ACRP

Final Report – Activity Report

Program control:
Climate and Energy Fund
Program management:
Kommunalkredit Public Consulting GmbH (KPC)

1 Project Data

Short title	VitisClim	
Full title	Modelling epidemiological and economic consequences of Grapevine Flavescence dorée phytoplasma to Austrian viticulture under a climate change scenario	
Project number	B060361	
Program/Program line	ACRP 2nd Call for Proposals	
Applicant	Austrian Agency for Health and Food Safety GesmbH (AGES) Business Area Agriculture: Institute of Plant Health Project leader: Robert Steffek	
Project partners	AGES – Business Area Data, Statistics, Risk Assessment Styrian Government, Department 10B (P1) Styrian Chamber of Agriculture, Department of wine (P2) Economica, Institute of Economic Research (P3)	
Project start and duration	Project start: 01.04.2011	Duration: 24 months
Reporting period	from 01.04.2011 to 31.03.2013	

Synopsis: Climate warming allows invasive plant pests to establish in areas where they have not been known before. Grapevine Flavescence dorée (GFD), a quarantine disease of grapes was first found in the 1950's in South France, from where it spread significantly north- and eastward. In 2009 it was detected in the southeast of Styria. The assessed the potential distribution of GFD in Europe considering climate change and developed models to simulate (1) the spread and (2) the economic impact of GFD in Austria. Model input parameters were gained through a thorough literature search and field surveys. The models were calibrated by using spread data of the disease from two recent outbreaks in Austria. The effect of different pest management strategies was tested and discussed with key-stakeholders in an on-going process throughout the project.

Content

2 Technical /Scientific Description of the Project

2.1. Project abstract (max. 2 pages)

2.1.1 Brief project description (initial situation, target, methodology–activities)

Grapevine Flavescence dorée (GFD) is a severe grapevine yellows disease caused by GFD phytoplasma (*Candidatus* Phytoplasma vitis), which is transmitted by its principal vector, the Nearctic leafhopper *Scaphoideus titanus*. The vector was first reported in Europe in the late 1950s in vineyards of South-west France, from where it spread the disease progressively in many Mediterranean countries. Since the late 1990ies it is extending the northern border of its range. It is expected that the vectors northern distribution is limited by climate. During short summers insects have difficulties to complete their development and may therefore only form transient populations. *S. titanus* completes its life cycle on grapevines. In a vineyard adults are extremely mobile and thus responsible for the epidemic spread of GFD: the incidence in vineyards may reach up to 95% affected vines. GFD affects the vigour, the yield and the quality of grapevine and is therefore of high economic impact. The year after the warm summer of 2003, *S. titanus* was found for the first time in Austrian vineyards (southeast of Bad Radkersburg); since then it has spread and is now established in parts of Styria. In autumn 2009 GFD was detected for the first time in Austria in southeast Styria.
As GFD is a new invasive disease in Austria and control experience is limited, the project targets to provide scientific evidence for the control of GFD and its vector. In consecutive work packages the project aims (1) to determine the current and future potential distribution of the disease and its vector in Europe (2) to provide datasets for the modelling of the spread of GFD and its economic impact, (3) to develop a spread model which allows to test the effect of different pest management options; (4) to apply Input-Output analysis to assess the potential economic impact and (5) to communicate the results to stakeholders, decision makers and the public. Model input parameters were gained through literature survey and field experiments. Moreover, specific statistical data from the region were available.

2.1.2 Results and conclusions of the project

The potential distribution of *S. titanus* in Europe was modeled by using the Compare Locations mode of the CLIMEX® software. Growth indices were inferred from the vectors' main distribution area in the east of North America and physiological data from the scientific literature. Stress indices were adjusted to model its limited distribution in the west of the USA. The CLIMEX® model adequately displays European regions of high vector abundance (e.g. in France, Italy). Vine growing regions in in Austria, the Czech Republic, Germany, Hungary, Slovakia, Romania and Bulgaria which are not yet invaded, provide good climatic conditions for the establishment of *S. titanus*. The CLIMEX® model clearly shows that a prolonged summer would facilitate vector establishment and the development of stable populations there. However, the establishment potential of *S. titanus* exceeds the area where vine is grown in Central Europe. Further spread to the north is therefore rather limited by host distribution (*Vitis* sp.) than by climate. The risk of substantial vector spread in South-Europe is low, as conditions of dry stress in many areas limit its establishment.

A stochastic Monte-Carlo simulation model was implemented, in order to assess the efficiency of different intervention strategies. The model simulates the spread of the disease, and of its vector, and incorporates different parameters (geography, intensity of initial infestation, intensity of applied intervention strategies etc.). The simulations are run for different model domains: the municipalities of (1) Tieschen in South-Eastern Styria and (2) Glanz an der Weinstraße in Southern Styria. These municipalities are typical for their region and differ in the abundance of wild arbours, the average acreage of vineyards and the presence of organic vineyards. The model results confirm the importance of scenario-adapted pest control and of the early detection of GFD. It shows the potential of uncontrolled arbours with high vector population densities to act as disease reservoirs and thereby having a significant role in the spread of the disease.

For a macroeconomic impact analysis the most appropriate method is input-output analysis (IOA). In the the project we used a multi-regional IOA to determine the economic impact of GFD in South-East Styria based on a multiregional input-output table. Based on the existing data and the results of the spread model all in all eight scenarios were calculated to show specific economic impact of selected intervention scenarios as reaction to given infestation scenarios. The potential losses calculated vary from zero (scenarios 2, 4, 6, 8) to more than 5 Mio Euro (scenario 3 and 7). In addition we see a positive economic impact in terms of value added based on the control costs for each of the scenarios.

2.1.3 Outlook and summary

Early springs and an extended growing season is an effect of climate change that influences the survival potential of a poikilothermic species. *S. titanus* has a long developing period of 5 larval instars and completes its life-cycle as adult laying eggs in 2 year old canes. Climate change with longer and warmer summers would allow the vector of this quarantine disease to establish high population densities in vine growing areas where it is currently not known.

The project developed a scientific basis to understand the different factors involved in the local spread of the disease in a vine growing area. It incorporates topographic conditions and thereby allows to decide in each outbreak-case on the best specific risk reduction option, both with respect to its efficacy on the spread of GFD and on its cost-effectiveness. The main factors are the initial disease and pest infestation, the occurrence of arbours and hedges as disease and vector reservoir and the applied pest control measures. Based on these three risk factors, following conclusions can be derived:

(I) an intensive monitoring program and a rising public awareness increase the chance of early detection of GFD outbreaks and occurrence of *S.titanus*,
(II) regular testing of latent infections in arbours and hedges reduce the risk of a fast increase of the infested vector population,
(III) vector control strategies should be based on larvae monitoring and control and the monitoring should include arbours and hedges in areas where they are abundant;

(IV) applying of a scenario specific pest control option with respect to its efficacy on the spread of the disease and on its cost-effectiveness

Both the spread and the economic impact models are generic and can be adopted for the use in other Austrian and European wine growing areas in the future. The results of the spread model are directly used by risk managers as they serve as a scientific basis for the case sensitive selection of obligatory pest management decisions to eradicate or contain outbreaks of GFD. The results of the project are also risk information sources for stakeholders, authorities and political decision makers. This should lead to reinforce the development of preventive measurements and to encourage the regional integration of harmonized control strategies derived from national and international coordination activities.

2.2. Contents and results of the project (max. 20 pages)

2.2.1 Initial situation / motivation for the project

Grapevine Flavescence dorée (GFD) is a severe grapevine yellows disease caused by GFD phytoplasma (*Candidatus* Phytoplasma vitis), which is of quarantine concern in Europe. Hence, measures to reduce the risk of further spread are obligatory applied within the EU. It is transmitted by its principal vector, the leafhopper *Scaphoideus titanus*, which was introduced from North America and reported for the first time in Europe in the late 1950s in vineyards of South-west France (Schvester et.al, 1963). Since then the disease and the vector have spread extensively in the Mediterranean climate. However, *S. titanus* is progressively extending the northern border of its range too: in France it has settled in Burgundy and Savoie (Herlemont, 2002; Boudon-Padieu, 2003), it is present in Switzerland, where it spread from canton Ticino to Vaud and Geneva (Schaerer et al., 2007), Austria (Zeisner, 2005) and Hungary where it was first found in the southern comitats Bacs-Kiskun, Somogy and Zala (Der et al., 2007), but spread up to the northeastern wine growing comitat Szabolcs-Szatmár-Bereg (Orosz and Zsolnai, 2010). As *S. titanus* requires warm summer temperatures to complete its life-cycle it is expected that its northern distribution is limited by climate (Boudon-Padieu, 2000): short summers may represent a barrier to the leafhoppers' further spread, since insects have difficulties to complete their development and may therefore only form transient populations. Climate change with longer and warmer summers would consequently favour the spreading of S. titanus further to the north by extending the favourable developing season (Boudon-Padieu and Maixner 2007).

S. titanus completes its life cycle on grapevines. In a vineyard adults are extremely mobile and thus responsible for the epidemic spread of GFD (Boudon-Padieu, 2000). It appears incapable to move actively from its host plant (Lessio and Alma 2004 a,b; 2006), long distance spread is assumed to be either by eggs in infested plants for planting or by wind drift (Torres et al., 2003; Maixner, 2005; Zeisner 2009). Depending on the variety, GFD affects the vigour, the yield and the quality of grapevine. The disease is of high economic impact. In France, Corsica, parts of Italy and Serbia GFD has destroyed large vine growing areas. The disease is still progressing in spite of mandatory uprooting of diseased grape-vines and compulsory insecticide control of the vector (Smith et al., 1997). Since its first introduction in Austrian vineyards in 2004 the vector of GFD has spread and is now established in parts of Styria (Zeisner, 2009). In autumn 2009 GFD was detected for the first time in Austria (Reisenzein and Steffek, 2011). Local outbreaks are under eradication.

2.2.2 Objectives of the project

The objectives of the project are to:

(1) assess the potential current and future distribution of the disease in Europe considering climate change and to define vine growing areas of high risk (WP1)

(2) provide data for modelling spread of GFD and its economic impact (WP2)

(3) develop a stochastic spread model to simulate the temporal and spatial spread dynamics of GFD and its vector in a vine growing area (WP3)
(4) assess the potential economic impact of GFD to Austrian viticulture as a function of different pest management options (WP4)
(5) communicate project results to stakeholders, decision makers and the public (WP5).

2.2.3 Activities performed within the framework of the project, including methods employed; description of the results and project milestones (on WP basis)

Below for each WP an introduction followed by the description of the methods applied and the results is given. More detailed information on the results of the WP can be retrieved in the Annexes 1-6.

2.2.3.1 WP 1: Risk mapping (Milestones 1-3)

2.2.3.1.1. Introduction and methods applied (WP1):

The ultimate geographic distribution of a poikilothermic species like e.g. an insect is determined by its climatic requirements for establishment and development (Krebs, 1978; Sutherst et al. 2004). From the geographical range, phenology and relative abundance of a species, its climatic requirements can be inferred. We applied the modelling software CLIMEX®, which is commonly used in pest risk assessments to estimate the potential distribution and relative abundance of a species in a given area (Watt et.al, 2009, Poutsma, et al., 2008; Desprez-Loustau et al., 2007). It is based on the assumption that all non-climatic constrains are absent (Sutherst and Maywald 1985). CLIMEX® uses an annual growth index (GI) and four stress indices (cold, dry, hot, wet) to calculate an index of climatic suitability, the ecoclimatic index (EI), scaled from 0 (no growth) to 100 (optimal growth).

The EI indicates the overall suitability of a given location for the establishment of a specific species. EI values of 20 and above are considered favorable for population persistence, while values below 10 indicate locations of marginal suitability (Sutherst et al. 2004).
CLIMEX® parameters were estimated via inference from climate data of locations where *S. titanus* is native (North America) or has been introduced (areas in Europe). Moreover, physiological data of *S. titanus* from the scientific literature was used. Therefore, the scientific literature and databases were reviewed with regard to the distribution of *S. titanus* and GFD. Information about the current status of occurrence of GFD and *S. titanus* in North America and Europe was compiled in tables and in maps using ArcGIS (see Annex 1). These maps were further used for comparison with the modeled distribution of *S. titanus*.

