Development of representative groundwater leaching scenarios for greenhouse crops

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Introduction and objectives

The recently published EFSA (2014) guidance document on emissions of plant protection products emitted from greenhouses (GH) provides a general framework for exposure assessment. Although an example scenario for leaching to groundwater is provided, it is stated that the representativeness of the scenario on national and European level has not been established and is, thus, merely illustrative. The objective of this study was to develop more detailed representative scenarios for low-tech greenhouses. Key parameters incorporated into FOCUS leaching scenarios were modified to reflect conditions in a typical greenhouse scenarios (GHS). FOCUS PEARL version 4.4.4 was used to support groundwater modeling. The scenario provided by EFSA (2014) guidance was also employed and compared with DuPont-developed GH scenarios as well as standard field scenarios. For sake of ease, scenarios developed by DuPont in FOCUS and EFSA will be mentioned as DuPont-Sevilla GHS and EFSA-Pistoia GHS, respectively.

Fig. 1. Typical greenhouses in Spain

Soils

The FOCUS groundwater group defined a generalised soil profile for each scenario. DuPont used the Sevilla scenario without modification of soil parameters. By comparison, EFSA guidance (2014) proposes to use FOCUS Piacenza soil.

Crop

A cropping scenario for tomatoes, a commonly grown soil-bound crop in greenhouses, is available within the FOCUS framework. For DuPont-Sevilla GHS, the application dates were modified to represent a typical long-cycle crop which includes transplanting in late summer and harvesting in late spring. Cropping dates of transplants were set to 01 Aug, harvest beginning in Nov and final harvest on 31 May. EFSA-Pistoia GHS cropping dates are similar to that of open field FOCUS-Piacenza with transplant in March and harvest in August.

Temperature

Respective temperature profiles from FOCUS scenarios for tomatoes (Chateaudun, Piacenza, Thiva, Sevilla and Porto) were compared with monthly average temperatures from the main greenhouse areas in Spain (Fig 3). Data was obtained from public sources for weather stations in Barcelona, Alicante, Valencia, Murcia, Almería and Jerez de la Frontera. It can be seen that FOCUS Sevilla is most representative of primary GH regions followed by Thiva. All other scenarios, including EFSA-Pistoia, reflect much lower temperatures and are thus not representative for Spanish greenhouse areas. Hence, modeling was based on Sevilla temperatures.

