.0	15,630.0	642.5	0.0	0.0
SK	13,257.5	8,165.0	4,435.0	657.5	0.0
UK	1,042.5	0.0	1,042.5	0.0	0.0

Weblink: http://ec.europa.eu/eurostat/data/database
Source: EUROSTAT, table popermreg, average calculated.

Table D.6: Production area in hectare for grapes of different uses for 28 regions with reported FDp

Harvested area [ha] **Average of the years 2005, 2007, 2010 and 2013**					
Region[(a)]	**All grapes**	**Quality wines**	**Other wines**	**Table grapes**	**Raisins**
FR81	245,893.3	163,337.5	91,612.5	677.5	0.0
FR61	144,236.7	143,660.0	2,820.0	262.5	0.0
FR82	93,543.3	79,175.0	11,667.5	3,572.5	0.0
FR53	82,290.0	3,605.0	78,467.5	42.5	0.0
ITD3/H3	79,573.3	53,167.5	25,120.0	467.5	0.0
PT11	79,166.7	66,155.0	14,240.0	150.0	0.0
ITE1/I1	61,223.3	42,497.5	15,887.5	662.5	0.0
ES51	60,973.3	56,750.0	4,615.0	95.0	7.5
ITD5/H5	56,166.7	30,862.5	26,060.0	297.5	0.0
FR71	50,833.3	45,347.5	6,940.0	50.0	0.0

Harvested area [ha] Average of the years 2005, 2007, 2010 and 2013					
Region[(a)]	**All grapes**	**Quality wines**	**Other wines**	**Table grapes**	**Raisins**
ITC1	47,923.3	42,485.0	5,985.0	465.0	0.0
FR62	38,433.3	23,345.0	14,385.0	1,705.0	0.0
FR26	31,303.3	31,040.0	262.5	0.0	0.0
ITC4	25,043.3	19,940.0	4,437.5	130.0	0.0
ITF3	22,893.3	7,572.5	16,207.5	335.0	0.0
FR24	21,856.7	20,587.5	1,702.5	5.0	0.0
ITD4/H4	19,506.7	16,072.5	2,942.5	307.5	0.0
ITE3/I3	16,503.3	12,222.5	5,640.0	285.0	0.0
HR04	13,450.0	7,140.0	5,170.0	220.0	0.0
HU23	10,366.7	7,365.0	2,522.5	292.5	0.0
SI01	9,636.7	9,185.0	512.5	0.0	0.0
ITD2/H2	9,263.3	8,595.0	602.5	30.0	0.0
SI02	6,583.3	6,445.0	130.0	0.0	0.0
FR83	6,416.7	4,712.5	1,730.0	82.5	0.0
AT22	4,686.7	4,520.0	0.0	0.0	0.0
HU22	4,216.7	2,305.0	2,317.5	162.5	0.0
ITD1/H1	3,913.3	3,547.5	225.0	10.0	0.0
ITC3	1,490.0	697.5	840.0	95.0	0.0

(a): For full name see Table B.1.
Source: EUROSTAT, Table B.1 popermreg, average calculated.

D.2.3. Conversion factors

In the modelling, a constant conversion factor was used to calculate the wine production.

Table D.7: List of used conversion factors

Conversion	**Abbr**	**Factor**	**Reference**
Conversion of harvested weight of wine grapes to litre of wine	$Conv_{l/kg}$	0.74 l/kg = 7.4 hL/tonnes = 7,400 hL/1,000 tonnes	Eurostat Handbook for Annual Crop Statistics (2015), chap.2.4

D.3. The impact model

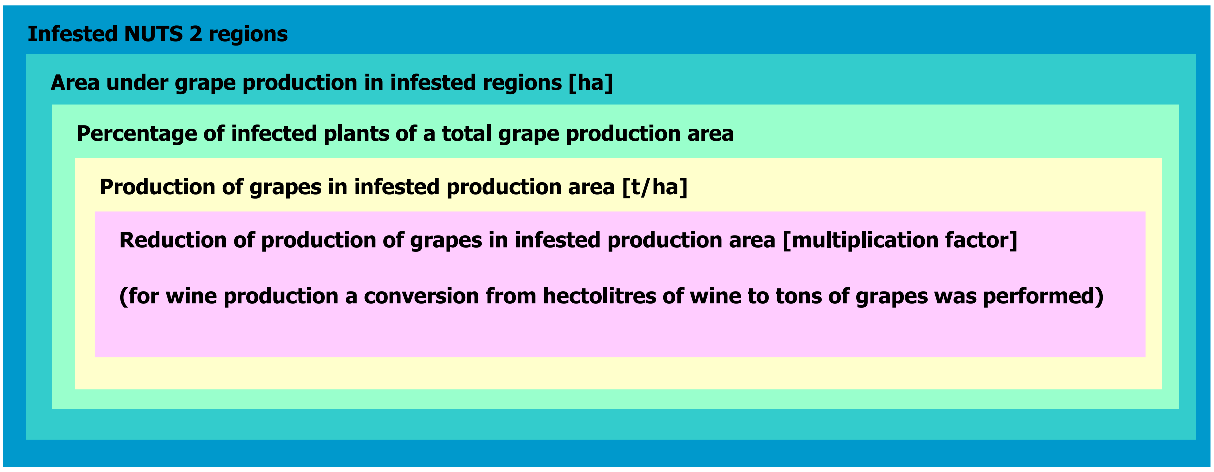

Figure D.2: The impact model

Table D.8: Parameter and model equation of the impact model

Abbreviation	Explanation	Evidence
N_{cont} [−]	**Step 1:** The number of infested NUTS 2 regions at the 10-year time horizon	Reports on FDp, elicitation
$Area_{grape}$ [ha]	**Step 2:** The area under grapevine production in individual regions, expressed in hectares for table grapes, wine-producing grapes (quality and other wine) and raisins, for EU regions with grape production	EUROSTAT average 4 years for 28 regions
$Prop_{inf}$ [−]	**Step 3:** The average abundance of FDp in wine and table grapes production in infested regions, expressed as the percentage of infected plants calculated over the complete region	Elicitation
Prod [tonnes/ha]	**Step 4:** The grape production in individual regions, expressed in tonnes per hectare for table grapes and wine grapes, for EU regions with grape production	EUROSTAT for 10 years weighted EU average
Red [−]	**Step 5:** A multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection	Elicitation
Conv [hL/tonnes]	**Step 6 (Only for wine production):** Conversion factor to calculate produced wine from harvested wine grapes	Constant (see Table D.7)

$$\mathbf{Loss} = \mathbf{N_{cont}} \times \mathbf{Area_{grape}} \times \mathbf{Prop_{inf}} \times \mathbf{Prod} \times \mathbf{Red}\ (\mathbf{{*}Conv}).$$

A detailed description of how the probability distributions for the various parameters were obtained and these distributions themselves are provided in Appendix E.

D.3.1. Step 1

Table D.9: The number of infested NUTS 2 regions at the 10-year time horizon under different scenarios (Values from fitted distributions on expert elicitations)

Percentile	Number of infested regions in 10 years (N_cont)		
	Baseline (A0)	**Scenario 1 (A1)**	**Scenario 2 (A2)**
[%]	**[−]**		
1	20.5	22.4	14.9
5	25.0	25.3	19.4
10	27.7	27.1	22.0
15	29.7	28.3	23.9
20	31.4	29.3	25.4
25	32.9	30.2	26.7
50	39.9	34.1	32.3
75	48.4	38.5	37.9
80	50.8	39.7	39.3
85	53.7	41.1	40.9
90	57.6	42.9	43.0
95	63.9	45.9	45.9
99	77.6	51.8	51.1
Mean	**41.6**	**34.6**	**32.4**
SD	**12.1**	**6.3**	**8.0**

D.3.1.1. Baseline (A0)

Table D.10: Elicitation results and fitted distribution for the number of infested regions in 10 years (A0_N_cont) under the baseline scenario

Elicitation results A0_N_cont	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	27	34	37	52	65
Fitted values	20.5	32.9	39.9	48.4	77.6

Fitted distribution: LogNormal(μ = 41.588, σ = 12.120).

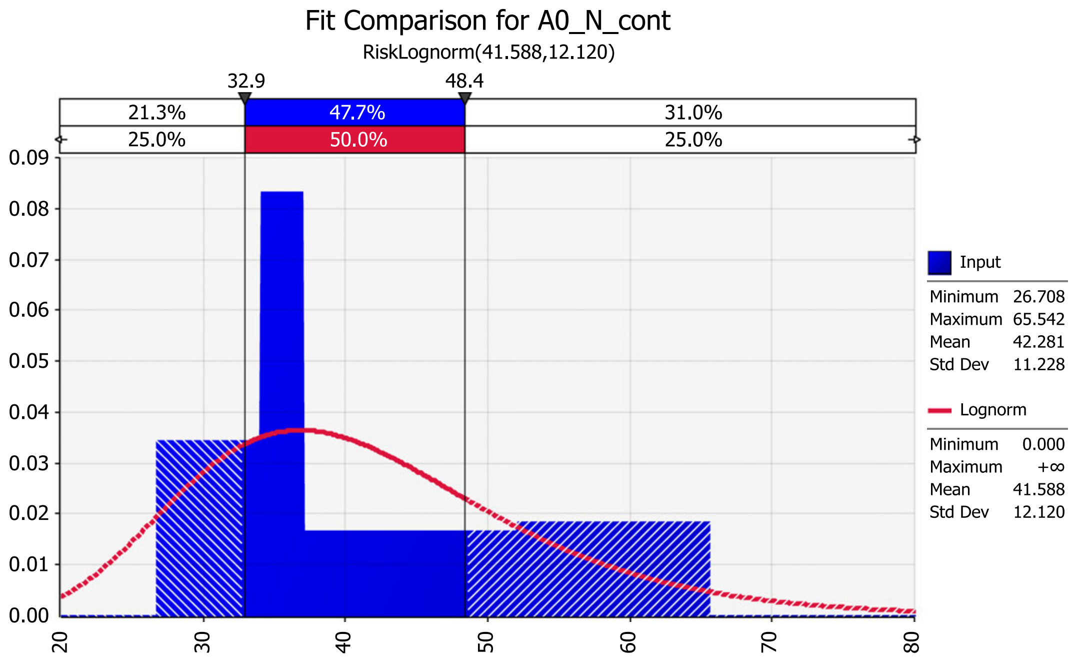

Figure D.3: Comparison of elicited (blue) and fitted (red) probability density for the number of infested regions in 10 years (A0_N_cont) under the baseline scenario

D.3.1.2. Scenario 1 (A1)

Table D.11: Elicitation results and fitted distribution for the number of infested regions in 10 years (A1_N_cont) under scenario 1

Elicitation results A1_N_cont	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	27	30	33	40	48
Fitted values	22.4	30.2	34.1	38.5	51.8

Fitted distribution: LogNormal(μ=34.642, σ=6.2985).

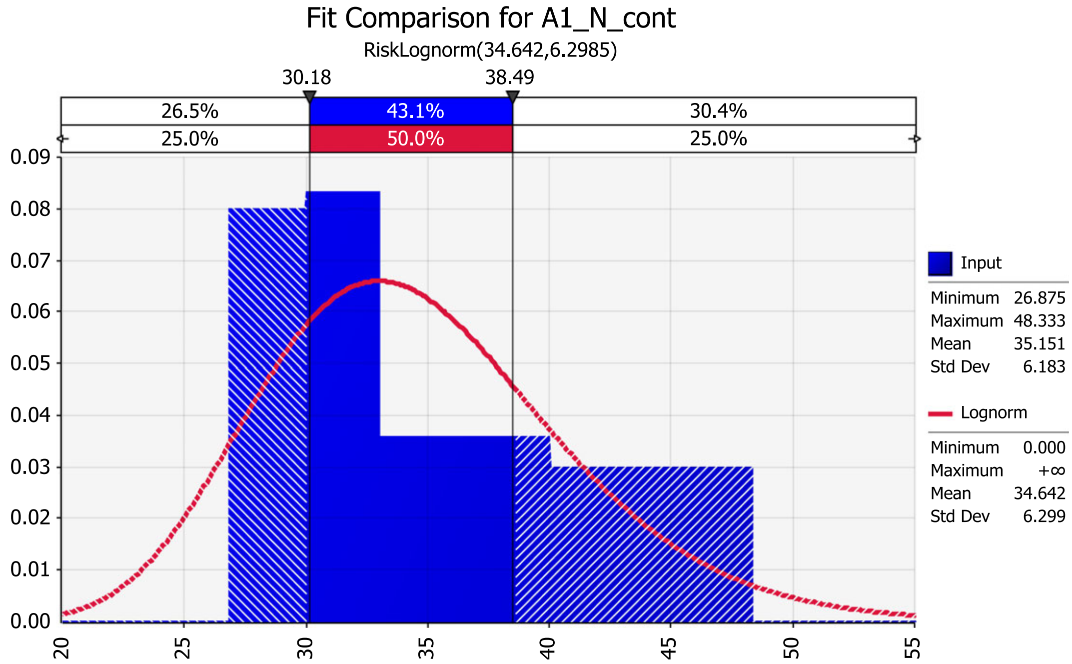

Figure D.4: Comparison of elicited (blue) and fitted (red) probability density for the number of infested regions in 10 years (A1_N_cont) under scenario 1

D.3.1.3. Scenario 2 (A2)

Table D.12: Elicitation results and fitted distribution for the number of infested regions in 10 years (A2_N_cont) under scenario 2

Elicitation results A2_N_cont	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	20	26	32	39	46
Fitted values	14.9	26.7	32.3	37.9	51.1

Fitted distribution: BetaGeneral(μ = 32.405, σ = 8.039, min = 0, max = 73.413).

