Appendix 3

Scenario selection procedure for volatilization from plant surfaces

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1. Introduction

After spraying a pesticide onto the plant or soil surface, various processes influence the subsequent fate of the pesticide. Depending on the physic-chemical properties of the pesticide and the soil and weather conditions, the relative contribution of processes such as leaching, transformation and volatilization to the overall fate will differ. For BROWSE project volatilization process from soil and plant surfaces will be simulated with an improved version of PEARL model (Leistra et al., 2001) and a new modelling tool will be developed (BROWSE-PEARL model). In order to determine vapour concentrations at appropriate locations within a landscape, there is a requirement to couple an emission model such as BROWSE-PEARL to a dispersion model. For this reason BROWSE-PEARL has been coupled to the atmospheric dispersion model OPS (Van Jaarsveld, 2004). OPS (Operational atmospheric transport model of Priority Substances) is a model that simulates the atmospheric process sequence of emission, dispersion, transport, chemical conversion and finally deposition. The output of multiple runs using the coupled BROWSE-PEARL/OPS models will be used in the software tools developed in the BROWSE project for regulators to evaluate the exposure of operators, workers, bystanders and residents after volatilisation of PPPs from treated areas.

To test the new modelling tool example scenarios have been developed for the South and Centre EU two EU-Zones (Fig.1) used in the registration procedure of plant protection products in the EU and described in Annex 1 of Council Regulation (EC)1107/2009.

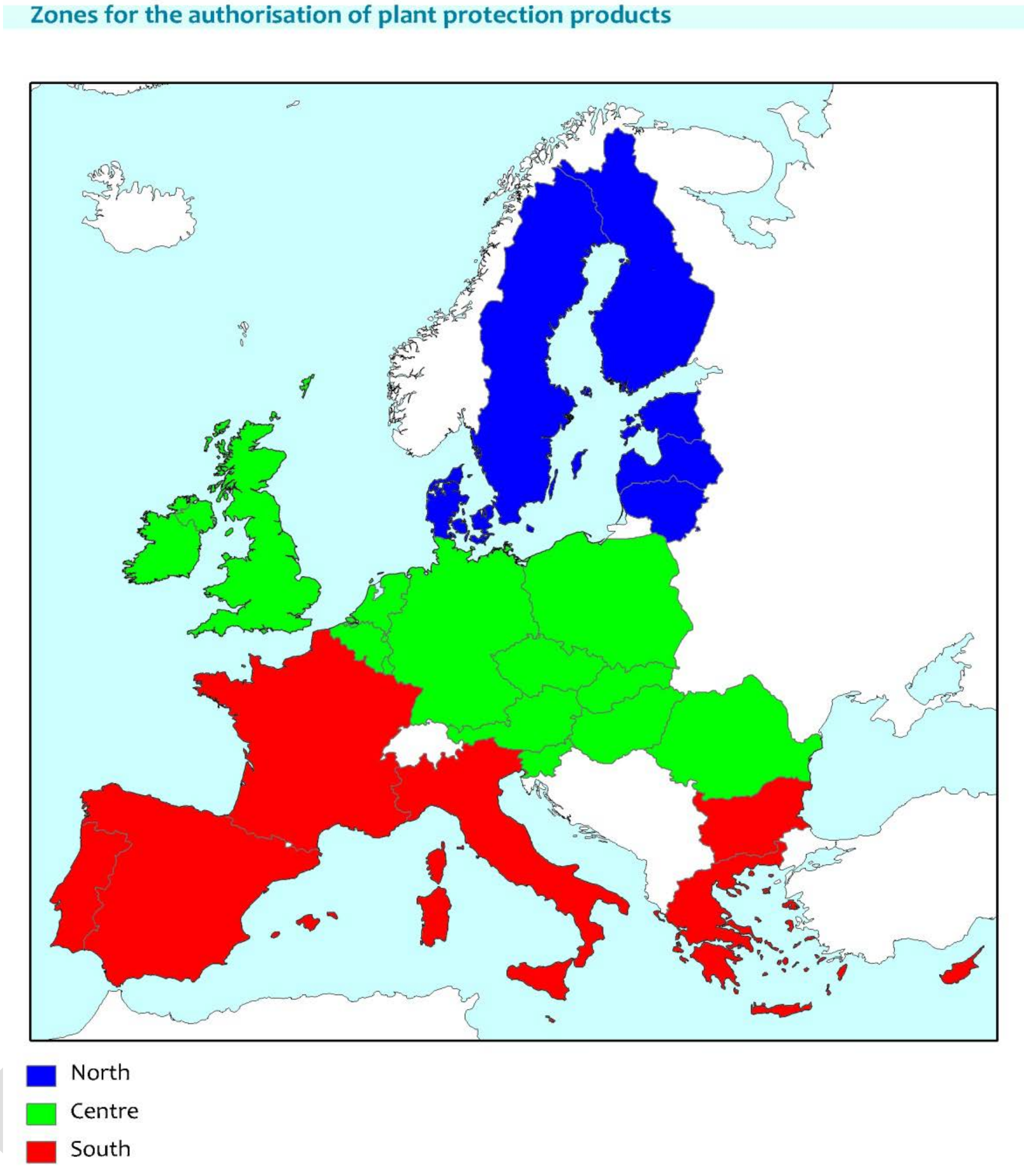

Figure 1. Map of the three regulatory zones used in the registration procedure of plant protection products in the EU.

Volatilisation from plant surfaces is normally greater than volatilisation from soils because plants have fewer sorption sites than soil. Therefore it has been decided that initially, for the development of the BROWSE-PEARL/OPS modelling tool, only volatilization from plant surfaces will be considered.

