Nordic Council of Ministers

PLANT PROTECTION PRODUCTS IN THE LIGHT OF CLIMATE CHANGE

– steps towards a re-validation of methods and models used in the risk assessment

Contents

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Summary

Many methods and models used in the risk assessment of plant protection products (PPP) (under Regulation (EC) No 1107/2009) were developed more than 20 years ago, describing the environmental, climatic, and agricultural conditions at that time or prior to that time. As a response to a changing climate, the Northern zone will have to re-validate and possibly adapt the current risk assessment to be fit for purpose in the coming decades and maintain the same protection level for human health and the environment.

The project had the objectives to (1) collect information from relevant stakeholders (authorities, industry, and research institutes) about past / ongoing / planned research projects related to the impact of climate change on the methods and models used for the registration of plant protection products (e.g. environmental fate, ecotoxicology, human toxicology, chemistry, residues, efficacy), (2) compile a list of climate-sensitive parameters and procedures used in the risk assessment of plant protection products in light of the Northern zone Guidance and prioritise them according to importance or impact on the risk assessment, and (3) perform a gap-analysis to identify the information lacking to assess whether the climate sensitive parameters are still representative for today's Nordic climate, in what way they are expected to change and if this change would change the protection level of the risk assessment

Responsible authorities of member states (MS), industrial companies, consultancies, and research institutions/universities were contacted about relevant projects. Their feedback was evaluated and summarised. A list of climate-sensitive parameters and procedures used in the risk assessment was compiled and prioritised for importance or impact. A gap analysis was performed to identify the information lacking to assess whether the 'climate-sensitive parameters' used in the risk assessment are still representative, in which way they are expected to be changed, and to specify further work and specific tasks that need to be performed to conclude on these points.

The section with the largest number of identified climate-sensitive parameters was environmental fate, hence a large part of the report was focused on this area. To identify the direct impact of climate data on Predicted Environmental Concentrations in groundwater (PECgw), an impact assessment with nine test substances and two climate projections for the FOCUS PELMO Hamburg scenario was performed. The direct impact assessment of changed weather data in PELMO yielded that PECgw values decreased with increasing temperature despite increasing rainfall. Increasing temperature enhances degradation and evapotranspiration, while increasing precipitation increases leaching. Changes in rainfall intensity were not considered in this sensitivity analysis.

For surface water, high rainfall intensities may have a stronger impact on Predicted Environmental Concentration calculations. Especially runoff and drainage are driven by rainfall intensities. The usage of daily precipitation may introduce an error which will increase in the future when high intensity rainfalls become more common. It should therefore be considered to include weather data with e.g. hourly timesteps.

Indirect impact is expected from changes in soil microbial communities due to drought and flooding. which can affect field dissipation studies as well as the samples taken for laboratory degradation studies.

Other indirect effects are shifts in agronomic dates or an extension of agricultural land further north into potentially vulnerable areas. Further it is expected that new management practices will become more important. This may include precision farming techniques like application via drones and spot applications, and mitigation options such as micro-dams or conservation tillage.

Prioritised work packages were identified for the authorities in the Northern zone including literature reviews, updates and development of guidance, updates of weather files and agronomic dates in FOCUS, as well as re-evaluation of the relevance of FOCUS crops and scenarios.

1. List of Abbreviations

BBA	Biologische Bundesanstalt
BBCH	Plant growth stage as defined by BBA, Bundessortenamt and the Chemical Industry
BN	Bayesian Network
CN	Curve number
CPM	Climate protection scenario without seasonal variation
CPS	Climate protection scenario with seasonal variation
DEFRA	Department for Environment, Food and Rural Affairs
DEPA	Danish Environmental Protection Agency
DT_{50}	Degradation half life
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Environmental Agency
EFSA	European Food Safety Authority
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FOCUS	Forum for the Co-ordination of pesticide fate models and their use
GAP	Good Agricultural Practise
HEM	High emission scenario without seasonal variation
HES	High emission scenario with seasonal variation
HSE	Health and Safety Executives

HTDF	Higher Tier Drainflow model
IPCC	Intergovernmental Panel on Climate Change
IPPC	International Plant Protection Convention
ISMC	The International Soil Modeling Consortium
KEMI	Kemikalieinspektionen (Swedish Chemicals Agency)
K_{FOC}	Freundlich sorption coefficient to organic carbon
MARS	MARS meteorological database of the Joint Research Centre (JRC)
MS	EU Member State
NAP	National Action Plan for the Sustainable Use of Plant Protection Products
OECD	Organization for Economic Cooperation and Development
PEC	Predicted Environmental Concentration
PEC_{air}	Predicted Environmental Concentration in air
PEC_{gw}	Predicted Environmental Concentration in groundwater
PEC_{soil}	Predicted Environmental Concentration in soil
PEC_{sw}	Predicted Environmental Concentration in surface water
PSD	Pesticide Safety Directorate
PPP	Plant Protection Product
RCP	Representative Concentration Pathways
UBA	Umweltbundesamt (German Environment Agency)
UK	United Kingdom
SDLM	Spatially Distributed Leaching Modelling
SETAC	Society of Environmental Toxicology and Chemistry
SSP	Shared Socioeconomic Pathways

2. Introduction and Objectives

Within the project "Steps towards a re-validation of methods and models used in the risk assessment of plant protection products in the light of climate change," the Swedish Chemicals Agency (KEMI) has assigned knoell Germany to collect information from relevant stakeholders on past/ongoing/planned research initiatives related to the potential impact of climate change on pesticide registration in Europe.

In recent years a rapid warming of the climate has been observed in Europe, and especially in the Nordic countries, which is significantly faster than the average global warming today. In 2021, the European Commission issued a new EU Strategy on Adaptation to Climate Change (EC, 2021). The long-term vision of the EU Strategy is that "in 2050, the EU will be a climate-resilient society, fully adapted to the unavoidable impacts of climate change."

A recent European Climate Risk Assessment report (EEA, 2024) identified that 2023 was the warmest year on record with the average global temperature exceeding pre-industrial levels by 1.5 °C. It further points out that Europe is the fastest-warming continent in the world (2.5 times of the global mean temperature increase) with increasing extreme heat and changes in precipitation patterns. Especially for Northern Europe enhanced warming was observed, mainly due to warming in winter. This affects both snow depth and permafrost. Further, for Northern Europe increased rainfall has been observed, which is mainly attributed to the winter period, while the summer became drier. At the same time (despite higher rainfalls) increased evaporation leads to a drying trend in Europe which in turn reduces soil moisture. This effect is immanent over the whole year in Southern Europe, and in spring and summer in Western and Northern Europe.

Depending on the climate projections over Europe, increased mean temperatures, decreased frost days, and increased heatwave days are predicted (EEA, 2024). Especially for Northern Europe the projections and models show, in strong agreement, that the total precipitation as well as heavy rainfalls over 1 and 5 days will increase. At the same time an increased meteorological and consecutively also agricultural drought is predicted, which indicates that the trend of increased winter precipitation and decreased precipitation in summer will continue.

Based on these trends and predictions EEA (2024) concludes that uncertainties in food productions in the mid- and long term are related mainly to pollinator decline, pests and diseases in crops, livestock and aquatic environment. Currently heat stress, droughts and excessive rainfall already negatively affects European crop protection. This trend most probably will continue and intensify.

A literature review of Yang et al. (2024) concludes that "climate change will likely exacerbate the already large environmental impacts of agricultural production. It would do so by (i) directly and negatively affecting agricultural productivity; (ii) reducing the efficacy of agrochemicals and increasing their loss to the environment; and (iii) increasing crop pests and soil erosion."

Hence, national governments in Northern Europe have issued national strategic climate change adaptations (e.g. Finnish Government Helsinki (2024), Swedish Government (2018)).

The Finnish Government Helsinki (2024) points out that the mean temperature in Finland has increased by 1.3 °C when comparing the 30-year reference period from 1961–1990 to the period of 1991–2020. Permanent snow cover has reduced by more than a month between the same periods. Similar to EEA (2024) also the Finnish Government expects an increase in temperature and precipitation which is more severe in winter than in summer and above the global average (1.6 times for temperature).

The Swedish Government (2018) mentions an increase in temperature by 3–5 °C until 2080 in comparison to 1960-1990, with an increase in winter temperatures as high as 10 °C. This warming will lead to an extended growing season. An increase in precipitation mainly during winter and Southern Sweden of up to 20% is expected. Changes in precipitation are smaller in summer or might be negative (depending on the model). In general, the degree of uncertainty for prediction of precipitation might be larger than for temperature.

EEA (2019) concludes that for Northern Europe the conditions for growing crops may improve due to longer growing seasons and more suitable crop conditions, but the number of extreme events negatively affecting agriculture is projected to increase. This has multiple impacts on e.g. pest pressure and resistance, crop quality and yield and shifts in cropping zones (Brown et al. (2019), Carter et al. (1996), Franke et al. (2021), Gautam et al. (2013), Harvell et al. (2002), Juroszek and Tiedemann (2012), Kaur et al. (2024), Lu et al. (2022), Ma et al. (2021), Mboup et al. (2011), Miedaner and Juroszek (2021a and b), Ramesh et al. (2017), Skendzic et al. (2021)).

Based on these findings it is obvious that also the risk assessment of plant protection products (PPP) might need to be reconsidered.

Many methods and models used in the risk assessment of PPP (under Regulation (EC) No 1107/2009) were developed more than 20 years ago, describing the environmental, climatic, and agricultural conditions at that time or prior to that time. However, several of these methods and models contain parameters that are related to the climate and therefore may need to be revised or updated to account for a changing climate. As a response to a changing climate, the Nordic zone will have to re-validate and possibly adapt the current risk assessment to be fit for purpose in the coming decades.

This report has the following objectives:

1. Collect information from relevant stakeholders (authorities, industry, and research institutes) about past / ongoing / planned research projects related to the impact of climate change on the methods and models used for the registration of plant protection products (e.g. environmental fate, ecotoxicology, human toxicology, chemistry, residues, efficacy).
2. Compile list of climate-sensitive parameters and procedures used in the risk assessment of plant protection products in light of the Northern zone Guidance (Guidance document on work-sharing in the Northern zone in the authorisation of plant protection products. Version 11, July 2023) and prioritise them according to importance or impact on the risk assessment
3. Perform a gap-analysis to identify the information lacking to assess the following questions:
    a. Are the 'climate-sensitive parameters' used in the risk assessment still representative for today's Nordic climate or are they already outdated?
    b. In which way are the 'climate-sensitive parameters' expected to be changed by the future climate?
    c. Are changes in the protection level of the risk assessment (under-/overestimation of risk) expected if these parameters are not updated to reflect the changes in the future climate?

The gap-analysis aims in the identification of further work and specific tasks (e.g., modelling work, sensitivity analysis, literature reviews) that need to be performed to conclude on these questions above.

The evaluation is done based on the information provided by the stakeholders, further targeted literature analysis, and statements from experts in the field of registration of PPP in Europe. It is supported by a limited impact analysis to evaluate the impact of climate parameters on PEC_{gw}-values for prioritisation.

This report is not a research paper aiming at exhaustively covering the impact of climate change on the registration procedure of PPP. It rather aims at evaluating the status of available research and to provide recommendations for further tasks on the road to updating the registration procedure in the light of climate change.

3. Objective 1: Stakeholder Analysis

3.1 Methods

A questionnaire with the following questions were sent to stakeholders from authorities, industry, and research institutes from Europe. A list of institutions to which the questionnaire was sent can be found in Appendix 1. In total the responsible authorities of 27 member states (MS), Lichtenstein, Norway and United Kingdom were contacted and additionally EFSA and ECHA (group "authorities"). Also 6 industrial companies producing plant protection and 2 consultancies (group "industry") and 21 research institutions/universities were contacted (group "research institutions").

The following questions were sent:

1. Did your organisation engage in or is currently planning any research activities related to the impact of climate change on the methods and models used for the registration of plant protection products (e.g., environmental fate, ecotoxicology, human toxicology, chemistry, residues, efficacy)? This may include research on the direct impact or indirect impact, e.g. on environmental compartments, species or crop distributions, new emerging pests, etc.
2. If possible, please provide more details (such as a research title, references, or web links) of any such activity.
3. Are you aware of further research activities from other organisations on this topic? If yes, please provide details or contacts if possible.

Additional question:

Do you think it would be important to review the risk assessment methods and models currently used in light of climate change? Please provide a short motivation for why or why not.

The feedback from the different group of stakeholders is summarised in section 3.2.

3.2 Feedback and results

Details on the questionnaire participation can be found in Table 1. The results were grouped by the three stakeholder groups. In general, a high participation rate was observed, which was the highest for industry, followed by research institutions and authorities.

Table 1: Details on questionnaire participation

Type	Number of contacts	Number of replies	Partici-pation rate
Authorities	32 (MS, LI, NO, UK, EFSA, ECHA)	11	34 %
Industry	8	6	75 %
Research Institutions	20	13	65 %

3.2.1 Summary feedback "authorities":

From most MS no feedback was received. Most authorities which provided feedback acknowledged the importance of the topic. However, there are often no activities regarding climate change adaptation of the registration process of PPP on authority level ongoing. It appears that often this is due to limited capacities and consequently a backlog of planned activities from recent years, or a higher prioritisation of other topics such as integrated pest management or application via drones.

However, from some authorities additional feedback has been received highlighting further activities on the topic.

The Umweltbundesamt (UBA) in Germany stated that in the past a research project was initiated to evaluate the potential impact of climate change on PPP use. It was focused on 1) The changes to be expected in the occurrence of pest organisms, 2) Changes to be expected in the regional farmers' cropping preferences owing to shifts in yield patterns and plant protection strategies, and 3) Possible changes of the ecological potential of the agricultural landscapes supporting the compensation of negative effects of pesticide application, e.g. on biodiversity. So far, the results have not been published. They further raised awareness to the KLIMAtiv project ongoing at the Julius-Kühn-Institute, which deals with the very specific topic "Climate-neutral fumigation processes and alternative treatment methods for the export of round timber." Also, at their webpages UBA-publications regarding climate change can be found. For example, the "2023 Monitoring Report on the German Strategy for Adaptation to Climate Change" (UBA, 2023), which gives insights on expected changes in climate in Germany. While the report does not provide details on PPP fate directly, it gives insight on relevant topics which directly impact the environmental fate of PPP, like trends in soil moisture (decreasing), rainfall erosivity (increasing due to higher rainfall intensities), soil temperature (increasing) and organic carbon content (appears to be relatively stable in a case study). It also provides information on how climate change is impacting plant growth, crop distribution, and irrigation in Germany.

The Health and Safety Executive (HSE) Environmental Fate and Behaviour Team (for Great Britain and Northern Ireland) has recently updated the higher tier drainflow (HTDF) assessment using MACRO5. In this context the meteorological files were updated to use data from 1989 to 2020 instead of 1957 to 1989, as used previously. They are also in the process of updating the cropping statistics which are used for the approach 2 in the HTDF assessment, which will reflect crop and weather data from 2018–2020. Further a research project was performed investigating the impacts of climate change on pesticide use and integrated pest management strategies (Bradshaw, 2024) using a case study of the Cabbage Stem Flea Beetle in oilseed rape crops. It concluded that "the case study demonstrates the high value of using models in the decision process. However, significant knowledge gaps were identified that currently limit the utility of modelling approaches to properly evaluate the impacts of climate change. The impact of floods and droughts on the soil ecosystem was highlighted as a research priority, together with the role of rainfall in pest and predator life cycles."

More relevant publications on climate change and its impact on pesticide for Great Britain can be found at the APHA Science blog[1] and the UK Government's Climate risk Assessment portal[2]. Also, it was pointed out that a recent EPPO Bulletin (Kriticos et al., 2024) compiles several publications around the impact of climate change on pest risk assessment. IPCC and FAO published a report on how climate change impacts plant health (IPPC Secretariat, 2021).

A report ("An assessment of the impacts of climate change on the fate and behaviour of pesticides in the environment") was shared by HSE (DEFRA, 2004), which despite being 20 years old, appears to be highly relevant in the current context. "The work in this report is in response to a call from the Pesticide Safety Directorate (PSD) of the Department for Environment, Food and Rural Affairs (Defra) (call CTX 0313) for Expressions of Interest to 'explore climate change and its implications for regulatory assessment of the fate and behaviour of pesticides in the environment', to 'examine how such potential changes will impact on pesticide

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1. https://aphascience.blog.gov.uk/2023/05/11/climate-change-plants-and-plant-pests/ (accessed 27th September 2024).
2. https://www.ukclimaterisk.org/ (accessed 27th September 2024).

levels in the soil, ground and surface waters and air compartments', and to answer the question 'will weather [climate] information used in environmental exposure and fate modelling of pesticides continue to be appropriate or will changes need to be incorporated?'." Since the principals in the risk assessment of PPP in the EU have not been changed to a larger extend in the recent 20 years, it is assumed that the conclusions drawn in DEFRA (2004) are in principle still valid.

In section 4.2 an evaluation is presented in which the findings from year 2004 for the UK are put into context for Northern Europe in year 2024.

The Danish Environmental Protection Agency (DEPA) has published the findings of the PRECIOUS project (DEPA, 2013). It evaluated the implication of direct (precipitation, actual evapotranspiration, and temperature) and indirect (crop rotations, crop management, and pesticide use) climatic factors on pesticide-leaching use the MACRO-model version 5.1. It was concluded that no major increase in pesticide leaching of strongly sorbing herbicides, fungicides and insecticides is to be expected. An increased leaching of low dosed herbicides and a minor increase of leaching of other normally-dosed herbicides was found. Direct climatic factors will have implications especially in loamy soils (increased macropore flow), while indirect factors may only have a limited impact. Overall leaching risk by future climatic factors was found to decrease for sandy soils and increase for loamy soils.