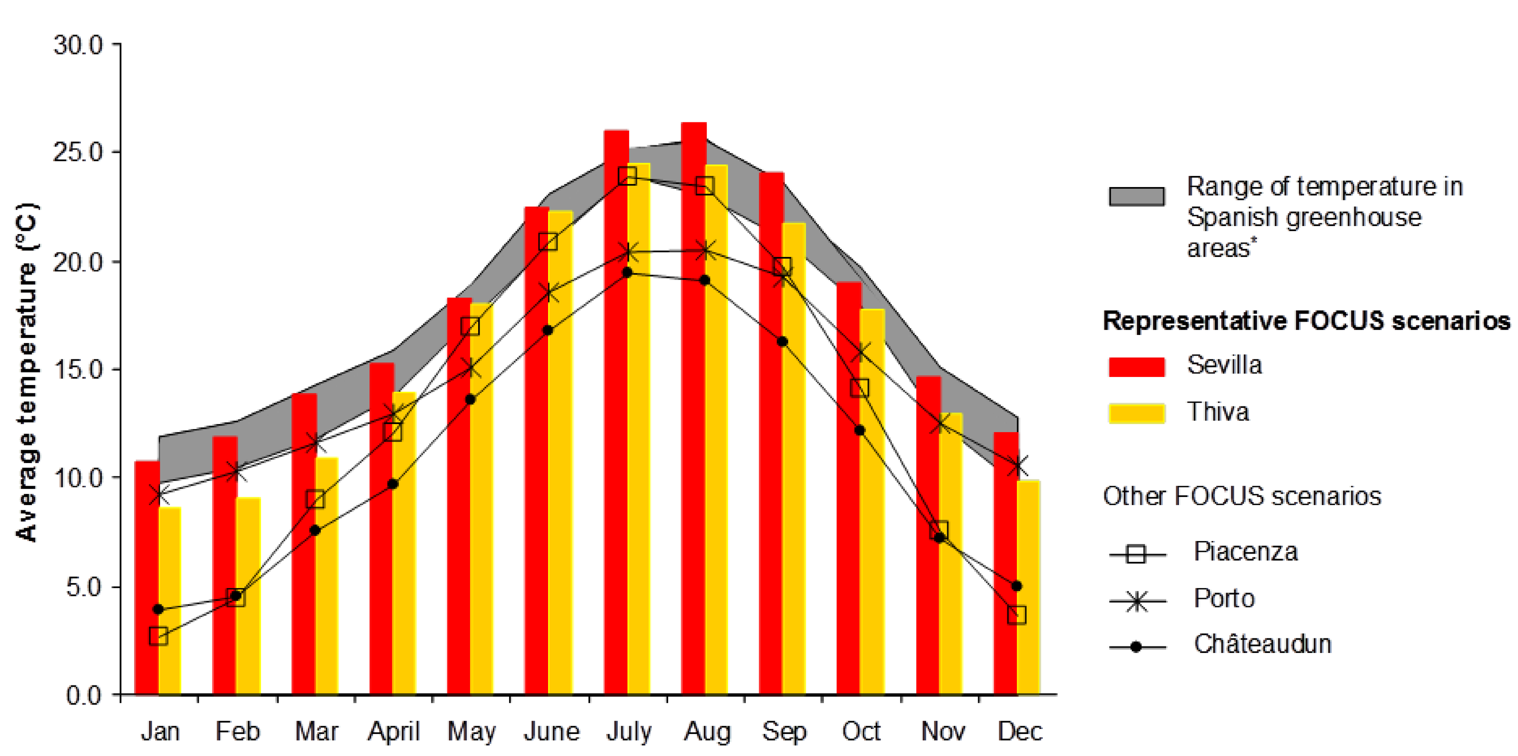

Fig. 3. Comparison of Sevilla scenario with temperatures in Spanish greenhouses and other FOCUS scenarios

ET

For DuPont-Sevilla GHS, temperature values from FOCUS Sevilla scenarios were used, therefore, ET was not modified. EFSA-Pistoia scenarios drew upon experimental observations in tomato crop in GHS and suggest-slightly higher ET values than FOCUS Piacenza scenarios (Fig 2). ET in the greenhouse is expected to be slightly lower than open field due to higher humidity in the GHS.

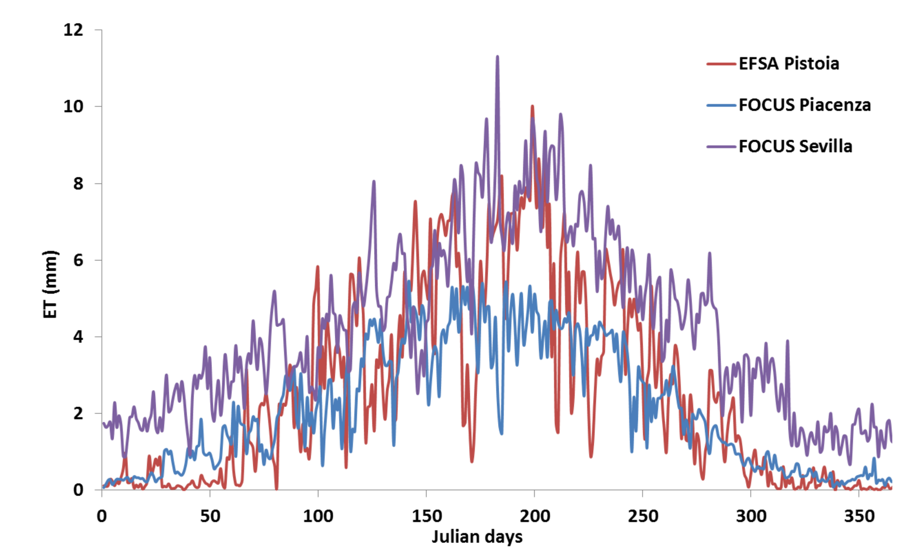

Fig. 2. Comparison of ET values in EFSA-pistoia, FOCUS-Piacenza and FOCUS-Sevilla scenarios

Irrigation

In DuPont GHS, FOCUS Sevilla scenario was modified to reflect typical irrigation volumes in greenhouses using data from experimental station "Las Palmerillas" in Almería. Autumn planted tomatoes usually receive higher volumes of irrigation water (817 mm/crop cycle (daily water consumption 1.5-4 mm/day – fig. 4) due to the longer growing cycle. Crop water requirements in Almería represents the upper boundary of crop water consumption in Spain due to very high evapotranspiration rates in the arid climate of Almería. Loss through evapotranspiration of 336 mm and a calculated irrigation requirement of 450 mm in the first 180 days of the crop was estimated using standard calculation methods of Doorenboos and Pruitt (Anton et al. 2009). Irrigation profile from Almería used in DuPont Scenarios can therefore be considered a worst-case for irrigation volumes in Spanish greenhouses.

In EFSA-Pistoia scenario, irrigation requirements of the crop was calculated using the water balance method. The calculation assumes that soil moisture in the top 60 cm can be depleted by 15 % without causing water stress (equivalent to a water layer of 20 mm based on available data). To avoid salt accumulation in the soil and accounting for non-uniform water distribution, an over-irrigation of 20 % was considered. This amounts to an average annual rainfall of 1082 mm/year. The irrigation method proposed by EFSA is represented in a form similar to precipitation as opposed to irrigation procedures in GH.