2.2.3.1.2. Specification of CLIMEX® indices of S. titanus (M1)

CLIMEX® Growth indices
Temperature index: The temperature parameters DVO, DV1, DV2 and DV3 define the temperature range that is suitable for population growth and development.

DV0 is the limiting low temperature at or below which no population growth takes place. DV0 was set to 8°C. This value allows growth of *S. titanus* in the southern regions of Canada (from New Brunswick to Saskatchewan). The minimum average temperature in Fredericton, New Brunswick in June of 8.9°C was used as a reference where *S. titanus* is known to occur (Source: http://mappedplanet.com). With a DV0 of 8°C, *S. titanus* has a limited distribution northwards in Canada and only a local distribution in West-Canada (Alberta), where it is not reported to occur. Laboratory studies on the larval development of *S. titanus* have shown that the optimal temperature with the fastest development of embryo and larvae and the lowest mortality is 24°C (Privet et al., 2007). In France, first-instar nymph start to hatch in the middle of May and population growth rate is maximized in June. DV1 and DV2 are the lower and upper optimum temperatures, which were set to 20°C and 27°C, respectively. DV3 is the limiting high temperature for population growth. *S. titanus* is established in Catalonia and Valencia (Batlle et al. 1997; Rahola et al. 1997) but is absent in the center of Spain (Castile-La Mancha), where the summers are hot and dry. DV3 was inferred from the prevailing temperature in this region. In Toledo, the capital of Castile–La Mancha, the average daily maximum temperature in July is 32.4°C (Source: www.mappedplanet.com) whereas the maximum temperature in Tortosa (Valencia) is 29.4°C (Source: CLIMEX monthly Met. Data). DV3 was set to 31°C, accordingly.

Thermal accumulation: In a fifth parameter the minimum thermal accumulation during the growing season that is necessary for completion of the life-cycle of a species is defined (PDD number of degree days above DV0). In south-east Styria, Austria, first-instar nymphs begin to hatch at the beginning of June and females start to oviposit on grapevine (*Vitis vinifera*) in the beginning of August (Strauss unpublished data). In 2011 degree-days of the *S. titanus* population in Styria was calculated from the beginning of nymph hatching until egg laying by accumulating the daily differences between the average temperature of each day and the lower temperature threshold for development of 8°C. 1100 degree-days are necessary to complete the development from the first-instar to the adult stage that lay eggs again.

Diapause: In France, females oviposit on grapevine from late summer until autumn. Then eggs enter diapause before larvae hatch from May to July of the following year (Boudon-Padieu, 2000). Chuche and Thiery (2009) showed that *S. titanus* egg hatching requires sufficient cooling to initiate diapause termination, what is evident regarding the Nearctic origin of the vector. Therefore, the winter diapause function was set (DPSW=0). The respective temperature and day length were estimated according to field observations: females start to lay eggs in two year old canes in late July, early August. Therefore, the Diapause Induction Day length (DPD0) was set to 14:30h (the day length in Bad Radkersburg, south-east Styria, on August 1st (http://www.solartopo.com)). The Diapause Induction Temperature (DPT0) to 13.6°C according to the average monthly minimum temperature in Bad Radkersburg in August (source: http://www.zamg.ac.at). Accordingly, diapause is induced as day length decreases below 14:30 hours at temperatures below 13.6°C. A period of 30 days below the threshold was set to reflect the conditions in Southern USA, which allow the occurrence of *S. titanus*.

Moisture index: S. titanus occurs in high numbers in the north of the Mediterranean region, e.g. North of Italy, in Istria and south of France. Moisture indices were set according to the Mediterranean template provided by the CLIMEX User Guide (Sutherst et al., 2004).

CLIMEX® Stress indices

Cold stress: was not set as it is known, that *S. titanus* has an obligate winter diapause and is well adapted to cold winters thereby.

Dry stress: S. titanus does not occur in the center of Spain, in Castile-La Mancha, an important vine-growing region. A reason for the absence of the vector species is assumed to be the hot summer and low precipitation in this area (400-450 mm/year; source: International Institute for Applied Systems Analysis, 2008) leading to dry stress for *S. titanus*. Dry stress was therefore set: SMDS: 0.1 and HDS: -0.1.

Heat stress: S. titanus occurs in the southern States of the USA, according to the literature (Barnett 1976; Lessio, 2009). In a preliminary CLIMEX map simulating the known distribution of *S. titanus* in North America, locations in Florida and Texas had high EI values, which is not in accordance with the low abundance of the leafhopper in this area. Therefore heat stress parameters were adjusted following the Mediterranean template provided by CLIMEX User's Guide (Sutherst et al., 2004). Heat stress temperature threshold (TTHS) was set according to the upper temperature threshold (DV3) of 31°C, with an accumulation rate of 0.002. Parameters were tested and adjusted in an iterative process until the model closely fitted the current distribution pattern of *S. titanus* in North America. Then the parameter values were used for modeling the potential distribution in Europe. The CLIMEX® parameter settings giving the best accordance with the known present distribution are shown in Annex 1.

2.2.3.1.3. Results and Discussion (WP1)

Areas of potential establishment of GFD (based on the potential establishment of the vector) and grid distribution maps of GFD for Austria and European countries (M2)

The Ecoclimatic index (EI) integrates the annual growth index, which describes the potential for population growth, with the annual stress index that limit survival and with the thermal accumulation (PDD) during the developmental season. EI indicates the overall potential of a given location for establishment. The results of the CLIMEX modelling of the potential distribution of *S. titanus* in North America are presented in Figure 1: The species is known to be very abundant in the North-Eastern part of the USA, especially in the area around the great lakes. EI values in this area range from 20 and 29, indicating very good climatic conditions for establishment of *S.titanus*. The reported absence of *S. titanus* in British Columbia and Alberta in Canada as well as in Washington, Oregon, Nevada and Wyoming in the USA is accounted by very low EI values (e.g. EI of 5 in parts of Alberta, Washington, Oregon and Wyoming), indicating that *S. titanus* is unable to establish stable populations there. In Europe, *S titanus* is widespread in Northern Mediterranean areas: northeastern Spain, south of France, north of Italy, Slovenia, Croatia, moreover in Serbia and Hungary. All known distributions areas of *S. titanus* in these countries are indicated as being suitable in the model. Furthermore, areas where *S. titanus* is reported to be more abundant are indicated with high EI values e.g. EI up to 38 in Cotes-d'Azur in France (Aquitaine, Poitou-Charentes, Centre, Midi-Pyrenees, Languedoc-Roussillion, Provence-Alpes-Cotes-d'Azur and Rhone-Alpes) and in the north of Italy (EI up to 33). In some areas (e.g. the center of Spain, Greece) *S. titanus* could not establish; there the EI values are very low (1-9) due to low precipitation resulting in dry stress for *S. titanus* in this regions. Only in Catalonia EI values are high (EI up to 37) reflecting the suitable climate and presence of *S. titanus* as reported in the literature (Lavina et al. 1995; Batlle et al. 1997).

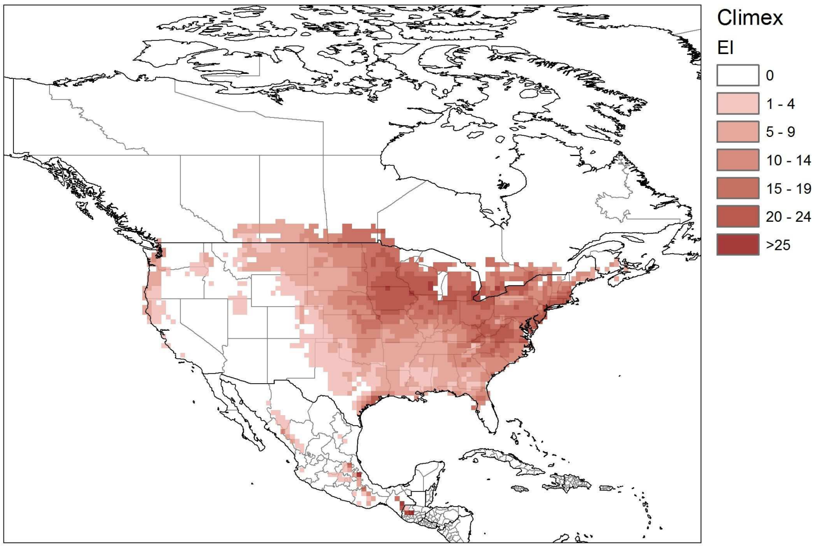


Figure 1: Geographical distribution of S. titanus *in its native area in North America, CLIMEX results using grid-data model (resolution: 30' longitude/latitude). The Ecoclimatic index (EI) indicates the overall potential of a location for establishment. The higher the EI, the more suitable a location is.*

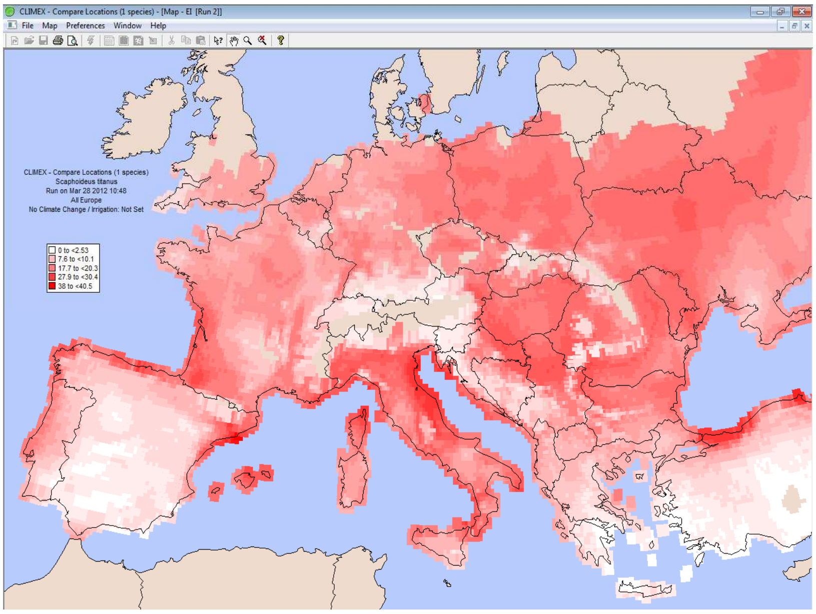


Figure 2 Predicted potential distribution of S. titanus in Europe under current climate conditions applying the CLIMEX software. (a) grid-data model (resolution: 10' longitude/latitude).

Risk maps of current climate and climate change (M3)

S. titanus feeds mainly on *Vitis* spp. (European and American *Vitis* spp) and requires grapevine for oviposition and completion of its life cycle. Grapevine is the major host plant of *S. titanus* and the endangered crop on which GFD phytoplasma causes significant economic impact. To define areas in which *S. titanus* would find suitable conditions for further establishment. the vine growing regions in Europe were combined with the EI values of the CLIMEX® model and imported to a geographical information system to create composite risk maps (ArcGIS® 10.0) (Figure 3).