With the catchment scale model MACRO-MIKE SHE changes in pesticide concentration in the aquatic environment was performed. The simulations showed that drainage increases, while baseflow and surface runoff receive less water. Again, concentrations for low dosed herbicides increased under future climatic conditions, while concentrations of normally-dosed herbicides and fungicides decreased.

Further opinions shared were that besides adapting the weather data it should be reviewed if the normalisation to 20 °C is still appropriate and in how far temperature dependency of sorption plays a role and might be enhanced due to climate change.

3.2.2 Summary feedback "industry":

Industry is primarily engaged in climate change activities by anticipating new or changing pest pressures and the necessity to adapt GAPs or to introduce new uses in response to that. Research activities appear to be focused on the discovery of crop protection solutions and application methods that will provide adapted and sustainable support to farmers in the future (e.g. possible changes in cropping patterns, agronomic practices, pest populations, diseases or weeds, that are induced by climate change).

Some examples of climate change impact were provided. Crops like sugar beets may be subject to increased pressure of weeds (Ramesh et al., 2019), and the dormancy of oilseed rape might be affected by mild winters leading to earlier growth and higher exposure to pathogens (Gautam et al., 2013; Brown et al., 2019). Also, it is expected that fungi can adapt to and benefit from higher temperatures and CO_2 concentrations (Mboup et al., 2011; Carter et al., 1996). Warm winters and higher precipitation will result in that the number of pathogens moving northward will increase as increasing temperature makes the previously inclement areas more conducive, as well as an increased pest resistance (Gautam et al., 2013; Harvell et al., 2011; Juroszek and Tiedemann, 2013; Ma et al., 2021; Skendzik et al., 2021).

Regarding extreme weathers it is observed that the seed production sector is affected by droughts and floods, sorghum is slowly replacing maize in some areas, as it uses less water, and some crops are slowly disappearing from crop rotation programs. Also access to crops become challenging in wet weather, which may lead to changes in equipment towards e.g. drones.

Adaptations by industry include breeding for improved drought tolerance and increased disease-resistance (Miedaner and Juroszek, 2021 a and b) and developing crop varieties with increased resilience to climate change/extreme weather events applying plant breeding techniques like gene editing (CRISPR).

Climate change was also identified for its relevance to research on implications for pollinators in e.g. Willcox et al (2023).

Kühnel and Wang (2024) compared PEC_{sw} values calculated with weather data from 1975–1994 with calculations based on weather data from 2004–2023. They found that in some cases the risk is potentially underestimated and conclude that an update of the current FOCUS surface water scenarios is suggested, taking recent weather and the high variability between years into account.

Otherwise, there is continued involvement of industry members in working groups updating and developing scenarios for pesticide registration (e.g. SETAC SDLM and FOCUS SW repair). It was pointed out that SETAC SDLM prepared adjusted pedoclimatic association maps using the grid-based MARS 25 meteorological database[3] which suggest an expansion of some scenarios from southern Europe, while some scenarios from central and northern Europe appear to become less relevant. For further details on updated weather series and spatial extend of crops etc. the SETAC SDLM working group should be contacted.

FOCUS SW repair (EFSA et al., 2020) has updated weather data of the FOCUS surface water scenarios to replace the 1-year assessment with a 20-year assessment period. However, it was pointed out that it was not in the remit of this working group to reassess the validity of the current FOCUS surface water scenarios with respect to weather, soil or crop conditions. Nevertheless, it is

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3. More information is available at the JRC Agri4Cast Resources Portal (https://agri4cast.jrc.ec.europa.eu/DataPortal/Index.aspx, accessed 19th November 2024).

expected that at some point in the future EFSA might initiate a reconsideration of the weather files.

It is considered readily accepted that climate change is changing agricultural strategy. Existing modelling scenarios may remain a valid basis for evaluation of exposure potential if they continue to provide a form of "pedoclimatic risk envelope" to support risk assessments. The 80^{th} percentile values currently used for calculation of predicted environmental concentrations in groundwater and surface water might still be representative for changes in rainfall.

The relevance of the scenarios for the Member States may change but they might continue to have validity. A review of the representation of specific soil type and climate scenarios for different Member States could be necessary to ensure the appropriate scenarios are being applied in order to ensure that modelling outcomes reflect local conditions with a changing climate.

The timings of when crops reach certain growth stages in the FOCUS scenarios (as provided in AppDate (Klein, 2019)) or in Sweden as proposed by Myrbeck (1998) might need reconsideration and update. CropLife Europe published an open-source pan-European Crop Development database and noticed a deviation of observed dates and dates suggested by AppDate (Hughes et al., 2023). It was concluded that "C2D2 has the potential to assist with the parametrization and calibration of more dynamic crop models in FOCUS with varying levels of complexity. At the simplest level, the key crop development dates for each FOCUS scenario could be revised; at an intermediate level, the growing degree days between the key crop development stages could be determined (PEARL can already use heat sums to dynamically grow crops); and at an advanced level, the data could be used to calibrate more sophisticated crop models."

Further, increased temperatures would affect microorganisms, with different functional temperature ranges and effects on these might affect degradation of substances.

From the effects side, no need was identified to amend the standard ecotox species required in the assessment as these have been selected based on their sensitivity to stressors and not on their representativity of a crop type or environmental conditions. Climatic conditions are controlled in the laboratory and standardized accordingly, and so toxicity data for the risk assessment would still be applicable.

However, implications on field studies may need to be considered. With weather conditions becoming more variable this could impact the spatial and temporal abundance of different species. For example, in earthworm field trials conducted during hot dry summers would result in natural low abundance which would increase the variability shown in field. Normal operating ranges under different conditions should be established to balance this variability from actual effects of crop protection products. This is a critical point for high tier testing and monitoring purposes to ensure correct interpretation of data.

Also, it was pointed out that initiatives on EU level are taken to change the fundamentals of the risk assessment to a more landscape-based process, which also might include effect modelling and combined assessment with other chemicals (e.g. EU-PARC project[4]).

3.2.3 Summary feedback "research institutions":

The majority of the feedback from the research institutions displayed the opinion that certain adaption to climate change will be required. In the Northern zone, crops, agricultural practices, and crop protection needs will change (and have already begun to do so). Moreover, in the future, boreal areas might become more important food producers as climate will decrease crop yields in currently intensively cultivated areas. Pesticide fate should be studied in the new environment. The new environmental conditions should be represented in pesticide registration. Realistic climate scenarios for PPP registration would be a step and could include recent extreme years.

However, some researchers were of the opinion that the effects based on climate change are smaller than the diversity throughout Europe and/or the uncertainty of the models and therefore an adjustment would not necessarily be required.

Fate and Exposure:

Many of the existing fate and exposure models and methods are based on climatic and environmental conditions that are now outdated due to the rapid climate change observed in recent decades. Updating these models is essential to ensure that they remain accurate and reliable in predicting the environmental behaviour, efficacy and safety of plant protection products under new climate conditions. For example, heavy rain events will increase entries of plant protection products from fields into water bodies by run-off and erosion. Irrigation affects the transport of substances in the soil. Degradation processes are affected by temperature and, in the case of photolysis, light conditions.

It was pointed out that short-term intense rainfalls have and will become more frequent. Current models (like FOCUS PEARL and FOCUS PELMO) usually use daily weather data and it is unclear if the models can accept high-resolution weather data on hourly or sub-hourly basis. In case the models can deal with this higher resolution (e.g. MACRO) a limiting factor might be the availability of reliable long-term data with respective high resolution over time. Also processes or parameters like the runoff curve number (as used in PRZM) might need to be adapted. The curve number approach is an event-based approach and can by definition not use sub-event rainfall intensities. The usage of the CN-approach to calculate surface

4. https://www.eu-parc.eu/ (accessed 2nd October 2024).

runoff in models like PRZM is generally problematic since the approach was developed to estimate the direct combined runoff (excluding baseflow) and not only surface runoff. Further it was developed for single large rainfall events on catchment scale and not for continuous time series on plot or field scale (Garen and Moore, 2005).

A member of the ISMC (The International Soil Modeling Consortium) pointed out that the representation of the soil in most of the current models is insufficient. They are considered as rigid and temporally invariable with limited consideration of their structure. The inclusion of a dynamic soil structure and temporally variable soil properties has been recommended and supported by the publications of Hirmas et al. (2018), Sullivan et al. (2021), and Weber et al. (2024). These assumptions of dynamics in soil might become more important with climate change in the Northern Zone due to more frequent freezing-thawing cycles.

Effects:

Climate change will affect pest pressure including the presence of invasive pest species. Crops may be more sensitive to pests due to environmental stress (high temperature, droughts). Non-target organisms may be more sensitive to pesticides due to additional stress caused by climate change.

Detailed feedback was received from Prof. Dr. Matthias Liess from Helmholtz-Centre for Environmental Research (UFZ):

- Insecticides are currently used sparingly, especially in northern Europe. It is to be expected that more insecticides will be used in northern regions of Europe due to climate change. The main reason for this is the increased occurrence of harmful insects due to higher temperatures. (Kattwinkel et al., 2011).
- Furthermore, it is expected that there is a change in a variety of other ecologically relevant factors. These include, for example, the temperature in water bodies and a changed runoff regime. At first glance, it is to be expected that this multitude of stressors will lead to an increased sensitivity of the organisms in the ecosystem. In a large number of studies, we have found that the same amount of an insecticide can be up to 100 times more potent if an additional stressor such as temperature (Shahid et al., 2024), pH, lack of food (Liess et al., 2020), oxygen deficit, and the like is present. Based on such knowledge, we have developed a model that can quantitatively predict the effect of these combined stressors on populations (Liess et al., 2016). An increased sensitivity, especially of sensitive species, can thus be expected (Moe et al., 2013).
- However, all levels of biological organisation adapt to stressors. Individual tolerance against pesticides increases when individuals are exposed to pesticides (Becker et al., 2020). Also, the community composition adapts to pesticides but also to other environmental stressors as temperature.

Accordingly, the adaptation of the community to pesticide stress in the field can be used as an indicator of pesticide pollution. For example, the national monitoring of small streams in Germany showed that 80% of these habitats showed a reduction in pesticide-vulnerable species (Liess et al., 2021).

- However, the adaptation of the community to stressors also means that fewer potentially synergistic stressor combinations enhance the effect of pesticides. This is also the reason for the observation that the pesticide indicator described above is applicable in different climate regions and that comparable toxicity also causes a comparable effect. For example, in Northern and Southern Europe (Schäfer et al., 2012), as well as in Central Africa (Ganatra et al., 2021).
- For risk assessment in a world of changing climate, this means that it is crucial to evaluate the degree of adaptation of the communities under investigation to climate change in order to be able to detect any synergistic effects of pesticides at elevated temperatures.

Further research on the effect of climate change on efficacy (including resistance risk), bee protection, impact on beneficials is performed within several projects at the Julius-Kühn-Institute (e.g. OPTAKLIM, KARO, AVOID, KLIMATIV).

A number of relevant scientific publications were performed at research institutions in the Nordic zone.

From 2006 to 2009 the "Ilmasopu [Adaptation to climate change in the agricultural and food economy]" project took place at LUKE in Finland. Pesticide fate modelling played a minor role, but calculations were performed for a single soil and climate scenarios based on IPCC A2 scenarios and measured long term data. Results are published in Ilmasopu (2009) in Finnish language.

Steffens et al. (2015) performed simulations with the regional model MACRO-SE for south-west Sweden in order to assess the direct and indirect effects of climate change on herbicide leaching to groundwater. One of the main conclusions was that the increased temperature (enhancing degradation) and increased rainfalls (promoting leaching) cancel each other at regional scale, so that only a minor increase in concentrations were observed. Indirect effects (such as increase of land-use area in Sweden and increase of herbicide use) may have a larger effect on groundwater contamination. Steffens et al. (2014) point out the importance of uncertainty analysis when assessing climate change impacts on pesticide leaching and suggest that climate uncertainty should be accounted for by applying an ensemble of different climate scenarios. Both magnitude and direction of predicted changes in pesticide leaching strongly depended on the particular climate scenario. They conclude that an aggregated ensemble prediction has the potential to provide robust probabilistic estimates of future pesticide losses.

Besides changes in land-use also more frequent freezing-thawing episodes in the Northern Zone may become more important. Holten et al. (2018 and 2019) found that significantly more pesticides leached from frozen than from unfrozen soil columns and that rapid breakthrough of pesticides indicated preferential flow in frozen soil. This indicates that more frequent changes will have an impact on the dynamics of pesticide leaching.

Wenng et al. (2020) found that the thermal growing season length has significantly increased in 4 out of seven Norwegian catchments (from 1991–2017). Additionally, a couple of long-term monitoring studies (hydrology and pesticide) in the Northern Zone have been performed, pointing out the importance of continued monitoring to observe trends over time (Stenrod, 2015; Wenng, 2021).

Mentzel et al. (2021) employed the WISPE model to model predictions of risk quotients of pesticides in Northern Europe. A Bayesian Network (BN) model was used to account for variabilities of the predicted pesticide exposure in agricultural streams, and inter-species variability in sensitivity to the pesticide among freshwater species. The conclusions were similar to the findings of Steffens et al. (2014 and 2015). Direct effects of climate change (temperature and rainfall) had a limited effect on predicted concentrations, however indirect effects (like increase in use rates) of course lead to a larger increase. Mentzel et al. (2021) concluded that a probabilistic approach including multiple climate models and scenarios may have the potential to support regulatory needs.

Hader et al. (2022) reviewed existing "literature to identify research that will enable scenario-based forecasting of environmental exposures to organic chemicals in European agriculture under global change." They identified the following key research gaps: improved understanding of relationships between global change and chemical emissions in agricultural settings; better understanding of environment-microbe interactions in the context of chemical degradation under future conditions; and better methods for downscaling climate change-driven intense precipitation events for chemical fate and transport modelling. Based on this a set of narrative Agricultural Chemical Exposure Scenarios are introduced as a framework for forecasting chemical exposure in European agriculture.

Several working groups exist with participation from research institutions which indirectly consider impacts of climate change. For example, the above mentioned SETAC SDLM group (Spatially Distributed Leaching Modelling). "The goal is to establish a standard SDLM method to be used according to the FOCUS groundwater tiered approach (FOCUS, 2014, Sanco/13144/2010, version 3, 10 October 2014) where this is foreseen as Tier 3b."[5] It should also support groundwater monitoring which is included as Tier 4 in the FOCUS tiered approach. In this activity new actual data (e.g. climate maps, soil maps, FOCUS zone maps) will be used.

5. https://esdac.jrc.ec.europa.eu/projects/sdlm (accessed 9th October 2024).

The QTOX working group[6] ("Quantitative extrapolation in ecotoxicology") "will develop mechanistic knowledge and data efficient modelling tools to bridge the gap between standard toxicity data (typically acute effects of single chemicals) and ecologically relevant end points arising from chronic, time variable exposures to chemical mixtures. The results will be achieved through an interdisciplinary and intersectoral research and training program in which 10 doctoral candidates will characterise the mechanistic processes describing the successive events from exposure to ecosystem-level effects and develop models for extrapolation of adverse effects across levels of biological organisation under environmentally realistic conditions. Notably, the effects of chemical mixtures, dynamic exposure conditions and their interaction with climate change scenarios will be characterised in a series of mesocosm experiments at three sites in central and southern Europe."[6]. Part of this project is "Model validation and climate change scenarios" in which mesocosm studies are conducted to analyse effects of chemicals and will be used as case studies for modelling.

The EESE project (EU Environmental scenarios for ERA of non-target organisms, Reference OC/EFSA/PREV/2023/02)[7] does not address effects of climate change directly. However, the main goal of the project is to collect, generate and analyse data to develop environmental scenarios to advance the environmental risk assessment of PPP under Regulation (EC) No 1107/2009. Thus, using literature data as well as field monitoring will provide data on non-target organisms in agricultural landscapes covering different biogeographical regions and climatic zones.

The UFZ has several research projects in Europe and Africa of which results are related to climate change. They are leading the EU PARC project "Reduce complexity of models for predictions of environmental effects of plant protection products while ensuring their predictive capacity." and "Implementation of the National Action Plan for the Sustainable Use of Plant Protection Products (NAP) - Part 4: Analysis of the contamination of small water bodies in the agricultural landscape with pesticide residues. UBA small water body monitoring."

6. https://cordis.europa.eu/project/id/101072531/de (accessed 9th October 2024).
7. https://www.efsa.europa.eu/sites/default/files/2023-05/webinar-on-call-for-tender-on-eu-environmental-scenarios-for-era-of-non-target-organisms-2023-may-11.pdf (accessed 9th October 2024).

4. Objective 2: Climate-sensitive parameters and an evaluation of their effects on the risk assessment of plant protection products (GAP-analysis)

4.1 Environmental fate studies

Environmental fate studies are laboratory or field studies and usually described by OECD or EFSA guidance. Please find a more detailed evaluation of relevant topics in Appendix 3.

The laboratory tests are standardised and performed under artificial / optimised conditions and e.g. degradation parameters are normalised for modelling. Most studies for PPPs consider an optimum temperature condition of around 20 ± 2 °C or 25 ± 2 °C. Since normalisation to actual temperatures is done within the modelling process these laboratory temperatures do not have a significant impact.

Due to climate change some studies may become more relevant than they used to be. In certain regions anaerobic degradation may occur more frequently if soils are flooded regularly, and soil photolysis may become more or less important depending on if more sunshine days are expected or not.

Extended drought periods or frequent flooding may also directly impact the degradation behaviour of pesticides in laboratory soil studies, if, for example, samples are taken shortly after a drought period or a flooding event. The effects of these events on soil parameters and microbial organisms could lead to different results as under the conditions considered as “standard” at the moment or even to non-reliable studies. The current guidance gives no information, how sampling and pre-incubation after drought or flooding events should be handled or how study results could be interpreted for the risk assessment.