The potential amount of volatilisation may be reduced by various competing processes such as uptake (penetration) into the leaves or degradation on the plant surface, especially photo-degradation. Furthermore, pesticide deposit is vulnerable to wash-off by rainfall. Consequently, the main factors that influence pesticide volatilisation from crop surfaces are the physicochemical properties of the pesticide, the pesticide persistence on the plant surface and the environmental conditions.

The scenarios that have been developed will are realistic worst-case scenarios. The position of the realistic worst-case scenarios is determined by the meteorological data that influence pesticide volatilization from plant surfaces and subsequent atmospheric dispersion. A higher ***air temperature*** tends to favor volatilization from plants, because the vapor pressure of the compound is temperature-dependent and additionally the adsorption to the leaf surface decreases with increasing temperature. Due to its effect on air temperature and leaf-surface temperature, ***solar irradiance*** also enhances volatilization. Furthermore, pesticide deposit is vulnerable to wash-off by ***rainfall***. Under rainy conditions, parts of the pesticide deposit may be washed-off from the leaves, resulting in a drastic reduction in pesticide volatilisation rate. Finally, the resistance in air to the volatilization of substances is often described assuming a boundary laminar air layer through which the pesticide has to diffuse before it can escape into the atmosphere. The thickness of the laminar air boundary layer is influenced by parameters like ***wind speed*** and ***atmospheric turbulence***. Generally, increasing wind speed and more turbulent climatic conditions are expected to decrease the air boundary layer. Summarizing, the position of the realistic worst-case scenarios for pesticide volatilization from plant surfaces and subsequent atmospheric dispersion must be in geographical areas with high annual average air temperature and solar irradiation, low annual rainfall, low wind speed and atmospheric turbulence. For the scenario selection procedure a high average air temperature over the crop growing season has been chosen as the predominant meteorological parameter that favors volatilization from plants.

To test the coupled BROWSE-REARL/OPS modelling tool, one scenario has been developed for the South EU regulatory zone and one scenario for the Centre EU regulatory zone. For the South EU-Zone the scenario has been developed in Italy. For the Central EU-Zone the scenario has been developed in The Netherlands while for the North EU-Zone the position of the selected scenario (to be developed) will depend on data availability in the North EU countries. The target was to define 90 percentile spatial properties for the selected scenarios. For volatilization from plant surfaces, the target was the 90th spatial percentile of the average air temperature over the crop growing season.

2. South EU Zone-Italian scenario

2.1 Crop data

For the Italian scenario vines have been chosen as representative crop. For BROWSE project scenarios crop growth data are taken from FOCUS groundwater report (FOCUS, 2000) for the FOCUS Piacenza scenario. For vines FOCUS groundwater scenarios assume initial leaves early May and harvest mid-September. The ground-cover is 40-50 % at mid-season. The meteorological situation is humid, light to moderate windy.

Allowing models to calculate interception presents no benefits either in terms of accuracy or consistency. As stated in FOCUS (2000): “For reasons of consistency, simplicity and accuracy, FOCUS recommend that the internal interception routines in all models are disabled and the application rate is manually corrected for interception. Therefore interception values for vineyards are according to interception in Sanco/321/2000 rev.2 (FOCUS, 2000) and BBCH growth stage of the crop (Table 1). The ground water interception values are considered to be a realistic representation of what happens in the field at the first tier of simulation. To account for realistic worst case scenario pesticide application will be post-emergence application with 70 or 85% crop interception.

Table 1. Interception (%) by vines dependent on growth stage

Crop	**Stage**				
Vines	without leaves 40	first leaves 50	leaf development 60	flowering 70	ripening 85

2.2 Geographical position of the BROWSE-Volatilization Italian scenario.

2.2.1 Vine growing area in Italy and South EU Regulatory Zone

To define the position of the Italian BROWSE volatilization scenario, the Corine Land Cover 2000 seamless vector data (version 15, 08/2011) have been processed, to define the areas in Italy where vine crops are grown (Fig. 2). Corine Land Cover 2000 is the year 2000 update of the first CLC database which was finalized in the early 1990s as part of the European Commission program to COoRdinate INformation on the Environment (Corine).

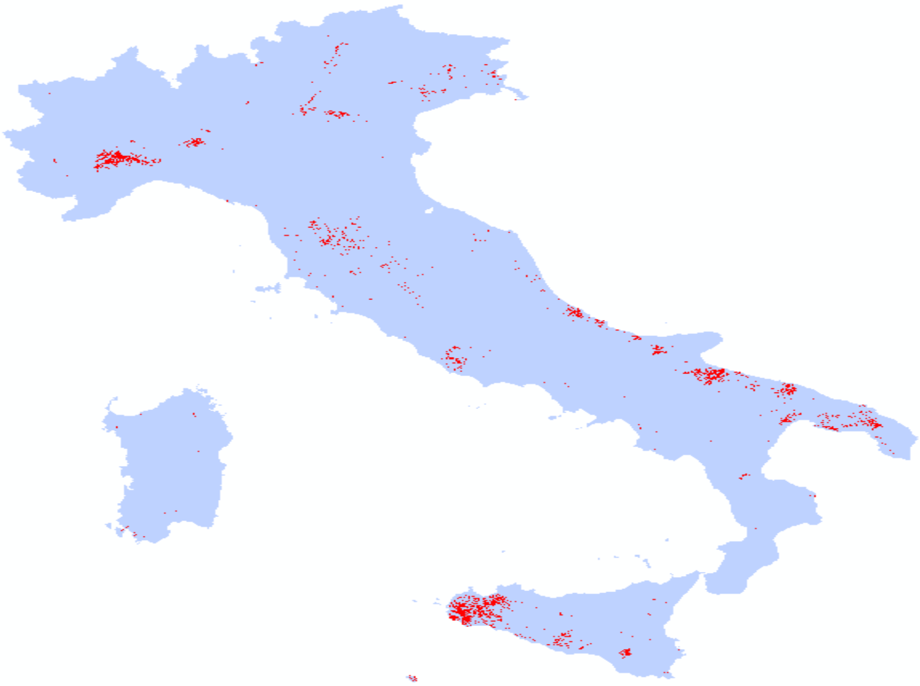

Figure 2. Vine growing area in Italian territory (Corine, Land Cover 2000, v15)

In Figure 3 is given the vine growing area in the South EU Regulatory Zone.