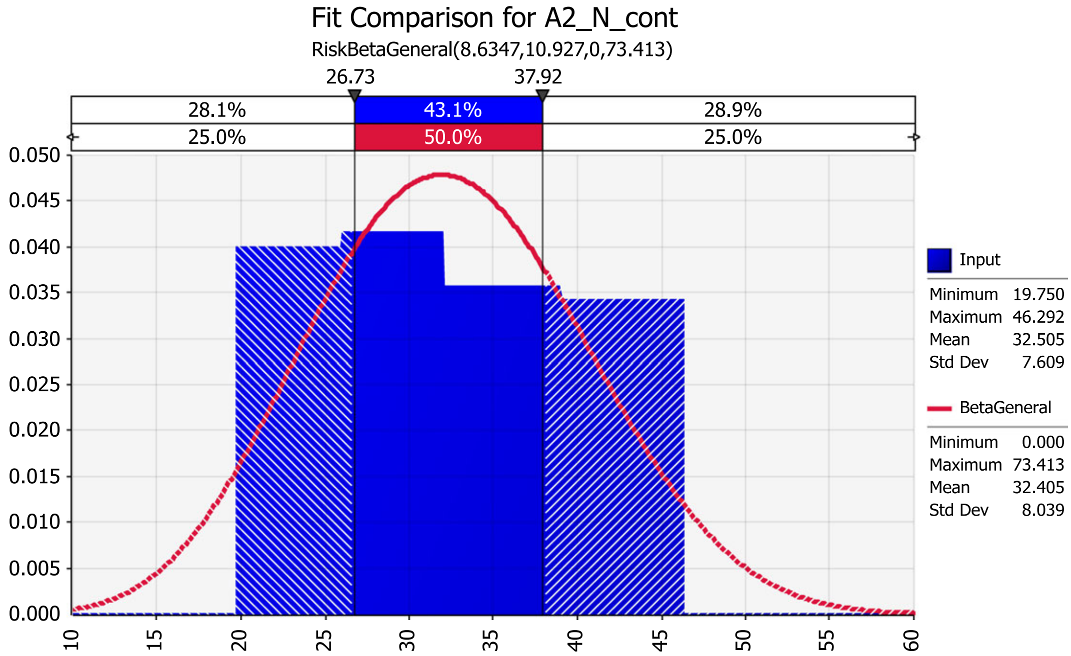

Figure D.5: Comparison of elicited (blue) and fitted (red) probability density for the number of infested regions in 10 years (A2_N_cont) under scenario 2

D.3.2. Step 2

The area under grapevine production in individual regions, expressed in hectares for table grapes, wine-producing grapes (quality and other wine) and raisins, for EU regions with grape production and reported (former) infestation with FDp.

See Table D.6 for data used in the model fitting. Production of raisins was not used in the model.

Table D.13: Production area in hectare (Area) per region (with reported FDp infestation) (Estimated distributions and their percentiles)

Percentile	Production area per region (with reported FDp presence)			
	All grapes	Grapes for quality wine	Grapes for other wines	Table grapes
[%]	[ha]	[ha]	[ha]	[ha]
1	285	144	4	1
5	1,682	953	77	6
10	3,682	2,199	276	18
15	5,903	3,637	586	34
20	8,335	5,255	1,005	53
25	10,991	7,058	1,536	75
50	28,631	19,597	6,212	245
75	60,893	43,829	17,030	594
80	71,637	52,123	20,923	713
85	85,683	63,090	26,133	871
90	105,797	79,003	33,757	1,099
95	140,898	107,240	47,336	1,499
99	225,013	176,688	80,461	2,457
Mean	**44,412**	**32,371**	**12,705**	**433**
SD	**48,402**	**37,721**	**17,215**	**530**

Fitted distributions	
All grapes:	Weibull(μ = 44,412.26, σ = 48,405.57)
Grapes for quality wines:	Weibull(μ = 32,371.34, σ = 37,725.08)
Grapes for other wines:	Gamma(μ = 12,705.13, σ = 17,215.84)
Table grapes:	Gamma(μ = 433.44, σ = 529.71)

D.3.2.1. All grapes

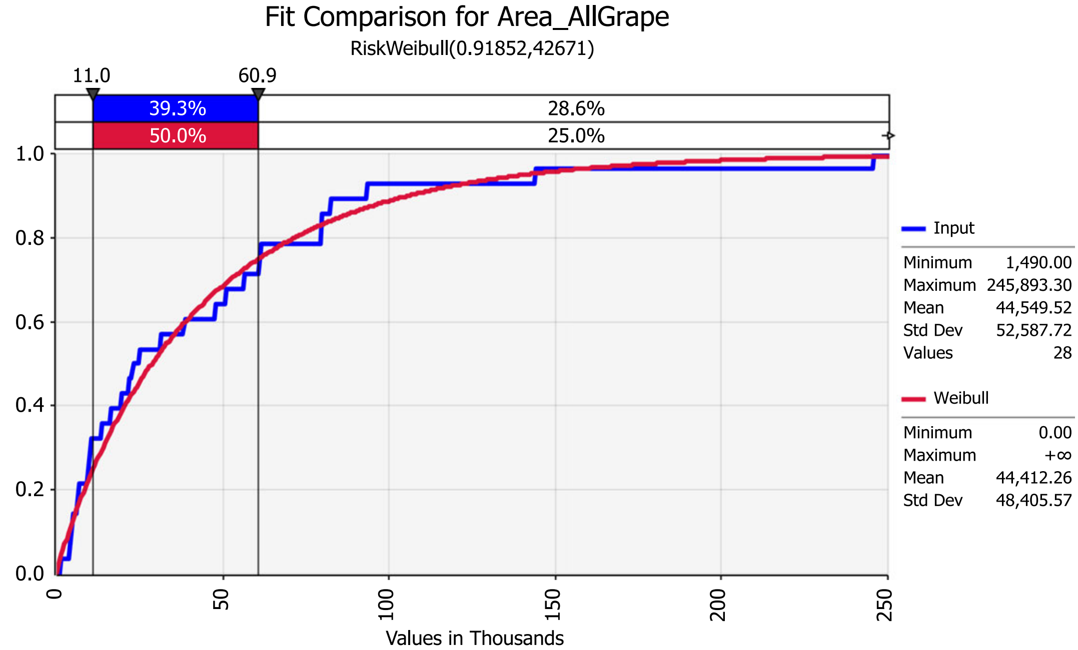

Figure D.6: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the production area per region (with the reported FDp presence, Area_AllGrapes, in [ha]) for total grape production

D.3.2.2. Grapes for quality wines

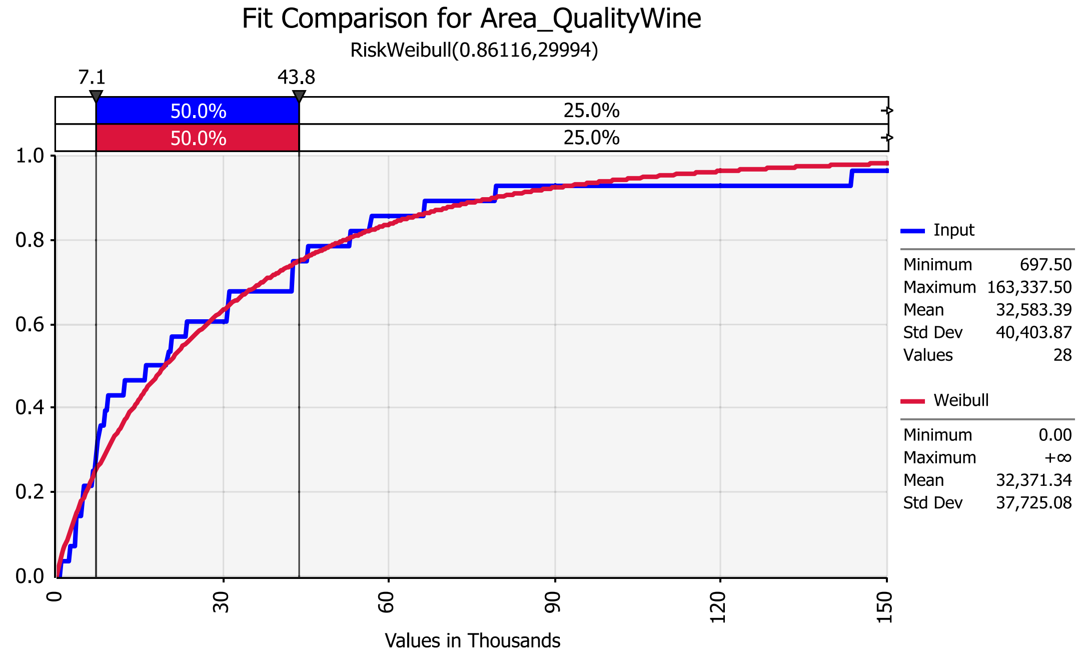

Figure D.7: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the production area per region (with the reported FDp presence, Area_QualityWine, in [ha]) for grape production for quality wine

D.3.2.3. Grapes for other wines

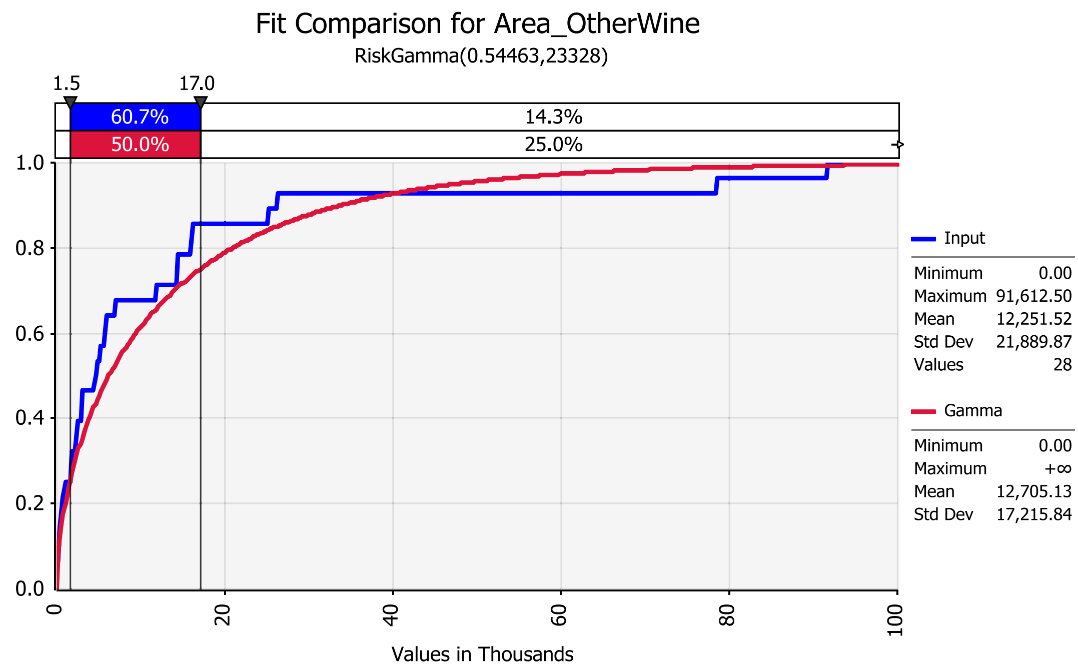

Figure D.8: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the production area per region (with the reported FDp presence, Area_OtherWine, in [ha]) for grape production for non-quality wine

D.3.2.4. Table grapes

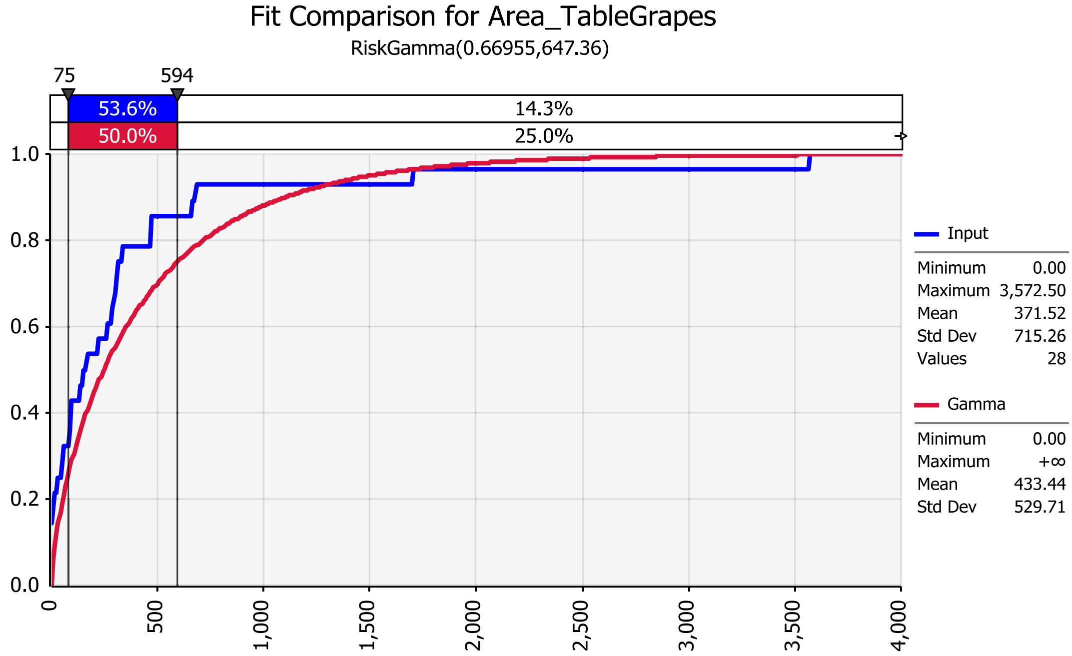

Figure D.9: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the production area per region (with the reported FDp presence, Area_TableGrapes, in [ha]) for table grape production

D.3.3. Step 3

The average abundance of FDp in wine and table grapes production in infested regions, expressed as the proportion of infected plants calculated over the complete region.