Similarly, also terrestrial field dissipation studies can be impacted by longer drought periods and flooding. While longer drought periods may lead to reduced degradation of PPPs in the field, flooding could lead to longer periods of anaerobic conditions or even result in a destruction of the trial site. Current guidance gives recommendations on how to perform irrigation and to evaluate the validity of terrestrial field dissipation studies in case of droughts (e.g. EFSA, 2014). It should be reviewed if recommendations for irrigation are still valid and if the exclusion criteria are sufficient. Potentially more trials would need to be performed because the probability risk of invalid trials is increasing. On the other hand, strategies could be developed how to handle data of affected trials as their number is expected to increase. Furthermore, it could be useful to consider testing regarding microbial biomass for field trials as well to ensure an active microbial community throughout the trial periods.

Currently in the risk assessment for soil and groundwater anaerobic metabolites are often not considered relevant. More frequent flooding may make anaerobic metabolites more important in affected areas.

Groundwater- and surface water monitoring programs may become more relevant in the future as a higher tier refinement. In some countries publicly available monitoring data is available. But also specific monitoring from applicants might be considered. As Gimsing et al. (2019) and EFSA (2023) describe, the selection of suitable realistic worst case groundwater monitoring sites is important but difficult. EFSA (2023) concludes that "well-conducted monitoring studies provide more realistic exposure assessments and can therefore overrule results from lower tier studies. Groundwater monitoring studies involve a high workload for both regulators and applicants. Standardised procedures and monitoring networks could help to reduce this workload." Currently the use of monitoring data in the regulatory process is limited but is expected to increase. The impact of climate change on monitoring data and the selection of monitoring sites needs to be further assessed.

Action points Priority 1:

- Guidance for terrestrial field dissipation studies should be reviewed in terms of how to deal with extended drought or flooding and the results of affected trials.

Action points Priority 2:

- Guidance on sampling timing or pre-incubation after drought or flooding should be developed as well as a guidance for the interpretation of the results for the risk assessment

4.2 Environmental fate modelling

Please find a more detailed evaluation of relevant topics in Appendix 3.

4.2.1 Evaluation of validity of DEFRA (2004) for Northern Europe and year 2024

In year 2004 DEFRA published a report of the project "An assessment of the impacts of climate change on the fate and behaviour of pesticides in the environment" (DEFRA, 2004). It provides a detailed overview of the potential impact of climate change on the environmental factors relevant for PPP registration and risk assessment.

The underlying assumption in DEFRA (2004) is the climate change projection UKCIP02 which is summarised in Table 2.

Table 2: Summary of the climate changes predicted using the UKCIP02 scenarios (DEFRA, 2004) (H = High, M = Medium, L = Low)

Variable	UKCIP02 summary	Confidence level
Temperature	Annual warming by 2080s of between 1 and 5 °C depending on the region and scenario	H
	Greater summer warming in the south east than in the north west	H
	Greater night-time than daytime warming in winter	L
	Greater warming in summer and autumn than in winter and spring	L
	Greater daytime than night-time warming in summer	L
	The number of very hot days increases, especially in the summer and autumn	H
	The number of very cold days decreases, especially in winter	H
Rainfall	Generally wetter winters for the whole UK	H
	Substantially drier summers for the whole of the UK	M
	Rainfall intensity increases in winter	H

Seasonality	Rainfall: greater contrast between wetter winters and drier summer seasons	H
	Temperature: summers warm more than winters	L
Variability	Years as warm as 1999 become very common	H
	Summers as dry as 1995 become very common	M
	Winter and spring rainfall become more variable	L
	Summer and autumn temperatures become more variable	L
Humidity	Specific humidity increases	H
	Relative humidity decreases in summer	M
Soil moisture	Soil moisture decreases in summer and autumn in the south east	H
	Soil moisture increases in winter and spring in the north west	M
Thermal growing season length	Increases everywhere, with the largest increases in the south east	H
Cloud cover	Reduction in summer and autumn cloud cover, especially in the south	L
	Small increase in winter cloud cover	L
Snowfall	Totals decrease significantly everywhere	H
	Large parts of the country experience long runs of snowless winters	M

Since this report is 20 years old and was specifically prepared for UK, it needs to be evaluated if these assumptions (and consecutively its conclusions) can be considered valid for the Northern zone in 2024.

The assumptions most relevant for the environmental risk assessment are assumed to be related to changes in rainfall and temperature.

As described in the table above in DEFRA (2004) it was assumed that the temperature may increase by up to 5 °C until 2080 with greater summer warming than winter. Depending on the emission scenario rainfall in winter will increase between 5 to 30%, while summer rainfall will decrease by 20–40%.

In comparison, the Swedish Government (2018) mentions an increase in temperature by 3–5 °C until 2080 in comparison to 1960–1990, with an increase in winter temperature as high as 10 °C. An increase of precipitation mainly in winter and Southern Sweden of up to 20% is expected. Changes in precipitation are smaller in summer or might be negative (depending on the model). In general, the degree of uncertainty for prediction of precipitation might be larger than for temperature.

The assumption of the Finnish Government Helsinki (2024) is similar to Sweden, with an expected temperature increase of 2–5 °C in comparison to year 2000, with stronger warming in the winter than in the summer. Rainfalls also are expected to increase between 5–20% with strong seasonality and larger changes in winter.

Therefore the climate change expectations of DEFRA (2004) are in line with the more recent expectations for Sweden and Finland. The only major difference is that in the UK it was expected that warming in summer is to be larger than in winter, which is expected to be the other way around in the Nordic Zone.

Therefore in principle the main conclusions and recommendations from DEFRA (2004) remain valid and can be assumed to be applicable for the Nordic Zone as well.

DEFRA (2004) concluded that there are direct and indirect implications of climate change on pesticide fate modelling. It was "not possible to rigorously assess the direct impact of climate change on FOCUS models without a systematic sensitivity analysis, however, qualitative assessment of individual climate parameters indicates that the models may be more sensitive to extreme daily variables and less sensitive to average values." Regarding the indirect implications it is concluded that the FOCUS models appear to be resilient, so that they represent the climate sensitive processes with sufficient physical realism to account for changes due to climate variables. However, climate sensitive parameters such as crop growth cycles are fixed in FOCUS. This has been identified as a vulnerability.

It was also pointed out that socio-economic changes (like adaptation of agricultural practices, climate-dependent societal changes…) may play an important role, which might be more important than the direct climate effects.

DEFRA (2004) concluded on a in a number of important changes that need to be accounted for within the regulatory framework.

- Changing patterns of pesticide use brought about by changes in cropping patterns.
- **Introduction of new crops**
- **Different geographical spread of existing crops**
- **Faster maturity of crops**
- Changing patterns of pesticide pests and diseases
- Changes to accepted pattern of soil moisture deficit development and soil re-wetting
- Delayed onset of recharge and drainage
- Shorter recharge/drainage season
- Increase rainfall intensity in winter
- By-pass flow conditions occur more frequently
- Less interaction between leached pesticide and the soil
- Increased winter pesticide degradation
- Higher levels of metabolites generated
- Less dilution available in water bodies during summer
- Increased water pesticide concentrations from spray drift events

Most of these points appear to be covered within the processes in the FOCUS models (e.g. changes in drainage season and degradation). The points in bold however would need adjustment in the current modelling scenarios and their interpretation.

4.2.2 Evaluation of effect of climate change on environmental parameter

4.2.2.1 Background of scenario data

Soil scenarios

The PEC_{soil} calculation used for European registration is described in FOCUS (1997). A simple scenario is used assuming that the initial applied mass of active substance is mixed over a soil depth of 5 cm with a dry soil bulk density of 1.5 (g/cm^3). For multiple applications degradations between the applications is assumed. For accumulation potential multiple years of consecutive applications are calculated. No temperature or moisture data is used in the process for normalisation.

As described in Northern Zone (2024) the Nordic PECsoil calculator needs to be used for the Northern European Zone. The principal is similar to the process described in FOCUS (1997), however for the Nordic Zone the Finnish scenario for Jokioinen (Finland) with temperature data **from 1979–1998** should be used.

Work for potential update of the temperature data for the Finnish scenario is currently investigated by Nibio within the scope of a research project.

In the future the model PERSAM might become relevant based on EFSA (2017). PERSAM in Tier3a also uses scenario and weather data within the PEARL and PELMO models. The weather data is the same as for the groundwater scenarios (from the MARS meteorological data base (50 × 50 kms grid cells) **from year 1971–2000**).

Groundwater scenarios

The standard FOCUS groundwater scenarios are described in FOCUS (2000) (Table 3). These scenarios were selected based on the criteria that it should be maximum 10 scenarios and with realistic combinations of crop, soil, climate and agronomic conditions. The overall vulnerability should approximate the 90th percentile of all possible situations, which represents a realistic worst case. The vulnerability should be split evenly between soil properties and weather. Finally, the 80th percentile value for soil and 80th percentile value for weather is used to approximate the overall 90th percentile.

Locations were selected to represent major agricultural regions, span the range of temperature and rainfall in EU and to be distributed across the EU with no more than one scenario per Member State. This evaluation was based on available data available in multiple publications from 1994 to 1998.

The selection of soil types and characteristics was based on expert judgement. Soil maps were used to obtain information on texture and organic matter content. Also the SEISMIC data base (for Okehampton), local expert judgement, and a formal national scenario for Germany (based on a soil survey intended to locate a worst-case leaching soil (Kördel et al., 1989) were taken into account.

For the weather selection FOCUS (2000) states that: "As part of the scenario selection process, targets for annual rainfall were also developed for each site based on tables of annual rainfall (Heyer, 1984). These target values were used by the weather subgroup to identify appropriate climatic data [...] for a 20-year period [...]. Four locations (Châteaudun, Piacenza, Sevilla, and Thiva) were identified as having irrigation normally applied to at least some crops in the region." The final weather data was derived from the MARS meteorological data base (50 × 50 kms grid cells) **from year 1971–2000**.

Details on the process how the irrigation schedules were defined can be found in FOCUS (2000). The irrigation scheduling software IRSIS (Irrigation Scheduling

Information System) (Raes et al., 1988) developed by the Institute for Land and Water Management, Katholieke Universiteit Leuven was used.

Together with new weather data also new irrigation schedules would need to be developed. Schedules could be developed based on irrigation models as mentioned above and be evaluated by local experts.

The decision which main crop types to include and for which scenarios to parameterise them was based on expert judgement in the 1990s.

Reviews and minor changes regarding the above-mentioned points were published in FOCUS (2011) and EC (2014).

Table 3: Overview of the nine groundwater scenarios. "I" indicates that rainfall is supplemented by irrigation (FOCUS, 2011)

			Surface Soil Properties	
Location	**Mean Annual Temp. (°C)**	**Annual Rainfall (mm)**	**Texture**	**Organic Matter (%)**
Châteaudun	11.3	648 + I	Silty clay loam	2.4
Hamburg	9.0	786	Sandy loam	2.6
Jokioinen	4.1	650	Loamy sand	7.0
Kremsmünster	8.6	899	Loam/silt loam	3.6
Okehampton	10.2	1038	Loam	3.8
Piacenza	13.2	857 + I	Loam	2.2
Porto	14.8	1150 + I	Loam	2.5
Sevilla	17.9	493 + I	Silt loam	1.6
Thiva	16.2	500 + I	Loam	1.3

Additionally, to the standard FOCUS scenarios national groundwater scenarios for Sweden, Norway and Denmark were developed. Similar to the $FOCUS_{gw}$ scenarios also the weather data for the national scenarios were derived from data between 1961 to 1995 (as summarised in Burns et al. (1995)) and for the scenarios Krusenberg and Näsbygård irrigation is used.

The weather data for the Swedish scenarios is currently under review and in the process to be updated by the Swedish University of Agricultural Sciences (SLU).

Burns et al. (1995) reviewed the protectiveness of the national MACRO scenarios and found that overall it was only slightly lower than of the FOCUS scenarios Hamburg and Jokioinen, but more variable with occasional negative outliers. "Consequently, the uncertainty of regulatory decisions at the zonal level based on the FOCUS scenarios Hamburg and Jokioinen would be higher than the uncertainty of decisions based on results of the national MACRO scenarios." They suggest for higher tier-simulations a GIS-based, fully spatially probabilistic approach should be used.

Surface water scenarios

STEP1-2:

The STEP1-2 scenarios follow a relatively simplistic and very conservative approach as described in FOCUS (2001): "At Step 1 inputs of spray drift, run-off, erosion and/or drainage are evaluated as a single loading (sum of individual applications) to the water body and "worst-case" water and sediment concentrations are calculated. If inadequate safety margins are obtained (Toxicity Exposure Ratios < trigger values), the registrant proceeds to Step 2. At Step 2, loadings are refined as a series of individual applications, each resulting in drift to the water body, followed by a run-off/erosion/drainage event occurring four days after the last application and based upon the region of use (Northern or Southern Europe), season of application, and the crop interception. Again, if inadequate safety margins are obtained (Toxicity Exposure Ratios < trigger values), the registrant proceeds to Step 3. Step 3 requires the use of deterministic models such as PRZM, MACRO and TOXSWA."

Drift loadings, runoff, erosion, and drainage loadings have been determined and those are directed into a standard water body of fixed dimension. The drift loadings at STEP 1 and 2 are based on Rautmann et al. (2001). Runoff/erosion/drainage entries in STEP1 were set to 10% as a very conservative estimate for a reported maximum loss of 8-9% for drainage and 3-4% for runoff. The runoff/drainage entries in STEP2 are defined as 2%-5% depending on the region and season and have been calibrated against STEP3 calculations.

Due to the increased rainfall amount and intensity in recent years (and predicted in the future), it should be checked if the assumptions are still conservative enough. After FOCUS Surface Water Repair published the new surface water scenarios it should be checked if STEP2 still leads to systematically higher PEC_{sw} values than STEP3.

STEP3:

Similar to the groundwater scenarios, a set of scenarios were developed for surface water (FOCUS, 2001) to define "a limited number of "realistic worst-case" surface water scenarios which were broadly representative of agriculture as practised in the major production areas of the EU. These scenarios should take into account all relevant entry routes to a surface water body, as well as considering all appropriate target crops, surface water situations, topography, climate, soil type and agricultural management practices." In contrast to the groundwater scenarios (which explicitly do not represent specific sites) it is mentioned for surface water that "wherever possible, selected scenarios should be represented by specific field sites with monitoring data to allow subsequent validation of the scenario."

A set of representative realistic worst-case scenarios was selected based on data sets covering the European community for climate, landscape characteristics and land use and cropping (Table 4). Data included is from the 1990s and before. A pragmatic approach was then used for initial scenario selection. This was based upon "climate using temperature and recharge together with soil drainage status to identify broad drainage scenarios, and temperature and rainfall together with slope to identify broad run-off scenarios".

Table 4: Inherent Agro-environmental characteristics of the Surface water scenarios (FOCUS, 2001)

Scenario	Mean spring & autumn temp.(°C)	Mean annual rainfall (mm)	Mean annual recharge (mm)	Slope (%)	Soil
D1	<6.6	600–800	100–200	0–0.5	Clay with shallow groundwater
D2	6.6–10	600–800	200–300	0.5–2	Clay over impermeable substrate
D3	6.6–10	600–800	200–300	0–0.5	Sand with shallow groundwater
D4	6.6–10	600–800	100–200	0.5–2	Light loam over slowly permeable substrate
D5	10–12.5	600–800	100–200	2–4	Medium loam with shallow groundwater
D6	>12.5	600–800	200–300	0–0.5	Heavy loam with shallow groundwater
R1	6.6–10	600–800	100–200	2–4	Light silt with small organic matter
R2	10 – 12.5	>1000	>300	10–15	Organic-rich light loam
R3	10 – 12.5	800 – 1000	>300	4–10	Heavy loam with small organic matter
R4	>12.5	600–800	100–200	4–10	Medium loam with small organic matter

For each scenario then a main range of crops was characterised based on local knowledge and cropping databases.

Similar to the groundwater scenarios the MARS database (50 × 50 km grid cells, years 1971–1998) was used to derive weather data for the scenarios (for details refer to FOCUS (2001)). In contrast to groundwater the assessment for surface water is based only on a six-year warm up period and a 16-year evaluation period (drainage) and a 20-year period from which only 12 months will be fed from PRZM to TOXSWA.

Drift calculation is based on BBA (2000) and Rautmann et al. (2001).

For FOCUS surface water the ISAREG model (Teixeira and Pereira, 1992) was used to derive irrigation schedules. This model was developed and validated for Southern European conditions and was considered particularly appropriate for the runoff scenarios.

Together with new weather data also new irrigation schedules would need to be developed. Schedules could be developed based on irrigation models as mentioned above and be evaluated by local experts.

For surface water it is assumed that new irrigation schedules have been development within FOCUS surface water repair. It should be evaluated if the same methods can be applied for updated weather data.

It should be mentioned that the FOCUS Surface Water repair group (EFSA et al., 2020) has updated the most important issues of the surface water scenarios. One of the main changes was the extension of the evaluation period to 20 years. For this the weather time series had to be prolonged. However, as discussed in section 3.2.2 no update to more recent data or consideration of climate change was in the scope of this group.

Additionally in FOCUS (2001) the relevance of each scenario was evaluated for the different regions in Europe.

STEP4:
At STEP4 mitigation options can be used as described in FOCUS (2007a and b) based on e.g. drift and runoff buffer. For drift the mitigation efficiency is based on the Rautmann et al. (2001) drift curve. The efficiency of the runoff buffer has been implemented in the SWAN software (ECPA, 2018) based on Reichenberger et al. (2007), who compiled a review of buffer efficiency. 90th percentile efficiencies were implemented in FOCUS as a conservative approach. It is assumed that these conservative estimates are still valid also under climate change conditions. Since 2012 SWAN also includes an alternative option to model the efficiency of vegetative filter strips (VFS), using the mechanistic, event-based model VFSMOD (Muñoz-Carpena and Parsons, 2022; Muñoz-Carpena et al., 1999). VFS scenario parameters for SWAN have been derived by Brown et al., (2012).

Potential impact by climate change

Based on the above description climate change may have impact on the following aspects of the background data used to derive the FOCUS scenarios.