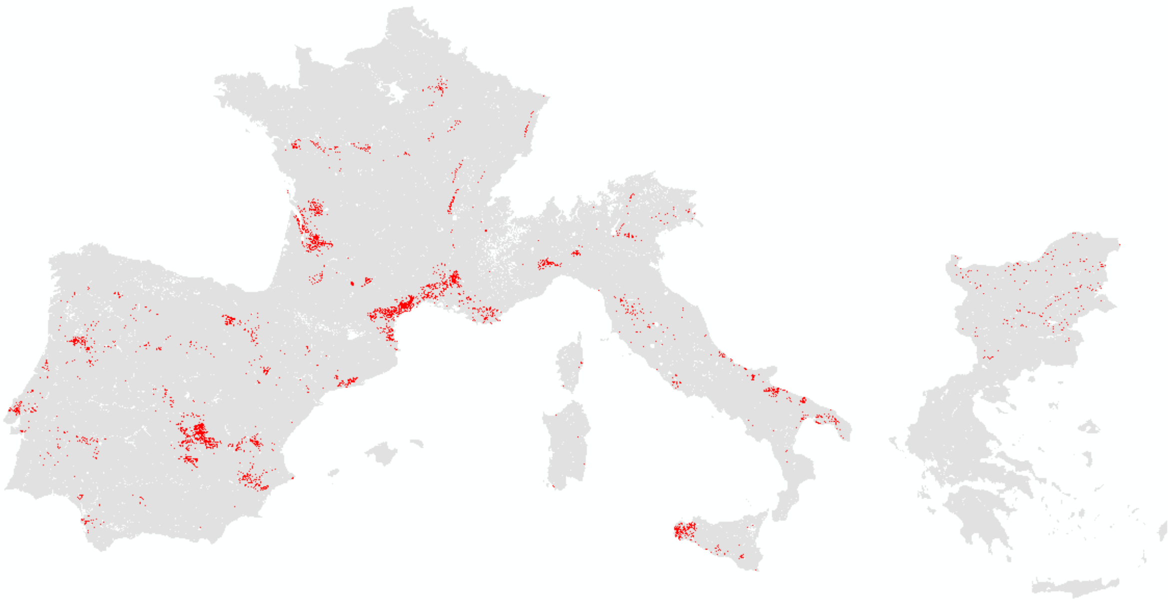

Figure 3. Vine growing area in South EU Regulatory Zone (Corine, Land Cover 2000, v15)

2.2.2 Meteorological data for South EU regulatory Zone scenario

Meteorological maps of mean monthly air temperature have been available from JRC-Joint Research Center, Ispra, Italy, (Gardi et al., 2010; Panagos et al., 2012). These maps have been created by JRC within the activities realized within the Service Level Agreement between JRC and EFSA. The data released, produced in EFSA Project, were elaborated by Joint Research Centre of the European Commission (JRC) and by the experts of EFSA PPR FATE Working Group(WG), through the processing of data available at the European Soil Data Centre (ESDAC), Harmonized World Soil Database, Worldclim database, Capri database. The dataset consists of 12 maps containing the monthly mean temperature (deg C) for the period 1960-1990. The dataset is described in Hijmans et al. (2005).

Common metadata properties for the maps are shown in Table 2 (Gardi et al., 2010). The Corine Land Cover 2000 seamless vector data used to define the vine growing area in Italy and South EU Regulatory Zone have been processed to bring the Corine Land Cover maps to a common resolution and projection as the JRC-EFSA maps (Table 2).

Table 2. Common metadata properties for the maps provided by JRC (Gardi et al., 2010)

Format:	compressed ASCII grid
Reference system:	ETRS 89 LAEA
Rows:	4098
Columns:	3500
Lower left:	2500000
Upper left:	1412000
Cell size:	1000
Unit:	m
Nr of cells with a value:	3997812

For vines FOCUS groundwater scenarios assume initial leaves early May and harvest mid-September, therefore the mean monthly air temperature maps for the months April to October (7 maps) have been processed to obtain a map with the mean air temperature for the vine growing period in Italy (Fig. 4).