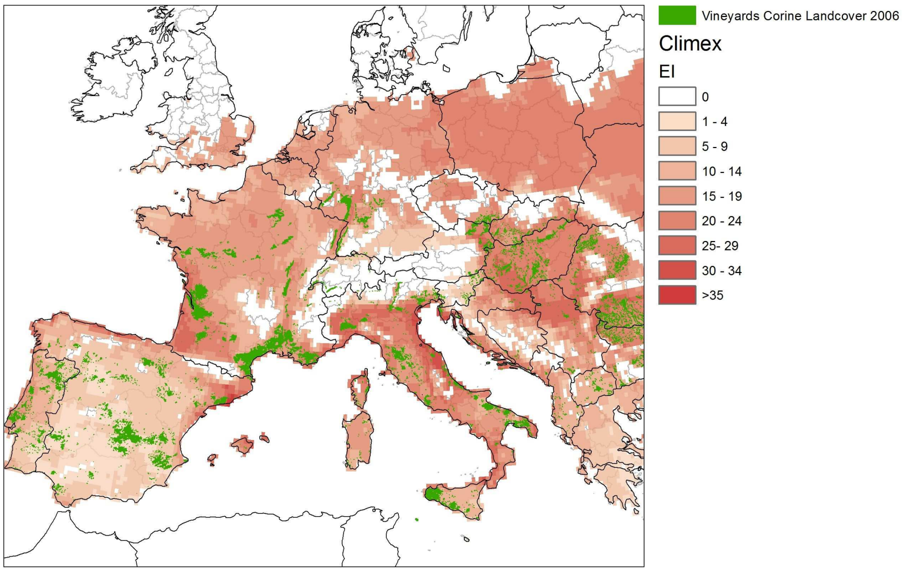


Figure 3: Predicted potential distribution of S. titanus *in Europe under current climate conditions modeled with the CLIMEX software combined with the vine growing areas in Europe (CLC 2006).*

The projection of climatic suitability for *S. titanus* in Europe reveals that this species would be capable to establish in the east of Austria, south of the Czech Republic, Germany and Poland. Thus, the following vine growing regions are at high risk for the establishment of *S. titanus* and GFD: (a) Germany: Mosel-Saar-Ruwer (11.500ha) as well as Rheinhessen, Pfalz and Baden (together about 76100ha), with EI values of 15-21; (b) In Austria, the largest vine growing regions that are located in the federal states of Lower Austria and Burgenland and contain 91.8% of the total Austrian vine growing area are highly suitable for *S. titanus* with EI values ranging from 15-24; (c) the vine growing areas in southern Moravia, in the Czech Republic, are climatically suitable with EI values of 15-19. In contrary, the majority of the vine growing areas in Spain are situated in less suitable regions (EI values ranging from 1-9).

CLIMEX® allows estimating the impact of climate change on the occurrence of a species. Different temperature and precipitation scenarios can be modelled and the effects in terms of changes in the distribution and abundance of a specific species can be examined. A1B-emission scenario was chosen from IPCC SRES which predicts a moderate GHG emission increase till 2100 with an increase in temperature of 2.8°C in average (IPCC, 2007). To generate climate conditions representing the climate conditions in 2100 according to the A1B-emission scenario the CLIMEX® input parameters were adjusted: the minimum and the maximum average temperature in winter and summer was increased by 2.8° Celsius. Generally, increasing winter and relieving summer precipitation are expected in the IPCC synthesis report. This was take into account in the CLIMEX modelling by increasing precipitation in winter by 20% and decreasing it in summer by 20%.

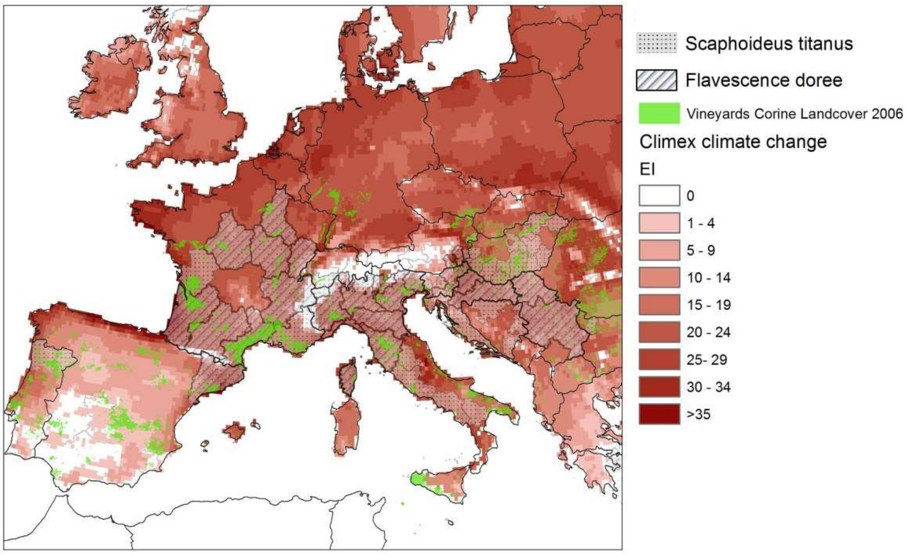


Figure 4: Predicted potential distribution of S. titanus *in Europe under the climate conditions of A1B emission scenario modeled with the CLIMEX software.*

<u>Overall conclusion of the CLIMEX study:</u>
Generally, CLIMEX proofed to be a useful tool to model the present distribution of *S. titanus* in North America and Europe as reported in the literature and to indicate areas not yet invaded by *S. titanus* that provide suitable climatic conditions for the establishment of this species. Regions where *S. titanus* is known to occur have a high EI value in the CLIMEX model, whereas areas where its absence is confirmed provide no growth or very low EI values (e.g. Nevada and Alberta in North America; Central Spain in Europe).
By combining the output data of the CLIMEX model with the host distribution in Europa, it was possible to define further vine growing areas with high risk of establishment of the vector species. Using this approach it became clear that the area climatically suitable for establishment of *S. titanus* extends over the present vine-growing area in Europe. *S. titanus* is currently established in the south of Europe but there is further scope of expansion to the north, e.g. northeast Austria, south of Czech Republic (Moravia and Bohemia) and to the west of Germany, where important connected vine growing areas are located.
The CLIMEX® modelling clearly shows that a prolonged summer would facilitate vector establishment and the development of stable populations in Central Europe. However, the establishment potential of *S. titanus* clearly exceeds the area where vine is grown in Central Europe. Therefore, it can be assumed that the limiting factor for spread of the vector is the distribution of the host plant *Vitis vinifera*. If, due to climate warming the production area of

Vitis vinifera would expand to regions where formerly no vine was produced (Eitzinger, et.al, 2009), the vector species would find climatic conditions for establishment.

2.2.3.2 WP 2: Provision of dataset

Below, only the spread model concept and data inputs are described. More information on WP2 is given in Annexes 2, 3 and 4.

2.2.3.2.1. Determining risk factors, developing a spread model concept (M1)

Spread of a pest is defined as 'the expansion of its geographical distribution within an area (FAO, IPPC 1995). Figure 5, illustrates the two aspects involved in the expansion of GFD in an area: (I) the number of foci in a given area; (II) the expansion of these foci.

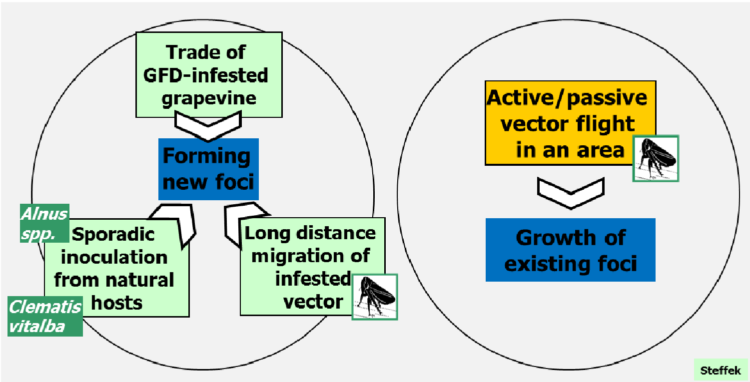


Figure 5: Illustration of the two aspects of spread of GFD (the formation of new foci and the growth of existing foci)

(I) New foci of GFD may occur through (a) the trade of infested plant material, (b) the long distance migration of the vector or (c) sporadic events of phytoplasma inoculation from natural hosts [(GFD was detected in plants of *Clematis vitalba, Alnus glutinosa* and *Ailanthus altissima* (Angelini et al., 2004): a planthopper: *Dictyophara europaea* was confirmed to transmit GFD from *C. vitalba* to *V. vinifera* (Filippin et al., 2009)]; *Oncopsis alni* transmits GFD from *Alnus* spp. (Maixner et al., 2000). Another potential vector is *Orientus ishidae*, which was repeatedly found in yellow sticky traps in the observed vineyards and was tested GFD positive (Reisenzein, unpublished data). However, the ability of *O. ishidae* to transmit GFD is not proven.

(II) The expansion of the infested area depends solely on the activity of the principal vector *S. titanus*. In areas where it is present, epidemic outbreaks of GFD may originate from single infected vines.

It should be stressed that in areas where the principal vector of GFD (*S. titanus*) is not present, the trade of infested planting material and the sporadic activity of alternative vectors do not lead to an increase of the infested area. In areas where the vector is present, its flight activity is the main factor that leads to the epidemic spread of GFD. Therefore, the model focus' on the increase of the infested area through the activity of the vector.

<u>Spread model concept</u>

Figure 6 describes the idea behind the spread model, which includes both the activity of the vector and the spread of GFD in an area. The development of a population of *S. titanus* in a single vineyard includes the three stages: eggs, larvae (5 instars) and adults. Mortality occurs in all stages of the development and is largely due to natural mortality and the use of insecticides that determine the population size of *S. titanus* in a vineyard. At the end of the season the life cycle is completed by females (N_{y2}) laying eggs (N_0) in two year old wood, which is expressed by the "year to year multiplication" of the vector population in a vineyard. A certain part of the population migrates in and out of the vineyard (and, more important from arbours and hedges) to spread to vineyards in the vicinity, lay eggs and form new populations in the following year.

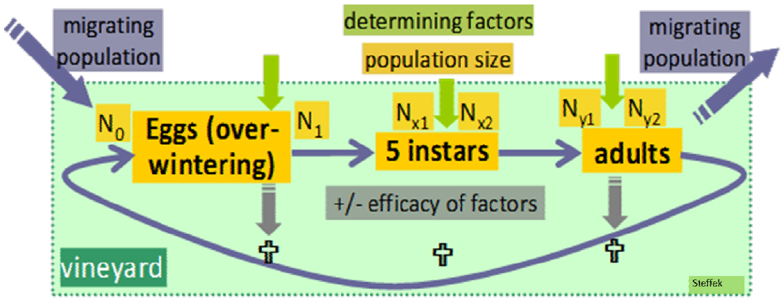


Figure 6 concept of spread used for the model

Vertical movement and migration was observed for many different Cicadellid (Günthart, 1987; Taylor, 1985, Taylor 1974). According to Taylor, 1974 insect vertical distribution is divided into the boundary layer, where the flight speed of the insects is greater than the wind speed and insects are able to control their flight and the 'free air zone', where the wind speed is higher than the flight speed. In the 'free air zone', insects are seen as inert particles, which may be carried out of the vineyard by a gust of wind. Figure 7 illustrates this concept.

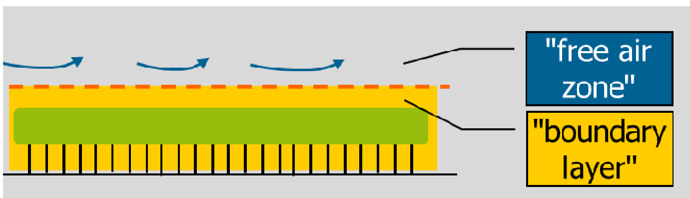


Figure 7: concept of the boundary layer used in the spread model

Although long distance spread is not fully proven for *S. titanus* and this species is considered to be incapable of active dispersal from the vineyard, the vertical movement of *S. titanus* in a vineyard during two years was shown by Lessio and Alma, 2004, who caught a fraction of the vector population in the 'free air zone' above the canopy.

S. titanus is native to North America, where it inhabits mainly wild American grapevines in woods and is found only occasionally in cultivated wines (Maixner et al. 1993). The presence on wild grapes was also reported for Europe (e.g. Pavan et.al, 2012; Lessio et al. 2007). In the South-East of Styria arbours and hedges are very common (Figure 8). As insecticides are usually not applied *S. titanus* is often found in high numbers. In summer 2011 we conducted field surveys to investigate the spatial diffusion of the vector from such arbours to cultivated vines. The results are summarized in Annex 2 and confirm that arbours and hedges not only act as a refuge for the vector but also as a source for its further spread (see also Pavan, 2012).