Climate data, soil data, crop distribution maps etc., which were used to prepare the scenarios and to analyse their relevance for the member states are from the 1990s and earlier. It has to be noted that the scenarios were designed to cover the climatic and agricultural variability throughout Europe, and that the changes induced by climate change are expected to range within this spatial variability. Therefore, the concept of the FOCUS scenarios remains valid. Details on potential adjustments of scenario data are discussed in the following chapters.

However, due to the outdated data background adjustments on how to use the FOCUS scenarios might be required:

1. A shift of the agricultural zones from south to north is taking place and will further take place in the future (Franke et al. (2021), UBA (2023)). Therefore, the extent of each scenario has most probably changed in the recent years. The spatial extent of each scenario should be re-evaluated, and the member states should update their list of required scenarios if necessary. SETAC SDLM group could be approached for further details.
2. In the same process it should be evaluated if some scenarios do not cover any relevant agricultural area anymore and should be omitted. Further if there is a relevant portion of agricultural land which is not covered by any scenario the development of additional scenarios might need to be considered.
3. It should be reviewed if the main FOCUS crops defined for each scenario are still sufficient (e.g. by examining current crop distribution maps). It can be expected that cropping zones of crops like e.g. maize or oil seed crops shift further to the North (DEPA, 2013). Therefore, a parameterization of further crops for e.g. Jokioinen or the Nordic groundwater scenarios might be useful. Also new crops might have become more relevant in Europe which have not been considered relevant at the initial set up of the scenarios. Additional FOCUS crops might need to be defined. This is indicated as well in the increasing need to select surrogate crops for non-parameterised FOCUS crop/scenario combinations. Guidance should be developed to establish rules for selection of surrogate crops.
4. The STEP 2 runoff and drainage percentages should be reviewed if they are still conservative (based on literature review and comparison against new FOCUS-scenarios from FOCUS surface water repair activities).

Action points Priority 1:

- Member states to re-evaluate spatial extent of FOCUS groundwater and surface water scenarios and to re-define relevancy of scenarios for their national risk assessment
- Member states to re-evaluate if further FOCUS scenarios, FOCUS crops, or combinations of both need to be defined to cover all major agricultural areas and to avoid increased necessity to use surrogate crops
- Development of guidance on how to select surrogate crops for those scenarios which are not defined for FOCUS crops

Action points Priority 2:

- Re-evaluation of conservatism of STEP2 runoff and drainage percentages in light of recent FOCUS surface water repair activities (e.g. literature review)

4.2.2.2 Weather data and irrigation

Northern Europe is expected to experience higher temperature increases compared to the global average. These projections, typically based on Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP) scenarios, highlight the region's sensitivity to climate change due to its high latitude. By 2100, under a high-emission scenario (RCP8.5 or SSP5-8.5), the mean annual temperature could rise by 4 °C to 6 °C in many parts of Northern Europe. In a moderate scenario (RCP4.5), the increase is projected to be around 2 °C to 3 °C. Winters will warm significantly, potentially shortening the snow season, especially in southern and coastal areas. Summer temperatures are also projected to rise, with more frequent heatwaves.

Projections generally indicate a rise in winter rainfall, with more precipitation falling as rain rather than snow, particularly in southern Scandinavia. Snowfalls may still occur but are predicted to be less frequent and occur later in the season. Summer precipitation may decrease slightly in some areas, leading to a higher risk of droughts, particularly in parts of Sweden. Scandinavia is also expected to experience longer growing seasons due to earlier springs and delayed autumns.

Carvalho et al. (2021) investigated future changes in mean, maximum, and minimum surface temperatures over Europe using CMIP6 projections. The study found that temperatures are projected to increase across Europe, particularly in northern and southern latitudes, with warming reaching 2–3 °C by mid-century and

5–6 °C by the end of the century under SSP5–8.5. Carvalho also noted that frost days are expected to decrease across Europe, with fewer than 50–70 days per year in central Europe and even less in Scandinavia and north-eastern Russia.

Lind et al. (2023) used high-resolution climate modelling to assess future projections for Fenno-Scandinavia (Norway, Sweden, Finland, and surrounding areas). The study employed the HARMONIE-Climate model (HCLIM38) and found that by the end of the century, temperatures could increase by 2–3 °C under RCP4.5 and by 4–7 °C under RCP8.5. Higher precipitation amounts are projected for fall, winter, and spring, while summer precipitation may decrease in southern areas. Both daily and sub-daily intense precipitation events are expected to become more frequent, with the most significant changes occurring in summer.

Analyses of measured and remote sensing data confirm the trends predicted by climate models. Kjellström et al. (2022) reanalysed data from 1961 to 2020 and found significant warming across all seasons in Northern Europe, with reduced daily temperature variability in winter and increased variability in summer. Precipitation has generally increased over the past 30 years, although daily precipitation variability has not shown consistent trends. Montibeller (2021) focused on the Baltic countries (Lithuania, Latvia, and Estonia, data from 2000 to 2018) and reported temperature increases, particularly in late spring, summer, and early autumn, with mixed trends in precipitation.

The Interministerial Working Group on Adaptation to Climate Change in Germany (UBA, 2023) has reported a temperature increase of 0.8 °C since the early industrialization period, with further warming expected. They additionally analysed two scenarios: the 'Climate protection scenario' (RCP2.6) aiming for a maximum of 2 °C global warming by 2100, and the 'High emissions scenario' (RCP8.5), which anticipates significant temperature rises due to continued carbon-rich fossil fuel use. For the period 2031–2060, projected temperature increases range from 0.8 to 1.5 °C under RCP2.6 and 1.5 to 2.3 °C under RCP8.5. Precipitation projections for the short-term planning horizon (2031–2060) suggest no significant annual changes, with variations between ±0% to +6% under the climate protection scenario and -1% to +9% under the high emissions scenario. In winter, precipitation could increase by 3% to 23%, while the trends for summer and autumn are less clear. The number of days with heavy precipitation (at least 20 mm per day) is expected to rise across all regions.

As discussed above the most important weather variables for the environmental fate modelling of PPP are changes in rainfall amounts and intensity (which influences the leaching of substances to groundwater as well as the occurrence of runoff and drainage), air temperature (which is used to calculate soil temperature relevant for degradation of the substances), and evapotranspiration (influencing the water balance of the soil and therefore also has impact on the leaching of PPPs).

Below an evaluation is performed on which impact these changes have on the predicted environmental concentrations (PECs) in the different environmental compartments.

PEC_{soil}

As described above for the soil scenarios, weather data plays a minor role for PEC_{soil} calculations. The initial PEC_{soil} does not change with changing climate. On European level also for the plateau or accumulation PEC_{soil} the weather data has no influence.

The Finnish PEC_{soil} calculator temperature plays a role. Increased temperature would lead to a faster degradation of parent substances, which would lead to lower concentrations. Metabolites calculated being formed in a pathway from the parent would also degrade faster but at the same time they would be formed faster. Overall, a decrease in concentrations with increasing temperature would be expected.

Work for potential update of the temperature data for the Finnish scenario is currently done by Nibio.

Once PERSAM will be used a similar impact from climate data can be expected as for the groundwater scenarios.

PEC_{gw}

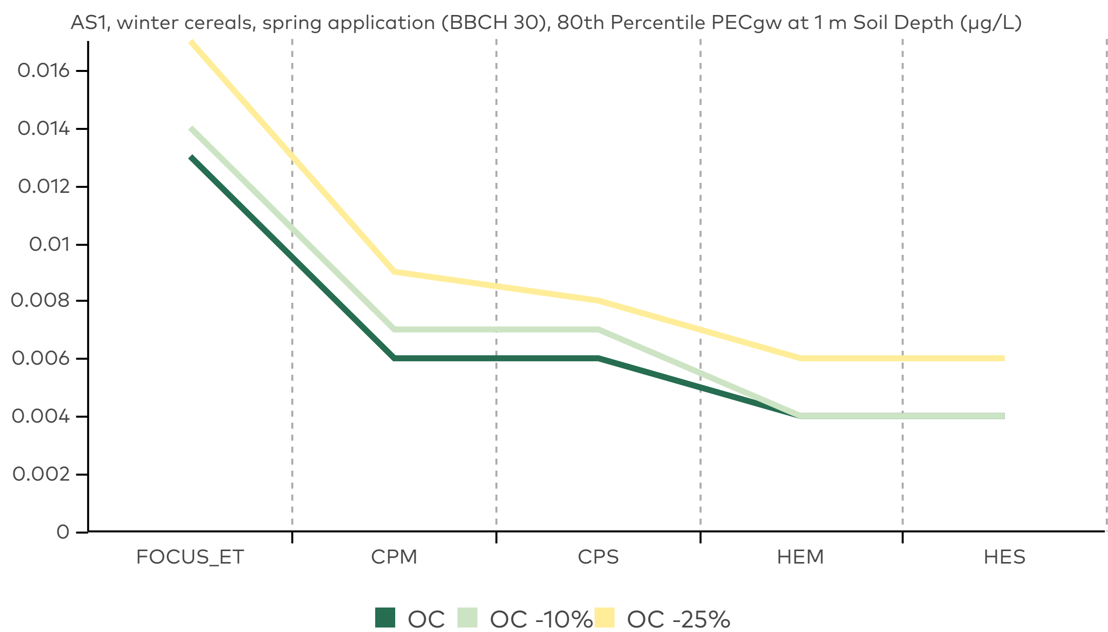
For PEC_{gw} calculations three models are used (FOCUS MACRO, FOCUS PEARL, and FOCUS PELMO). FOCUS MACRO is the only model included which simulates macropore flow.

An impact assessment of the MACRO model was done by Steffens et al. (2014 and 2015) as discussed in section 3.2.3. Steffens et al. (2015) performed simulations with the regional model MACRO-SE for south-west Sweden in order to assess the direct and indirect effects of climate change on herbicide leaching to groundwater. One of the main conclusions was that the increased temperature (enhancing degradation) and increased rainfalls (promoting leaching) cancel each other at regional scale, so that only a minor increase in concentrations were observed. Indirect effects (such as increase of land-use area in Sweden and increase of herbicide use) may have a larger effect on groundwater contamination.

This conclusion might not be directly transferable to FOCUS MACRO or the national MACRO scenarios for the Nordic zone. Since weather data for the MACRO scenarios for Sweden are currently under review by SLU, an impact assessment of the weather data on PEC_{gw} will be discussed in that framework.

FOCUS PELMO and FOCUS PEARL consist of the same or similar processes. For the risk assessment in the Nordic zone the Hamburg scenario calculated with FOCUS PELMO is the most relevant (Northern Zone, 2024). Therefore, an impact assessment of climate change on the PEC_{gw} for this scenario calculated with FOCUS PELMO is performed in Appendix 2. Nine substances with different $DT_{50,soil}$ and K_{FOC} values were tested with application to winter cereals at BBCH 10 and BBCH 30. Four different climate scenarios were tested based on climate protection assumptions and high emission assumptions based on UBA (2023) with an average annual increase of rainfall and with seasonal variability. The results show for the majority of substances that the PEC_{gw} values decrease from FOCUS weather over the climate protection to the high emission scenario. Consideration of seasonality in the changes in precipitation appear to play a minor role.

Please see Figure 1 as an example for active substance 1 (DT_{50} in soil = 10 d, K_{FOC} = 10 mL/g). The different climate scenarios are FOCUS_ET = FOCUS with updated evapotranspiration, CPM = climate protection scenario without seasonal variation, CPS = Climate protection scenario with seasonal variation, HEM = high emission scenario without seasonal variation, and HES = high emission scenario with seasonal variation.



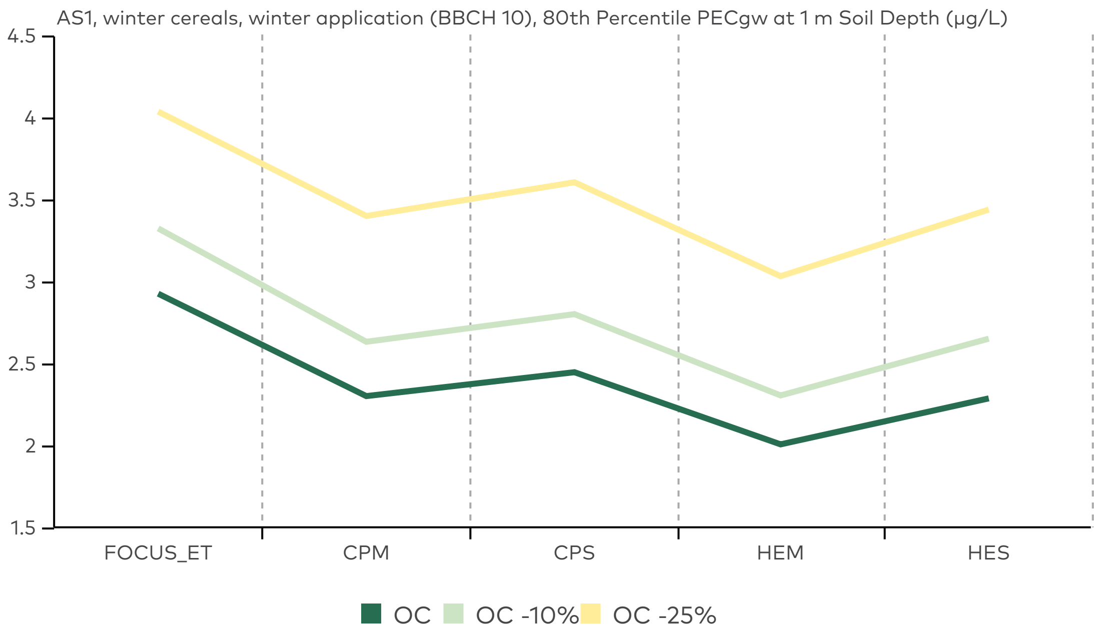


Figure 1: PEC_{gw} values of active substance 1 for Hamburg scenario (PELMO) calculated with different climate scenarios

While a change in rainfall pattern and amount was considered in the impact assessment it is important to note that changes in rainfall intensities were not considered. Extreme rainfall intensities are becoming more frequent, with strong rainfalls of sub-daily duration. In the current FOCUS models daily weather data is included, which disregards any variation of precipitation on sub-daily level. This may lead to an overestimation of infiltration and leaching in case the actual rainfall intensity exceeds the actual infiltration capacity of the soil. This might occur more often due to climate change.

In general, the usage of hourly climate data in empirical water flow models on which e.g. PELMO and PRZM are based on, might make less sense than in physics-based models like PEARL and MACRO.

For FOCUS PELMO the runoff function is deactivated (CN=0). Even if switched on only the daily precipitation volume would play a role, so that an impact of changed intensity is only expected if also the daily volume is changed.

Test calculations in FOCUS (2014) showed that the estimated runoff volume increases drastically for most FOCUS scenarios in PEARL, when the averaging period is not 24 h, but decreased to as low as 1 h. FOCUS (2014) concluded that runoff information should be updated, but that no suitable data was obtainable at that time.

In MACRO higher hourly rainfall intensity (or a higher value of the parameter RINTEN) would primarily lead to a higher macropore flow at the surface. Higher surface runoff is only expected once the infiltration capacity of the macropore domain is exceeded. As a consequence, increased rainfall intensity will primarily lead to increased leaching. In MACRO an algorithm used to derive hourly data from daily values (Olsson (1998) and Güntner et al. (2001)).

It should be evaluated if inclusion of e.g. hourly weather data is possible and if the FOCUS models are able to handle higher resolution weather data or would need to be updated. Further it needs to be evaluated if data sources with long term data on sub-daily level are available, or if algorithms are suitable for use also in other models.

PEC_{sw}

For FOCUS PEC_{sw} calculations the entry pathways of drift, drainage and runoff to three different water bodies (pond, ditch and stream) are relevant.

Drift calculation is based on BBA (2000) and Rautmann et al. (2001). Actual drift strongly depends on the onsite weather conditions at time of application (especially wind velocity and direction). The variability of the field conditions is higher than the changes introduced due to climate change. Therefore, it is expected that no update of the drift values will be required. However, also induced by climate change more precision farming techniques (e.g. application via drones, spot application) are expected. It would be important to develop drift curves for regulatory purposes for these techniques.

Runoff and drainage are strongly influenced by rainfall amount, intensity and timing. Therefore, it is expected that PEC_{sw} values will be strongly impacted by climate change. While larger rainfall amount will lead to more transport of pesticides into the water bodies also the water volume increases, and with it the dilution of the pesticides.

Kühnel and Wang (2024) updated the weather data of FOCUS SWASH from the years 1975-1994 to the time frame of 2004–2023. They found that PEC_{sw} values differ noticeably if recent weather data is used. For autumn applications PEC_{sw} values increased, while they decreased for spring applications. This is due to the fact that mainly precipitation in autumn and winter increased, while in spring and summer mainly the temperatures increased. They concluded that "These results indicate that FOCUS weather data should be updated regularly to take account of climate change. As weather extremes and the variability of precipitation have increased, multiyear PEC_{sw} should also be used instead of using one reference year only."

An update of the PEC_{sw} calculations was performed within the FOCUS SW repair group which includes a multi-year approach similar to the PEC_{gw} calculations. However, an update to more recent weather data is not foreseen within this context (EFSA et al. (2020).

As discussed already for PEC_{gw}, high rainfall intensities may have a stronger impact on PEC_{sw} calculations. Especially runoff and drainage are driven by rainfall intensities. The usage of daily precipitation may introduce an error which will increase in the future when high intensity rainfalls increase. It should therefore be considered to include weather data with e.g. hourly timesteps.

Adjustments in the code of the FOCUS models might be required and would need to be discussed with the model developer (e.g. the usage of runoff and erosion curve numbers which are based on daily assumptions). As mentioned above, the usage of hourly climate data in empirical water flow models on which e.g. PRZM is based on, might make less sense than in physics-based models.