Table D.14: Proportion of infected plants within a plot under different scenarios (Values from fitted distributions on expert elicitations)

Percentile	Proportion of infected plants within a plot (Prop_inf)		
	Baseline (A0)	**Scenario 1 (A1)**	**Scenario 2 (A2)**
[%]	**[–]**	**[–]**	**[–]**
1	0.00000	0.00000	0.00000
5	0.00000	0.00000	0.00000
10	0.00001	0.00000	0.00000
15	0.00002	0.00001	0.00000
20	0.00005	0.00003	0.00001
25	0.00008	0.00005	0.00002
50	0.00052	0.00037	0.00020
75	0.00183	0.00138	0.00086
80	0.00234	0.00179	0.00113
85	0.00304	0.00235	0.00152
90	0.00409	0.00320	0.00213
95	0.00602	0.00476	0.00325
99	0.01087	0.00873	0.00615
Mean	**0.00145**	**0.00112**	**0.00073**
SD	**0.0023**	**0.0018**	**0.0013**

D.3.3.1. Baseline (A0)

Table D.15: Elicitation results and fitted distribution for the proportion of infected plants within a plot (A0_Prop_inf) under the baseline scenario

Elicitation results A0_Prop_inf	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	0.00000	0.00010	0.00045	0.00200	0.00800
Fitted values	0.00000	0.00008	0.00052	0.00183	0.01087

Fitted distribution: Gamma (μ = 0.001448, σ = 0.002292)

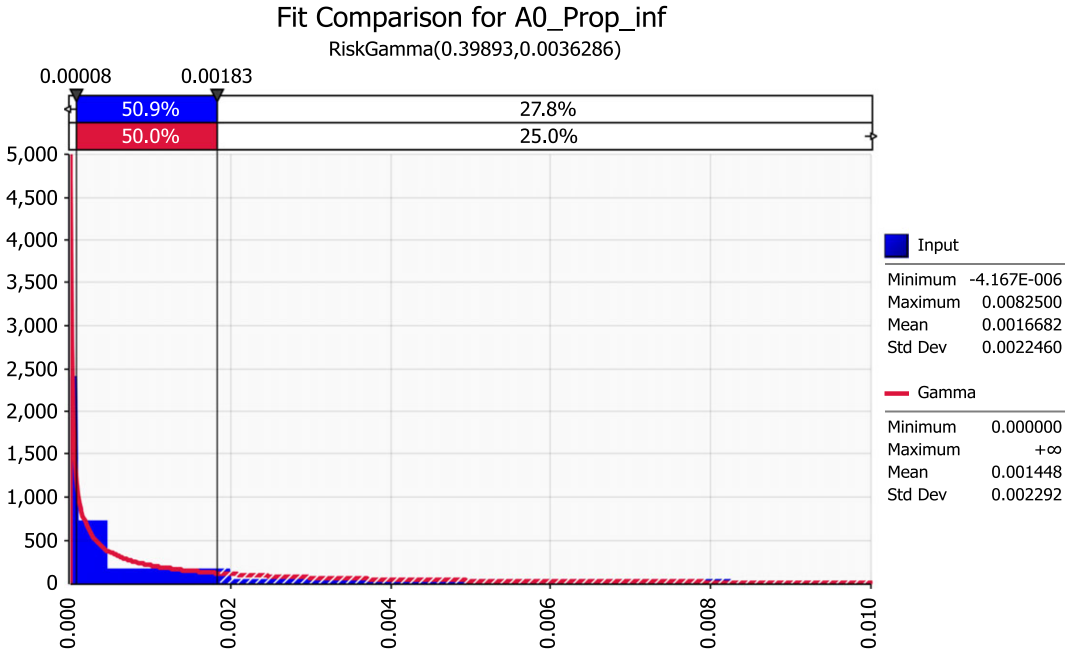

Figure D.10: Comparison of elicited (blue) and fitted (red) probability density for the proportion of infected plants within a plot (A0_Prop_inf) under the baseline scenario

D.3.3.2. Scenario 1 (A1)

Table D.16: Elicitation results and fitted distribution for the proportion of infected plants within a plot (A1_Prop_inf) under scenario 1

Elicitation results A1_Prop_inf	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	0.000000	0.000070	0.000300	0.00150	0.00800
Fitted values	0.000000	0.000053	0.000371	0.00138	0.00873

Fitted distribution: Gamma(μ = 0011176, σ = 0.0018336)

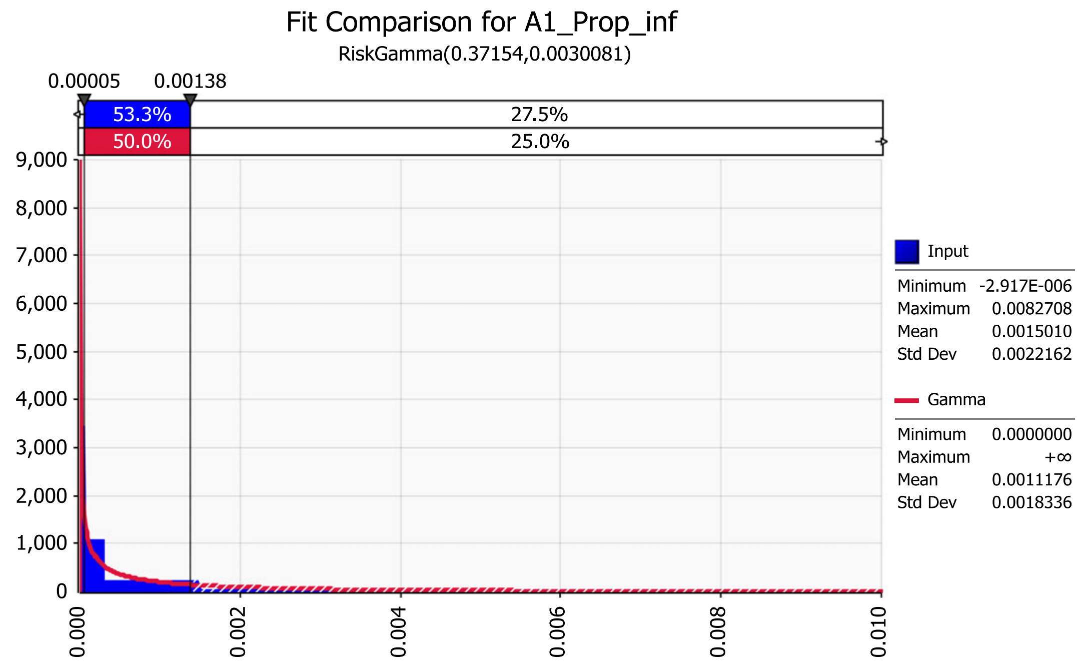

Figure D.11: Comparison of elicited (blue) and fitted (red) probability density for the proportion of infected plants within a plot (A1_Prop_inf) under scenario 1

D.3.3.3. Scenario 2 (A2)

Table D.17: Elicitation results and fitted distribution for the proportion of infected plants within a plot (A2_Prop_inf) under scenario 2

Elicitation results A2_Prop_inf	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	0.00000	0.00003	0.00015	0.00100	0.00400
Fitted values	0.00000	0.00002	0.00020	0.00086	0.00615

Fitted distribution: Gamma(μ = 0.0007274, σ = 0.0012819)

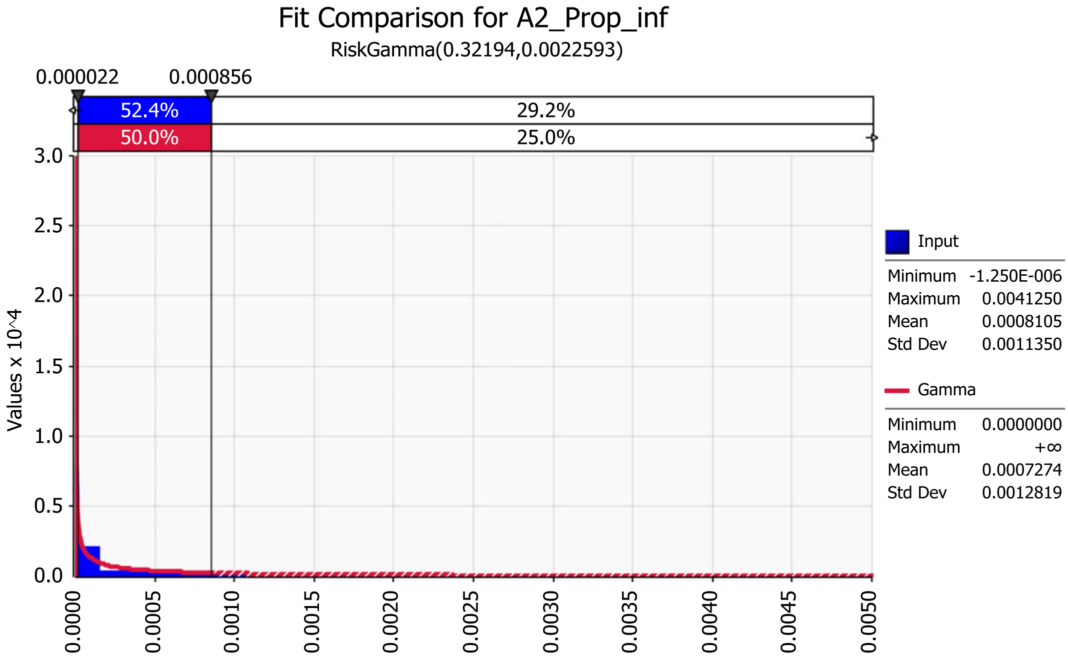

Figure D.12: Comparison of elicited (blue) and fitted (red) probability density for the proportion of infected plants within a plot (A2_Prop_inf) under scenario 2

D.3.4. Step 4

The grape production in individual regions, expressed in tonnes per hectare for table grapes and wine grapes, for EU regions with grape production.

See Table D.3 for empirical data used for modelling.

Table D.18: Productivity in tonnes per hectare (Prod) of European countries (average of 10 years) for different types of grape production (Estimated distributions and their percentiles)

Percentile	Productivity of different countries (Prod)		
	All grapes	Grapes for wine (quality or other)	Table grapes
[%]	[tonnes/ha]	[tonnes/ha]	[tonnes/ha]
1	2.6	2.6	1.6
5	3.4	3.4	2.8
10	3.9	3.9	3.7
15	4.3	4.2	4.4
20	4.7	4.6	5.0
25	5.0	4.9	5.5
50	6.5	6.3	8.2
75	8.4	8.2	11.6
80	8.9	8.7	12.6
85	9.6	9.4	13.8
90	10.5	10.3	15.4
95	12.1	11.8	18.0
99	15.7	15.3	23.6
Mean	**6.9**	**6.8**	**9.0**
SD	**2.76**	**2.68**	**4.77**

Fitted distributions	
All grapes:	LogNormal(μ = 6.9450, σ = 2.7625)
Grapes for wines:	LogNormal(μ = 6.7801, σ = 2.6838)
Table grapes:	Gamma(μ = 8.999, σ = 4.765)

D.3.4.1. All grapes

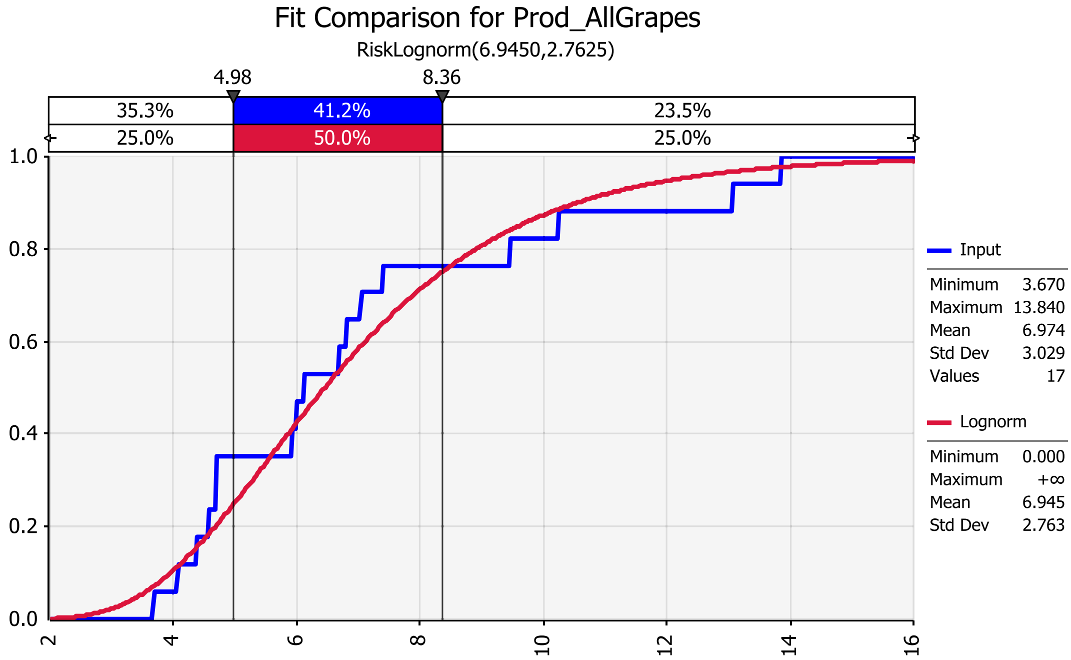

Figure D.13: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the productivity (Prod_AllGrapes in [tonnes/ha]) of European Countries for total grape production