Figure 8: arbours and hedges are common in parts of Styria

2.2.3.2.2. Providing a dataset on the spread of GFD (M2)

To develop the spread model of GFD, data requirements were defined together with WP3:

a. the efficacy of different measures having an influence on the population size of the vector in a vineyard (estimates for conventional and organic production systems)
b. the year to year multiplication factor of the vector in a vineyard
c. the rate of the vector population that migrates and the flight distances
d. the infection rate of a vector population in an area (particularly of the established one)
e. the cultivars used and how their susceptibility effect the infection rate of the vector
f. the natural mortality of the vector
g. the vector carrying capacity on a vine in an arbour / vineyard

The dataset was assembled on the basis of a thorough literature review and field trials, the results are provided in Annex 2 and 3 of this report.

2.2.3.2.3. Providing the dataset on the costs for eradication and control of GFD (M3)

The dataset on costs for eradication and control of GFD (in the infested area in Styria), which includes potential losses as well as costs for the growers (for eradication and maintaining) and for public authorities was developed together with WP4 is provided in Annex 4.

2.2.3.3 WP 3: Modelling the dynamics of spread

2.2.3.3.1. Introduction, methods and requirements for epidemiological data (M1)

The knowledge and understanding of the biology and the behaviour of both, the vector and the disease agent, is essential when planning effective control measures. Stochastic spread simulation can be a very useful tool, providing insight into the spread dynamics and enabling the identification of critical control points and the prediction of high risk areas. Simulation models are used in population ecology to describe the spread potential of plant pests (Albani et.al, 2010; Robinet and Liebhold, 2009) and they can be utilized in pest risk assessments (Rafoss, 2003; Yemshanov et.al, 2009, Harwood et.al, 2009). Using an individual-based Monte-Carlo simulation model, geographic and topographical information can be incorporated into the spread model and intricate dynamic processes can be broken down into simpler operations, thus providing a very flexible overall framework.
Within WP3 a stochastic Monte-Carlo model was implemented. However, the definition of a realistic model involves various input factors. The aim of this first milestone was to define the input factors and data requirements of the simulation model and to coordinate data search and the experimental setup of the field surveys with WP2; see Annex 3 for further details.

2.2.3.3.2. Simulation model for the dynamics of the spread of the disease (M2)

Due to the length of the development from egg hatching to the adult leafhopper (approx. 18 weeks), the basic time unit was set at one day in order to achieve a temporal resolution that allowed a detailed insight into the seasonality of the spread. Two selected Austrian municipalities acted as the geographic domain of the model. Data from GFD outbreaks in these municipalities were used to calibrate the model. The unit of observation in the model is one plot, i.e., a vineyard or an arbour. For each plot and each day, the number of leafhoppers per development stage occupying the plot is recorded. Furthermore, the model records the number of infected and infective leafhoppers, the number of infected and infective plants, as well as the number of uprooted vineyards. The simulation model was implemented using the open source statistical software R (R Development Core Team, 2012), version 2.15.0.

Geographic data
For the model domain, we considered the two municipalities of Tieschen in South-Eastern Styria and Glanz an der Weinstraße in Southern Styria. These municipalities are typical for their regions and differ in the abundance of wild arbours, the average acreage of vineyards and the presence of organic vineyards. The municipality of Tieschen covers an area of 18.17 km^2 (Source: www.statistik.at). According to the vineyard register of the federal state of Styria, there are 483 registered vineyards in Tieschen (spring 2012); all of them in a conventional production system (no organic vineyards). The vineyards in Tieschen, on average, cover an area of 1735.61 m^2. For each vineyard, the coordinates of the centroids, the shape files and the area were made available through the vineyard register. Furthermore, the different planted grapevine varieties and the respective planted areas were known.

Based on expert opinion, the varieties were categorized into robust and susceptible varieties (see Annex 3). These differ in the ability to acquire and transmit FD-phytoplasmas. In addition to the vineyards, the coordinates of 505 arbours and hedges in Tieschen were surveyed and provided by the municipality of Tieschen. A map of Tieschen with its vineyards and arbours is depicted in Figure 9.

In contrast to Tieschen, a significant number of organic vineyards are located in the municipality of Glanz (604 conventional, 41 organic). The average acreage of vineyards is higher in Glanz (10287 m^2) and – typical to the region of South Styria – arbours and hedges of different species of *Vitis* are not very common. No precise data are available; on basis of information provided by the local extension service it is assumed that arbours are present in 5% of the 490 households and randomly distributed in the municipality.

For both model domains, the common plant density of 3500 vines per ha is chosen for the vineyards. It is further assumed that, on average, an arbour consists of 10 vines, each plant approximately covering 3 times the leaf area of one grapevine in a vineyard. For each vine in an arbour the maximal carrying capacity was assessed as 288 leafhoppers of larval stage L1 (Annex 3). Consequently, for a plant in a vineyard, the maximal carrying capacity is 96 leafhoppers, reflecting the reduced leaf area of plants in vineyards.

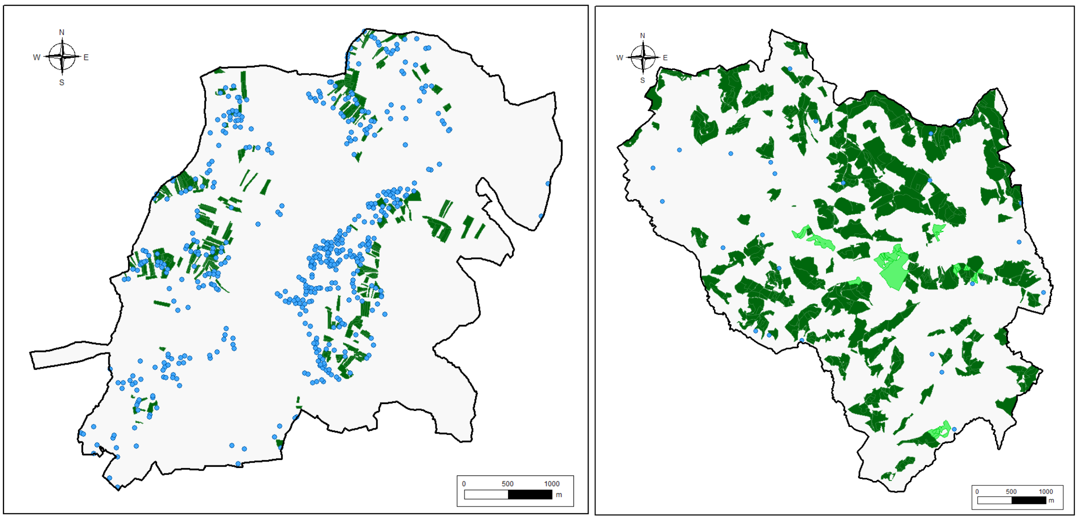


Figure 9: Municipality Tieschen (left) and Glanz (right): conventional vineyards (dark green), organic vineyards (light green) and hedges (blue dots; randomly distributed in Glanz).

Data structure

Each vineyard or arbour is represented by a set of static data. The data comprises: a unique identifier, the coordinates of the centroid, the type (vineyard or arbour), the number of plants, the number of susceptible plants, the number of plants that exhibit symptoms when infected and a list of neighboring plots including the distance and topographical information (elevation profile etc.). In the simulation model, data is created for each plot and each day in the season reflecting the spread of the vector and the disease. This dynamic data includes: the number of infested, infected and infectious plants; the number of plants exhibiting disease symptoms;

the total number of leafhoppers for each development stage; the number of eggs that have been laid in the current season and the total number of infected and infectious leafhoppers.

Initialization

At initialization, a predefined number of arbours and vineyards are assumed to be infested with leafhoppers. The arbours/vineyards are randomly selected and 90 % of the plants in the selected plots are set to be colonized by leafhoppers, carrying 10% of their maximal carrying capacity each. None of the plants and none of the leafhoppers carry GFD-phytoplasmas at initialization, reflecting the low infection rate of the Austrian vector population.

One fixed vineyard is chosen as the index plot from which the disease spreads. Within this plot, a predefined number of plants are set to be infected with GFD. Additionally 90 % of the plants in the index plot are set to be colonized by leafhoppers, each plant carrying 10% of their maximal carrying capacity (L1).

Different scenarios regarding the intensity of the initial disease spread (high/low) and the size of the initial leafhopper population (large/small) are considered. An initially high intensity of the disease spread reflects the situation where the disease remained undiscovered in a vineyard for some time and was able to spread within the vineyard before appropriate measures were set in place, which was the case in Tieschen in 2009. A low initial disease spread, on the other hand, is to be expected if the disease is detected early due to an intense monitoring program and an increased public awareness. The considered initialization scenarios are described in more detail in Annex 5.

Model layers

The spread of the vector and the disease is simulated for 10 consecutive years, starting with 2009. Each year, a season of 18 weeks during which the leafhoppers are active, is modeled. The season starts late spring and lasts until autumn. The spread model encompasses a number of different layers, characterizing the biology of the vector, vector movement and rates of infection. For each day in the season and each plot, these elements are applied sequentially to the static data and the dynamic historical data in order to generate the new data representing the current day in the simulation. In detail, the model layers are:

1. The biological development of the leafhoppers: the numbers of leafhoppers that transition from one development stage to the next are sampled.
2. The spread of the leafhoppers within the plot: the number of infested plants is determined, depending on the number of leafhoppers within the considered vineyard or arbour.
3. The movement of the leafhoppers between plots: the emigration of leafhoppers to neighbouring plots is simulated; the probability of emigration to a neighbouring plot is proportional to the inverse of the squared distance between the plots and furthermore depends on the maximum altitude that a leafhopper would have to ascend to in order to reach the neighbouring plot.
4. The natural mortality of the leafhoppers: the number of leafhoppers dying of natural causes (predators etc.) is sampled each day. Infected leafhoppers are assumed to have a higher daily mortality rate than leafhoppers not carrying FD-phytoplasmas.
5. Transfer of FD-phytoplasmas from infected host plants to the vector.

6. Transfer of FD-phytoplasmas from vectors to susceptible plants.
7. Detection and uprooting of infected host plants: infected plants of certain varieties exhibit symptoms at the beginning of August in the year following the infection. The disease is detected in these plants and they are uprooted and replanted in the following season. If more than 20% of the plants in a vineyard show symptoms, the entire vineyard is uprooted. The newly planted grapevines can be inhibited by leafhoppers. Eggs, however, can only be laid into the bark of plants that are at least 2 years old.
8. Intervention strategies: on fixed days, pesticides are applied, removing a percentage of the leafhoppers from the system. Four different intervention scenarios were considered: scenario A (high intensity), scenario B (moderate intensity), scenario C (low intensity) and scenario D (no insecticides applied).

The various model layers and the scientific evidence on which they base are discussed in more detail in Annex 3. At the end of the season, all remaining living leafhoppers (larvae and adults) are removed from the model. At the beginning of the following season, all leafhoppers (eggs) are set to be free from GFD-phytoplasma. Uprooted plants are replanted.

Monte-Carlo Simulation

For each model region, each initialization scenario and each intervention scenario, the spread of the disease is simulated for the simulation period of 10 consecutive years (2009–2018). One such cycle constitutes one simulation replication. In each replication, the infested vineyards/arbours and the initially infected vineyard are randomly assigned at initialization. For the model region Glanz, the locations of the arbours are also randomly assigned at the beginning of each replication. For each recorded parameter (number of infected vineyards/arbours, number of infested vineyards/arbours, number of uprooted vineyards etc.), the median value over the replications is evaluated. The variability of the computed parameters is expressed in terms of the 2.5 and the 97.5-percentiles.