PEC_{air}

Contamination of and transport by air mainly occurs via volatilisation and deposition. Volatilisation is mainly influenced by the vapour pressure of the active ingredient. The FOCUS air group (FOCUS, 2008) has established the vapour pressure thresholds of 10^{-4} Pa (at 20 °C) for volatilisation from soil and 10^{-5} Pa (at 20 °C) from plants. If vapour pressure is higher than these thresholds volatilisation and deposition need to be considered in the aquatic exposure assessment and should be either calculated with EVA 2.0 or based on experiments.

The usage of the vapour pressure at 20 °C appears to still be conservative for the Nordic Zone, where average daily temperatures are below 20 °C. Additionally, for typical application timings in autumn and spring temperatures are expected to be below 20 °C. Therefore, an amendment of this procedure might not be required.

Conclusion

The weather data used in the current risk assessment is outdated (usually from 1970s–1990s). Due to changes in rainfall, temperature, and evapotranspiration the impact on PEC-values is depending on the environmental compartments and application timing.

Rainfall intensities of sub-daily / hourly time steps should be included in the physics-based models (such as MACRO and PEARL) to adequately depict runoff and drainage conditions. MARS data appears to be available for download only in daily resolution. Different sources (other gridded values or direct data from weather stations) would need to be considered to extract relevant data or statistical models for temporal rainfall disaggregation should be considered (as e.g. for MACRO). Models might need to be updated to appropriately reflect changes in the time resolution of weather data. Increased rainfall intensities might make it more relevant to re-evaluate the methods of how runoff is calculated (FOCUS, 2014).

An update of the recent weather data should be considered for the national Nordic scenarios. Potentially also discussion on updating the weather data of the FOCUS scenarios on European level should be initiated.

Within the current framework a regular update (every 5–10 years) of climate files should be considered. A potential option would be to make new weather files available for download in regular intervals, with newest measured data (e.g. based on MARS 25) for the respective scenarios in the appropriate file formats. A procedure would need to be developed to assure that this data still covers the 90^{th} percentile protection goal. The interval should not be larger than 10 years to ensure that for substance renewal updated weather data is available.

This approach ensures that relatively recent actual weather data is used for risk assessment. However, it does not consider any climate projections for the future time frame for which registration is granted (usually around 10 years). The use of climate projection for the Nordic zone was recommended by Burns et al. (2015).

Climate projections bring a further degree of uncertainty which could be addressed by Bayesian Network models. Example applications of these approaches were discussed in section 3.2.3 (e.g. Steffens et al. (2014 and 2015) and Mentzel et al. (2021)). These predictions aim however at time frames > 10 years, where the usage of projections is required.

For the regulatory process of up to 10 years the additional effort of these assessments might not be justified. However, these options should be discussed especially if the regulatory process is overhauled in general in the future (see EU-PARC project).

Action points Priority 1:

- Update climate data and irrigation schedules used in models for environmental risk assessment to new time series. Data sources as used in original FOCUS scenario could be used.
- Develop process on how to update and distribute climate data regularly (every 5–10 years) for relevant models and scenarios to stakeholders.
- Initiate discussions with model developers if sub-daily climate data can be used and perform impact assessment on PEC groundwater and surface water calculations. Availability of weather data of e.g. hourly resolution or options of temporal rainfall disaggregation needs to be checked.

Action points Priority 3:

- Initiate discussions on European level (EFSA, EU-PARC project) if in an updated future risk assessment scheme climate projections could and should be implemented instead of past weather data

4.2.2.3 Application dates/growth stages

Soil temperature and water content of the soil play a major role in the development of the plants. UBA (2023) mentions that a soil temperature of 5 °C is required to induce plant growth and that especially temperature in spring is important for scheduling of farmers management practices. In case temperatures are high enough a limiting factor might be the water supply. Too low or too high water content in the soil is inhibiting plant growth.

This leads to the conclusion that the predicted higher temperatures in winter and spring lead to an earlier crop development and/or shorter dormancy of e.g. winter crops. At the same time potential drought conditions may limit the plant growth in summer. Both effects would lead to a prolonged growth season and a shift in the dates when a BBCH stage is reached. This has been already observed in the northern zone (Wenng et al., 2020) and is expected to increase in the future.

In the regulatory process the application timings are usually defined relative to the BBCH stage. Most often the tool AppDate v3.06 (Klein, 2019) is used to define the specific dates for the FOCUS groundwater and surface water scenarios. For each defined BBCH stage of the main FOCUS crops a date is associated and linear interpolation is used for intermediate growth stages. For the Nordic zone additionally the publication of Myrbeck (1998) is frequently used, which is partially outdated as well. Scenario specific emergence and harvest dates for the FOCUS crops are also implemented in some of the FOCUS models.

In FROGS (2013) the application timing can be directly based on the BBCH stage. The application timing for the different regions in France is then calculated based on the temperature sum. This routine is similar to routines implemented in SWAP (the hydrological model used in PEARL) and WOFOST.

Similar to the weather data also the BBCH-dates relationship should be reviewed in regular intervals. This could be done within the AppDate tool as a standard approach. Also, the timings for Sweden in Myrbeck (1998) would need to be updated.

For more refined options the usage of crop growth models (such as WOFOST) could be employed to define new relationships based on the updated weather data.

As an additional option the C2D2 database published by industry (Hughes et al., 2023, see section 3.2.2) and potentially further databases could be a good source of information. It should be discussed if an extension of this database with recent field trial data in a regular interval would be feasible. This data could be used to define appropriate application timings directly or to verify dates from AppDate or from model calculations by e.g. WOFOST.

Action points Priority 1:

- Update of agronomic dates in FOCUS and national scenarios (especially emergence and harvest dates of FOCUS crops)
- Update of BBCH – date relationships in AppDate and for national scenarios

Action points Priority 2:

- Development of more flexible approach of defining BBCH-date relationships with field data (e.g. C2D2-database) or crop modelling

4.2.2.4 Field management practices

Standard application techniques like boom spray, air blast, and incorporation are currently available as standard approaches in the FOCUS framework. However, further field management practices related to precision farming are used more and more frequently. These might be especially application via drones, spot applications, conservation tillage, or no tillage.

They might become more important in the future to avoid increased loss of pesticides and soil via runoff and erosion due to climate change.

A regulatory framework is required to provide guidance on how a risk assessment for these novel practices shall be done. Especially drift curves for the non-standard application techniques need to be developed.

Action points Priority 1:

- Develop regulatory framework for precision farming techniques. Detailed guidance and implementation in FOCUS models is required (e.g. new application types, drift curves, mitigation options in SWAN and VFSmod)

4.2.2.5 Soil parameters

As described in FOCUS (2000) for the groundwater scenarios soil profiles were defined by experts based on real soil profiles. Main criteria for selection of the profiles were soil texture, soil pH, dry bulk density and percentage of organic carbon content down to a depth of at least 1 m.

Soil hydraulic properties of the profiles are described with van Genuchten parameters (van Genuchten, 1980), which were either measured or estimated with HYPRES (Wösten, 1998). These parameters are dependent mainly on soil texture, bulk density, and organic carbon content.

The most important input parameters in regard to leaching of pesticides is hence soil texture, bulk density and organic carbon content.

It is assumed that soil texture in general is relatively stable over the time period of 50 years, and hence would not require review. Also, bulk density is relatively stable as long as soil management does not change. It should be mentioned that changing field management practices such as conservation or no tillage may have impact on bulk density and pore network and might therefore need further attention when these techniques become more relevant.

The main variable which might change over shorter time periods and may have a high impact on pesticide fate is the organic carbon content. Higher temperature might lead to faster decomposition of organic material in soil, while longer growth periods may lead to increased input of organic material into the soil (UBA (2023) and Varney et al. (2020)). A case study in UBA (2023) shows relative stability of organic matter content over the last decades. A modelling and uncertainty analysis of global changes in soil carbon content indicates a decrease of soil carbon content over time considering global warming of 2 °C (Varney et al., 2020). It is mentioned that a common assumption is that the turnover time of carbon decreases by 7%

per °C of warming. However, these modelling results are subject to high uncertainty.

An impact analysis of changes of soil organic carbon content of -10% and -25% on the FOCUS PELMO Hamburg scenario is presented in Appendix 2. Nine substances with different $DT_{50,soil}$ and K_{FOC} values were tested with application to winter cereals at BBCH 10 and BBCH 30. The original OC-content of the FOCUS Hamburg scenario was reduced by 10% and 25%. No further changes e.g. in the van Genuchten parameters has been considered. A decrease in organic matter content by 10% and 25% led to an increase in PEC_{gw} by approximately 3% and 9%, respectively. However, in how far such significant changes in OC-content can be expected within the next 30–50 years is unclear.

Please see Figure 2 as an example for active substance 1 (DT_{50} in soil = 10 d, K_{FOC} = 10 mL/g). The different climate scenarios are FOCUS_ET = FOCUS with updated evapotranspiration, CPM = climate protection scenario without seasonal variation, CPS = Climate protection scenario with seasonal variation, HEM = high emission scenario without seasonal variation, and HES = high emission scenario with seasonal variation.

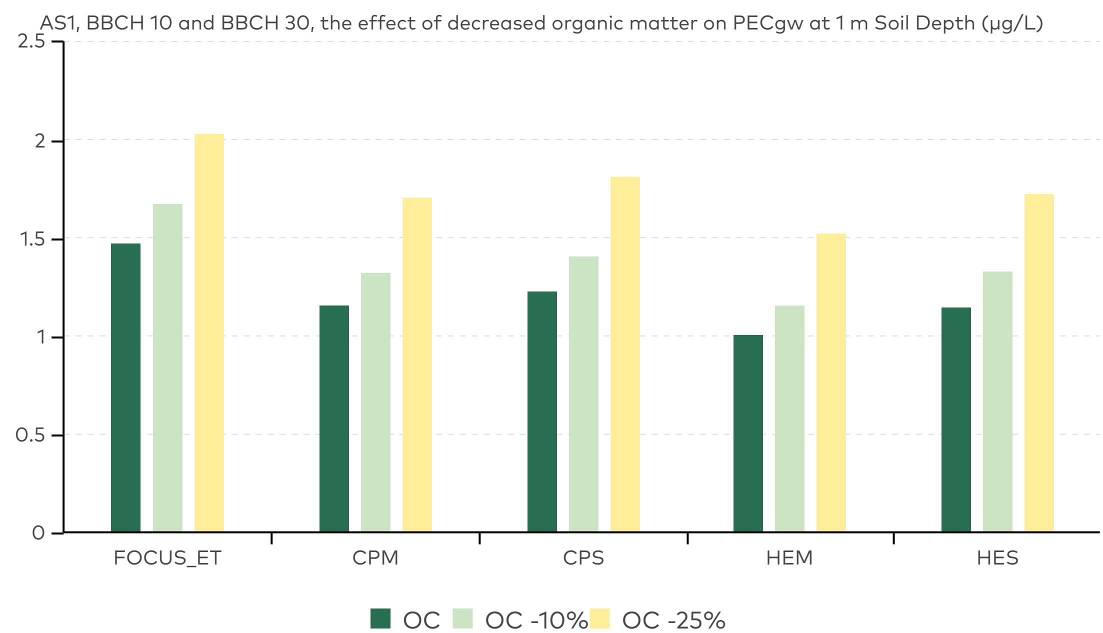


Figure 2: PEC_{gw} values of active substance 1 for Hamburg scenario (PELMO) calculated with different climate scenarios and soil organic carbon contents

Further work on the validity of organic carbon content in FOCUS groundwater calculations and PERSAM is done by the SDLM working group.

Also, the soil pH might be impacted by climate change and changed management practices. But currently usually pH-dependency is not directly considered within FOCUS calculations. If pH-dependency is addressed this is mainly done by separating the substance data set into an alkaline and acidic data set and running both through the standard FOCUS scenarios without considering the implemented pH values of the soils. Therefore, pH values in the soil profiles are assumed to be of less importance. However, the Nordic countries should review if the range of relevant pH-values mentioned in Northern Zone (2024) remains valid also under changed climate and management practices.

Action points Priority 2:

- Literature research on expected development of soil organic carbon content and soil pH values is recommended to decide if current scenarios cover future developments conservatively

4.2.2.6 Crop parameters

FOCUS (2000) mentions that vulnerability of the scenarios is more dependent on soil and weather data rather than on crop data. Therefore, average or median values were selected for crop parameters like rooting depth, leaf area index or kc-factors and were based on expert consultation and a limited set of literature data. In principle it can be assumed that changes in temperature and moisture regime will have a certain impact on these parameters. It is assumed that this has a rather limited effect on the outcome of PEC-calculations. Thus, no further measures were taken to evaluate a potential refinement.

No Action points identified

4.2.2.7 Models

The FOCUS models are processed based. The underlying processes are independent of external factors such as climate. The climate dependency is introduced by the input files based on the parameters discussed above.

It is therefore expected that no changes in the models themselves are required. Only exception might be potential changes required to handle weather data on sub-daily basis as discussed in section 4.2.2.2.

No Action points identified

4.3 Ecotoxicology

Please find a more detailed evaluation of relevant topics in Appendix 3.

4.3.1 Testing guidelines

Regulatory ecotoxicology studies are conducted to published internationally agreed testing guidelines to estimate the toxicity of a substance to non-target organisms. These guidelines stipulate various conditions and parameters to which the studies are conducted to ensure the outcome of the study can be considered relevant and reliable. This allows different substances to be tested against the same standardized guidelines, in any laboratory, which enables comparisons to be made, risk assessments to be conducted and data used for regulatory decision making in a harmonized approach.

Several of the OECD guidelines are now around 20 years old and although they are being updated to meet state-of-the-art science, with the environmental changes that are occurring the parameters specified in these guidelines may no longer be as representative of the conditions deemed suitable in previous years.

A brief summary of the type of parameters considered in a selection of the OECD guidelines and the parameters which may be considered climate sensitive are listed in Appendix 3, however, some questions are then raised:

1. Is the species stated as the most relevant indicator species in the guideline still the most relevant indicator species for our future climate?
2. Are the parameter ranges in the laboratory study designs still relevant?
    a. water temperature 18–22 °C,
    b. ambient air temperature 20 ± 2 °C,
    c. relative humidity 50–70%,
    d. light intensity Lux 540–1000, wavelength and photoperiod,
    e. are the test media compositions still appropriate for tests conducted in water and soil; organic matter content, sand content, pH, microbial content, water holding capacity, salinity, water hardness etc.,
    f. sensitivity of the toxic reference used in the test designs,
    g. acclimation conditions of the test species prior to testing.

Similar questions concerning the parameters specified above for use in the laboratory studies, could also be applied to higher tier semi-field and field studies.

Ecotoxicology testing covers a wide range of aquatic and terrestrial organisms. Some groups of organisms may be able to adapt or tolerate the change in environmental conditions, for example if the ambient air temperature or water temperature was to increase by a few degrees, and some species may become stressed. When put under stress, organisms may indicate a higher sensitivity to the test substance. Thus, it is important to evaluate the tolerance threshold of the test organisms.

Action points Priority 1:

- Identify if the 'indicator' species being tested are still appropriate considering the changing environmental conditions.
- Evaluate if the study designs are still representative of the changing environmental conditions.
- Establish if the current indicator species can tolerate a change in the study design parameters.

4.3.2 Risk assessment considerations

Various endpoints are measured from the regulatory ecotoxicological studies and used in the risk assessments. Depending on the type of study performed, a range of endpoints may be derived; a LC50, a NOEC or an EC10, based on survival, reproduction, biomass and growth etc. An evaluation should be made to see if these endpoints are still the appropriate parameters to be derived from the regulatory laboratory studies considering the environmental changes that are occurring. The assessments use the toxicity endpoints from these studies together with the Predicted Environmental Concentrations (PEC) to estimate potential risk to non-target organisms in a step wise harmonized approach. As described in section 4.2 of this document, any potential environmental changes could impact the PEC values for surface water, sediment and soil, calculated for use in the ecotoxicological risk assessments. This could make it harder to find an acceptable risk for the aquatic and soil risk assessments and more often higher tier refinements could be triggered or mitigation measures increased. An evaluation should be made to understand the impact of the PEC values on the risk assessments considering the environmental changes that are occurring.

In the agricultural environment, a change in environmental conditions could mean a change in timings of food item availability, shifts in diets and ultimately have an impact on growth and reproduction of the non-target organisms. There are various considerations that are taken into account when conducting a risk assessment that could be impacted by environmental changes:

1. country/zonal specific focal species considered for a particular BBCH growth stage of a crop (due to food availability and dietary exposure),
2. certain flowering stages of a crop and nectar/pollen availability are specified as being important for pollinator exposure, the timing of when flowering crops/weeds being available to pollinators might change,
3. short cut values used in the avian and mammal assessments (based on body weight and diet, food intake, habitat range).

The above list is not exhaustive, but an evaluation should be made of the impact on focal and indicator species, of a potential shift in the timings of when a BBCH stage of a crop is reached (see also section 4.2.2.3 of this document) due to environmental changes.

Regulatory ecotoxicological guidance on assessing the impact of plant protection products on biodiversity is currently being developed. Thus, it is currently unclear what the protection goals are and what needs to be protected. However, the impact of climate change on biodiversity from a regulatory ecotoxicology point of view should be evaluated: landscape change, movement of mobile organisms, ecosystems and their services, etc.

With the current environmental changes, as mentioned above, it is possible that a change in species sensitivity could occur which would influence if the focal/indicator species are still appropriate. Furthermore, the 'target pest' that the plant protection products are aimed at could also change, which could lead to a potential impact on beneficial species that exist in off-field habitats which could re-colonise in-field areas following application. It is recommended that an evaluation is made on the impact of a change in 'target pest' on off-field habitats and recolonisation.

Action points Priority 1:

- It is recommended that an evaluation be made to understand the impact of the PEC values on the risk assessments considering the environmental changes that are occurring.