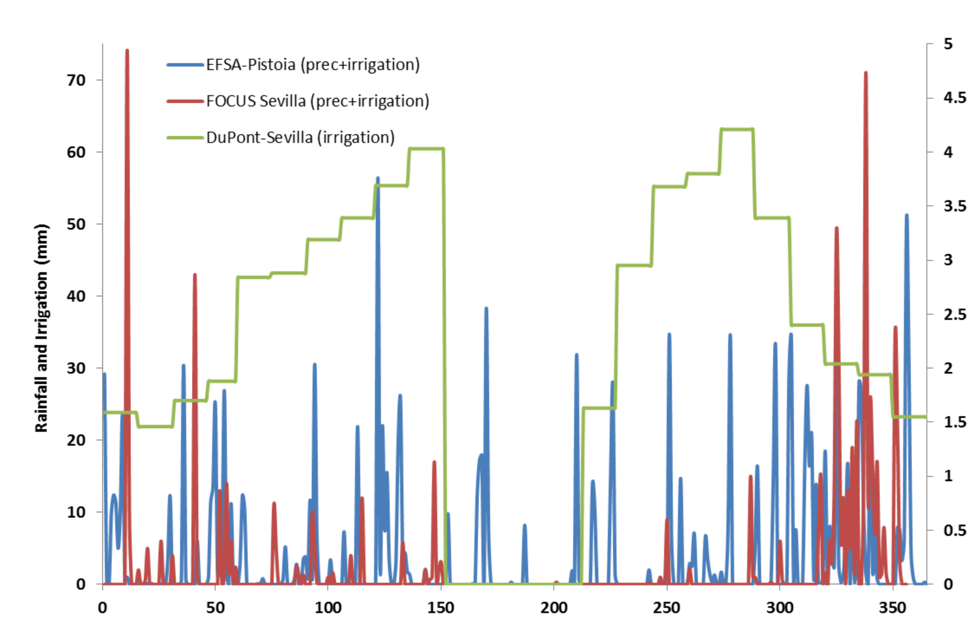

Fig. 4. Comparison of Irrigation amounts and pattern in EFSA vs DuPont Scenarios

Results

Results of simulations conducted using the FOCUS-Sevilla field scenario vs DuPont Sevilla GHS and FOCUS-Piacenza field scenario vs EFSA-Pistoia GHS were compared. Model simulations indicated that predicted environmental concentrations in groundwater can vary by up to two orders of magnitude depending on the scenario used in the calculations in Table 1. As expected due to increased temperature in greenhouses, degradation rates of compounds may be faster which lowers groundwater concentrations. By comparison, groundwater concentrations in EFSA-Pistoia GHS is ~30-100% higher than in open field scenarios. The results from EFSA-Pistoia GHS is considered unrepresentative given significantly higher temperatures encountered in Spanish greenhouses.

Table 1. PEC_{GW} (ug/L for the standard field tomato scenarios and the equivalent scenarios

Scenario	A		B		C / MET-C		D	
	field	protected	field	protected	field	protected	field	protected
FOCUS-Sevilla	0.298	<0.001	0.259	<0.001	<0.001 / 9.953	<0.001 / <0.001	0.003	<0.001

Table 2. PEC_{GW} (ug/L for standarad FOCUS-Piacenza vs EFSA-Pistoia scenario

Scenarios	A	B	C / MET-C	D
FOCUS-Piacenza	4.217	2.501	<0.001 / 21.275	0.206
EFSA-Pistoia (GHs)	5.622	3.776	<0.001 / 26.792	0.495

Conclusion

FOCUS PEARL 4.4.4 was parameterized to predict 80th percentile GW concentrations in leachate after applications to greenhouse crops. For dummy compounds, results showed that EFSA-Pistoia produce higher concentrations in GW compared to FOCUS-Piacenza scenarios. With temperatures expected to be significantly higher in greenhouses than field scenarios, degradation of a product is expected to be quicker and therefore, lower groundwater risks may be anticipated. Results from FOCUS standard field scenarios and protected cropping (DuPont-Sevilla GHS) demonstrate that there can be a significant reduction in PEC-GW following use in a protected cropping scenario.

Further adaptations to modeling scenarios

Based on the limitations of the EFSA guidance identified, as well as scientific understanding of the processes in GHS, there is industry interest in developing more realistic, improved frameworks of exposure assessment – including refined scenario development. Further adaptations in the scenarios maybe achieved by:

- Inclusion of multiple crop as opposed to a single crop which is typical in Southern EU GH
- Establishment of minimum temperature for closed/high-tech GH based on literature references which suggest minimum temperature for growing tomatoes is 16°C.
- Refined ET value to account for higher humidity in GH
- Irrigation: Currently, the irrigation proposed by EFSA is represented in a form similar to precipitation. A more realistic soil moisture deficit-driven strategy for irrigation definition as an alternative can be justified.

References

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