D.3.4.2. Grapes for wines

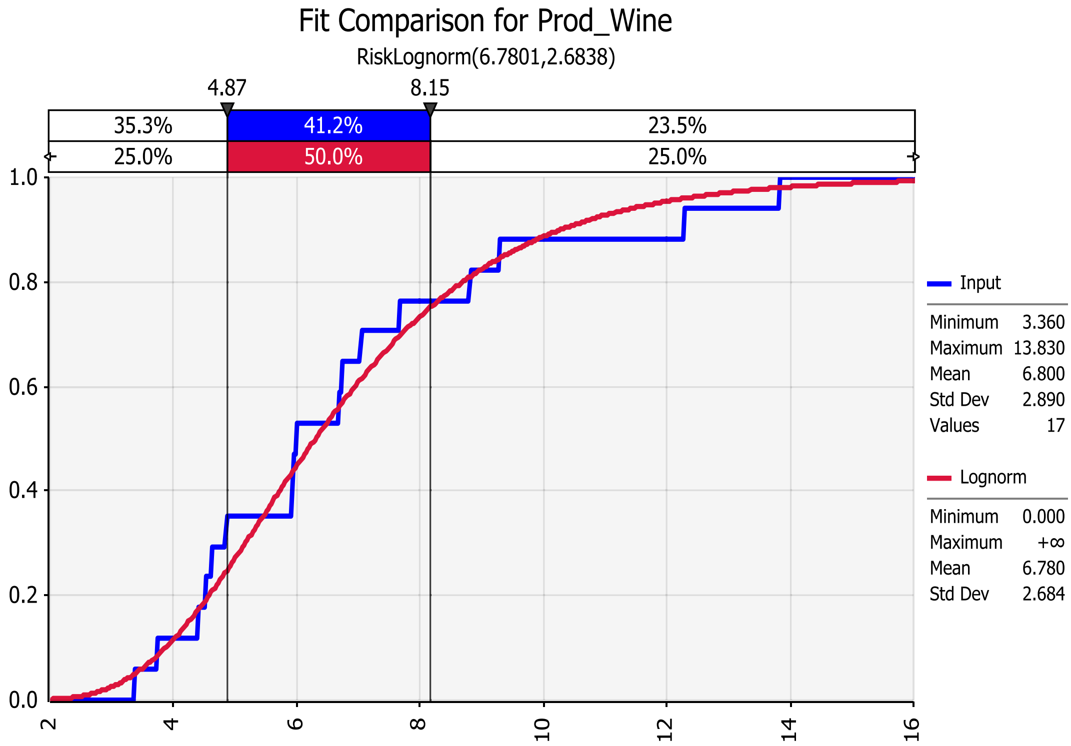

Figure D.14: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the productivity (Prod_Wine in [tonnes/ha]) of European Countries for grape for wine (quality and other) production

D.3.4.3. Table grapes

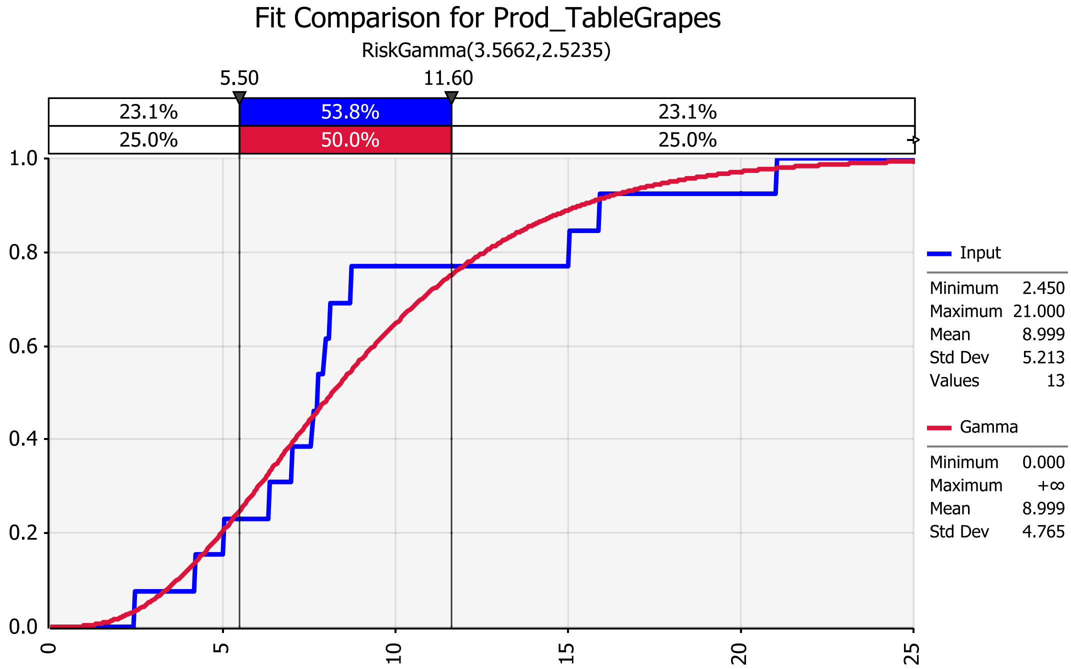

Figure D.15: Comparison of empirical (blue) and fitted (red) cumulative distribution function for the productivity (Prod_TableGrapes in [tonnes/ha]) of European Countries for table grape production

D.3.5. Step 5

A multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection.

Table D.19: Loss factor (Red) of yield of infected plants under different scenarios (Values from fitted distributions on expert elicitations)

Percentile	Loss factor (Red)		
	Baseline (A0)	**Scenario 1 (A1)**	**Scenario 2 (A2)**
[%]	**[–]**		
1	1.28	1.28	0.78
5	1.80	1.80	1.42
10	2.09	2.09	1.82
15	2.28	2.28	2.10
20	2.44	2.44	2.32
25	2.57	2.57	2.50
50	3.08	3.08	3.14
75	3.56	3.56	3.54
80	3.67	3.67	3.59
85	3.80	3.80	3.65
90	3.95	3.95	3.69
95	4.18	4.18	3.73
99	4.57	4.57	3.75
Mean	**3.05**	**3.05**	**2.93**
SD	**0.72**	**0.72**	**0.74**

D.3.5.1. Baseline (A0) and Scenario 1 (A1)

Table D.20: Elicitation results and fitted distribution for the loss factor (A0A1_Red) of yield of infected plants under the baseline scenario and scenario 1

Elicitation results A0A1_Red	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	0.00	2.55	3.10	3.55	4.50
Fitted values	1.28	2.57	3.08	3.56	4.57

Fitted distribution: Weibull(μ = 3.0472, σ = 0.7217)

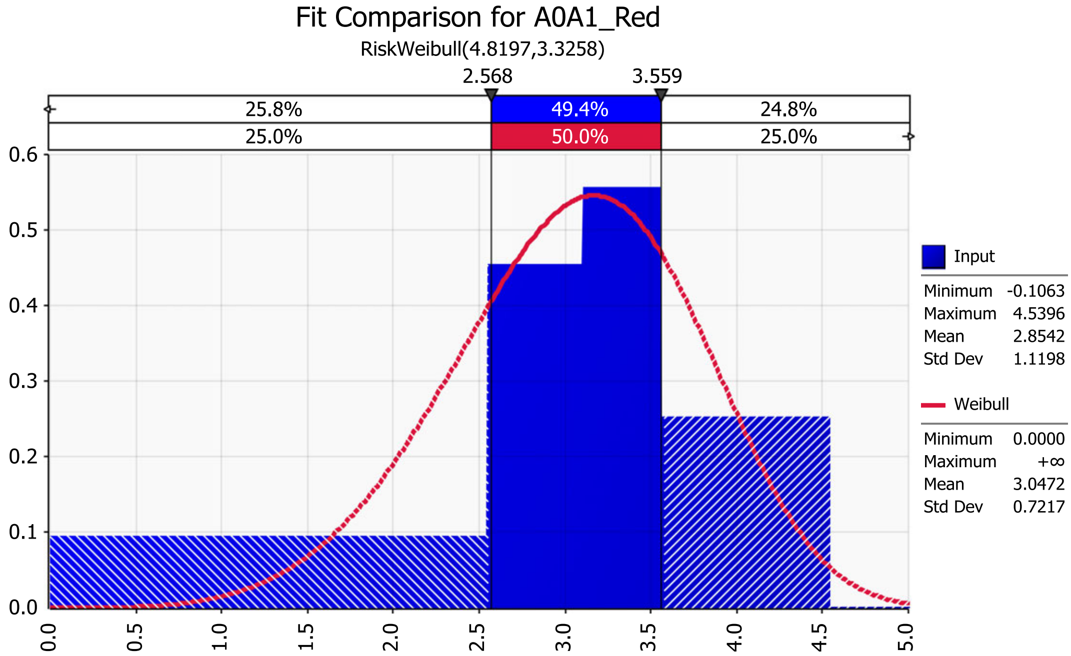

Figure D.16: Comparison of elicited (blue) and fitted (red) probability density for loss factor (A0A1_Red) of yield of infected plants under the baseline scenario and scenario 1

D.3.5.2. Scenario 2 (A2)

Table D.21: Elicitation results and fitted distribution for the loss factor (A2_Red) of yield of infected plants under scenario 2

Elicitation results A2_Red	Lower limit (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Upper limit (99%)
Expert consensus	0.00	2.55	3.10	3.55	3.75
Fitted values	0.78	2.50	3.14	3.54	3.75

Fitted distribution: BetaGeneral(μ = 2.9295, σ = 0.7402, min = 0, max = 3.7534)

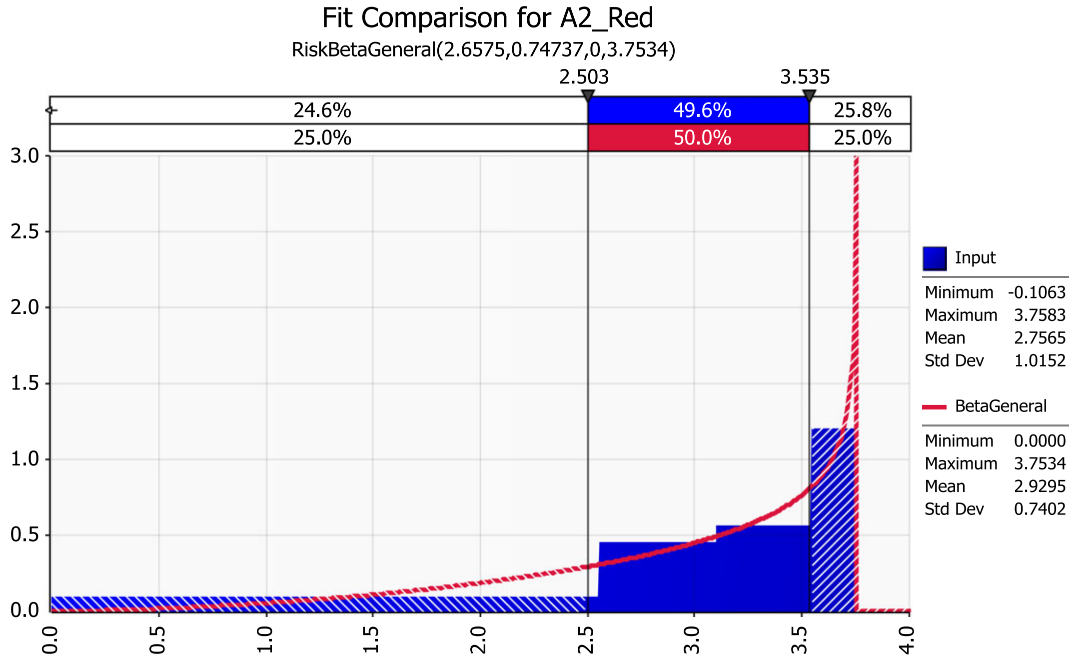

Figure D.17: Comparison of elicited (blue) and fitted (red) probability density for loss factor (A2_Red) of yield of infected pants under scenario 2

D.4. Results: Impact as loss in production

D.4.1. Baseline (A0)

Table D.22: Loss in Grape or wine production (A0_Loss in [tonnes] or [hL]) for different types of grape production under the baseline scenario

Percentile	Loss under the baseline scenario			
	All grapes	Quality wine	Other wines	Table grapes
[%]	[tonnes]	[hL]	[hL]	[tonnes]
1	0	1.2	0.1	0.00
5	15	69.6	9.7	0.09
10	88	408.8	67.1	0.60
15	251	1,172.3	217.4	1.84
20	543	2,572.5	517.0	4.14
25	1,001	4,793.7	1,033.5	7.95
50	8,131	40,561.3	11,226.3	76.08
75	41,625	216,567.4	73,128.5	454.10
80	59,104	310,308.6	108,939.3	668.43
85	87,412	462,783.9	168,548.2	1,018.94
90	138,687	743,152.9	280,458.2	1,679.92
95	259,286	1,416,149.8	559,471.5	3,321.96
99	729,300	4,053,865.0	1,768,313.0	10,170.81
Mean	**56,084**	**306,149.7**	**121,184.8**	**714.26**
SD	**165,609.54**	**965,244.4**	**423,929.2**	**2,369.80**

D.4.1.1. All grapes

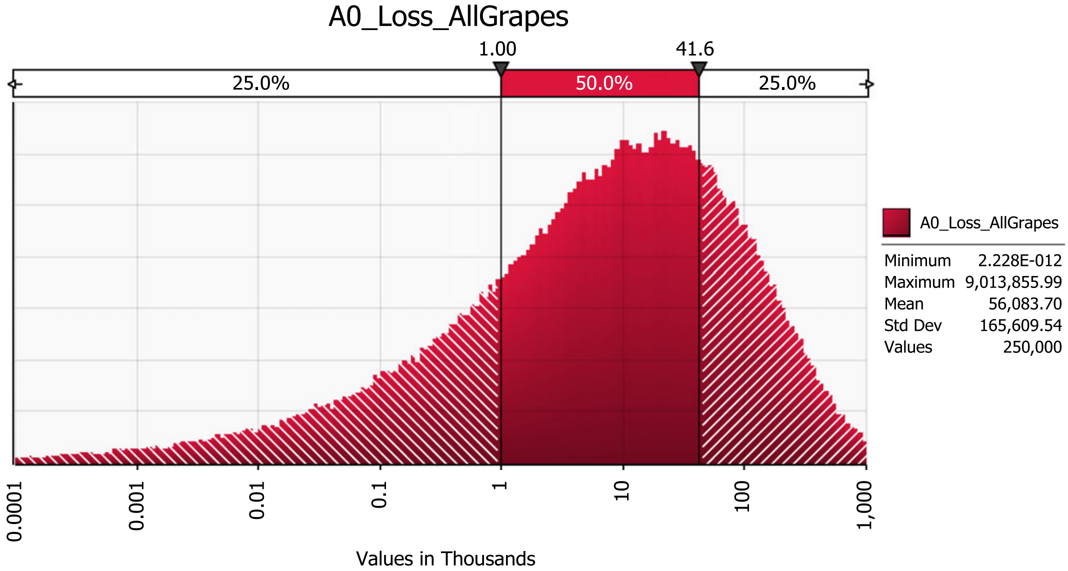

Figure D.18: Combined uncertainty of loss in all grape production (A0_Loss_AllGrapes in [tonnes], logarithmic scale) under the baseline scenario. In solid pattern is the uncertainty interval for the loss