Action points Priority 2:

- An evaluation should be made to see if the toxicity endpoints are still the appropriate parameters to be derived from the regulatory laboratory studies considering the environmental changes that are occurring.
- The impact of climate change on biodiversity from a regulatory ecotoxicology point of view should be evaluated: landscape change, movement of mobile organisms, ecosystems and their services, etc..
- An evaluation should be made of the impact on focal and indicator species, of a potential shift in the timings of when a BBCH stage of a crop is reached.
- It is recommended that an evaluation is made on the impact of a change in 'target pest' on off-field habitats and recolonisation.

4.4 Toxicology

No climate sensitive parameters were identified for toxicology. However, outcomes of the risk assessment may change due to changes from other sections (e.g. environmental fate and modelling).

No Action points identified

4.5 Chemistry

Most parameters in this section were identified as not climate sensitive. Please find a more detailed evaluation of relevant topics in Appendix 3.

Only exception is the storage stability or shelf-life. According to EC (2021) "the tests should be conducted at ambient temperature or 20 °C, 25 °C or 30 °C" and "storage temperatures must reflect the maximum and minimum temperatures likely to be experienced in a warehouse, farm store or garden store for amateur products dependent on the expected geographical areas of use." Therefore, testing of shelf-life is dependent on ambient temperature which is defined for moderate/temperate (18–22 °C), hot (23–27 °C), and very hot climate (28–31 °C).

Considering the increased frequencies of hot days due to climate change member states should review if the selection of their current temperature range needs to be updated. Potentially for some regions a shift to hotter climates for this test would need to be considered. For Southern Europe it should be reviewed if the upper testing period of 30 °C can still be considered as worst case, or if a higher temperature (e.g. 35 °C) needs to be tested and another range of "> 31 °C" should be introduced.

Action points Priority 1:

- Review of relevant temperature ranges for shelf-life test. Potentially introduction of new temperature ranges for Southern Europe.

4.6 Residues

No immediate action points were identified. Please find a more detailed evaluation of relevant topics in Appendix 3.

However, outcomes of the risk assessment may change due to changes from other sections (e.g. environmental fate and modelling).

For the consumer risk assessment and the animal diet changes may be required once "typical" consumption may change when climate change triggers a change in local diet / local grown and available crops. However, this is currently not considered an immediate risk.

No Action points identified

5. Conclusions

The report summarises the potential direct and indirect impact of climate change on the risk assessment of plant protection products.

Regarding the experimental studies, concerns were raised that extended drought and more frequent flooding of soils may impact the microbial communities in the soil or sediment. Therefore, specific care should be taken when soil or sediment samples are taken for laboratory tests. Also, the terrestrial field dissipation studies may be impacted by these events and an increased risk of invalid results from field studies was identified.

The main impact was identified in the area of environmental fate modelling. In the relevant environmental fate models and scenarios outdated weather data is used (mainly derived from time series between year 1970 – 2000). An impact analysis showed that the effect of increased temperature and changes in rainfall patterns potentially lead to decreased leaching of pesticides to groundwater (calculated for the Hamburg scenario with FOCUS PELMO). Other publications based on leaching calculations with MACRO show slight increases in leaching concentrations and with FOCUS surface water calculations increases or decreases in surface water concentrations depending on the application timing.

Indirect factors such as shifts in agronomic dates (emergence and harvest dates, dates when BBCH stages are reached), an increased use of plant protection products due to warmer and wetter conditions and an increased pest pressure, or an extension of agricultural land further north into potentially vulnerable areas could have a larger impact on the fate of plant protection products than the outdated climate data of the models.

At the same time, it is expected that new management practices will become more important. This may include precision farming techniques like application via drones and spot applications, and mitigation options such as micro dams or conservation tillage.

For Ecotoxicology it is concluded that testing guidelines should be reviewed to evaluate if the environmental parameters in these guidelines are still relevant and conservative or would need to be updated. The aquatic and terrestrial indicator species may react differently to changed temperature conditions. It needs to be evaluated if the indicator species are still appropriate considering changing environmental conditions. A change in environmental conditions could mean a change in timings of food item availability, shifts in diets and ultimately have an impact on growth and reproduction of the non-target organisms. An evaluation should be made of the impact on focal and indicator species, of a potential shift in the timings of when a BBCH stage of a crop is reached.

It further is concluded that changes in the environmental parameter and modelling input may have a significant impact on the aquatic and terrestrial risk assessment. An impact assessment should be conducted when environmental fate or ecotoxicological parameters or processes are changed to be aware of the impact on the risk assessment.

The following work packages were identified based on the action points described in the different sections (EFT = Environmental fate studies; MOD = Environmental fate modelling; ECO = Ecotoxicology; CHE = Chemistry):

Table 5: Suggested Priority 1 work packages

ID	Title	Priority	Description
EFT 1	Guidance review for terrestrial field dissipation studies	1	• Literature review to be performed to evaluate in detail the impact of drought and flooding on soil microbial communities • Guidance for terrestrial field dissipation studies should be reviewed in terms of how to deal with extended drought or flooding, to avoid the increasing risk of invalid results or how the results of affected trials can be interpreted for the risk assessment
MOD 1	Update of weather files	1	• Update climate data and irrigation schedules used in models for environmental risk assessment to new time series. Contact SDLM working group for input. • Develop process on how to update and distribute climate data regularly (every 5-10 years) for relevant models and scenarios to stakeholders. • Initiate discussions with model developers if sub-daily precipitation data can be used. Availability of weather data of e.g. hourly resolution or options of temporal rainfall disaggregation needs to be checked. • Impact assessment on PEC groundwater and surface water calculations.
MOD 2	Re-evaluation of relevance of FOCUS crops and scenarios	1	• Member states to re-evaluate spatial extent of FOCUS groundwater and surface water scenarios and to re-define relevancy of scenarios for their national risk assessment. Contact SDLM working group for input. • Member states to re-evaluate if further FOCUS scenarios, FOCUS crops, or combinations of both need to be defined to cover all major agricultural areas and to avoid increased necessity to use surrogate crops • Development of guidance on how to select surrogate crops for those scenarios which are not defined for FOCUS crops

MOD 3	Re-definition of agronomic dates and practices	1	• Update of agronomic dates in FOCUS and national scenarios (especially emergence and harvest dates of FOCUS crops) and BBCH – date relationships in AppDate and for national scenarios in Myrbeck (1998) • Develop regulatory framework for precision farming techniques. Detailed guidance and implementation in FOCUS models is required (e.g. new application types, drift curves, mitigation options in SWAN and VFSmod)
ECO 1	Testing guidelines	1	• Identify if the 'indicator' species being tested are still appropriate considering the changing environmental conditions. • Evaluate if the study designs are still representative of the changing environmental conditions. • Establish if the current indicator species can tolerate a change in the study design parameters.
CHE 1	Temperature selection for shelf-life testing	1	• Review of relevant temperature ranges for shelf-life test. Potentially introduction of new temperature ranges for Southern Europe

Table 6: Suggested Priority 2 work packages

ID	Title	Priority	Description
EFT 2	Guidance development for soil sampling	2	• Guidance on sampling timing should be developed to ensure that microbially active soils are taken which are not influenced by drought or flood periods or include how the results of affected studies can be interpreted for the risk assessment.
MOD 4	Literature reviews	2	• Literature review of worst-case runoff and drainage entries to re-evaluate conservatism of STEP2 entries in light of increased rainfall intensities and update in FOCUS surface water repair. • Literature research and discussion with SDLM working group on expected development of soil organic carbon content and soil pH values is recommended to decide if current scenarios cover future developments conservatively or if updates in soil data would be necessary

MOD 5	Definition of BBCH-date relationship	2	• Development of a flexible approach of defining BBCH-date relationships with field data (or crop modelling
ECO 2	Risk assessment considerations	2	• An evaluation should be made to see if the toxicity endpoints are still the appropriate parameters • The impact of climate change on biodiversity from a regulatory ecotoxicology point of view should be evaluated: landscape change, movement of mobile organisms, ecosystems and their services, etc. • An evaluation should be made of the impact on focal and indicator species by shifts in BBCH timings • It is recommended that an evaluation is made on the impact of a change in 'target pest' on off-field habitats and recolonisation.

Table 7: Suggested Priority 3 work packages

ID	Title	Priority	Description
MOD 6	Discussions on implementation of climate projections	3	• Initiate discussions on European level (EFSA, EU-PARC project) if in an updated future risk assessment scheme climate projection could and should be implemented instead of past weather data

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Appendix 1: List of stakeholders

Contact	Country
Authority	
The Danish Environmental Protection Agency (DEPA)	DK
Agriculture and food board	EE
Finnish Safety and Chemicals Agency (Tukes)	FI
State Plant Protection Service of the republic of Latvia (VAAD)	LV
State Plant Service under the Ministry of Agriculture (Vatzum)	LT
Norwegian Food Safety Authority (Mattilsynet)	NO
Swedish Chemicals Agency (KEMI)	SE
Österreichische Agentur für Gesundheit und Ernährungssicherheit (AGES) / Bundesamt für Ernährungssicherheit (BAES)	AT
FPS (Federal Public Service) Health, Food Chain Safety and Environment	BE
Central Institute for Supervising and Testing in Agriculture (UKZUZ)	CZ
Central Institute for Supervising and Testing in Agriculture (BVL) /Umweltbudesamt (UBA)	DE
National Food Chain Safety Office (NEBIH)	HU
Department of Agriculture, Food and the Marine	IE
Ministry of Agriculture, Food and Viticulture (ASTA)	LU
Board for the Authorisation of Plant Protection Products and Biocides (CTGB)	NL
Ministry of Agriculture and Rural Development / Institute of Environmental Protection	PL
Autoritatea Nationala Fitosanitara (ANFDF), Agenția Națională pentru Protecția Mediului (ANPM), Institutul de Cercetare-Dezvoltare pentru Protecția Plantelor (ICDPP), Institutul National de Sanatate Publica (INSP)	RO

Ústredný kontrolný a skúšobný ústav poľnohospodársky v Bratislave (UKSUP)	SK
Administration for Food Safety, Veterinary and Plant Protection	SI
Lichtensteinische Landesverwaltung (LLV)	LI
Health and Safety Executive (HSE)	GB/NI
Ministry of food and agriculture (MZH), Bulgarian Food Safety Agency (BFSA)	BG
MPS (Ministry of Agriculture), Institute for Medical Research and Occupational Health (IMI), Croatian Agency for Agriculture and Food (HAPIH)	HR
Department of Agriculture	CY
French Agency for Food, Environmental and Occupational Health & Safety (ANSES)	FR
Ministry of Rural Development and Food / Benaki Phytopathological Institute (BPI)	GR
Ministero della Salute	IT
Malta Competition and Consumer Affairs Authority (MCCAA)	MT
Direção-Geral de Alimentação e Veterinária (DGAV)	PT
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), Ministerio de Agricultura, Pesca y Alimentación (MAPA), Ministerio de Sanidad	ES
European Food Safety Authority (EFSA)	EU
European Chemicals Agency (ECHA)	EU
Industry	
Geospatial Analytics	-
SWECO	-
Bayer AG (Bayer Crop Science)	-
BASF SE	-
Corteva Agriscience	-
FMC Agricultural Solutions	-

Syngenta	-
Adama	-
Research Institutes and Universities	
VITO	BE
Fraunhofer Institut für Molekularbiologie und Angewandte Ökologie (IME)	DE
University of Hohenheim	DE
Helmhotz Zentrum für Umweltforschung	DE
RPTU Kaiserslautern Landau	DE
University of Gießen	DE
Julius Kühn Institut (JKI)	DE
Geological Survey of Denmark and Greenland (GEUS)	DK
European Environmental Agency (EEA)	EU
Finnis Environment Institute (SYKE)	FI
Natural Resources Institute Finland (LUKE)	FI
National Research Institute for Agriculture, Food and Environment (INRAE)	FR
International Centre for Pesticides and Health Risk Prevention (ICPS)	IT
Univ. Piacenza	IT
Wageningen Environmental Research	NL
PBL Netherlands Environmental Assessment Agency	NL
NIBIO	NO
Norwegian University of Life Sciences (NMBU)	NO
Swedish University of Agricultural Sciences	SE
University of Ljubljana	SI

Appendix 2: Impact analysis of changes in weather and organic carbon on the FOCUS PELMO Hamburg scenario

Material and Methods

The Predicted Environmental Concentrations in groundwater (PEC_{gw}) of nine dummy active substances under different climate change scenarios have been assessed using the FOCUS PELMO (version 6.6.4) model.

PELMO is a one-dimensional simulation model that analyses the vertical movement of pesticides in soil through chromatographic leaching. It is an official FOCUS model for pesticide registration in the European Union (FOCUS, 2000, 2023). The primary goal of FOCUS is to create a harmonized European Tier 1 approach. Consequently, nine EU scenarios are implemented in FOCUS PELMO, collectively representing agricultural practices across Europe. These scenarios do not specifically imitate individual fields or reflect the agriculture precisely at their named locations or within the respective Member States.

The PEC_{gw} was assessed using the FOCUS Hamburg scenario (see Table 8).

Table 8: FOCUS Hamburg ground water scenario

Scenario	Mean Annual Temp. (°C)	Annual Rainfall (mm)	Topsoil Texture	Topsoil Organic Matter (%)
FOCUS Hamburg	9.0	786	Sandy loam	2.6

PELMO utilizes a capacity water flow model (tipping bucket approach) with a variable time step for all hydrological processes. In the FOCUS version, run-off and preferential flow are not considered. Pesticide movement is simulated using the convection-dispersion equation, while pesticide degradation in soil follows a first-order model, with degradation rate constants adjusted for depth, soil moisture, and temperature. Sorption to soil is calculated using the Freundlich equation.

In FOCUS PELMO, crop data is also defined for each scenario, including five crops suitable for growth across the EU. The simulations were carried out using the FOCUS standard crop 'winter cereals', considering a single annual foliar application at a rate of 100 g a.s./ha. Both winter and spring applications were simulated, at BBCH stages 10 and 30, respectively. Input parameters for these applications are detailed in Table 9.

Table 9: Application patterns to winter cereals used in modelling

FOCUS Groundwater Crop Group	Winter Cereals
Application rate (g a.s./ha)	100
Number of applications/interval (d)	1 / -
Modelled BBCH growth stage	10, 30
Crop interception[a] (%)	BBCH 10: 0 BBCH 30: 80
Application dates (absolute)[b]	BBCH 10: 02-November (306) BBCH 30: 04-May (124)
Frequency of application	Annual
Models used for calculation	FOCUS PELMO v6.6.4

[a] According to FOCUS (2023).
[b] According to AppDate v3.06 tool.

The current study considered hypothetical active substances defined by two key parameters that influence their environmental fate and transport in soil:

1. K_{FOC} (the Freundlich sorption constant normalised for organic carbon content): values of 10, 100, and 1000 mL/g indicate low, moderate, and high adsorption to soil organic carbon, respectively, impacting substance mobility.
2. $DT_{50\ in\ soil}$ (the half-life in soil): values of 10, 100, and 1000 days indicate short, moderate, and long persistence, respectively.

All possible combinations of these parameters yield nine unique substances, representing a spectrum of environmental behaviours from low adsorption and short half-life to high adsorption and long half-life. The input parameters for these dummy substances used in the modelling are presented in Table 10 and Table 11. All other input values were set at the default values unless otherwise stated.

Table 10: Regular grid of K_{FOC}/DT_{50} combinations considered for active substances for PEC_{GW} calculations (PELMO 6.6.4)

DT_{50} in soil (d) K_{FOC} (mL/g)	10	100	1000
10	**AS1**	**AS2**	**AS3**
100	**AS4**	**AS5**	**AS6**
1000	**AS7**	**AS8**	**AS9**

Table 11: Input parameters related to active substances[a] for PEC_{GW} calculations (PELMO 6.6.4)

Compound	AS1 – AS9 [a]
Molar mass (g/mol)	300
Water solubility (mg/L) (25 °C)	90 (20 °C)
Saturated vapour pressure (Pa)	1E-04 (20 °C)
1/n	0.9
Plant uptake factor	0
Transformation rate	to sink

[a] Input parameters based on FOCUS default substances (please see "FOCUS_defaults.PSM" file of PELMO 6.6.4)

To evaluate the impact of potential climate changes on Predicted Environmental Concentrations in groundwater (PEC_{gw}) for various active substances, projection outcomes from the UBA (2023) study were used. UBA (2023) provides modelling results for a 29-year period (2031–2060) under two climate scenarios: 'Climate Protection Scenario' (RCP 2.6) and 'High Emissions Scenario' (RCP 8.5). In the current study, two climate-related parameters—temperature and precipitation—and their potential impact on PEC_{gw} was the focus.

To align with the UBA report, the tested scenarios have the same names but abbreviated as Climate Protection (CP) and High Emissions (HE). For the CP scenario, a mean temperature increase of 1.5 °C was assumed, while for HE, an increase of 2.3 °C was applied. Precipitation adjustments included mean annual increases, with CP seeing an approximate rise of 3% and HE a rise of 4%, labelled as CPM and HEM, respectively.

In addition to annual changes, seasonal variability in precipitation was accounted for. For the Climate Protection Scenario with Seasonal Variation (CPS), maximum precipitation increase (7.5%) was set in spring, while minimum precipitation levels (-1.5%) were applied for summer. In the High Emissions Scenario with Seasonal Variation (HES), the maximum precipitation increase (12.5%) was applied to winter, while summer levels remained unchanged (minimum change).

These climate parameter adjustments are shown in Table 12. Daily temperature and precipitation data were adjusted within the FOCUS PELMO model's climate files (*.cli), specifically modifying the "Temp 14.00" (temperature at 14:00), "Temp mean" (daily mean temperature), and "Rainfall" parameters. The PELMO model uses one climate file (*.cli) per modelling year, requiring a total of 26 years for annual applications, with the first 6 years designated as a 'warm-up' period. The remaining 20 years are used to assess leaching behaviour. Temperature and precipitation adjustments were applied uniformly across the assessment period.