2.2.3.3.3. Results and discussion

Identification of critical parameters and evaluation of different intervention strategies (M3)

The vines in arbours and hedges are mostly of susceptible varieties which are either asymptomatic or display an unclear disease pattern. As a consequence, affected arbours and hedges are not recognized and uprooted. Hence, they can act as potent disease reservoirs and accelerate the transmission of the disease in a region.

For Tieschen, which has a high density of arbours, the simulation showed that the spread of the disease within the region is highly influenced by the initial spread of the disease within the initially infected vineyard, i.e., it depends on how early the disease is detected. For the initialization scenarios that assumed a high initial disease spread, the spread of GFD within the region can only be controlled using intervention measures with a very high intensity (scenario A); see Figure 10 (left). For all other considered intervention measures, a continuous increase of the number of infected vineyards and arbours can be observed over the course of the simulated period. If the initial spread, however, is low (early detection) then the disease spread can be controlled using intervention scenarios A–C. Only if no measures are applied to control the vector (scenario D), the disease spreads throughout the region. *S. titanus* spreads rapidly in the municipality and reaches nearly all vineyards within the simulation period of 10 years. Only for small initial populations and intensive intervention strategies the spread of the vector is slightly reduced; see Figure 10 (left, middle).

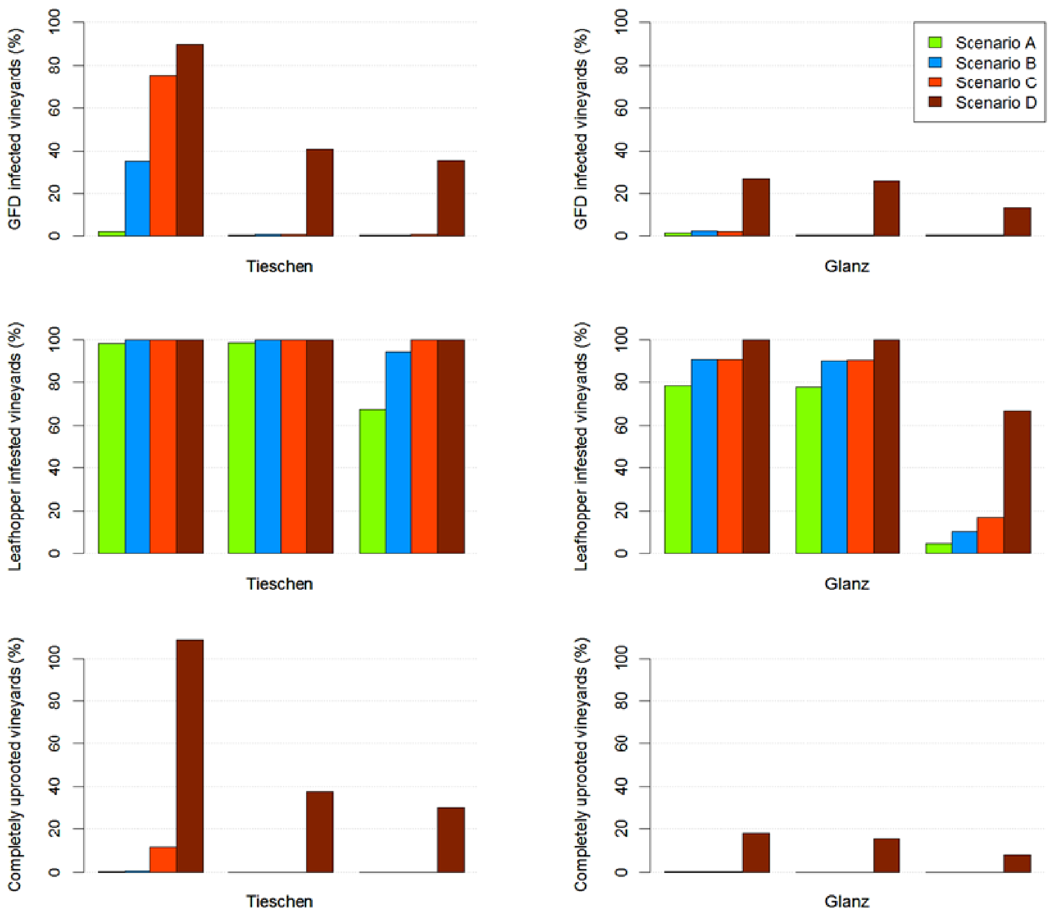


Figure 10: Median values of the total number of vineyards infected with GFD (top), the total number of vineyards colonized with leafhoppers (middle) and the total number of completely uprooted vineyards (bottom) for Tieschen (left) and Glanz (right). The intervention scenarios are marked using different colours, each group of bars corresponds to an initialization scenario: left = high initial spread/large vector population, middle = low initial spread/large vector population, right = low initial spread/small vector population. All values refer to the period 2009–2018.

Glanz has a very low number of arbours. Hence, the control of the vector and the disease is more efficient than in Tieschen. The simulation results showed that even if the initial spread is high, the spread of the disease can be controlled with all three intervention strategies (A–C). In the case of a large initial vector population, the colonization of the leafhopper again reaches nearly all vineyards within 10 years. If the initial vector population, however, is small, then spread can effectively be reduced with each of the considered intervention strategies (A–C); see Figure 10 (right).

For both model regions (Southeast- and South Styria), the spread simulation illustrated the importance of early detection. Furthermore, the result show that robust varieties in arbours favour the spread of the disease, as – apart from being the favourite host plant of *S. titanus* - they typically do not exhibit symptoms or display an unclear disease pattern and act therefore as a reservoir for the disease.

The results of the simulation runs are displayed in more detail in Annex 5.

2.2.3.4. WP 4: Modelling of economic impact

2.2.3.4.1. Introduction

The objective of WP 4 is to model the economic impact of GFD to Austrian viticulture, more precisely to the viticulture of South-East-and South Styria, with Styria being one of the nine federal states of Austria. The activities of WP 4 are based on the results of the CLIMEX® models, the various spread scenarios developed in WP2 and WP3 and on the economic dataset collected in WP2. The latter specifies the direct costs arising from the eradication of the first outbreak of GFD (per ton or per treatment/intervention). Aim of the economic impact analysis is to evaluate different intervention and abatement strategies regarding the spread of GFD. While the evaluation of the economic impact of plant pest has become a well-known topic in the past decades, there is an increasing interest in recent years in measuring the economic impact of climate change to the spreading of plant pest.

2.2.3.4.2. Literature review

There are various quantitative methods available for assessing the economic impact of plant diseases. The most important techniques described in the literature are partial budgeting, partial equilibrium analysis, computable general equilibrium analysis and input-output analysis. These techniques differ from each other particularly with respect to available data, time, experience, skills, funding etc. The simplest method is partial budgeting, which refers only to the damage cost for the farmer and the lost revenues caused by the plant disease. Partial equilibrium analysis is an approach suitable for measuring the damage impact on a specific market. When economic effects on the macro level are expected, computable general equilibrium models (CEG models, e.g. Wittwer et al. (2005, 2006)) are a possible choice, however this somewhat more sophisticated instrument requires additional data, skills and time compared with other approaches.
For a macroeconomic impact analysis the most appropriate method is input-output analysis (IOA). In the context of this project we used a multi-regional IOA to determine the economic impact of GFD based on a multiregional input-output table. The required data were provided by ECONOMICA. The table represents the integration of the individual production sectors in an economy as well as their contributions of value added created. Applications of IOA to pest risk analysis are provided e.g. by Elliston et al. (2005) and Julia et al. (2007).

2.2.3.4.3. Input-Output Methodology

Input-Output Analysis was developed by W. Leontief (1905-1999), who received the Nobel prize in economics in 1973 ``*for the development of the input-output method and its application to important economic problems*''. The IOA is a methodical instrument to record the mutually linked supply and demand structures of the sectors in an economy and to quantify the overall economic effect (Hauke, 1992, Hübler, 1979). As an instrument of economic impact assessment it is based on input-output tables provided by Statistik Austria. The input-output table consists of three sub-tables which contain data of the following macro-economic aggregates: the intermediary matrix, the final demand matrix (consumption, investment, exports) and the primary input matrix (value added and imports). Direct effects on gross production, gross value added and employment are assessed using supply as well as demand side data (Carter and Brody, 1970). The following factors contribute to the calculations: (1) Structural costs for inspection and monitoring, sampling and examination as well as costs for legislation; (2) incidental costs, which occur on the side of vine growers, nurseries and provincial governments (e.g. costs of decrease in yield and quality, costs for sunk investments, costs for control, eradication and replacement of planting material, additional costs for sampling, examinations and controls (Mumford, J.D. 2006) etc.); (3) export losses for vine growers, nurseries and the vine economy.
IOA not only captures mutually entangled supplier and acquisition structures of the economic sectors, it also quantifies the multiplicatively amplified macroeconomic impact thereof. For each final expenditure multiplier effects are assumed, since each business needs unfinished-goods as well as raw materials and supplies of other sectors for the production of its products and/or services. Multipliers derived from the input-output table reflect the integration of the various sectors, and are therefore used to sum up all indirect effects on the original direct ones. There are three categories of multiplier effects: The indirect effects address the whole macroeconomic value chain caused by input demand in the respective sectors of the economy, gross investment (change of capital stocks) and the induced effects – income effects (wages which in turn cause consumption) - which are caused by the above mentioned activities. These multiplier effects lead to further gross production, gross value added and employment in other sectors of the economy.

The calculations and analyses of direct effects (benefits and costs) and multiplier effects can be applied to different scenarios (depending on climate change and eradication policy) and may be compared with a reference scenario (status-quo) (Ehret, 1970; Parikh, 1979). In the end an exhaustive comparison of all alternative scenarios regarding value added, purchasing power and employment is possible (Ferng, 2009). The results of the IOA may finally be compared to the costs of applied measures and activities in a selected area.

2.2.3.4.4. Data description

Data on direct costs: The basis for IOT calculations were data on costs and potential losses associated with the management and abatement of GFD provided by WP2 (Annex 4). For various risk management and control scenarios control costs are considered, like vector control expenditures on the side of vine growers and nurseries (applications at bud break, applications to control larvae and adults, work expenditure/application in arbours) and control costs on the side of provincial governments, the chamber of agriculture (e.g. for legislation, monitoring, and sampling). Furthermore, costs occur in the sense of potential losses like uprooting and planting costs for single grapevines or complete vineyards and crop failure (due to eradicated grapevines in the year of uprooting and in four subsequent years). Further various cost schemes have to be used for the calculation of the economic impact of GFD abatement contingent to the production system (integrated/conventional production or organic production) and the particular intervention scenarios. Calculations are based on a period of 10 years.

Intervention scenarios for risk management: In the case of infested grapevines or vineyards the four different intervention or risk management scenrios A-D that were used in the spread model (see Annex 3 for details) are analysed regarding their economic impact.

Data used for further calculations of profit losses: Below an overview of the basic data used for further calculations of profit losses is given. The appropriate cost scheme has to be linked to results from spread simulations provided by WP 3. Costs are calculated depending on the number of grapevines and/or complete vineyards that have to be uprooted and planted per year in period 2009–2018, according to the results from simulations of spread dynamics. Regarding the uprooting of complete vineyards the average vineyard surface (“Stammfläche”) is 1,536 m^2(0.1536 ha) for Tieschen and 6,044 m^2 (0.6044 ha) for Glanz.[1]

Styrian communities for extrapolation to South-East Styria: to calculate control costs and potential losses for South-East Styria the results for Tieschen and Glanz are extrapolated to geographically comparable communities at potential risk for GFD infestation. Results for Tieschen are extrapolated to 49 Styrian municipalities, calculations for Glanz are extrapolated to 27 Styrian communities.

Gross wage rate per hour: for the assessment of working hours, expended e.g. on uprooting and planting single grapevines or complete vineyards, the authors used a gross wage rate of 7 Euro per hour. This value is the current official wage rate for non-permanent hourly wage earners for the agricultural sector.[2]

Assumptions for price elasticity of supply: for the operation of the IOT calculations data on the price elasticity of supply is required. As some data is only available on the national label, it is essential to analyse, whether national findings and results can be used for

[1] Note that one vineyard business may have more cultivation areas in different locations. Thus an average vineyard surface (“Stammfläche”) that has to be eradicated in the spread respectively the economic model is not identical with the average surface of all vineyard businesses.