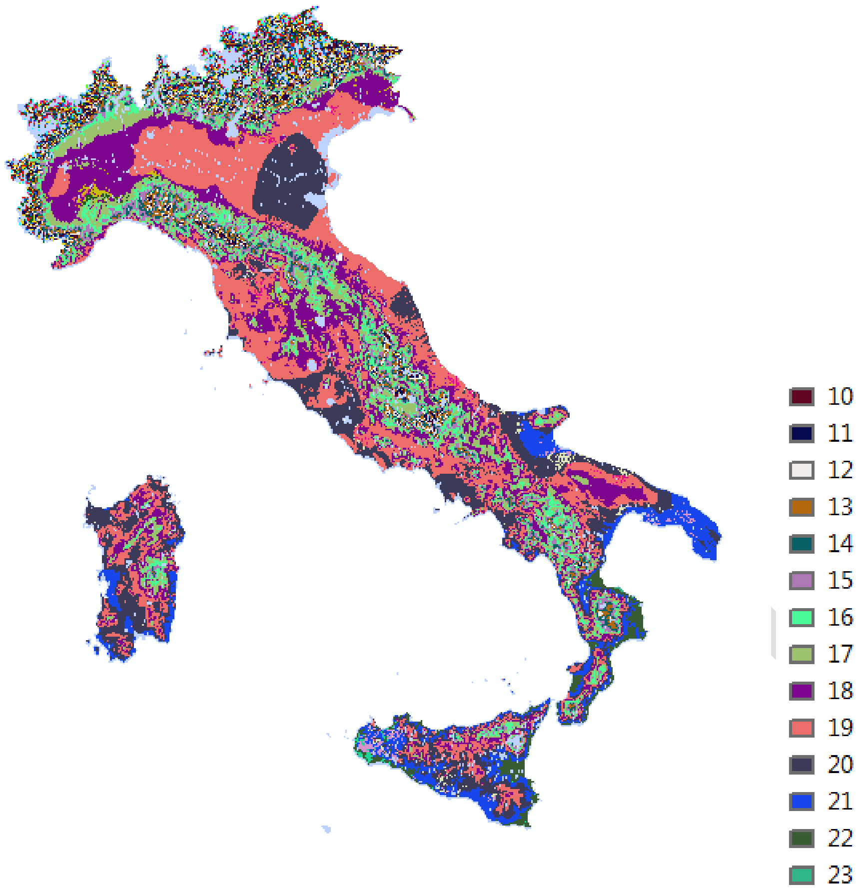

Figure 4. Spatial distributed mean air temperature (°C) in Italy for the vine growing period (April-October)

Next, the land cover map (Fig. 2) is overlaid to the map of mean air temperature (°C) in Italy for the vine growing period (Fig. 4) to derive a new map with the mean, vine growing period, air temperature only for the vine growing areas in Italy (Fig.5). All maps are 1X1 km2.

Figure 5. Spatial distributed mean vine growing period air temperature (^{o}C) for the vine growing areas in Italy

The Italian scenario must have a mean monthly air temperature close to the 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy and initially a number of candidate scenarios have been individuated. The 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy is 21 ^{o}C and the candidate Italian scenario is located in Sicily Region. In Figure 6 is given the mean vine growing period air temperature (^{o}C) for the vine growing areas in Sicily Region while in Figure 7 are given the candidate Italian scenarios with mean vine growing period air temperature (^{o}C) close to the 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy.

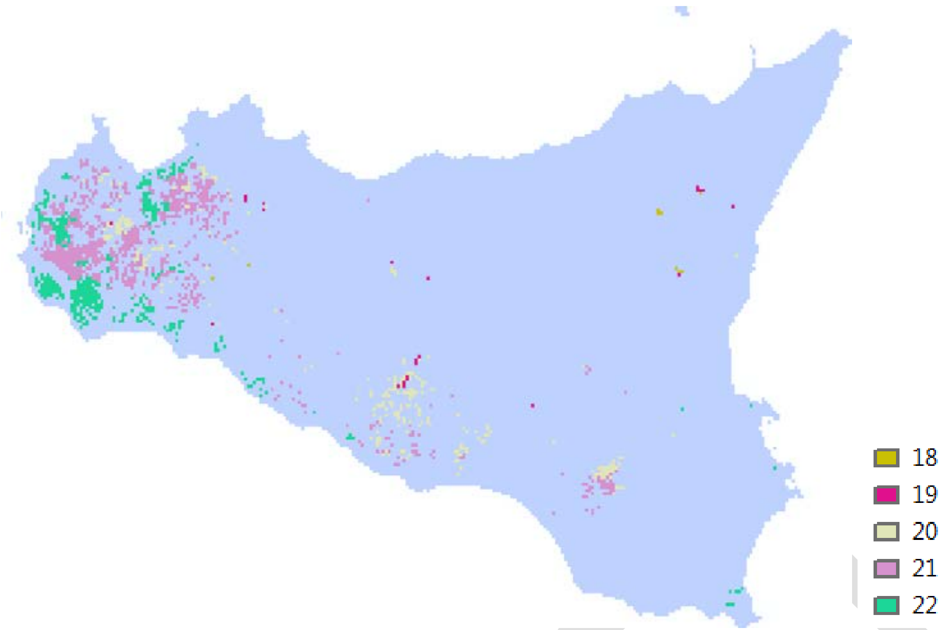

Figure 6. Spatial distributed mean vine growing period air temperature (^{o}C) for the vine growing areas in Sicily Region

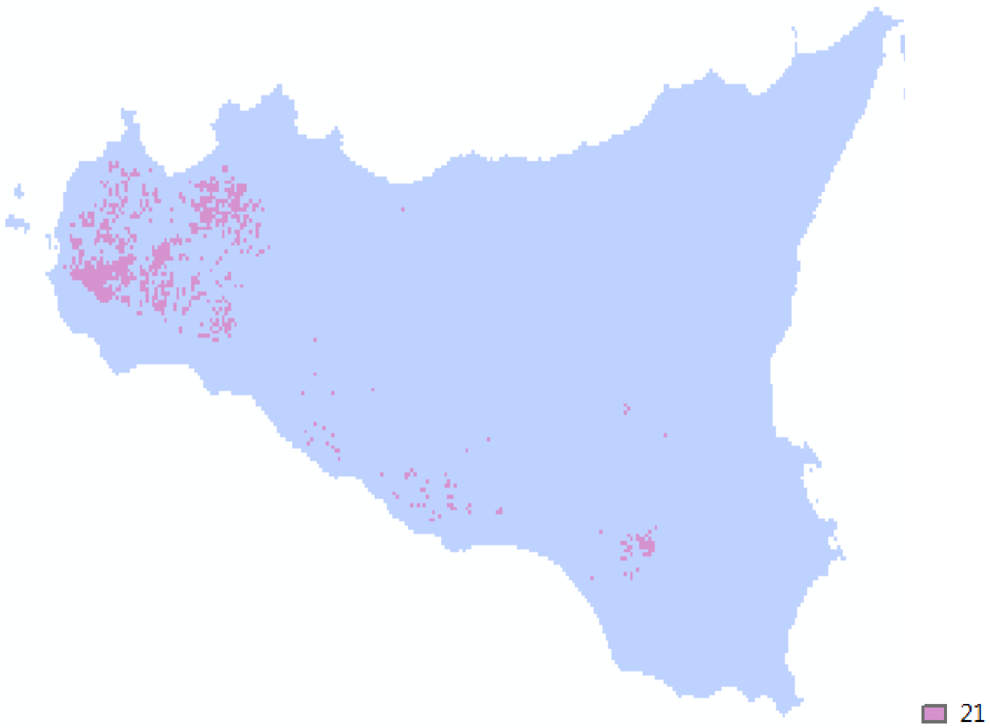

Figure 7. Candidate Italian scenarios with mean vine growing period air temperature (^{o}C) for the vine growing areas in Italy