Table 12: Temperature and precipitation variations due to climate change accounted for in the impact assessment

Scenario	Mean Annual Temp. (°C)	Annual Precipitation (mm)
Climate protection scenario (**CP**)	+ 1.5 °C	Mean (**CPM**): +3% Season (**CPS**): Winter (December–February): +7% Spring (March–May): +7.5% Summer (June–August): -1.5% Autumn (September–November):+0.5%
High emissions scenario (**HE**)	+ 2.3 °C	Mean (**HEM**): +4% Season (**HES**): Winter (December–February): +12.5% Spring (March–May): +10% Summer (June–August): +0% Autumn (September–November): +1.5%

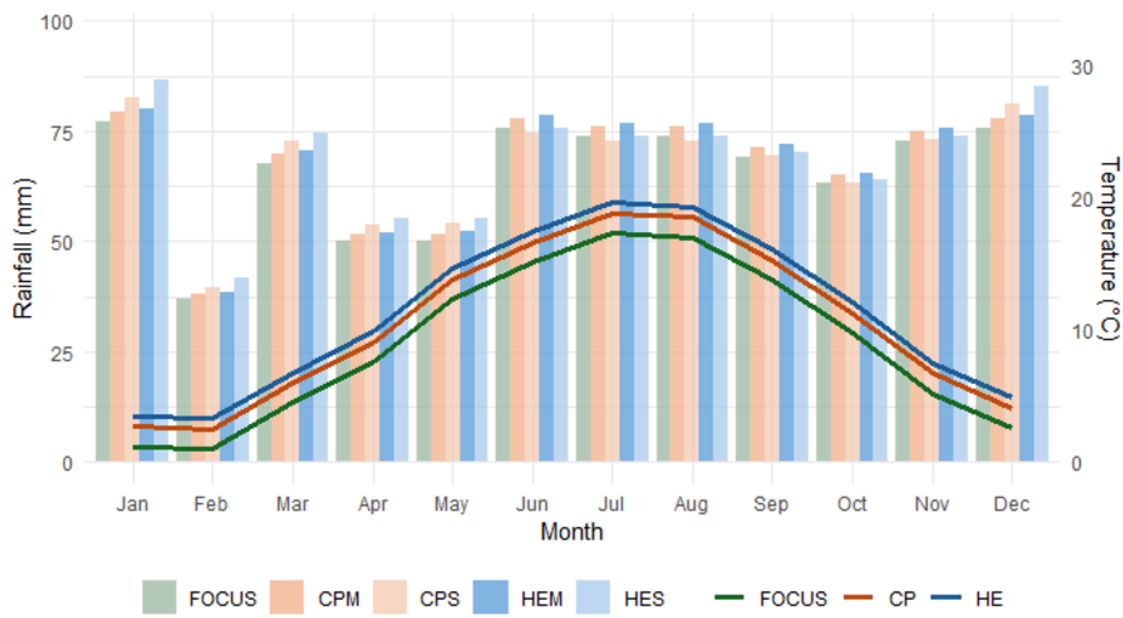

Figure 3: The monthly mean temperature (curves) and precipitation (columns) settings across various climate change scenarios, used to assess the impact of potential climate changes on Predicted Environmental Concentrations in groundwater (PEC_{gw}) for various active substances, modelled with FOCUS PELMO (version 6.6.4). The scenarios include: FOCUS (standard settings for the FOCUS Hamburg scenario), CP (Climate Protection scenario), CPM (CP with adjusted mean precipitation), CPS (CP considering seasonal precipitation variability), HE (High Emission scenario), HEM (HE with adjusted mean precipitation), and HES (HE considering seasonal precipitation variability).

Daily evapotranspiration data, along with rainfall and temperature, are entered directly into the climate data files, as these parameters are essential for modelling degradation processes. In PELMO, potential evapotranspiration for a grass reference crop (or alternatively pan evaporation) is read in as external input and then adjusted according to the crop type used in the simulation. This adjustment is made by applying a time varying crop Kc-factor, which modifies the standard reference evapotranspiration data.

For each tested scenario, potential evapotranspiration was recalculated to account for projected temperature changes, while assuming that radiation, wind speed, and relative humidity remained unchanged (Steffens et al., 2014). Calculations followed the FAO Penman-Monteith method (Allen, 1998), as detailed in Equation 1, using a grass reference crop. Potential evapotranspiration values were also recalculated for the FOCUS scenarios as a consistency check of this approach and to enable comparison between the tested scenarios and the FOCUS baseline.

$$ET_o = \frac{0.408\Delta(R_n - G) + \frac{900}{T+273}\gamma u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where reference evapotranspiration (mm day $^{-1}$)

net radiation at the crop surface (MJ m^{-2} day^{-1})

G soil heat flux density (MJ m^{-2} day^{-1}) (assumed to be negligible for daily time steps)

T mean daily air temperature (°C)

wind speed at 2 meters above ground (m s^{-1})

saturation vapour pressure (kPa)

actual vapor pressure (kPa)

psychrometric constant (kPa/°C)

slope of the saturation vapor pressure curve (kPa/°C)

Additionally, two rates of decrease in topsoil organic matter content due to global climate change were tested in the modelling: 10% and 25%. To implement these changes, the soil parameter files (*.soi) were updated accordingly.

Different combinations of climate change scenarios and topsoil organic matter content were tested for each dummy substance in the FOCUS PELMO model. The predicted environmental concentrations in groundwater were compared against those obtained using the FOCUS default settings for rainfall, temperature, and organic matter content. The various combinations are presented in the table below.

Table 13: Tested scenarios for each dummy substance

ID	Temperature	Rainfall	Topsoil Organic Matter (%)
0	FOCUS default	FOCUS default	FOCUS default
1	Climate Protection scenario (CP)	Climate Protection scenario, mean (CPM)	FOCUS default
2	Climate Protection scenario (CP)	Climate Protection scenario, seasonal variability (CPS)	FOCUS default
3	High Emission scenario (HE)	High Emission scenario, mean (HEM)	FOCUS default
4	High Emission scenario (HE)	High Emission scenario, seasonal variability (HES)	FOCUS default
5	FOCUS default	FOCUS default	-10%
6	Climate Protection scenario (CP)	Climate Protection scenario, mean (CPM)	-10%
7	Climate Protection scenario (CP)	Climate Protection scenario, seasonal variability (CPS)	-10%
8	High Emission scenario (HE)	High Emission scenario, mean (HEM)	-10%
9	High Emission scenario (HE)	High Emission scenario, seasonal variability (HES)	-10%
10	FOCUS default	FOCUS default	-25%
11	Climate Protection scenario (CP)	Climate Protection scenario, mean (CPM)	-25%
12	Climate Protection scenario (CP)	Climate Protection scenario, seasonal variability (CPS)	-25%
13	High Emission scenario (HE)	High Emission scenario, mean (HEM)	-25%
14	High Emission scenario (HE)	High Emission scenario, seasonal variability (HES)	-25%

Results

Evapotranspiration

The daily potential evapotranspiration (PET) values, recalculated for the FOCUS scenarios using the FAO Penman-Monteith method, closely matched the original values, with a Root Mean Square Error (RMSE) of 0.023 cm day^{-1}, a bias of -0.001 cm day^{-1}, and a percent bias of -0.392%. The recalculated PET values produced PEC_{gw} values approximately 2% higher than those calculated with the original FOCUS PET values, considering both levels of reduced topsoil organic matter.

To maintain consistency, PEC values for different climate change scenarios were compared against the FOCUS scenarios using PET values recalculated with the FAO Penman-Monteith method. A summary of precipitation, PET, actual evapotranspiration (AET), and percolation data for both FOCUS scenarios and various climate change scenarios is presented in Table 14.

Table 14: Summary of temperature, precipitation, evapotranspiration and percolation for modelled scenarios.

Scenario	Mean Annual Temp. (°C)		Annual PET (mm)	Annual AET (mm)	Annual Percolate at 1 m soil depth (mm)
FOCUS (PET original)	9	786	610	515	272
FOCUS (PET recalculated)	9	786	607	523	263
CPM	10.5	810	641	545	265
CPS	10.5	810	641	544	266
HEM	11.3	818	659	556	262
HES	11.3	830	659	556	274

Tested active substances

AS4, AS7, and AS8 are characterized by low mobility, strong soil binding, or rapid degradation. Their specific DT_{50} and K_{FOC} values contribute to their low leaching potential, as a result, they consistently show stable, near-zero PEC_{gw} values across varying seasons, climate conditions or OC levels.

AS1 and AS5 exhibit moderate mobility or moderate persistence in the soil, leading to moderate PEC_{gw} values. These substances show sensitivity to changes in organic carbon and climate conditions, with a tendency to leach more when organic carbon decreases or under climate scenarios involving increased temperatures and precipitation variability.

AS2, AS3, and AS6 are distinguished by their greater mobility and slower degradation rates. Among all the substances, they show the highest PEC_{gw} values. These substances are also sensitive to variations in organic carbon and climate conditions, with an increased tendency to leach as organic carbon levels decrease or under climate scenarios with higher temperatures and/or changes in precipitation patterns.

AS9 demonstrates consistently low PEC_{gw} values across all OC levels and climate scenarios. This is due to its very low mobility, strong soil binding, and extremely slow degradation, which results in low risk of groundwater contamination. For these persistent and immobile substances, a warm-up period of 6 years might not be sufficient.

Effect of Temperature and Precipitation Increases on PEC_{gw}

In climate scenarios with increased temperatures (CP and HE), most substances show a clear reduction in PEC_{gw} values compared to the FOCUS baseline (Figure 4 and Figure 5). The HE scenario, which represents the highest temperature increase, shows the lowest PEC_{gw} values, and this reduction trend is observed for both winter and spring applications. For example, for AS1, PEC_{gw} decreases in winter from 2.928 µg/L (FOCUS) to 2.288 µg/L (HES) and in spring from 0.013 µg/L (FOCUS) to 0.004 µg/L (HES). This decrease is likely due to faster degradation rates at higher temperatures, which reduce the amount of active substance available for leaching. The impact of increased temperatures is slightly greater for spring application, possibly because warmer baseline conditions further accelerate degradation in soil.

Seasonal precipitation variability, with increased precipitation in winter and spring, produced a PEC_{gw} change of around 1% in CP and 3% in HE. Notably, precipitation levels were slightly higher in HES than HEM, while CPM and CPS scenarios showed equivalent rainfall amounts. The effect on PEC_{gw} was higher in winter than in spring applications. Comparing CPM to CPS in winter applications shows that increased winter precipitation leads to higher PEC_{gw} values, particularly for more mobile substances. However, in HEM and HES with higher temperatures and precipitation, no similar trend was observed.

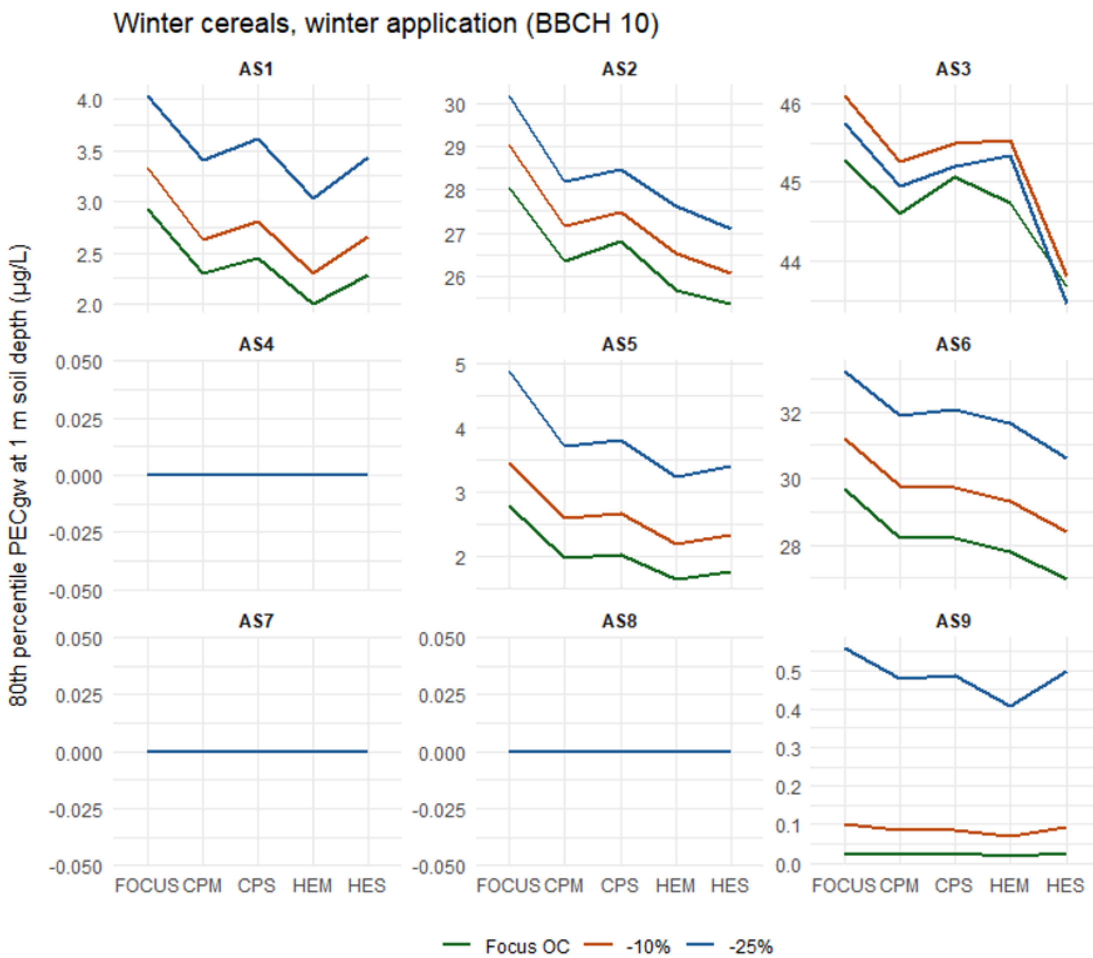

Figure 4: Predicted Environmental Concentrations in groundwater (PECgw) for various active substances (AS1-AS9) and scenarios, following winter application to winter cereals, modelled using FOCUS PELMO (version 6.6.4). The scenarios include: FOCUS (standard settings for the FOCUS Hamburg scenario), CPM (Climate Protection scenario with adjusted mean precipitation), CPS (Climate Protection scenario considering seasonal precipitation variability), HEM (High Emission scenario with adjusted mean precipitation), and HES (High Emission scenario considering seasonal precipitation variability). Two rates of decrease in topsoil organic carbon content (OC) due to global climate change were tested: 10% and 25%.

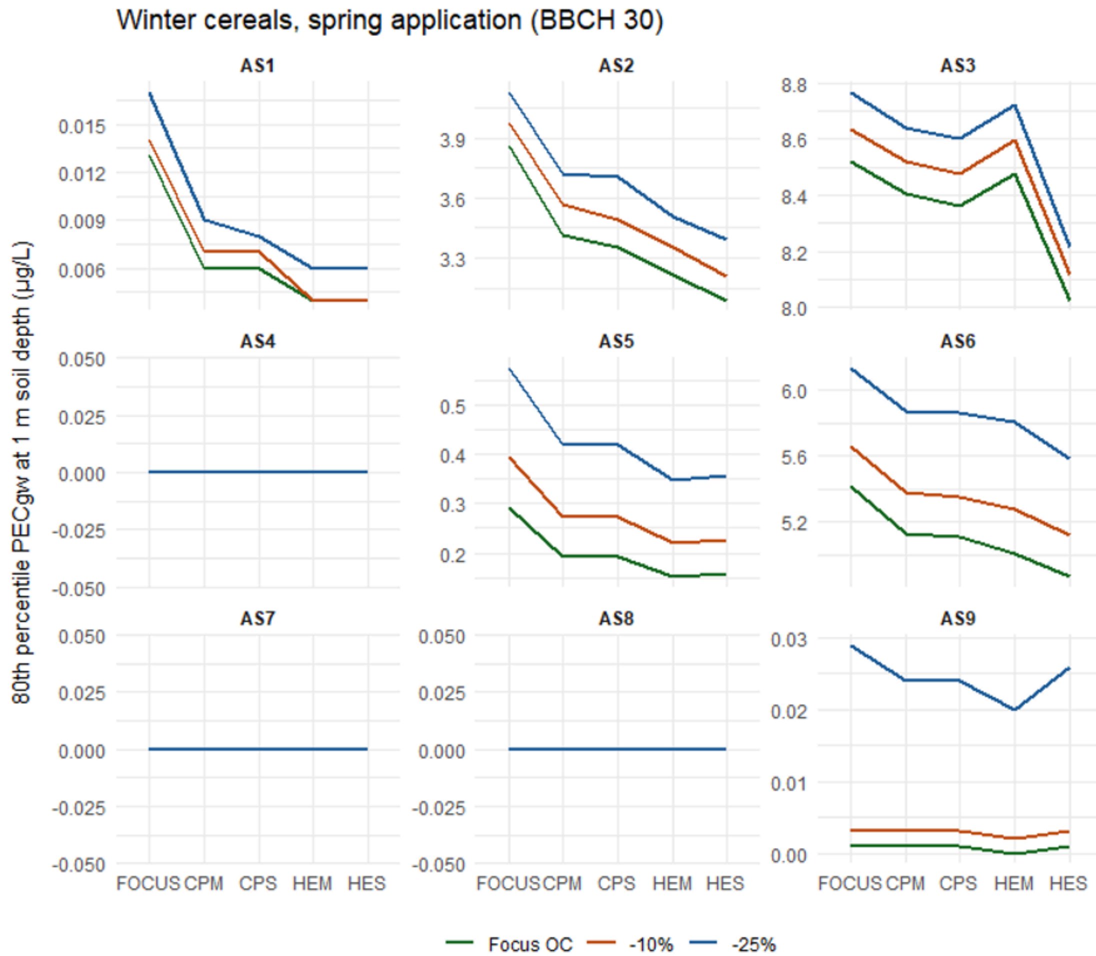

Figure 5: Predicted Environmental Concentrations in groundwater (PECgw) for various active substances (AS1-AS9) and scenarios, following spring application to winter cereals, modelled using FOCUS PELMO (version 6.6.4). The scenarios include: FOCUS (standard settings for the FOCUS Hamburg scenario), CPM (Climate Protection scenario with adjusted mean precipitation), CPS (Climate Protection scenario considering seasonal precipitation variability), HEM (High Emission scenario with adjusted mean precipitation), and HES (High Emission scenario considering seasonal precipitation variability). Two rates of decrease in topsoil organic carbon content (OC) due to global climate change were tested: 10% and 25%.