[2] Steiermärkische Landarbeiterkammer (2013): Kollektivvertrag für die ArbeiterInnen der land- und forstwirtschaftlichen bäuerlichen Betriebe, Gutsbetriebe und anderen nichtbäuerlichen Betrieben im Bundesland Steiermark (gültig ab 1.1.2013). http://www.landarbeiterkammer.at/steiermark/_lccms_/_00132/KV-Agrar.htm?VER=110119085543&MID=135&LANG=lak

questions regarding the Styrian wine production. Hence, in a first step, a comparison of data on wine production in Styria and Austria is conducted.

Cultivation area: in 2009 the cultivated area for wine in Styria was about 4,240 hectare (ha), which are 9 % of the cultivated area for wine in Austria (45,900 ha). More than half of the cultivated area of Styria is situated in the South of Styria in the area called „Südsteiermark" (2,340 ha or 55 %), about one third of the cultivated land is in the South-Eastern region named „Süd-Oststeiermark" (1,400 ha or 33 %) and 14 % are located in the Western area called „Weststeiermark" (500 ha). Shares are almost identical regarding the produced quantities in these wine regions (54%, 34%, 12%; 2012 data).

Production - quantity, products and qualities: in 2012 Styria produced 213,068 hectoliter (hl) wine. This was about 10 % of the wine production in Austria (2,154,755 hl). This share seems to be rather constant (it was the same in 2010 and 2011). More than 50 % of the Styrian wine production in 2012 came from the „Südsteiermark" (115,212 hl), about one third of the wine output was produced in the „Süd-Oststeiermark" (71,474 hl) and a share of 12 % stemmed from the area named „Weststeiermark" (26,381 hl). The analysis of the wine stock data („Weinbestand") regarding products and qualities for the years 2010 to 2012 indicates that Styria is on the whole comparable to Austria. Both in Styria and Austria the great majority of the wine stock is wine of the high/highest quality category „Qualitätswein" and „Prädikatswein", followed by the lower quality category „wine", „Rebsortenwein" and „Landwein". However, Styria's share of highest quality wines („Qualitätswein and Prädikatswein") is some percentage points below the Austrian level, whereas the share of the category „wine, Rebsortenwein and Landwein" lies some percentage points above. „Sparkling wines and other products" are of lower relevance in Styria and Austria, with a share of 3 % in Styria respectively 5 % in Austria according to the 3-years average (years 2010 to 2012). Differences regarding the shares of products and wine qualities occur to be even less remarkable looking at the wine harvest data („Weinernte") instead of the wine stock data. In 2012 more than 80 % of the wine harvest resulted in wine of high and highest quality - and prices – referred to as „Qualitätswein and Prädikatswein". In Styria the share of this category is only three percent points below the Austrian level. The share of wine with lower qualities and prices („Wein, Rebsortenwein and Landwein") in Styria is 14 % (compared with 12 % for total Austria). Because of the largely comparable production structure in Styria and Austria regarding „rough" categories of wine products and qualities data based on Austrian values will be used, whenever data for the province Styria, respectively for Tischen, is not available.

Domestic consumption and exports of Austrian wine: according to supply balance sheets („Versorgungsbilanzen für Wein") from Statistik Austria the five-years average of the wine production in Austria (2006/07 to 2010/11) amounts to 2,393,474 hectoliters (hl) or 239.3 million liters of wine. The majority of Austria's wine harvest is consumed by the domestic market (180.9 million litres or 76 %). Nearly one fourth of the average production in the years 2006/07 to 2010/11 (58.5 million litres) was produced for the export market.

Structure of Austrian wine consumption: according to the Austrian wine marketing company („Österreich Wein Marketing GmbH“) the majority of wine in Austria (own production plus imports) is consumed in restaurants, hotels or is sold on festivals (55 %), whereas 45 % of the domestic consumption is sold over food retailing („Lebensmittel-einzelhandel“).

Calculation of price elasticities - domestic consumption via retail trade: according to „Gfk Consumer Tracking 2010“ data, published by „Österreich Wein Marketing GmbH“), the price per liter wine sold over food retailing is steadily increasing, from 3.3 Euro/liter in 2006 up to 4.0 Euro/liter in 2010. This increase in prices is a result of increasing wine quality (increase in bottled wine). About 122.5 million liters of Austria’s wine harvest in 2010 were produced for the domestic market and about 45 % of wines sold in Austria are sold by retail trade – this are about 55 million liters wine in 2010. This value is widely consistent with the Gfk Consumer Tracking 2010 data, used for calculating the elasticity of supply (relative change in price/relative change in quantity). The average elasticity of supply for the period 2006/07 to 2009/2010 is 1.6.

Calculation of price elasticities – Exports: the export market shows the same picture regarding the development of turnover quantities and prices as the domestic market: turnovers in Euro increase while quantities decrease. As a result export prices per liter have been steadily increasing from 1.2 Euro/liter in 2005 to 2.8 Euro in 2012 (only exception year 2009). The average yearly growth rate (2005/06 to 2011/12) regarding quantities was negative with a value of minus 4 %, while the average yearly increase of turnover in Euro was plus 7.0 %. This implies a elasticity of supply of 1.8.

2.2.3.4.5. Results of the economic impact calculations

For each domain (Glanz, Tieschen) the spread model evaluated different initiation scenarios (Glanz 1-4 and Tieschen 1-3); these scenarios consider the intensity of the initial disease outbreak (severe/limited) and the size of the initial leafhopper population (large/small) (for details see Annex 5). Based on the existing data eight scenarios of potential economic impact were calculated depending on the selected intervention scenarios as reaction to given outbreak scenarios. Different current control strategies depending on the type of municipality were provided by project partners 1 and 2 and tested in the economic impact model.
The scenario combinations analysed in this setting are given as follows (Table 1):

Table 1: Eight economic scenarios depending on the selected intervention and outbreak scenarios

Economic Scenario	1	2	3	4	5	6	7	8
original outbreak in a municipality of type	Tieschen	Tieschen	Tieschen	Tieschen	Glanz	Glanz	Glanz	Glanz
outbreak scenario at initiation (1st year)	severe*	limited**	severe	limited	severe	limited	severe	limited
Municipality type and strength of implemented measures (A-C)*								
municipality in which the outbreak occurs	A	A	A	A	A	A	C	C
other municipality of the same type	B	B	C	C	C	C	C	C
municipality of the other type	C	C	C	C	B	B	C	C

*severe: initial outbreak 90% infected vines in a plot; S.titanus present in 60% of arbours and 10% of vineyards (~ spread scenario Glanz 4, Tieschen 1)
**limited: initial outbreak of 3 vines in a plot; S.titanus present in 10% of arbours (~ spread scenario Glanz 1, Tieschen 3)
*** explanation: strength of measures (for more details refer to Annex 3):
A) high intensity: measures against larvae and adults in vineyards, measures in arbours and hedges
B) medium intensity: (see A, but no measures against adults in vineyards)
C) low intensity: (see A, no measures in arbours and against adults in vineyards)

The results for the eight scenarios are presented in Table 2 and Figure 11. The potential losses calculated for these eight scenarios vary from zero (see scenarios 2, 4, 6 and 8) to 5-6 Mio Euro (scenario 3 and 7). In addition, we see a positive economic impact in terms of value added based on the control costs for each scenario.

Table 2: Eight scenarios combining the different spread scenarios and related control costs, gross value added and potential losses

Szenarienvergleich, in Mio. €, 2009 - 2018			
	Control Costs	Gross Value Added	Potential Losses
Scenario 1	10,1	7,4	0,5
Scenario 2	10,1	7,4	0,0
Scenario 3	5,1	3,8	5,4
Scenario 4	5,1	3,8	0,0
Scenario 5	10,1	7,4	0,5
Scenario 6	10,1	7,4	0,0
Scenario 7	4,3	3,2	5,9
Scenario 8	4,3	3,2	0,0

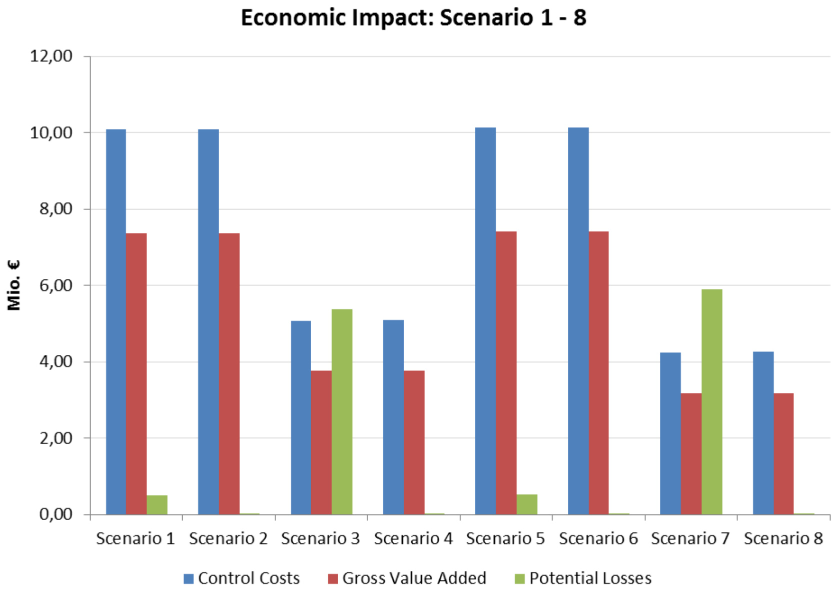


Figure 11: Eight scenarios combining the different spread scenarios and related control costs, gross value added and potential losses (2009-2018)

The scenarios demonstrate that in situations of limited outbreaks potential economic losses are not likely to occur. The two situations that result in high potential losses are both related to severe outbreaks. A severe outbreak in a community of type Tieschen (many wild *Vitis* plants in hedges and arbours) demands a control strategy that includes both cultivated vineyards and arbours or other wild *Vitis* sp. (compare scenario 1 and 3). In cases where outbreaks are limited, controls of the arbours are not effective from an economic point of view. In communities of type Glanz (limited number of wild plants) a high intensity control strategies (type A) are necessary only in cases of severe outbreaks in the municipality in which the outbreak occurs.

More details of the results of the economic impact assessment are shown in Annex 6.

2.2.3.5. WP 5: Project dissemination (Risk communication)

WP 5 was understood as a continuous process of involving different stakeholders into the project. During the project period, issues of the different WP were presented and discussed with researchers, decision makers and interest groups at various occasions. Project partners 1 and 2 are main stakeholders and ascertain the implementation of the project findings on farm level (for more details please refer to chapter 4.1. Utilization, Publications)

2.2.4. Description of difficulties encountered in the achievement of project targets

Due to the accompanying WP 5 the project was running smoothly; i.e. no noteworthy difficulties appeared during the project period.

2.2.5. Description of project "highlights"

- We used data of the observed distribution of the vector *S. titanus* in North America to estimate the potential distribution of GFD in Europe. The commonly applied computer model that that we employed (CLIMEX®) gave clear evidence that the future potential distribution of the disease and its vector in Europe is far beyond the currently area in which it has established. The results provide evidence that this disease poses a risk to Central European vine growing areas (e.g. in the northern parts of Austria, in Germany and the Czech Republic).
- Field experiments to investigate the role of uncontrolled (wild) vine arbours and hedges in the spatial diffusion of the vector have shown that arbours with high population densities are not only a refuge for the vector but also a source for the migration of a part of the population to cultivated vines and hence a risk for the spread of GFD.
- The implementation of a stochastic Monte-Carlo model that simulates the spread of the disease and incorporates different parameters (geography, intensity of initial infestation, intensity of applied intervention strategies etc.). The simulations were run for different type municipalities with focus and safety zones for GFD. Scenarios regarding the initial disease and pest infestation are considered. The results revealed the importance of the early detection of GFD infestations and the role of arbours to act as potential disease reservoirs. It also shows the significance of applying scenario specific pest control.
- A multi-regional IOA was used to determine the economic impact of GFD. Based on the existing data eight scenarios were calculated. Specific economic impact of selected intervention scenarios as reaction to given infestation scenarios were described. Results were calculated for control costs, gross value added and potential losses.
- the communication of project results to various stakeholders and their implementation in the decision making process of risk managers that use the results to ensure that the obligatory control measures applied to contain GFD will be based on scientific evidence.