D.4.1.2. Sensitivity analysis results

Table D.23: Sensitivity analysis of loss in all grape production (A0_Loss_AllGrapes) under the baseline scenario. The relative partition shows the contributions of each input factors to the total uncertainty of the loss

Rank	Input factor	SD regression coefficient	Partition of R^2 (absolute)	Partition of uncertainty (relative) (%)
#1	A0_Prop_inf	0.53	0.28	62
#2	Area_AllGrape	0.37	0.14	31
#3	Prod_AllGrapes	0.13	0.02	4
#4	A0_N_cont	0.10	0.01	2
#5	A0A1_Red	0.08	0.01	1
	Total	**R^2** =	**0.45**	**100**

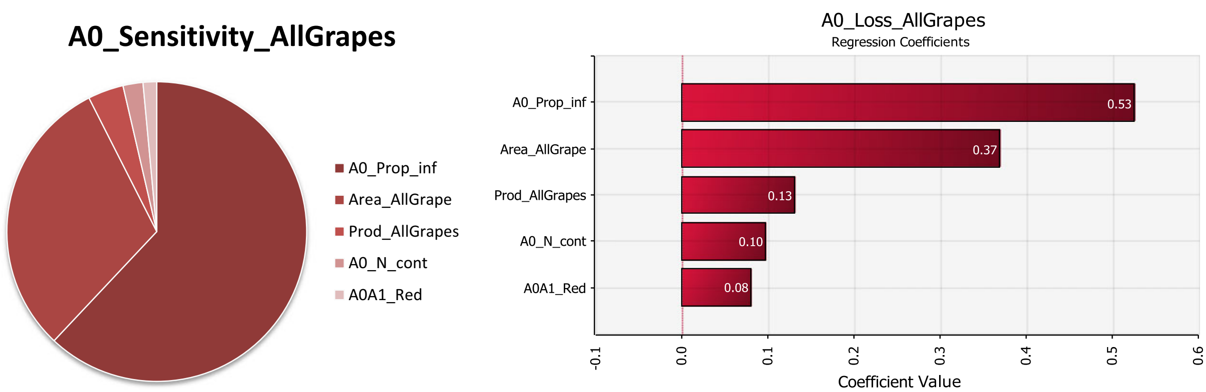

Figure D.19: Sensitivity analysis of loss in all grape production (A0_Loss_AllGrapes) under the baseline scenario. Left: Relative partition of the total uncertainty, right: Standardised regression coefficients of the input factors

D.4.2. Scenario 1 (A1)

Table D.24: Loss in Grape or wine production (A1_Loss in [tonnes] or [hL]) for different types of grape production under scenario 1

Percentile	Loss under scenario 1			
	All grapes	Quality wine	Other wines	Table grapes
[%]	[tonnes]	[hL]	[hL]	[tonnes]
1	0	0.4	0.0	0.00
5	6	29.7	4.3	0.04
10	42	194.3	31.9	0.29
15	128	604.7	108.9	0.93
20	288	1,370.8	271.2	2.21
25	546	2,612.7	557.2	4.36
50	4,904	24,496.1	6,720.9	45.83
75	26,431	136,889.3	45,975.9	285.42
80	37,885	197,858.9	68,952.7	421.87
85	56,090	296,561.1	107,266.1	649.42
90	88,921	476,087.9	181,140.6	1,064.81
95	167,651	912,136.1	363,387.4	2,108.20
99	482,630	2,636,010.9	1,129,191.6	6,599.28
Mean	**36,166**	**196,751.3**	**77,547.2**	**457.59**
SD	**107,968**	**627,809.0**	**267,419.6**	**1,595.42**

D.4.2.1. All grapes

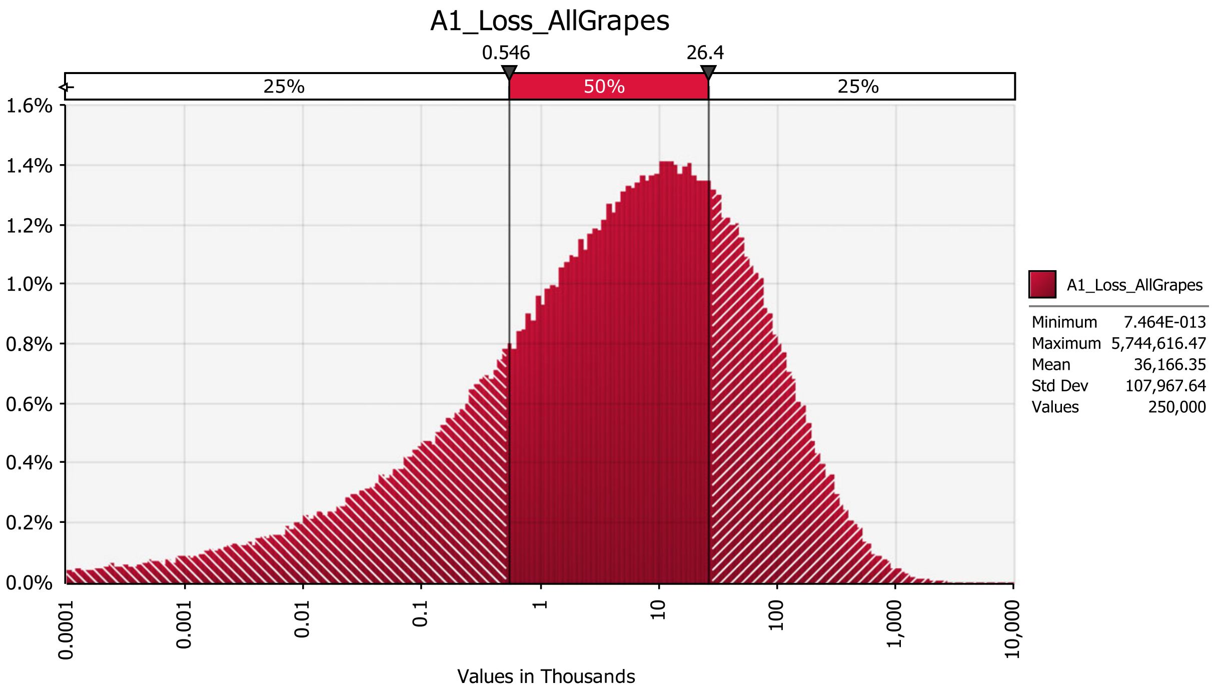

Figure D.20: Combined uncertainty of loss in all grape production (A1_Loss_AllGrapes in [tonnes], logarithmic scale) under scenario 1. In solid pattern is the uncertainty interval for the loss

D.4.2.2. Sensitivity analysis results

Table D.25: Sensitivity analysis of loss in all grape production (A1_Loss_AllGrapes) under scenario 1. The relative partition shows the contributions of each input factors to the total uncertainty of the loss

Rank	Input factor	SD regression coefficient	Partition of R^2 (absolute)	Partition of uncertainty (relative) (%)
#1	A1_Prop_inf	0.55	0.30	65
#2	Area_AllGrape	0.36	0.13	29
#3	Prod_AllGrapes	0.13	0.02	4
#4	A0A1_Red	0.08	0.01	1
#5	A1_N_cont	0.06	0.00	1
	Total	**R^2 =**	**0.45**	**100**

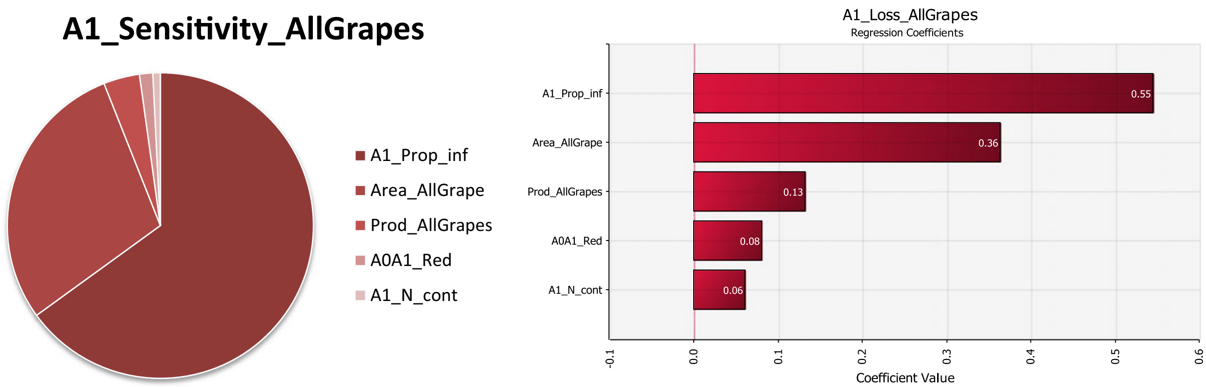

Figure D.21: Sensitivity analysis of loss in all grape production (A0_Loss_AllGrapes) under scenario 1. Left: Relative partition of the total uncertainty, right: Standardised regression coefficients of the input factors

D.4.3. Scenario 2 (A2)

Table D.26: Loss in Grape or wine production (A2_Loss in [tonnes] or [hL]) for different types of grape production under scenario 2

Percentile	Loss under scenario 2			
	All grapes	Quality wine	Other wines	Table grapes
[%]	[tonnes]	[hL]	[hL]	[tonnes]
1	0	0.0	0.0	0.00
5	1	5.8	0.9	0.01
10	11	51.0	8.8	0.08
15	38	183.7	34.1	0.28
20	95	455.4	91.2	0.74
25	196	947.7	202.4	1.56
50	2,234	11,161.8	3,020.1	20.48
75	13,936	71,608.4	23,748.2	148.21
80	20,551	105,983.6	36,415.1	225.70
85	31,334	162,560.1	58,179.3	355.57
90	51,300	269,676.7	99,959.1	608.67
95	99,406	539,170.2	210,072.0	1,249.75
99	298,042	1,640,495.1	697,108.8	4,078.79
Mean	**21,301**	**114,766.4**	**45,412.5**	**269.92**
SD	**68,750.52**	**392,847.1**	**178,898.3**	**989.60**

D.4.3.1. All grapes

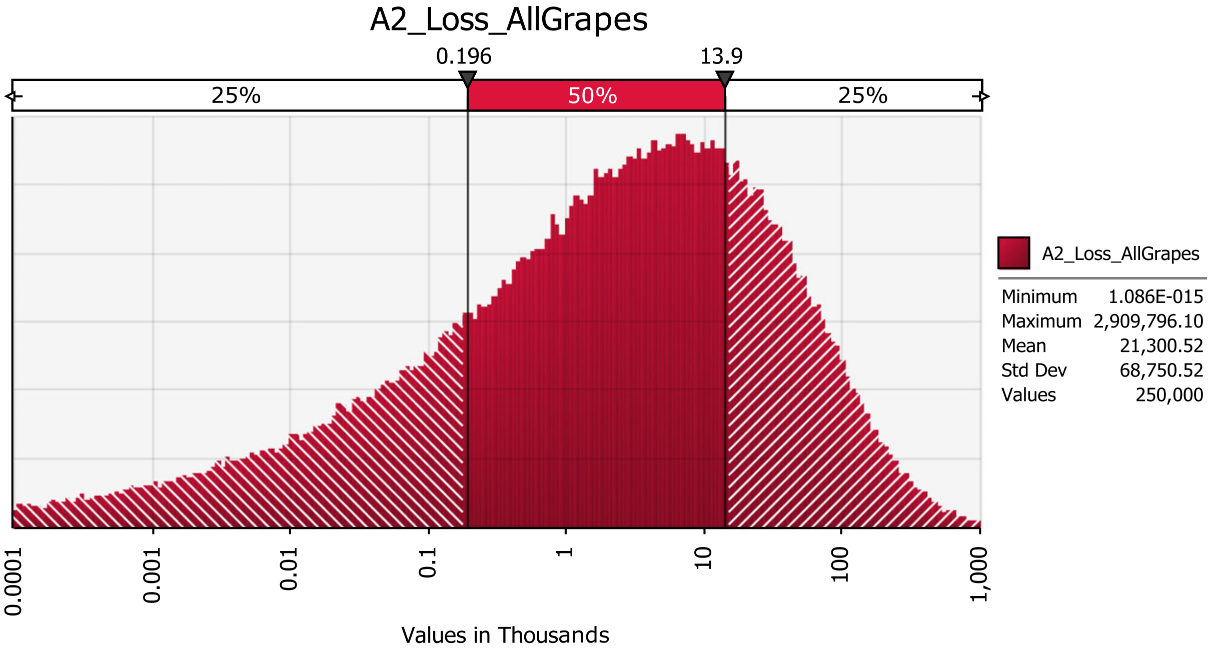

Figure D.22: Combined uncertainty of loss in all grape production (A2_Loss_AllGrapes in [tonnes], logarithmic scale) under scenario 2. In solid pattern is the uncertainty interval for the loss

D.4.3.2. Sensitivity analysis results

Table D.27: Sensitivity analysis of loss in all grape production (A2_Loss_AllGrapes) under scenario 2. The relative partition shows the contributions of each input factors to the total uncertainty of the loss

Rank	Input factor	SD regression coefficient	Partition of R^2 (absolute)	Partition of uncertainty (relative) (%)
#1	A2_Prop_inf	0.55	0.30	67
#2	Area_AllGrape	0.35	0.12	27
#3	Prod_AllGrapes	0.12	0.01	3
#4	A2_Red	0.08	0.01	1
#5	A2_N_cont	0.08	0.01	1
	Total	**R^2** =	**0.45**	**100**