However, both BROWSE PEARL and OPS models require hourly data of air temperature. For this reason, meteorological databases that provide meteorological data in hourly bases have been used. In Italy the ARPA-SIM database (Agenzia Regionale Prevenzione e Ambiente -Servizio IdroMeteoClima) provides hourly data of air temperature, air humidity, wind speed and direction, atmospheric pressure, rainfall and mean solar radiation for the Emilia Romagna and Lombardy regions where vine crops are grown. The same kind of data provides the SIAS (Servizio Informativo Agrometeorologico Siciliano) database for the Sicily Region. Once the candidate Italian scenarios have been individuated in Sicily Region, the SIAS meteorological database has been processed in order to identify the scenario(s) that satisfy both the 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy and the data availability in hourly bases.

BROWSE-PEARL model requires hourly data of:

- air temperature (^{o}C)
- global radiation (kj m^{-2} h^{-1})
- air humidity expressed as vapour pressure deficit (VPD) in kPa.

Usually data from weather stations are data on relative humidity expressed in %. Relative humidity can be converted in kPa if the air temperature is available.

- average wind speed (m/s) and the height (m) in which it was measured
- precipitation in mm/h

The air humidity and the global radiation are required by the model in order to estimate the reference evapotranspiration (mm/h). The potential evapotranspiration is calculated from the reference potential evapotranspiration by multiplication with a crop factor for a dry canopy that completely covers the soil. The crop factor can be varied during the crop cycle. The potential evapotranspiration is separated into the potential transpiration and potential evaporation on the basis of the leaf area index (LAI). The crop factors and the LAI for the Italian scenario are those specified by the FOCUS GW workgroup for Piacenza FOCUS scenario.

Several weather stations located in the northwestern part of Sicily Region (Trapani province) have been processed. The weather stations of Salemi and Castelvetrano in the Trapani province (Fig.8) satisfied both the 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy and the data availability in hourly bases. Therefore, the meteorological file that will be used to test the BROWSE PEARL/OPS model contains the average hourly air temperature of these two weather stations (Salemi and Castelvetrano). The other meteorological data (precipitation, global radiation, wind direction, wind speed at 10m, relative humidity of the air at 1.5m) are from Castelvetrano weather station. Weather data are for two years (from 01/01/2010 to 31/12/2011). The meteorological file for the Italian scenario that will be used to test the BROWSE PEARL/OPS model is given in Appendix I.

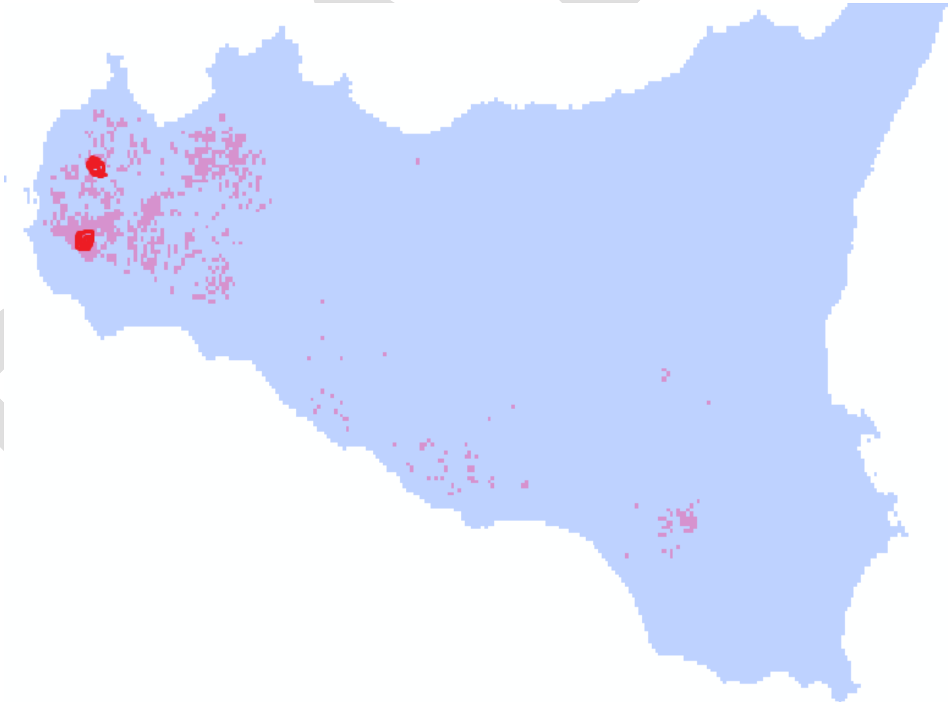

Figure 8. Location of the Italian scenarios that satisfied both the 90th percentile of the mean vine growing period air temperature for the vine growing areas in Italy and the data availability in hourly base

3. Centre EU Zone-Dutch scenario

3.1 Crop data

For the Dutch scenario flowers have been chosen as representative crop because Holland's leading position in agriculture is on full display in the ornamentals sector. More than half of internationally traded cut flowers and plants pass through The Netherlands and more than 40 percent of all flowers and plants grown worldwide are Dutch varieties. Every year 1800 new varieties enter the European market, 65 percent originates from The Netherlands.