2.2.6. Description and motivation of deviations from the original project application

See 2.2.4.

2.3. Conclusions to be drawn from project results (max. 5 pages)

Which findings have been derived from the project by the project team?

The potential distribution of S. titanus in Europe under current climatic conditions was modelled by using the Compare Locations mode of the CLIMEX® software. Overall climatic suitability of an area for establishment is indicated as Ecoclimatic Index (EI). High EI values indicate good climatic conditions for permanent establishment. Species specific parameters for S. titanus were defined (Fig. 2). Growth indices were inferred from its main distribution area in the east of North America (Fig. 3) and physiological data from the scientific literature. Stress indices were adjusted to model its limited distribution in the west of the USA.

Parameters were tested using known distribution data. The CLIMEX® model adequately displays known regions of high vector abundance (e.g. in France, Italy). Vine growing regions in the east and north of Europe which are not yet invaded, provide good climatic conditions for establishment of *S. titanus*. The risk of substantial vector spread in South-Europe is low, as conditions of dry stress in many areas limit its further spread. Vine growing areas in Austria, the Czech Republic, Germany, Hungary, Slovakia, Romania and Bulgaria have a high risk of invasion and establishment of S. titanus. The CLIMEX® model clearly shows that the establishment potential of S. titanus in Central Europe exceeds the area where vine is grown. Further spread to the north is therefore rather limited by host distribution (Vitis sp.) than by climate. If, due to climate warming the production area of *Vitis vinifera* would expand to regions where formerly no vine was produced, the vector species would find climatic conditions for establishment.

A stochastic Monte-Carlo simulation model was implemented, in order to assess the efficiency of different intervention strategies. The model simulates the spread of the disease, and of its vector, and incorporates different parameters (geography, intensity of initial infestation, intensity of applied intervention strategies etc.). The simulations are run for different model domains with established focus and safety zones for GFD: the two municipalities of Tieschen in South-Eastern Styria and Glanz a. d. Weinstraße in Southern Styria. These municipalities are typical for their region and differ in the abundance of wild arbours, the average acreage of vineyards and the presence of organic vineyards. Different scenarios regarding the initial disease and pest infestation are considered. The model results confirm the importance of effective pest control and of early detection of GFD and demonstrate the potential of arbours to act as disease reservoirs. The results of the spread model may directly be used by risk managers as they serve as a scientific basis for the case sensitive selection of obligatory pest management decisions. Due to the difficult control of natural dissemination, the main management strategy should be preventing the establishment of local population of *S. titanus*, mostly by control strategies against larval stages. Moreover, regional cooperation with transnational vine growing regions in neighbouring countries is essential for a successful management.

For a macroeconomic impact analysis the most appropriate method is input-output analysis (IOA). In the context of this project we used a multi-regional IOA to determine the economic impact of GFD in South-East Styria based on a multiregional input-output table. Based on the existing data all in all 8 scenarios were calculated to show specific economic impact of selected intervention scenarios as reaction to given infestation scenarios. The potential losses calculated for these eight scenarios vary from zero (see scenarios 2, 4, 6 and 8 -all of which displaying favorable starting conditions) to over 5 Mio Euro (scenario 3 and 7). In addition we see a positive economic impact in terms of value added based on the control costs for each of the scenarios.

The risk factors that results in a high risk of spread of the disease and consequently in an high economic impact were determined during the project: (I) an overlooked outbreak that results in a high initial infestation rate of GFD in a vineyard, (II) a high number of uncontrolled vine-arbours and hedges that act as shelter plants for the vector, (III) a high number of undetected pockets of latent infested grapevines that result in an increasing percentage of the infected vector population.

Which further steps will be taken by the project team on the basis of the results obtained?

Our aim was to provide scientific evidence for the development of an adaption strategy to eradicate or contain this newly introduced threat to Austrian vineyards. The results serve as a basis for the communication of optimized control options with various stakeholders. The implementation in the decision making process of risk managers that use the results to ensure that the obligatory control measures applied to contain GFD will be based on scientific evidence.

Depending on the model domain and the scenario, the project results allow a case specific decision on the best risk reduction options for a given municipality, both with respect to its efficacy on the spread of the disease and on its cost-effectiveness. Based on the identified risk factors, the following consequences can be drawn: (I) an intensive monitoring program and a rising public awareness increases the chance of early detection of GFD outbreaks and occurrence of *S.titanus*; (II) regular testing of latent infections in arbours and hedges reduce the risk of a fast increase of the infested vector population; (III) vector control strategies should be based on larvae monitoring and control and the monitoring should include arbours and hedges in areas where they are abundant; (IV) applying of a scenario specific pest control option with respect to its efficacy on the spread of the disease and on its cost-effectiveness

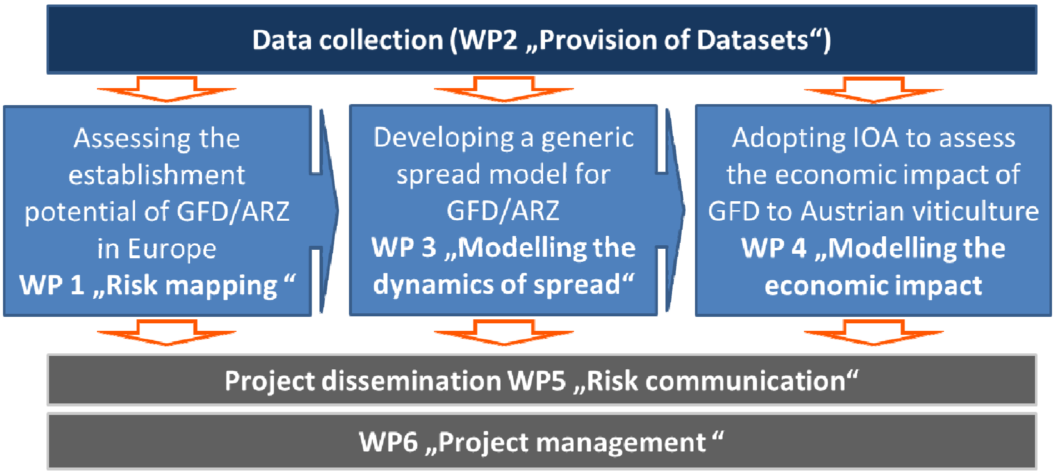
Which other target groups can draw relevant and interesting conclusions from the project results and who can continue working on that basis?

The results of this project have direct benefits for stakeholders in the Austrian vine sector. Both the spread and the economic impact models are generic and can be adopted for the use in other Austrian and European wine growing areas in the future. The results of the spread model are directly used by risk managers as they serve as a scientific basis for the case sensitive selection of obligatory pest management decisions to eradicate or contain outbreaks of GFD. The results can be considered for decision making to finance the establishing preventive measures against the spread of vector and disease.

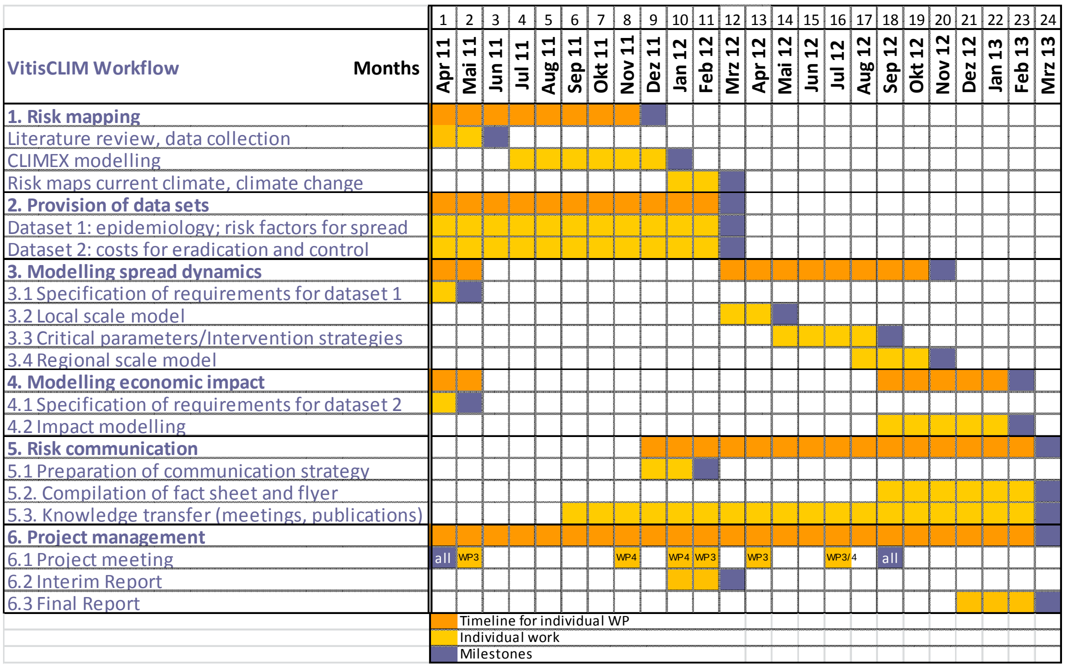
2.4. Work and time schedule (max. 2 pages)

2.4.1. Presentation of the final work and time schedule

The project consisted of six independent work packages (WP): risk mapping (WP 1), provision of datasets (WP 2)", "modelling spread dynamics (WP 3)", "economic impact assessment (WP 4)"; "project dissemination (WP 5)", "project management (WP 6)". The principal project structure is illustrated below.



The work plan and schedule of the project is shown in the Gantt diagram below.



Project meetings between project leader and different project partners were held to co-ordinate the next steps: after the official project Kick-off Meeting (12.04.2011, AGES, see report Annex1) project co-ordinator and partners have discussed issues of the project (e. g. tasks of the WPs, reviewing of the progress of the project, problems) on an ongoing process. Informal meetings of project leader and partners were held to discuss the data requirements of WP3 (12.05.2011; 02.02.2012; 12.04.2012, 02.07.2012) and WP4 (21.11.2011, 26.01.2012, 03.07.2012). Another official project meeting was held on 27.09.2012 to discuss the results of the WP1, WP2 and WP3 and to specify their use in WP4 (impact modelling) and to agree on further plans in disseminating project results (WP5). More details were discussed using media such as e-mail and telephone.

2.4.2. Explanations of deviations, if any, from the original work and time schedule contained in the project application

Deviations from the original project work plan (page 17 application) were minimal. The development of the spread model started after the interim report, when the datasets of WP2 were made available. To allow a longer testing period of the spread model and a better communication between WP3, 4 and 5 the overlapping periods of the WP were prolonged.