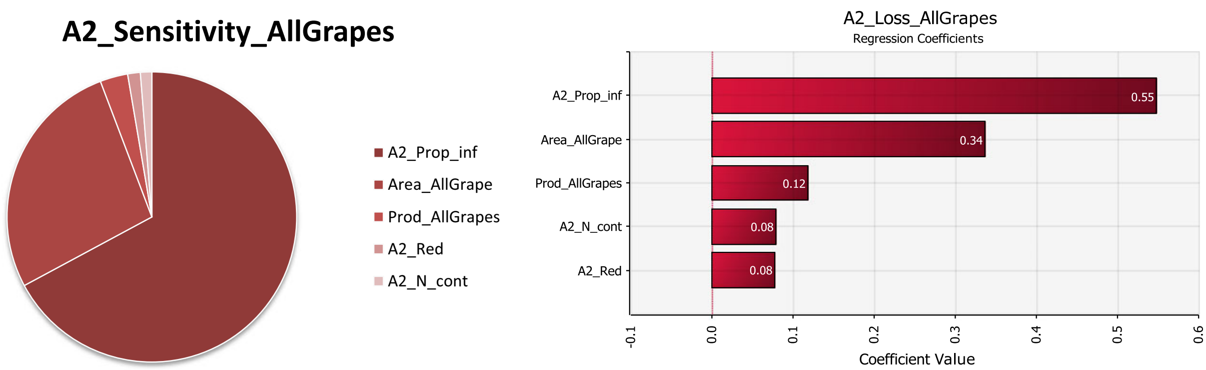

Figure D.23: Sensitivity analysis of loss in all grape production (A0_Loss_AllGrapes) under scenario 2. Left: Relative partition of the total uncertainty, right: Standardised regression coefficients of the input factors

D.4.3.3. Comparison of scenarios (A0–A2): All grapes

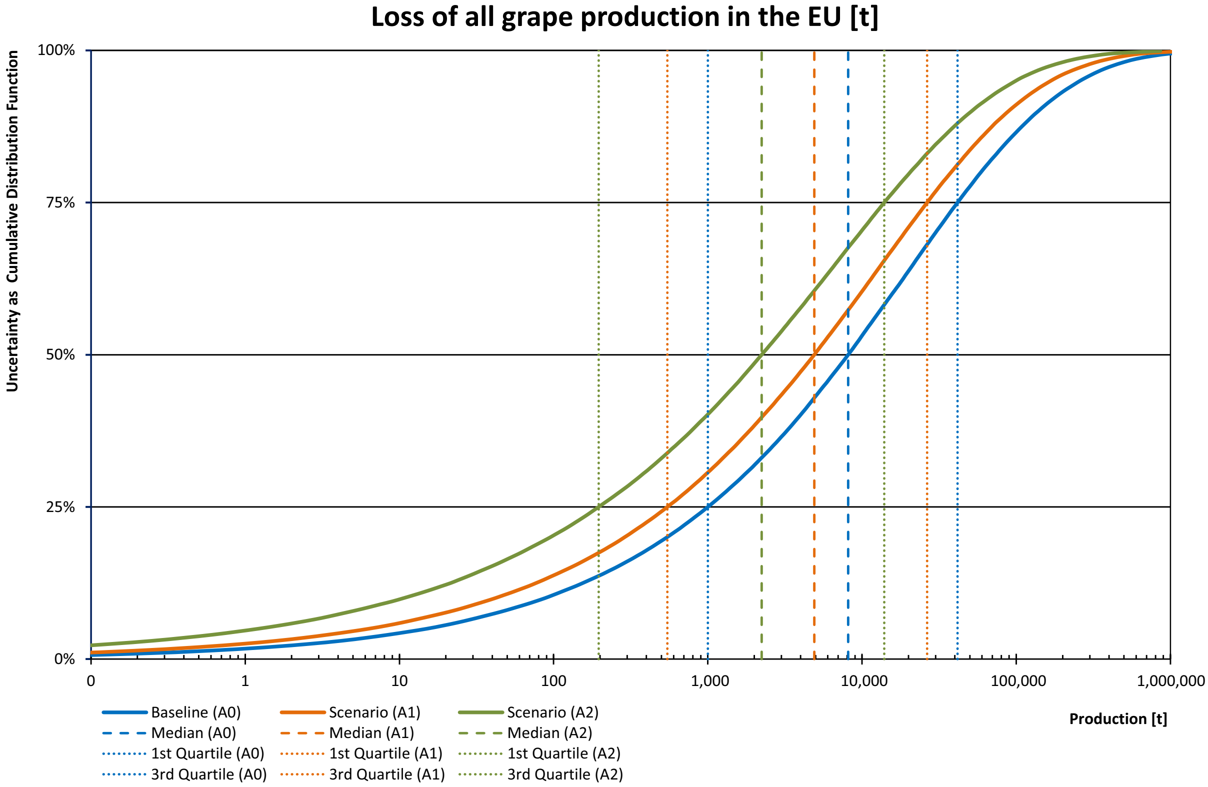

Figure D.24: Comparison of loss in grape production (Loss_AllGrapes in [tonnes], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the cumulative distribution function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

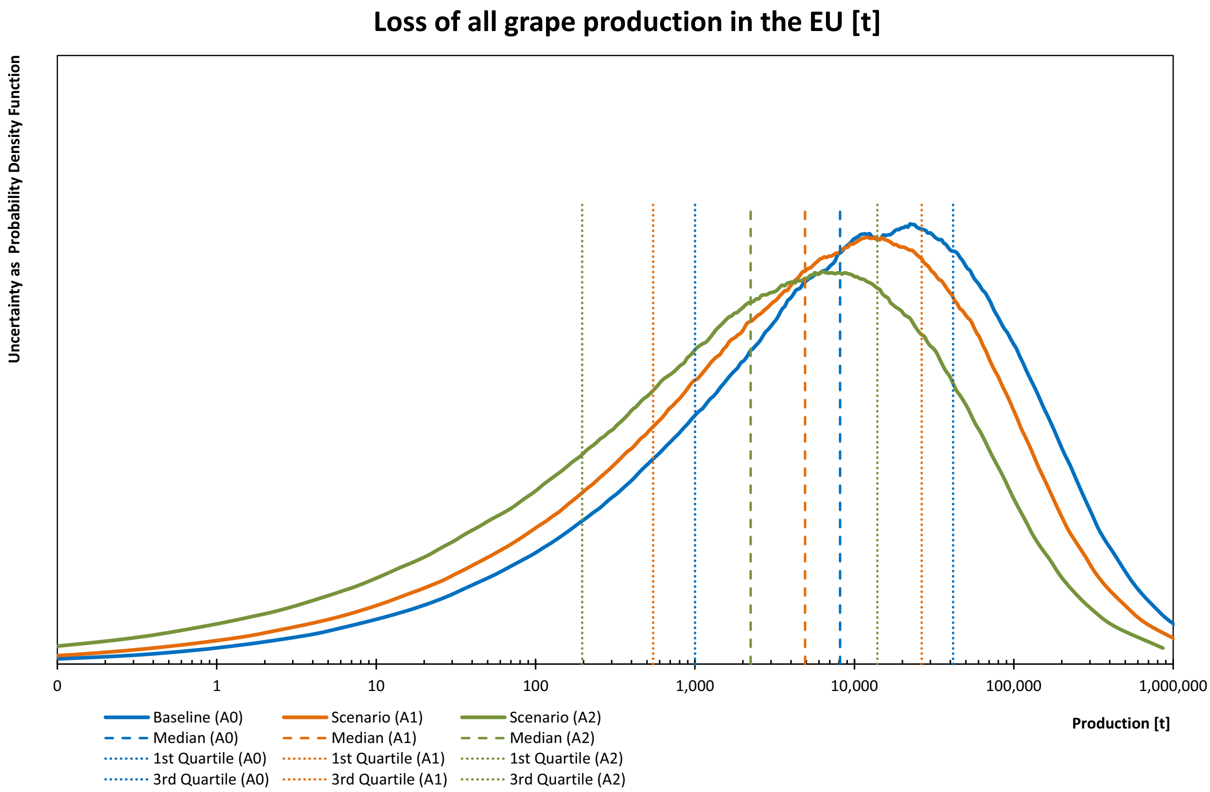

Figure D.25: Comparison of loss in grape production (Loss_AllGrapes in [tonnes], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the density function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

D.4.3.4. Comparison of scenarios (A0–A2): Quality wine

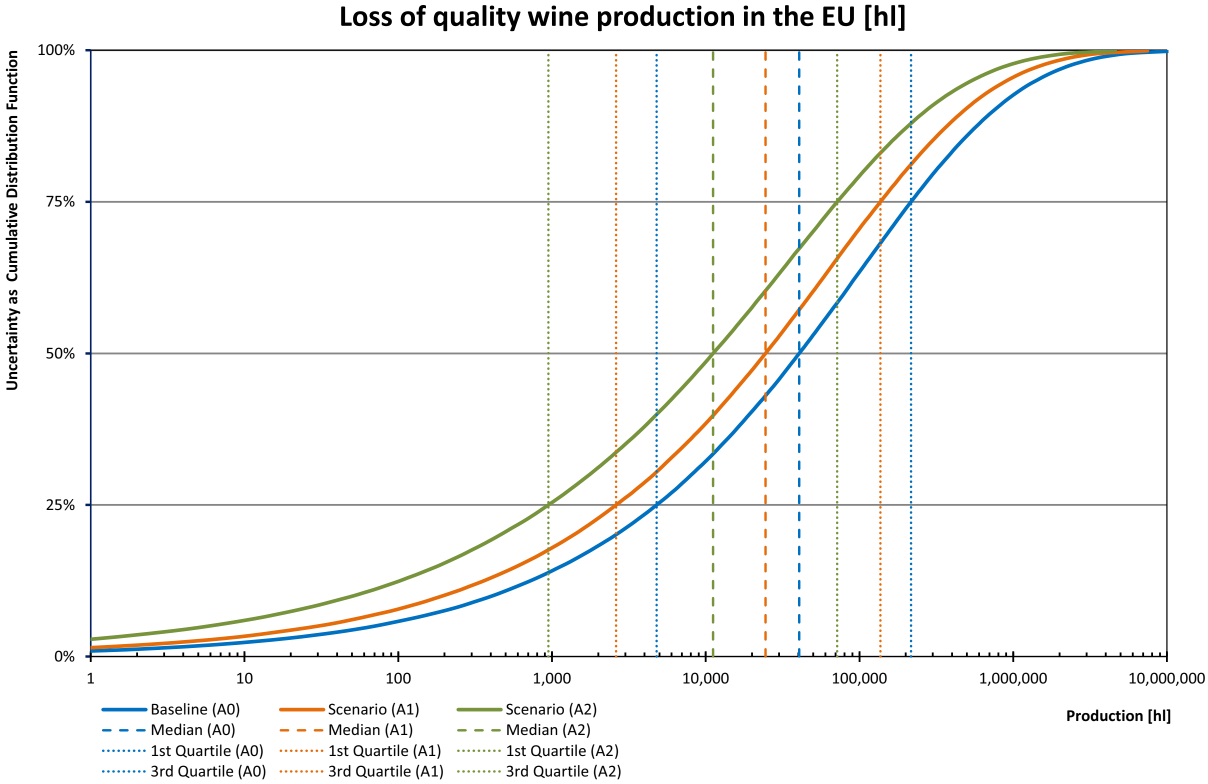

Figure D.26: Comparison of loss in grape production (Loss_QualityWine in [hL], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the cumulative distribution function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

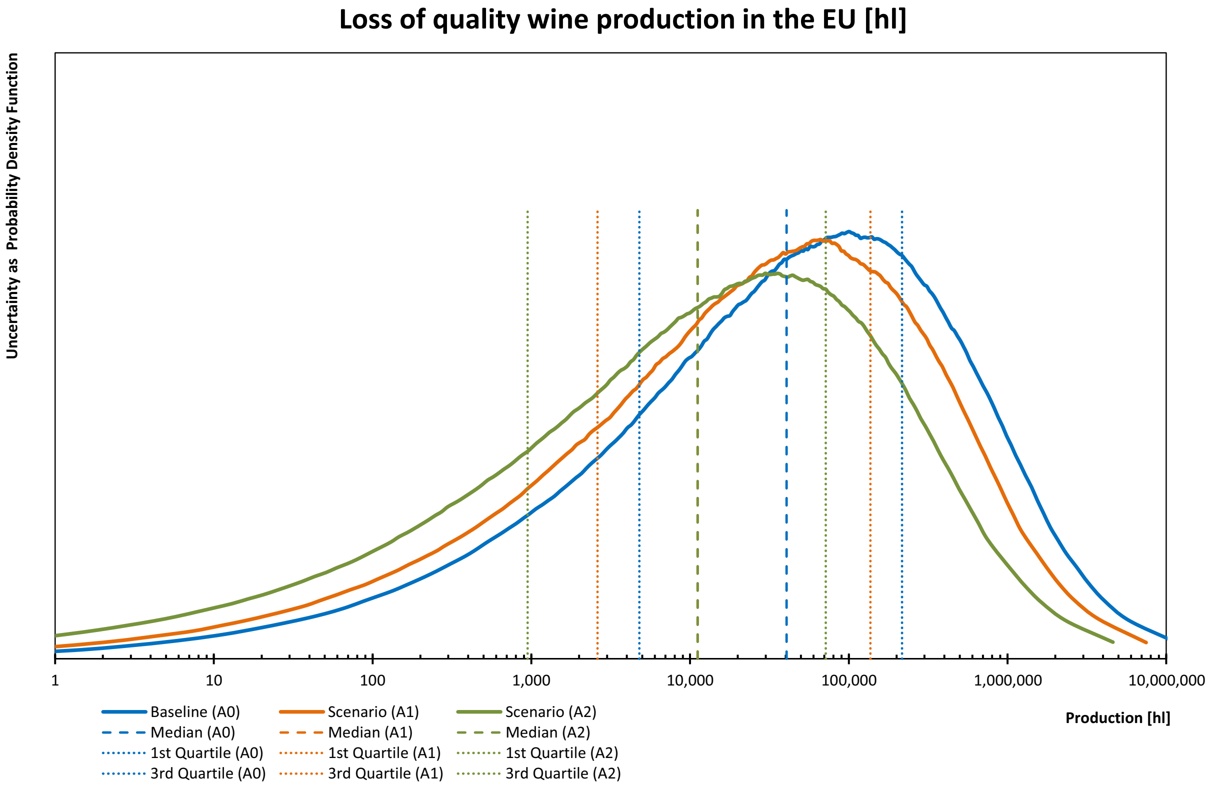

Figure D.27: Comparison of loss in grape production (Loss_QualityWine in [hL], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the density function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