As no FOCUS crop exists for ornamental flowers and no crop growth data are available for flowers, for the testing of the BROWSE PEARL/OPS model crop growth data for flowers will be taken from FOCUS groundwater report (FOCUS, 2000) for the FOCUS Hamburg scenario for winter cereals (unless crop growth data for flowers in The Netherlands become available).

3.2 Geographical position of the BROWSE-Volatilization Dutch scenario.

3.2.1 Flower growing area in The Netherlands and Centre EU Regulatory Zone

To define the position of the Dutch BROWSE volatilization scenario, Capri Land Cover maps have been processed, to define the areas in The Netherlands where flowers are grown. Capri maps show for each pixel of 1x1 km2 the area covered with a certain crop. The CAPRI maps were obtained (Gardi et al., 2010) by combining remote sensing data, administrative crop data, land suitability data and statistical modelling. The CORINE land cover map serves as a starting point. Subdivisions within CORINE land cover classes were made based on a statistical model, regressing point observations of cropping activities on soil, relief and climate parameters (land suitability). Statistical data of agricultural production and land cover available for administrative regions were additionally used to scale the land cover classes. 18 of the CAPRI land cover classes are classified as annual crops and are included in the EFSA dataset. See Leip et al. (2008) for a description of the dataset.

In Figure 9 is given crop cover map for floriculture in The Netherlands. In Figure 9 only the areas with crop coverage more than 10% for floriculture are shown (green color).

Figure 9. Crop cover map (100% of area) for floriculture in The Netherlands (more than 10% coverage with flowers)

In Figure 10 is given the crop cover map (% of area) for floriculture in the Centre EU regulatory Zone. The values range from 0 to 10000 (10000 is 100% area covered by a crop).

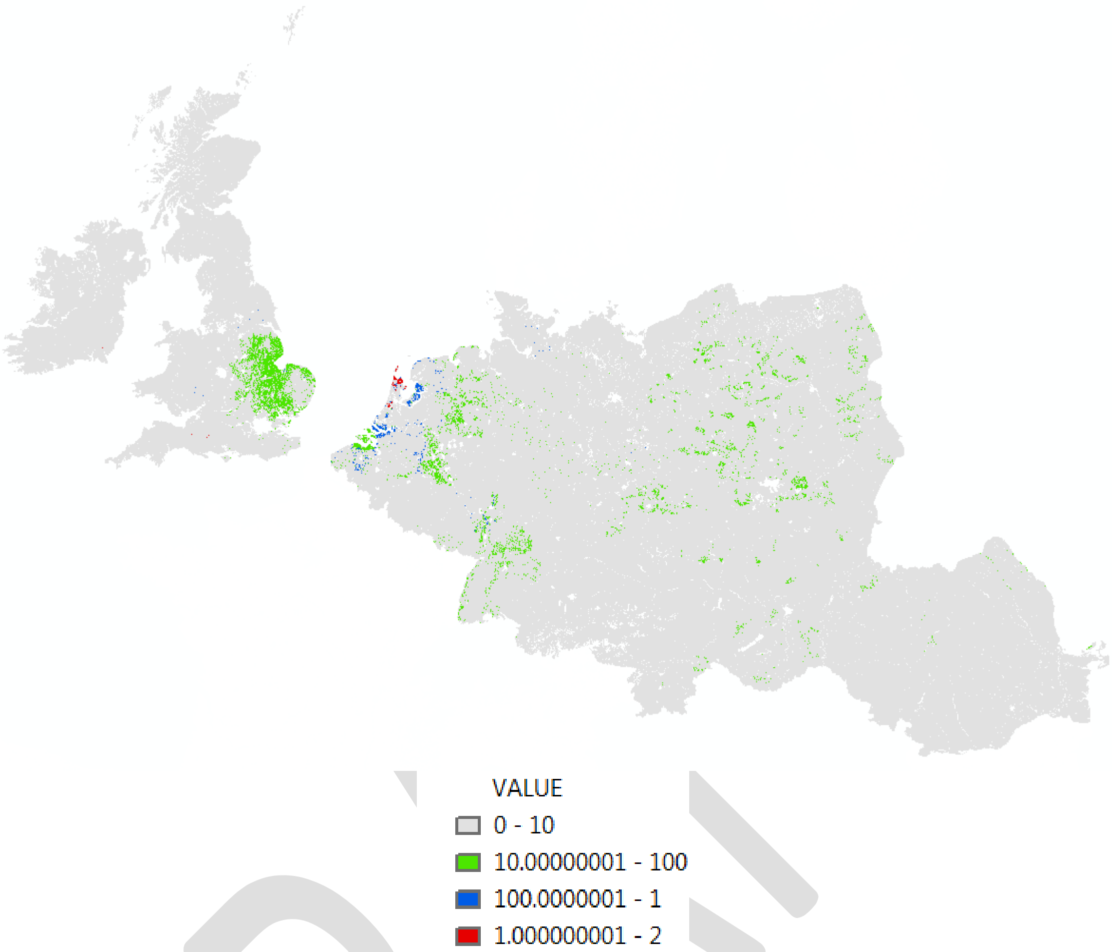

Figure 10 . Crop cover maps (% of area) for floriculture in Centre EU regulatory Zone.

3.2.2 Meteorological data for Centre EU regulatory Zone scenario

The meteorological maps of mean monthly air temperature for the period 1960-1990 that have been available from JRC-Joint Research Center, Ispra, Italy, (Gardi et al., 2010; Panagos et al., 2012) have been elaborated again, to define the mean air temperature for the flower growing period in The Netherlands.