2.5. Annex

The following annexes are provided supplementary to this report:

Annex 1: Current distribution of GFD and its vector *Scaphoideus titanus* in North America and Europe and CLIMEX parameter settings (WP1), 8pp.
Annex 2: Short term experiment to assess the percentage and flight distance of migrating vector populations of *Scaphoideus titanus* (WP2), 4pp.
Annex 3: Dataset to address the spread of GFD (WP2), 6pp.
Annex 4: Dataset to address economic impact (WP2), 3pp.
Annex 5: Results of the stochastic disease spread simulation (WP3), 49pp.
Annex 6: Results of the economic impact assessment (WP4), 9pp.
Annex 7: Bulletin of Insectology (64), 191-192: R. Steffek, H. Reisenzein, G. Strauss, T. Leichtfried, J. Hofrichter, I. Kopacka, M. Schwarz, J. Pusterhofer, R. Biedermann, W. Renner, J. Klement, W. Luttenberger, A. G. Welzl, A. Kleissner and R. Alt (2011): VitisCLIM, a project modelling epidemiology and economic impact of grapevine 'flavescence doree' phytoplasma in Austrian viticulture under a climate change scenario (WP5), 2pp.
Annex 7-1: Poster presentation at the Second International Phytoplasmologist Working Group meeting, Neustadt a.d. Weinstrasse, Germany, 12.-15.09.2011, 1p
Annex 7-2: Poster presentation at the 7th European Conference on Biological Invasions (11-14 September 2012, in Pontevedra, Spanien), 1p
Annex 8: Planned, but not yet released publications (WP5), 1p.
Annex 9: Agenda and protocol of the project kick off meeting (12. April 2011) (WP6),
Annex 10: Bibliography, 4pp

3. Presentation of Costs

3.1. Table of costs for the entire project duration

The following table provides an aggregated overview of the costs incurred by the applicant and the project partners throughout the entire project duration, broken down by staff costs, capital expenditure, travel expenses, administrative and material expenses, and third-party costs. It must correspond to the cost accounting form (annexed to the support contract and/or available for downloading under www.publicconsulting.at).

All figures in EURO.

Cost category	**Eligible total costs according to contract**	**Cumulative costs during the project term** Total costs for the consortium*	**Applicant** Costs incurred during the project term from - to	**Partner 1** Costs incurred during the project term from - to	**Partner 2** Costs incurred during the project term from - to	**Partner 3** Costs incurred during the project term from - to
Staff costs	121.962,00	154.604,00	85.542,00	-	34.515,00	34.547,00
Capital expenditure	-	-	-	-	-	-
Travel expenses	5.000,00	3.415,00	2.353,00	-	1.062,00	-
Administrative and material expenses	9.583,00	1.344,00	1.344,00	-	-	-
Third-party costs	-	-	-	-	-	-
Total	**136.545,00**	**159.363,00**	**89.239,00**	**-****	**35.577,00**	**34.547,00**

* Sum total of costs incurred / cost category of the applicant and all partners

**Partner 1 contributed mainly data to the project. All costs are carried by the project partner (own share of project). The time expended for data collection is shown in the xls-file.

3.2. Statement of costs for the entire project duration

The costs incurred in the outstanding reporting period and over the entire duration of the project must be stated for each partner and/or each set of activities according to the cost schedule specified in the contract and the underlying application.

The costs of the applicant and the partners are clearly represented in the X-CEL file "abrechnungsformular"

3.3. Cost reclassification

Presentation and motivation of cost reclassifications, if any (between partners and/or cost categories), during the duration of the project

A cost reclassification between cost categories on the side of the applicant is necessary.

The literature survey revealed that several factors influence the spread of GFD in a region; e.g. the model to be developed needs to incorporate both the biology and spread activity of the vector, as well as the transmission efficiency of the disease. Moreover, to develop a generic model that can be applied to other vine growing areas, it was necessary to include different topographic situations of the wine growing areas (as expressed by the two model municipalities). This resulted in a multifactorial spread model with a high demand for data and a prolonged testing period.

On the other hand, some of the expenses that were included in the original budget [covered under travel costs (e.g. kilometer allowance) and costs of materials (e.g. organization of meetings)] were covered by the applicant. Moreover, the cost of reagents for the laboratory tests of the actual infestation rate of the vector in the vine growing region were conducted in the frame of another project funded by project partner 1 – and were therefore not charged to the project budget. Other costs budgeted as costs of materials in WP5 (project communication) incurred as personnel costs (e.g. the development of a project homepage).

For this reason, we kindly ask to allocate costs of the categories: travel costs and costs of materials that were not fully expended to the category personnel costs.

Please note the following: for the purposes of final reporting, copies of invoices (e.g. for capital expenditure, travel expenses, etc.) as well as detailed information on staff costs must be annexed to the cost accounting form. The ACRP Program Management reserves the right to perform random checks of the invoices submitted within the framework of the examination of the reports.

4. Utilization (max. 5 pages)

4.1. Publication

Please describe the publication and dissemination activities carried out during the project term (presentations at external events, project workshops and publications)

Publications

- R. Steffek, H. Reisenzein, G. Strauss, T. Leichtfried, J. Hofrichter, I. Kopacka, M. Schwarz, J. Pusterhof-er, R. Biedermann, W. Renner, J. Klement, W. Luttenberger, A. G. Welzl, A. Kleissner, R. Alt. VitisCLIM, a project modelling spread and economic impact of Grapevine Flavescence dorée phytoplas-ma in Austrian viticulture under a climate change scenario. Bulletin of Insectology 64 (supplement), S191-192.
http://www.bulletinofinsectology.org/pdfarticles/vol64-2011-S191-S192steffek.pdf
- H. Reisenzein and R. Steffek (2011): First outbreaks of Grapevine Flavescence Dorée in Austrian Viticulture, Bulletin of Insectology 64 (supplement), S223-224.
http://www.bulletinofinsectology.org/pdfarticles/vol64-2011-S223-S224reisenzein.pdf
- Gudrun Strauss, Robert Steffek, Helga Reisenzein, Michael Schwarz: Modelling the establishment potential of Scaphoideus titanus, vector of Grapevine Flavescence doree phytoplasma, in Europe by using the CLIMEX model.
http://neobiota2012.blogspot.co.at/p/book-of-abstracts.html
- Furtheron, publication of project results of WP1 and 3 are planned

Presentations

- Robert Steffek: VitisCLIM, a project modelling spread and economic impact of Grapevine Flavescence dorée phytoplasma in Austrian viticulture under a climate change scenario. Second International Phytoplasmologist Working Group meeting, Neustadt a.d. Weinstrasse, Germany, 12.-15.09.2011
- Robert Steffek: VitisCLIM, a project modelling spread and economic impact of Grapevine Flavescence dorée phytoplasma in Austrian viticulture under a climate change scenario. 12. Österreichischen Klimatag; 21.09.2011 Exnerhaus der Universität für Bodenkultur, 1190 Wien. http://www.austroclim.at/index.php?id=101 (accessed on 28.02.2012).
- Gudrun Strauss: Erste Ergebnisse zur lokalen Ausbreitung von *Scaphoideus titanus* Rebschutzgebietsleitertagung 2012 AGES, 12.01.2012
- Robert Steffek: VitisCLIM, a project modelling spread and impact of GFD in Austrian viticulture under a climate change scenario - Spread model concept. Follow up meeting „Grapevine flavescence dorée and Scaphoideus titanus 2012: Phytosanitary measures against Grapevine Flavescence Dorée Phytoplasma (Agricultural and Forestry Institute Maribor, Slovenia; 13 March 2012)

- Gudrun Strauss: Short distance spread of *Scaphoideus titanus*. Follow up meeting „Grapevine flavescence dorée and Scaphoideus titanus 2012: Phytosanitary measures against Grapevine Flavescence Dorée Phytoplasma (Agricultural and Forestry Institute Maribor, Slovenia; 13 March 2012)
- Gudrun Strauss, Robert Steffek, Helga Reisenzein, Michael Schwarz: Modelling the establishment potential of Scaphoideus titanus, vector of Grapevine Flavescence doree phytoplasma, in Europe by using the CLIMEX model. Poster presentation at the 7th European Conference on Biological Invasions (11-14 September 2012, in Pontevedra, Spanien).
- Robert Steffek: Überblick zum Klimafondsprojekt VitisCLIM. Rebschutzgebietsleitertagung 2013; 17.01.2013, AGES, Wien
- Gudrun Strauss: CLIMEX Modellierung zur Etablierungswahrscheinlichkeit von Scaphoideus titanus in Europa. Rebschutzgebietsleitertagung 2013; 17.01.2013, AGES, Wien
- Ian Kopacka: *S. titanus* und GFD Ausbreitungsmodell. Rebschutzgebietsleitertagung 2013; 17.01.2013, AGES, Wien
- Robert Steffek: VitisClim: Ein Projekt zur Entwicklung von Modellen zur Etablierung, Ausbreitung und den wirtschaftlichen Folgen von GFD. Tag des Steirischen Weines 2013; 12.03.2013; Landwirtschaftlichen Fachschule für Weinbau und Kellerwirtschaft Silberberg, Leibnitz
- Gudrun Strauss: CLIMEX Modellierung zur Etablierungswahrscheinlichkeit von *Scaphoideus titanus* in Europa. Tag des Steirischen Weines 2013; 12.03.2013; Landwirtschaftlichen Fachschule für Weinbau und Kellerwirtschaft Silberberg, Leibnitz
- Ian Kopacka: Stochastische Simulation der Ausbreitung von Grapevine Flavescence dorée und des Vektors *Scaphoideus titanus* in ausgewählten steirischen Gemeinden. Tag des Steirischen Weines 2013; 12.03.2013; Landwirtschaftlichen Fachschule für Weinbau und Kellerwirtschaft Silberberg, Leibnitz
- Robert Steffek: Modelling epidemiological and economic consequences of Grapevine Flavescence dorée phytoplasma to Austrian viticulture under a climate change scenario (VitisCLIM). 14. Österreichischer Klimatag, Univ. für Bodenkultur, Wien, 4.-5. April 2013
- Ian Kopacka: Stochastische Simulation der Ausbreitung der Grapevine Flavescence dorée und des Vektors *Scaphoideus titanus* in ausgewählten steirischen Gemeinden. 68. ALVA-Jahrestagung 23 und 24.05.2013, HBLA für Wein- und Obstbau; Klosterneuburg.

Project meetings

Kick-off Meeting: 12.04.2011 and Interim meeting: 27.09.2012 (all partners)
Project leader and WP3: 12.05.2011; 02.02.2012; 12.04.2012, 02.07.2012
Project leader and WP4: 21.11.2011, 26.01.2012, 03.07.2012.

Project homepage

Knowledge transfer of the project results is facilitated by the creation of a project homepage that gives an overview on the project and its main results. It is available at the end of the project and can then be consulted by different target groups: www.vitisclim.org

Figure 12: Project homepage

4.1. Market:

Please outline the market outlook and the economic potential as perceived at the end of the reporting period

Not relevant for this project

4.2. Patents:

Please list the applications for patents filed during the reporting period on the basis of the project.

Not relevant for this project

4.3. Doctoral dissertations:

If applicable, please list the names of the doctoral students involved in the project and indicate the status of their dissertations (doctoral dissertation started, in progress, terminated).

Not applicable for this project

5. Outlook (max. 1 page)

Please draft recommendations for follow-up research and development activities.

Given that climate change will have continuous impact on agriculture and related industries in the following decades, intervention scenarios and structural change has to be developed and implemented by all relevant stakeholders. One example of the effects of climate change is the shifting of the distribution and abundance of poikilothermic species, such as plant pests and diseases. The dramatic increase of global trade offers opportunities for the introduction of new invasive plant pests. The quantitative models we developed and/or applied during the project can be adopted and used for other pest introductions in the future. Climex is a widely used software to assess the establishment potential of a new plant pest. Providing the availability of sufficient data of a pests biology and distribution in its native range, it can be used for other newly introduced pests. This project provides a generic spread model that can be adapted for predicting the spread patterns of GFD in other vine growing areas, in Austria and elsewhere in Europe. Furthermore, similar models could be derived for other emerging plant diseases. Particularly vector transmitted plant pests with a similar biology. Developing intervention strategies for plant pest imply also a thorough analysis of economic impact of potential measures to be taken by federal and provincial governments. In this project an economic impact analysis based on the Input-Output Analysis (IOA) approach proved to be a useful means for this purpose. Therefore it is suggested to performing further research using the IOA in pest risk assessments or other fields of agriculture and food production in order to guarantee most efficient use of tax payer’s money.

6. Signature

I herewith confirm that the report in its entirety has been accepted by the project partners.

Vienna, 28.06.2013

Place, date

Signature of the applicant (coordinator)

Please note: the signature has to be scanned in and inserted into the document.