D.4.3.5. Comparison of scenarios (A0–A2): Other wine

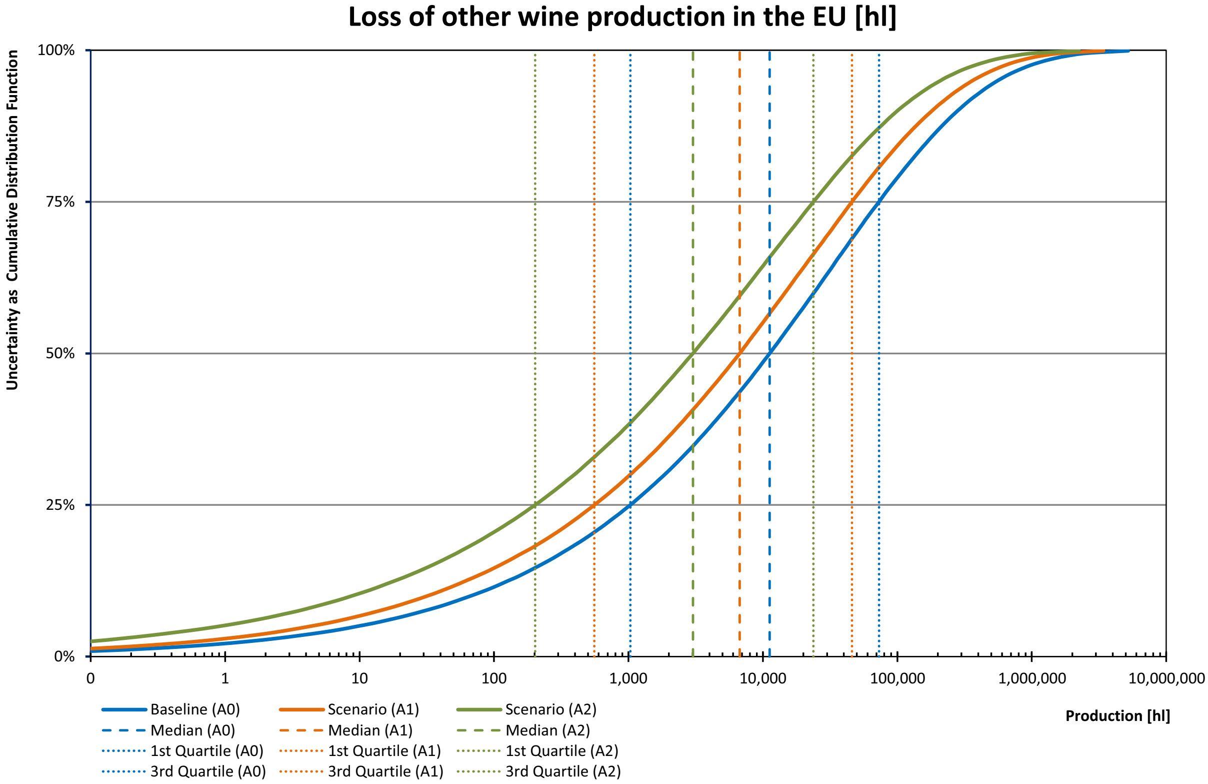

Figure D.28: Comparison of loss in grape production (Loss_OtherWine in [hL], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the cumulative distribution function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

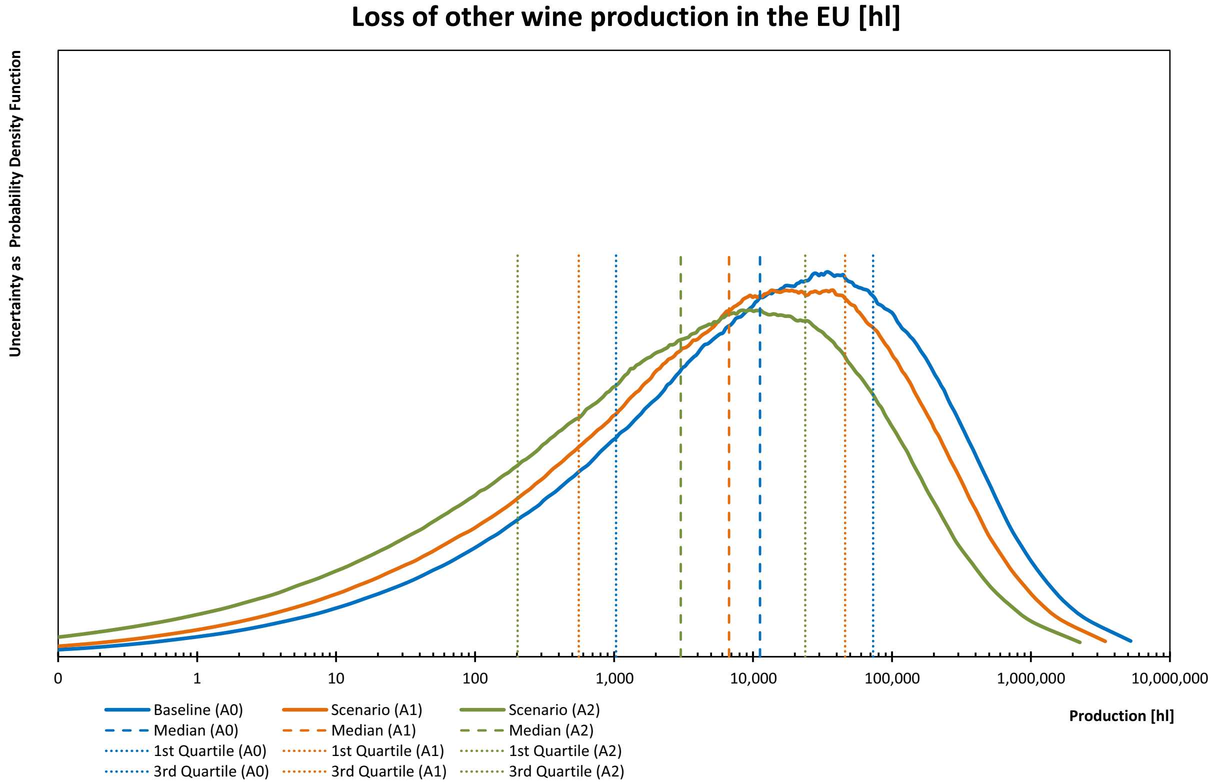

Figure D.29: Comparison of loss in grape production (Loss_QualityWine in [hL], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the density function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

D.4.3.6. Comparison of scenarios (A0–A2): Table grapes

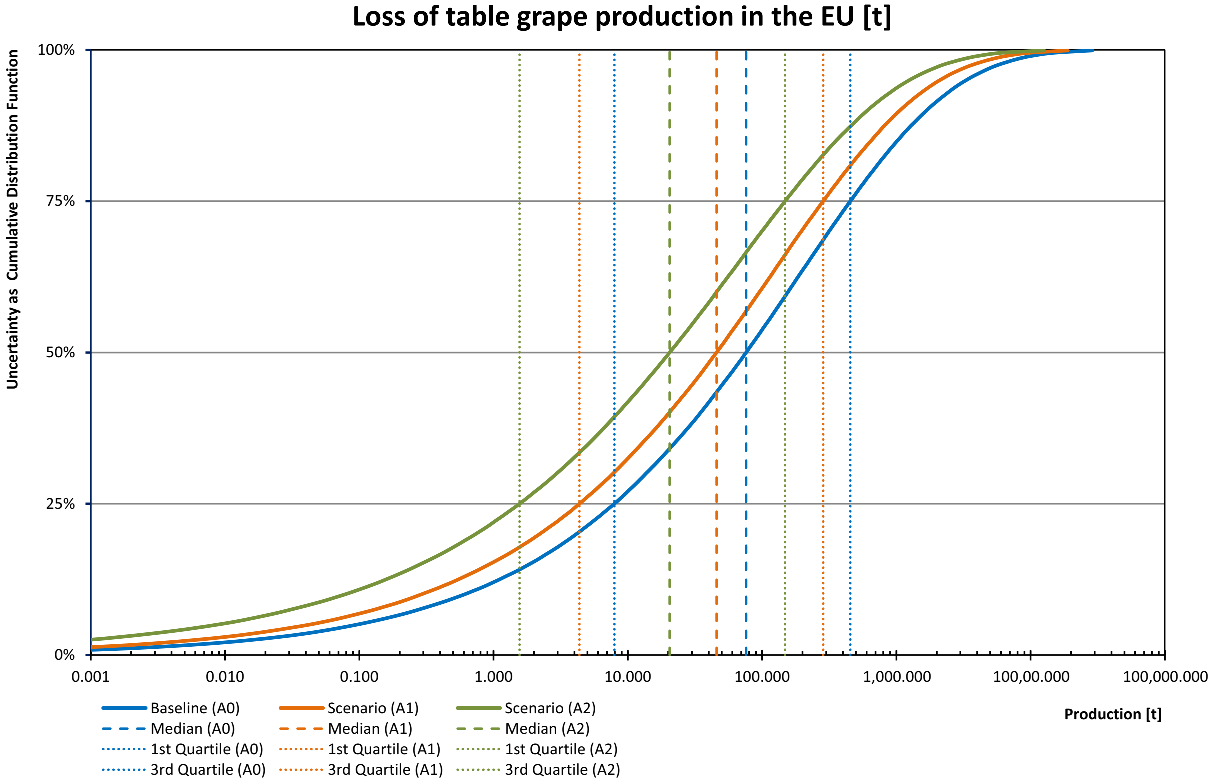

Figure D.30: Comparison of loss in table grape production (Loss_TableGrapes in [tonnes], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the cumulative distribution function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

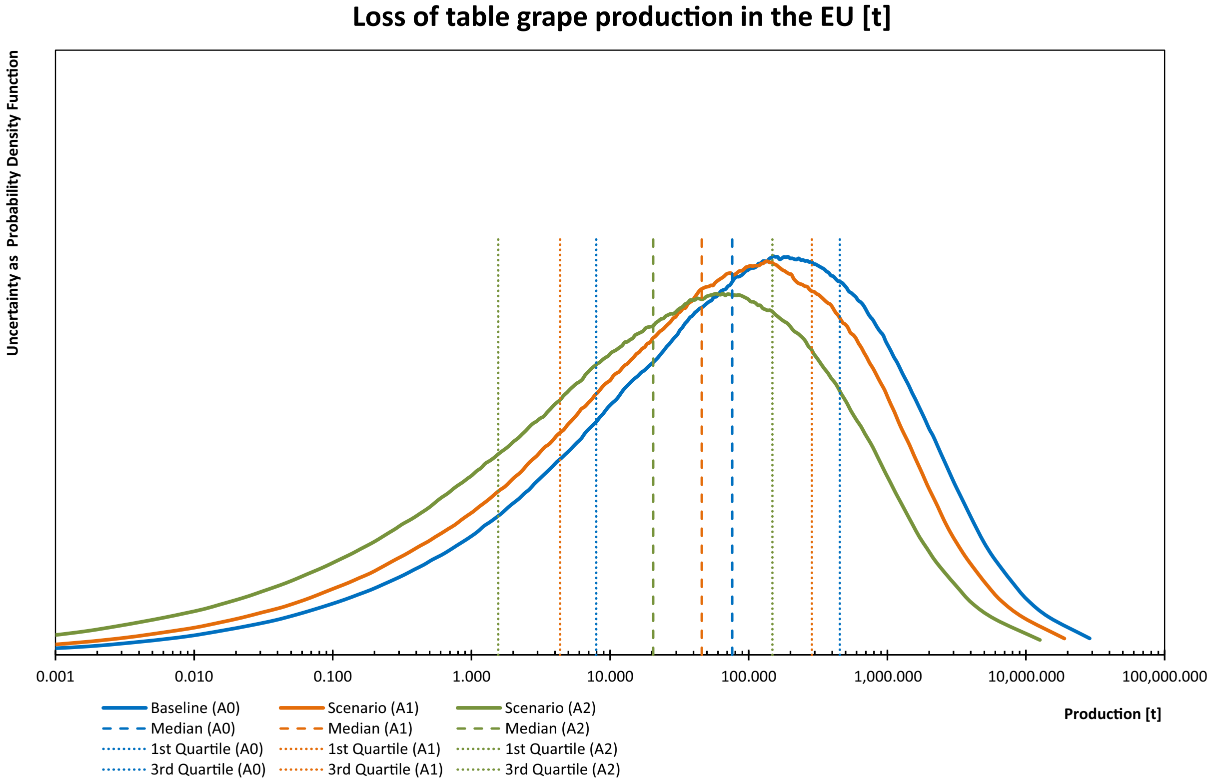

Figure D.31: Comparison of loss in grape production (Loss_QualityWine in [hL], logarithmic scale) for different scenarios: In blue is baseline, in red scenario 1 and in green scenario 2. Shown are the density function of the uncertainty (solid lines), the median (dashed lines) and the uncertainty ranges (dotted lines)

Appendix E – Detailed explanations for the ratings describing the probability distributions of the various parameters used in the model assessing the impact of FDp on wine and table grapes production under the different scenarios

This analysis takes into account five parameters:

1) the number of infested NUTS 2 regions at the 10-year time horizon as determined by the spread analysis (see Section 3.3);
2) the average area under grapevine production in NUTS 2 regions, expressed in hectares for table grapes or wine-producing grapes, for EU NUTS 2 regions with grape production;
3) the average abundance of FDp in wine and table grapes production in infested NUTS 2 regions, expressed as the percentage of infected plants;
4) the average grape yield in NUTS 2 regions, expressed in tonnes per hectare for table grapes and wine grapes, for EU NTS 2 regions with grape production;
5) a multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection.