Typically flower bulbs in The Netherlands are planted from half October to half December (planted period for tulip bulbs) depending on the weather conditions. The tulip growers start planting the tulip bulbs when the soil temperature has gone down to +/- 12^{o}C. When the soil temperature is higher there is a risk for diseases like Augusta sick and Fusarium. After the bulbs are planted, they start rooting in the soil. From November till February the tulips stay below the surface because the temperature is low during this period (-10 ^{o}C/ 5 ^{o}C). This period of low temperature is necessary for the tulips to get their length later on. When around the end of March the temperature starts rising in Holland, the tulips start growing out of the ground. When the leafs of the tulip plants start spreading, the tulip growers start selecting the tulip plants for viruses by looking for differentials on the leafs. Virus selection is taking out the sick plants which show differentials from the healthy plants. Around the end of April the tulips flower on the fields. During the flowering period the tulip growers select the tulip plants for viruses by looking for differentials on the flowers. After the tulips are "cleaned" from the viruses, the tulip growers cut the flowers from the tulip plants so the tulip plants can use all their energy to produce bigger bulbs. Half July the tulip plants have grown big bulbs and the tulip plants die. After the tulip plants have died the bulbs are ready for harvesting.

Therefore for the flower bulb growing period the whole year (12 months) has been considered and the mean annual air temperature map has been used. In Figure 11 is given the spatial distributed mean annual air temperature (^{o}C) for the Netherlands.

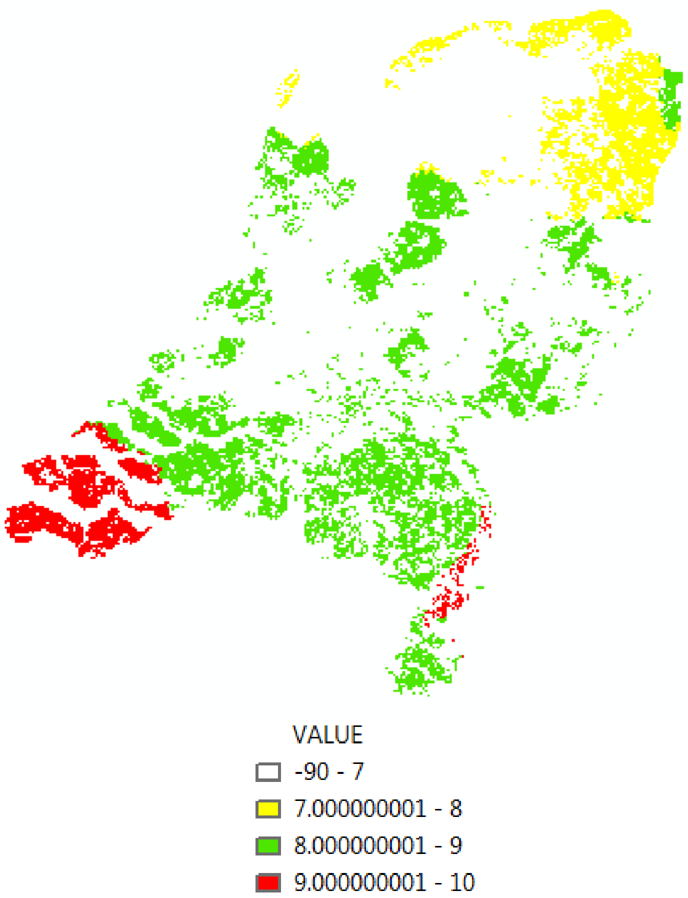

Figure 11. Spatial distributed mean annual air temperature (^{o}C) for the Netherlands

Next, the land cover map for floriculture in The Netherlands (Fig. 9) is overlaid to the map of mean annual air temperature (°C) in The Netherlands (Fig. 11) to derive a new map with the mean annual air temperature only for the flower bulb growing areas in The Netherlands (Fig.12).

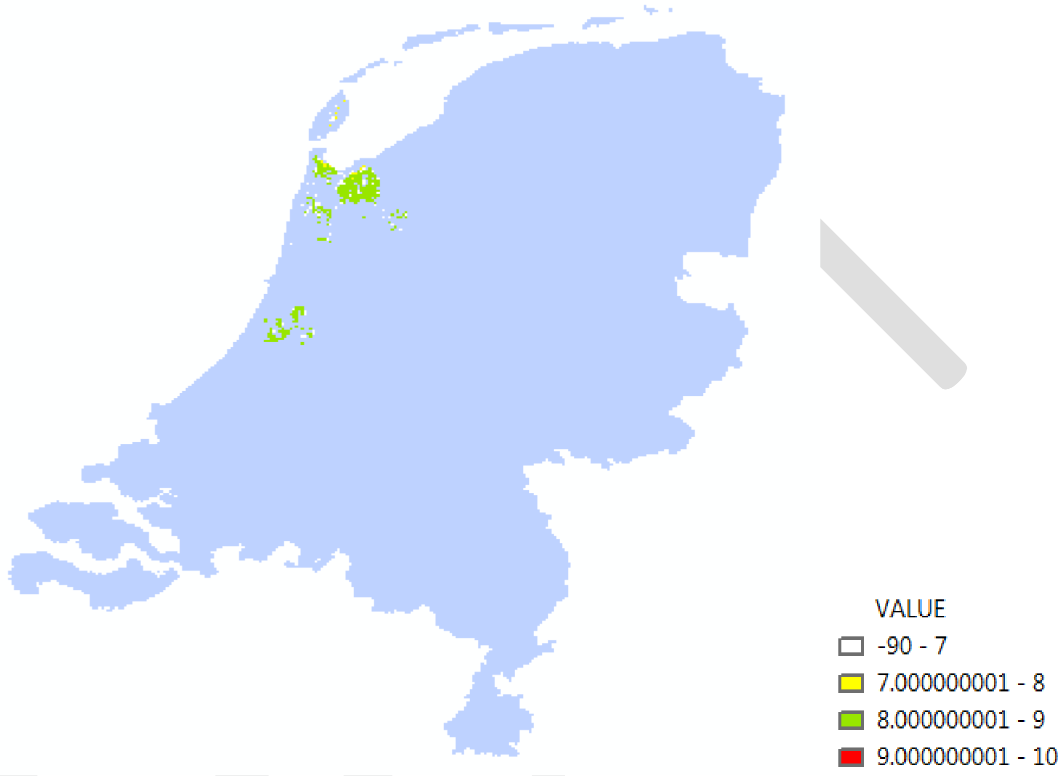

Figure 12. Spatial distributed mean annual air temperature (°C) for the flower bulbs growing areas in the Netherlands

The Common metadata properties for the maps are shown in Table 2 (Gardi et al., 2010). The CAPRI Land Cover maps used to define the flower bulbs growing area in The Netherlands and Centre EU Regulatory Zone have been processed to bring the Corine Land Cover maps to a common resolution and projection as the JRC-EFSA maps (Table 2).