In performing this analysis, the Panel considered that in the absence of *S. titanus*, no epidemic development is expected in grapevine and therefore FDp impact is expected to be minimal. However, it should be considered that from a historical perspective, establishment of *S. titanus* has always preceded the establishment of FDp by a few years, so that the *S. titanus* presence is not expected to be a limiting factor in the NUTS 2 regions corresponding to the output of the spread analysis.

E.1. Substep A: Estimation of the probability distribution of average wine and table grapes production area in individual NUTS 2 regions occupied by the pest

As explained in Appendix D, the distribution of the range of average wine and table grapes production outputs in the spatial units occupied by the pest as assessed in the spread step was obtained by fitting a curve to the actual production area data for all presently infested NUTS 2 regions. The distribution obtained is presented in the following table:

Table E.1: Probability distribution of average wine and table grapes production area in individual NUTS 2 regions occupied by the pest as assessed in the spread step

Overall assessment Percentile	Low (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	High (99%)
Values (A0, A1 and A2 scenarios)	285 ha	10,991 ha	28,631 ha	60,893 ha	225,013 ha

The uncertainties associated with this parameter are (i) the quality of the statistics used to provide the actual data, (ii) the use of current data as a proxy to the actual values at the 10-year time horizon and (iii) the process of fitting a distribution to the actual data in order to generate a continuous probability distribution (see Appendix D). Another level of uncertainty comes from the use of data from currently infested NUTS 2 regions as a proxy to data describing the infested NUTS 2 regions under the different scenarios at the 10-year time horizon, when the identity of these regions might actually vary between the different scenarios.

E.2. Substep B: Estimation of the uncertainty distribution of the average abundance of FDp in wine and table grapes production in NUTS 2 regions occupied by the pest as assessed in the spread step

Scenario A0: Below is a description of the reasoning that lead to the estimation of the various values describing the uncertainty distribution of pest abundance.

- Lower 1% probability bound: This was evaluated using the theoretical case of a recently NUTS infested 2 with a single infested plot containing a single infected plant. Given that a density of plantation of 4,000–8,000 plants/ha is expected to cover a wide range of EU agricultural situations, the overall infection level in this situation is estimated as being very close to zero. By extension, this value was used to represent the average infection level of all infested EU NUTS 2 under a best case scenario. For the sake of simplicity, instead of using an extremely low decimal value that might have conveyed a misleading image of precision, the Panel decided to use a zero value for the lower 1% probability bound.

- Upper 99% probability bound: This was evaluated by considering what appears to be, according to expert judgement, the situation of the EU NUTS 2 region with the highest FDp prevalence. Extrapolation of data available at a limited local scale provided an average prevalence of 0.8% infection for this NUTS 2. Extension of this current worst-case situation to represent the average situation of all infested EU NUTS 2 in 10 years was considered a suitable safety margin to provide an estimate of the upper 99% probability bound.
- Median: In order to estimate the median for average prevalence at the end of the 10 years horizon, expert judgement was elicited to identify NUTS 2 regions whose current situation might be considered as representative of the median EU situation 10 years from now. Two such regions were thus identified, for which available survey data puts prevalence at 0.04–0.05%. The average of these two values was considered as representative and used as the median.
- Lower and upper quartiles: Expert judgement was used to estimate the possible variation in surveys outcome for the two NUTS 2 regions used for median estimation. This provided a tentative prevalence interval (one to ten infected plants/ha with an estimated 7,000 plants/ha converting into 0.014–0.14% prevalence) estimated as having a 50% probability. As a safety precaution, this interval was then extended by rounding to the next lower or higher value, respectively. This 0.01–0.2% interval was used to define the quartiles for average prevalence in all infested EU NUTS 2 at the end of the 10 years horizon.

Scenario A1: Below is a description of the reasoning that lead to the estimation of the various values describing the uncertainty distribution of pest abundance.

- Lower 1% probability bound and upper 99% probability bounds: These values are considered to be similar between scenarios A0 and A1 because improvements brought about in the sanitary quality of grapevine propagative material in scenario A1 are not expected to affect the percentages of infection in best case (one infected plant in one plot of a newly infested NUTS 2) and worst-case (heavily infested NUTS 2) situations.
- Median and lower quartiles: A retrospective analysis of the spread mechanism responsible for the historical infection of European NUTS 2 regions (Appendix B) indicates that roughly one-third of novel outbreaks could originate from infected planting materials while the other two-thirds would represent spread by insect vectors. It was considered that the reinforced control measures of scenario A1 would virtually eliminate the outbreaks linked with planting materials, thus reducing by one-third the number of new outbreaks. The lower quartile and the median values for scenario A0 were therefore reduced by one-third to obtain the corresponding values under scenario A1.
- Upper quartile: A similar reasoning was used as for the lower quartile and median values but, taking into consideration the fact that the upper quartile represents a more degraded situation, a reduction factor of only one-fourth was applied to the corresponding value under scenario A0.

Scenario A2: Below is a description of the reasoning that lead to the estimation of the various values describing the uncertainty distribution of average pest abundance.

- Lower 1% probability bound: This value is considered to be similar between scenarios A0 and A2 because improvements in the containment and eradication efforts of scenario A2 are not expected to affect the percentage of infection in a best case situation (one infected plant in one plot of a newly infested NUTS 2).
- Lower quartile and median: It was considered that the reinforced containment and eradication measures in scenario A2 would virtually eliminate the outbreaks linked with natural spread by insect vectors, thus reducing by two-thirds the number of new outbreaks. The lower quartile and the median values for scenario A0 were therefore reduced by two-thirds to obtain the corresponding values under scenario A2.
- Upper quartile and upper 99% probability bounds: A similar reasoning was used as for the lower quartile and median values but, taking into consideration the fact that the upper quartile

and 99% upper bound represent more degraded or worst-case conditions, a reduction factor of only 50% was applied to the corresponding values under scenario A0.

Table E.2: Uncertainty distribution of the average abundance of FDp in wine and table grapes production in NUTS 2 regions occupied by the pest as assessed in the spread step

Overall assessment Percentile	Low (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	High (99%)
Scenario A0 – current control measures in place	0%	0.01%	0.045%	0.2%	0.8%
Scenario A1 – current control measures, with increased control of the propagative material	0%	0.007%	0.03%	0.15%	0.8%
Scenario A2 – current control measures, with increased local control aiming at containment or eradication	0%	0.003%	0.015%	0.1%	0.4%

E.2.1. Sources of uncertainty

Generally speaking, the estimation of the probability distribution of the average prevalence in all infested EU NUTS 2 at the end of the 10 years horizon faces many challenges. Besides the fact that it represents a prediction at a significant time interval, it should be stressed that there is no data available at such a high European-wide integration scale, so that the Panel had to rely on expert judgement and on assumptions/hypotheses whose accuracy is difficult to evaluate. It should be also stressed that the reasoning at the level of an average EU prevalence is largely foreign to the experts, who are used to reason on specific EU territories but not to such a wide scale integrated average covering highly divergent local situations (NUTS 2 regions with widely different grapevine acreage and infection prevalence). It is therefore difficult, even for experts, to think in terms of this highly integrated value, which may have affected the precision of their estimations.

List of assumptions made and considerations on their validity:

- For the median and the quartiles, the two NUTS 2 regions selected as being representative of the average EU situation 10 years from now might have been incorrectly identified.
- The validity of the strategy used to define the upper 99% bound, considering that the current worst NUTS 2 situation may become, with a 1% probability, the average EU situation, is clearly uncertain.
- The validity of the strategy used to define the lower and upper quartiles, based on the use of the expected variability of survey outcomes is similarly highly uncertain.

E.3. Substep C: Estimation of the probability distribution of the average grape production in individual NUTS 2 regions occupied by the pest as assessed in the spread step

As explained in Appendix D, the distribution of the range of average wine and table grapes production in the NUTS 2 regions occupied by the pest was obtained by fitting a curve to the actual production data for all presently infested NUTS 2 regions. The elicited quantiles are presented in the following table:

Table E.3: Probability distribution of the average grape production in individual NUTS 2 regions occupied by the pest as assessed in the spread step

Overall assessment Percentile	Low (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	High (99%)
Values (A0, A1 and A2 scenarios)	2.6 tonnes/ha	5 tonnes/ha	6.5 tonnes/ha	8.4 tonnes/ha	15.7 tonnes/ha

The uncertainties affecting this parameter are those associated with (i) the quality of the statistics used to provide the actual data, (ii) the use of current data as a proxy to the actual values at the 10-year time horizon and (iii) the process of fitting a distribution to the actual data in order to generate a continuous uncertainty distribution (see Appendix D). Another level of uncertainty comes from the use of data from currently infested NUTS 2 regions as a proxy to data describing the infested

NUTS 2 regions under the different scenarios at the 10-year time horizon, when the identity of these regions might actually vary between the different scenarios.

E.4. Substep D: Estimation of the uncertainty distribution of the multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection

It should be stressed that the present assessment was made taking into account the current legislation with (A1 and A2 scenarios) or without (A0 scenario) additional control measures. The removal of infected plants upon their discovery was therefore considered the rule. The potential effect of the recovery phenomenon, in which after an initial crisis grapevines may recover and return to productivity, was therefore not taken into account for the estimation of the multiplication factor.

In addition, the Panel considered that when plants are uprooted, even if new grapevines are replanted immediately, the new plants will not enter production for 2–3 years. Thus, in a worst-case situation, production would be completely lost for 3 years (loss of 1 year of production of the uprooted plants plus loss of the two-first years of production of the replants) and partially lost during the fourth year (limited production of the replants). The multiplication factor was therefore calculated so as to integrate this multiyear production loss.

Lastly, currently used control measures involve the complete removal of plots with more than 20% infection, resulting in the additional loss of the production of healthy plants in such plots. This element was also integrated in the calculation of the multiplication factor.

Below is a description of the way the various values describing the uncertainty distribution of the multiplication factor changing production outputs as a consequence of pest impact were estimated.

Scenario A0:

Lower 1% probability bound: The lowest impact situation concerns a recently infected plant, which may not show production reduction if infection occurs late in the growing season. Any damage that may occur in this plant in the following years as a consequence of infection development is considered by the Panel to be part of the damage assessment in those ensuing years. Taking into account this extreme, no impact situation, the Panel considered a zero multiplication factor (no yield loss) a representing an appropriate evaluation of the lower 1% probability bound.

Upper 99% probability bound: In a worst-case scenario, FDp kills grapevine plants (Credi, 1989; Pavan et al., 2012b), resulting in complete production loss. In addition, current control measures involve the complete removal of plots with more than 20% infection, resulting in more than 100% loss/infected plant since the production of healthy plants in such plots is also lost. Expert judgement was used to estimate a worst-case scenario of 5% of plots showing more than 20% infection, resulting in a calculated average loss of 120% of the production of infected plants. This represents the weighted average from 95% of infected plant with 100% loss and 5% of infected plants with 500% loss because they are in plots with 20% infection (and therefore the production of four healthy plants is additionally lost for each infected plant through the removal of the complete plot).

In addition when plants are uprooted, and even if new grapevines are replanted immediately, the new plants will not enter production for 2–3 years. Thus, in a worst-case situation, production would be completely lost for 3 years (loss of 1 year of production of the uprooted plants plus loss of the two-first years of production of the replants) and partially lost during the fourth year (limited production of the replants evaluated as 25% of the normal yield). Taking these various elements into consideration, the cumulated loss per infected plant is estimated at 450% of yearly production (120% $\times$ 3.75) or a multiplication factor of 4.5.

Median (interquartile ranges are given in parentheses): Expert judgement estimated median loss of an infected grapevine at 60% (quartiles 30–80%) on the year of infection (Credi, 1989 as cited in Chuche and Thiéry, 2014). Replant production loss is estimated as 100% for the first 2 years and 50% (quartiles 25–75%) on the third year. This gives an overall cumulated 310% loss of yearly production per infected plant (quartiles 255–355%). In the median situation, expert judgement estimated that the number of plots showing more that 20% infection would be very low (1% or less). The impact of the removal of such plots is therefore negligible and was not integrated in the calculation of the median loss multiplication factor or, for the same reason, in that of the quartile multiplication factors. The median multiplication factor was therefore estimated at 3.1.

Lower and upper quartiles: These were calculated using the corresponding lower or upper quartile of the individual parameters, yielding values of 2.55 and 3.55 for the multiplication factors for the lower and upper probability quartiles, respectively.

Scenario A1: According to expert judgement, the distribution of the multiplication factor is not expected to be different between scenarios A0 and A1, because the production losses of individual infected plants are not likely to be modified by the re-inforced control measures.

Scenario A2: The distribution of the multiplication factor is analysed as being only marginally affected under scenario A2 as opposed to A0. However, due to the reinforced containment and eradication measures, the 20% infection thresholds for the removal of complete plots is not expected to be reached, so that this term was removed from the computation of the multiplication factor under a worst case 99% probability bound, giving a value of only 3.75 instead of 4.5.

Table E.4: Uncertainty distribution of the multiplication factor providing an estimation of the loss of production of individual grapevines as a consequence of FDp infection

Overall assessment Percentile	Low (1%)	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	High (99%)
Scenario A0 – current control measures in place	0	2.55	3.1	3.55	4.5
Scenario A1 – current control measures, with increased control of the propagative material	0	2.55	3.1	3.55	4.5
Scenario A2 – current control measures, with increased local control aiming at containment or eradication	0	2.55	3.1	3.55	3.75

E.4.1. Sources of uncertainty

The main sources of uncertainty affecting the estimation of the probability distribution of the multiplication factor changing the production of infected plants concern:

- The estimation of the average loss of production on the year of infection. Although some data exist for individual grapevine varieties, the multiplication factor should be viewed as a weighted average taking into consideration all wine or table grape varieties and their respective acreage, an extrapolation and integration of data that is by essence complex and that adds to the uncertainty.
- The estimation of the time needed on average for replants to enter their production phase and the reduction in yield observed on their first year of production.
- The impact of the recovery phenomenon on yield losses as not all infected grapevines may be detected and pulled out, leaving the possibility that some of these plants may then recover from infection.
- The strategy used by the Panel to take into account the multiyear nature of yield loss in a perennial crop which takes several years to reach its productive phase.