As in the case of the Italian scenario, also the Dutch scenario must have a mean monthly air temperature close to the 90th percentile of the mean annual air temperature for the flower bulbs growing areas in The Netherlands and initially a number of candidate scenarios have been individuated. The 90th percentile of the mean annual air temperature for the flower bulbs growing areas in The Netherlands is 9 ^{o}C and the candidate Dutch scenario is located in the northwestern part of the Netherlands. In Figure 13 are given the candidate Dutch scenarios with mean annual air temperature (^{o}C) close to the 90th percentile of the mean annual air temperature (^{o}C) for the flower bulbs growing areas in The Netherlands.

However, both BROWSE PEARL and OPS models require hourly data of air temperature. For this reason, meteorological databases that provide meteorological data in hourly bases have been used. In The Netherlands the Royal Dutch Meteorological Institute (Koninklijk Nederlands Meteorologisch Instituut-KNMI, www.knmi.nl) provides hourly data of air temperature, air humidity, wind speed and direction, atmospheric pressure, rainfall and mean solar radiation for the Dutch territory. Once the candidate Dutch scenarios have been individuated in the northwestern part of Holland, the KNMI meteorological database has been processed in order to identify the scenario(s) that satisfy both the 90th percentile of the mean annual air temperature for the flower bulbs growing areas in Holland and the data availability in hourly bases.

Several weather stations located in the northwestern part of Holland have been processed (De Kooy, Wijkaan Zee, Cabauw and Gilze-Rijen). These weather stations satisfied both the 90th percentile of the mean annual air temperature for the flower bulbs growing areas in Holland and the data availability in hourly bases. Therefore, the meteorological file that will be used to test the BROWSE PEARL/OPS model contains the average hourly air temperature of these weather stations (De Kooy, Wijkaan Zee, Cabauw and Gilze-Rijen). The other meteorological data (precipitation, global radiation, wind direction, wind speed at 10m, relative humidity of the air at 1.5m) are from Gilze-Rijen weather station. Weather data are for two years (from 01/01/2010 to 31/12/2011). The meteorological file for the Dutch scenario that will be used to test the BROWSE PEARL/OPS model is given in Appendix II.

4. Substance data

The properties of the substance that will be used for the BROWSE scenarios in order to have realistic worst case scenarios must be decided. For volatilization from the plant surface the saturated vapour pressure will be the most sensitive parameter but when volatilization from soil will also be treated Koc and soil DegT50 will be important.

5. Scenarios for volatilization from soil surface

When it comes to volatilization from soil surfaces, also other parameters are import as well. A decrease in soil humidity means drying of the soil, resulting in increased sorption and less volatilisation but re-moistening of the soil surface can cause a rapid volatilisation.

The greater volatilisation from wet than from dry soils is due mainly to an increased vapor pressure resulting from displacement of the pesticide from soil surfaces by water. Thus, any meteorological condition or tillage practice that affects the soil moisture distribution near the soil surface will have a profound effect on the amount of volatilisation.

Soil organic matter content influences soil adsorption coefficient Koc and, since sorption is a competing process for volatilisation from soil, it also influences volatilisation. Consequently, when scenarios from volatilization from soil surface will be developed, the same procedure of the scenario selection for volatilization from plant surfaces will be followed but additional spatial maps will be used. The following maps are available for this reason: topsoil organic matter (OM), soil texture, soil water content at field capacity, rainfall, land cover, and EU countries. All maps are available from JRC and are 1X1 km^2. For more information on the maps the reader is referred to Gardi et al. (2010).

6. Conclusion

Summarizing the above, initially one scenario for volatilization from plant surfaces for the South and the Centre EU regulatory Zones has been be developed to test the coupled BROWSE-PEARL/OPS modelling tool. The driving environmental parameter that defined the position of the realistic worst case scenarios was the mean air temperature for the crop growing season in the intended area of use in the two regulatory zones and the target was be the 90^{th} spatial percentile of the mean air temperature for the crop growing season. For Italy (South EU Zone) vines have been chosen as a representative crop while for Holland (Centre EU Zone) flower bulbs were chosen as representative crops. The Corine Land Cover 2000 seamless vector data and the CAPRI land cover maps provided by JRC (Joint Research Center, Ispra, Italy, Gardi et al., 2010) have been be processed, to define the areas in the two regulatory zones where the chosen representative crops are grown. Next, the land cover maps have be overlaid to a map of average crop growing season air temperature, to derive the 90^{th} percentile of the mean annual air temperature for the chosen representative crop growing areas in the two regulatory zones. In order to be conservative enough, the selected scenarios have a mean annual air temperature close of the 90th spatial percentile of the of the mean crop growing season air temperature in the intended area of use, high solar radiation and low wind speed and atmospheric turbulence. Hourly data of air temperature, global solar radiation, wind speed, air humidity and rainfall have been acquired from meteorological stations close to the position of selected scenarios. For the North EU-Zone scenario the position of the selected scenario (to be developed) will depend on data availability in the North EU countries.

7. References

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