Impact of Organic Carbon Content on PEC_{gw}

Most active substances show increased PEC_{gw} values as organic carbon (OC) decreases (Figure 4–Figure 6). On average, a 10% and 25% reduction in OC led to an approximate increase in PEC_{gw} of 3% and 9%, respectively. Lower OC reduces the soil's adsorption capacity, allowing more of each substance to remain in the soil solution and potentially leach into groundwater. This trend is consistent across most substances and observed in both applications. The only exception is AS3, which exhibits an unusual pattern in the winter application, where the PEC_{gw} at -10% OC is higher than at -25% OC (Figure 4).

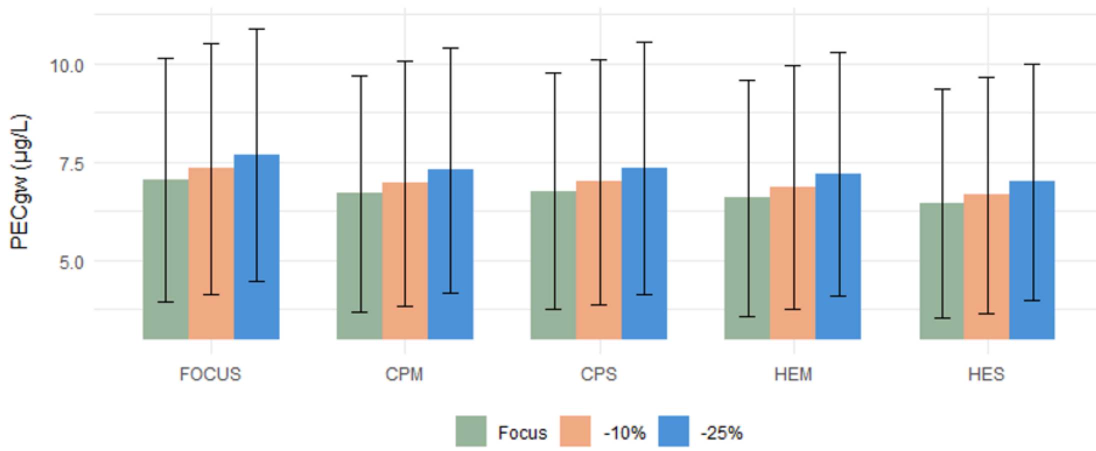

Figure 6: The effect of decreased topsoil organic matter content on Predicted Environmental Concentrations in groundwater (PEC_{gw}) for various active substances (AS1-AS9) and scenarios, following application to winter cereals, modelled using FOCUS PELMO (version 6.6.4). The scenarios include: FOCUS (standard settings for the FOCUS Hamburg scenario), CPM (Climate Protection scenario with adjusted mean precipitation), CPS (Climate Protection scenario considering seasonal precipitation variability), HEM (High Emission scenario with adjusted mean precipitation), and HES (High Emission scenario considering seasonal precipitation variability). Two rates of decrease in topsoil organic matter content due to global climate change were tested: 10% and 25%. The error bars represent the Standard Error of the Mean, introduced by the different substance properties.

Summary

In this modelling study, the effects of different climate change scenarios on the Predicted Environmental Concentrations in groundwater (PEC_{gw}) for nine dummy active substances using the FOCUS PELMO model (version 6.6.4) were assessed. The modelling study evaluated the impacts of increased temperature and precipitation (including seasonal variability) and reduced soil organic matter content. Our results indicate a general decrease in PEC_{gw} values with rising temperatures and precipitation, while a reduction in organic matter content leads to an increase in PEC_{gw} values.

Appendix 3: Climate- sensitive parameters: detailed evaluation of regulatory sections

Environmental Fate Studies

Efate Testing	Details	Test media parameters	Temperature	Moisture	Light	Considerations on how to update/refine parameter values	Climate Sensitive (yes/no/maybe)
OECD Guideline 307 (aerobic) (2002)	Laboratory DT50 in aerobic soil Metabolite determi-nation	Aerobic soil: temperature, moisture, organic carbon content, texture	20 ± 2	at a pF of between 2.0 and 2.5	carried out in the dark	Considerations: tests are performed under artificial / optimised conditions and degradation parameters are normalised for modelling --> thus an adjustment of test parameters is maybe not necessary (to be considered that biodegradation studies are performed at 12 °C under REACH) **Possible effects of climate change on study performance: in case of more droughts or flooding, soil sampling could become more challenging. Questions: How fast can the microbial communities recover after a drought? Should there be a guidance to interpret the results after extreme weather conditions as they are expected to increase?** Are additional tests needed to get more precise information to predict degradation under field conditions? How significantly are soil parameters generally affected by climate change: changes in microbial communities? Effects on organic carbon content and other parameters? Effects on non-extractable residues (NER) formation/degradation?	yes

OECD Guideline 307 (anaerobic) (2002)	Laboratory, DT50 in anaerobic soil Metabolite determination	Aerobic/ anaerobic soil: temperature, moisture, organic carbon content, texture	20 ± 2	at a pF of between 2.0 and 2.5 / flooded	carried out in the dark	Can anaerobic conditions become more or less relevant for registration? More precipitation? More droughts?	yes
OECD draft guideline (soil photolysis) (2002)	Laboratory, DT50 soil photolysis, Metabolite determination	temperature, moisture, organic carbon content, texture	20 ± 2	75% of field capacity / air dried	Samples irradiated under conditions simulating natural sunlight	Are there more sunny days expected in some areas which could affect the potential for soil photolysis under natural conditions? Effect of moisture on photolysis rate?	yes
OECD Series on Pesticides and Biocides No 82. (Terrestrial Field Dissipation) (2016)	Field study DT50 /DegT50 field soil for parent and metabolites, if possible	Soil moisture, soil temperature, organic carbon content, texture	natural conditions	natural conditions	natural sunlight	Changes in temperature and moisture directly influence the rate of dissipation and metabolite formation. Furthermore, effect of droughts and floods are expected, the risk for invalid trials can increase, for example flooding could ruin a field trial site. Leaching can be enhanced at higher precipitation rates than usual or if substance bound to organic carbon content is released again. Possible adjustments: more trials to be investigated to cover risks? Investigations needed to ensure microbial activity? Influence on irrigation scheme?	yes

OECD Guideline 106 (adsorption/ desorption) (2000)	Laboratory adsorption /desorption parameters in soil	temperature, pH, organic carbon content, soil texture	20 ± 2	soil/water slurry	carried out in the dark	Considerations: tests are performed under artificial / optimised conditions and parameters are normalised for modelling --> thus an adjustment of test parameters is maybe not necessary --> however, adsorption is also influenced by temperature / organic carbon content / pH and minerals	yes
Scientific Opinion on aged sorption (2018)	Laboratory, Aged sorption parameters	temperature, pH, organic carbon content, soil texture	20 ± 2	soil/water slurry	carried out in the dark		yes
OECD Guideline 312 (leaching in soil columns) (2004)	Laboratory Mobility in soil columns	temperature, pH, organic carbon content, soil texture	18–25 °C	saturated conditions	carried out in the dark		yes
OECD Series on Testing and Assessment No. 22 (Lysimeter studies) (2000)	Semi-Field Leaching behaviour	precipitation, temperature, pH, organic carbon content, soil texture	natural conditions	unsaturated/ saturated	natural sunlight at the top	Similar considerations as for TFD studies - however, the studies are only performed in rare cases	yes

OECD Guideline 111 (hydrolysis) (2004)	Hydrolysis at pH 4,7, 9 at 50 °C (and potentially 2 further temperatures	temperature and pH, sterile buffer solutions at 2 pH values	50 °C and 2 additional temperatures	-	carried out in the dark	The hydrolytic and photolytic behaviour is investigated under artificial conditions --> no adjustment is considered necessary	no
OECD Guideline 316 (direct photolysis) (2023)	Photolysis in sterile buffer	temperature, pH, sterile conditions	23 to 27 °C (25 ± 2) °C	-	Samples irradiated under conditions simulating natural sunlight / dark control	The hydrolytic and photolytic behaviour is investigated under artificial conditions --> no adjustment is considered necessary	no

OECD Guideline 316 (indirect photolysis) (2023)	Photolysis in natural water	temperature, pH	23 to 27 °C (25 ± 2) °C		Samples irradiated under conditions simulating natural sunlight	Considerations: tests are performed under artificial / optimised conditions and parameters are normalised for modelling --> thus an adjustment of test parameters is maybe not necessary (to be considered --> some studies for REACH are performed at 12 °C) **The following adjustments could be helpful: when can sampling be done after droughts or flooding to ensure representative microbially active water bodies?** Possible effects of climate change: How are water microorganism / particles / oxygen content and pH influenced by a changed temperature and changed precipitation or extreme events? How significant are the effects of droughts or rainfall events on particles / algae or microbial communities in the water? --> Changes could lead to different water parameters, more details for sampling times might be needed.	yes
OECD Guideline 309 (aerobic mineralisation in surface water) (2004)	DT50 in aerobic surface water	temperature, pH, oxygen concentration, redox potential	20 ± 2		carried out in the dark		yes
OECD Guideline 308 (aerobic degradation in water/sediment) (2002)	Degradation in water/ sediment systems	temperature, pH, oxygen concentration, redox potential	20 ± 2		carried out in the dark		yes
OECD Guideline 308 (irradiated aerobic degradation in water/sediment) (2002)	Degradation in water/ sediment systems under irradiated conditions	temperature, pH, oxygen concentration, redox potential	20 ± 2		Samples irradiated under conditions simulating natural sunlight		yes
OECD Guideline 301 (ready biodegradability) (1992)	Biodegra dability						yes

Guidance document on the impact of water treatment processes (2023)	Potential Residues in drinking water			yes
Atkinson approach (calculation of photodegradation in air)	DT50 Air			yes
OECD Guideline 104 (vapour pressure) (2006)	Vapour pressure			yes
Transport via air	Assessment based on available data			yes
Overall Residue definition	Decline of parent and formation of metabolites in soil, water/ sediment and groundwater		Increased temperatures could lead to a higher degradation of parent and higher amounts of metabolites, general changes in microbial communities or organic carbon contents could also have an effect on the degradation potential in soil	yes

Environmental Fate Modelling

Details	Parameter name (if possible)	Considerations on how to update/refine parameter values	Climate Sensitive (yes/no/ maybe)
Background / Scenario data			
Defined FOCUS crops for GW/SW		To be checked if new major crops are expected to emerge on the (Northern) European market and if they would need to be implemented as FOCUS crops See DEPA report...e.g. Grain maize and some new protein and oil seed crops	yes
FOCUS crop distribution		Is the distribution of the crops as provided in FOCUS reports still up to date? Or was / will a major shift in crop regions take place? Do some (SEU/CEU) FOCUS crop need to be parameterised for NEU scenarios (e.g. maize)?	yes
Extension of GW/SW-Scenarios in EU/NEU		Are the current GW and SW FOCUS scenarios still appropriate? Is it sufficient to update the weather files or would it be more suitable to adopt the concept on a larger frame? Do countries need to overthink "their" relevant scenarios?	yes
Drift curves		Are the Rautmann drift values still up to date even under changing climatic conditions? New values would be needed for further management/application techniques.	potentially
Weather parameters			
Model parameter/variable	Air temperature	Air temperature affects soil temperature, which in turn impacts soil moisture, organic matter decomposition, evaporation, and pesticide degradation	yes

Model parameter/variable	Precipitation	Climate change can lead to changes in the amount, intensity, and distribution of precipitation. This can result in more frequent or intense rainfall events or prolonged dry periods. Changes in precipitation can impact soil moisture dynamics, runoff patterns, and the frequency and intensity of erosion events. This can affect the model's predictions of water movement and pesticide leaching.	yes
Model parameter/variable	Solar radiation	Solar radiation drives the evapotranspiration process, which is crucial for modelling soil moisture and water movement. Radiation in the atmosphere might change with changing composition (e.g. H_2O and CO_2 content). However, impact expected to be low.	no / indirectly sensitive
Model parameter/variable	Light day hours	Not directly affected by climate change. It is primarily determined by the Earth's orbital parameters and axial tilt. Day length influences the amount of solar energy available for evapotranspiration. ==> no changes expected	no
Model parameter/variable	Humidity	Humidity affects the rate of evapotranspiration from soil and plants.	yes
Model parameter/variable	Wind speed		no / indirectly sensitive

	Dates of time series	Changes in weather data need to be considered and be updated on a regular basis: 1) Update to new time series based on recent data from MARS or local weather station. Update in regular (5-10 years) intervals. ==> better than current approach, however, still has the flaw that it only uses data from the past and is potentially still depending on single major events at specific dates 2) Implementation of scenarios/predictions/uncertainties of climate modelling ==> would make use of climate predictions for the future. Would need a major overhaul of the current status and potentially much more computing power. 3) A combination of both: Use recent (past) weather data and scale it up with climate predictions (e.g. temperature and rainfall factor, increased drought periods, extreme rainfalls...)	yes
	Length of time steps	Currently the time steps of the weather data are 1 day. However, especially run-off and drainage events are driven by rainstorms which are sub-daily (if not sub-hourly). It would be important to cover these strong short-term rainfalls appropriately in the weather data. Some models like MACRO and PEARL can handle sub-daily rainfall, while e.g. PRZM cannot.	yes
Application Dates / Growth Stages			
AppDate / BBCH stages for FOCUS crops / Emergence and Harvest dates for NEU GW scenarios		Application dates are usually defined by BBCH stages. Relationship is described in AppDate for FOCUS scenarios and the most relevant crops. These relationships might need to be reviewed. Second season crops in NEU? Additionally a more flexible approach could be envisaged e.g. using the temperature sum model (as e.g. implemented in FROGS). With this model BBCH stages could be "predicted" more flexible with changing weather time series.	yes

Model			
PELMO PEARL MACRO SWASH (SPIN, PRZM, TOXSWA, MACRO)		Models might need to be updated to be able to deal with extreme conditions, especially for short term rainfall events (sub daily or even sub-hourly). Usage of some models to be re-evaluated, since some models might not be adaptable.	yes
STEPS 1-2		Re-evaluation might be necessary to check if the percentages and assumption of drift/runoff/drainage, discharge volumes are still conservative	maybe
SWAN		Are the percentages for runoff/erosion reduction still appropriate? Or are more sophisticated models like VFSmod required? Consideration of runoff in NEU?	maybe
Nordic PECsoil calculator		Temperature in Finnish scenario	yes
PERSAM		Future model under discussion. OC content under discussion and climatic files potentially similarly impacted as in PEARL/PELMO	
Field management practice			
Model parameter/variable	Tillage	Potentially new farming practices are becoming more important e.g. to avoid erosion etc. No tillage and reduced tillage ==> might have impact on OC content	maybe
Model parameter/variable	Irrigation	To be evaluated weather irrigation as included in FOCUS needs to be adapted for crops/scenarios based on changing farmers practice and longer drought periods	yes
Soil parameters			
Model parameter/variable	Soil temperature	Calculated by models based on air temperature	no

Model parameter/variable	Soil water content	Calculated by models based on precipitation/irrigation	no / indirectly sensitive
Model parameter/variable	Field capacity	Soil Water Retention Curve might be impacted by changes in organic carbon content.	maybe
Model parameter/variable	Wilting point	The wilting point itself is not directly sensitive to climate change as it is a property of the soil that remains relatively stable under different climatic conditions.	no
Model parameter/variable	Surface roughness (Manning in PRZM)	Climate change can influence surface roughness through changes in land use, vegetation cover, erosion rates, and precipitation patterns. For ex., more intense or frequent rainfall can lead to increased erosion, changing surface roughness. Changes in vegetation due to altered growing conditions or land management practices can also affect surface roughness. Used in PRZM for erosion calculations (relevant for strongly compounds) and could also affect the performance of the filter strips. Depending on crop / crop stage. But currently it seems that this is not time dependent in FOCUS. ==> would need to be reviewed for SWASH and SWAN	no / indirectly sensitive
Model parameter/variable	organic matter content	Organic matter content may change over time which climate change. However, it is expected that changes take place over longer periods than the envisaged 10–25 years). Literature research and comparison of new/old database versions could give an indication of changes. Impact on PECs potentially large.	maybe
Model parameter/variable	Sand/Silt/Clay content	Indirectly sensitive: due to for ex. Erosion	no / indirectly sensitive

Model parameter/variable	Bulk density	Changes maybe in accordance with OC and management practices. Abundance of earth worms may affect the soil structure.	no / indirectly sensitive
Model parameter/variable	soil pH	Soil pH may change over time with climate change. However, it is expected that changes take place over longer periods than the envisaged 10–25 years). Literature research and comparison of new/old database versions could give an indication of changes. Impact on PECs potentially small. ==> review relevant pH values for NEU countries ==> relevance of PEC calculations for substances with pH-dependency might change	maybe
Model parameter/variable	Ground water depth/bottom boundary	Ground water depth may change depending on precipitation and temperature. Impact on PEC-values is unclear. Sensitivity analysis could be done to evaluate if a major impact on pesticide risk assessment is expected ==> to be evaluated in which models this is relevant	yes
Model parameter	van Genuchten parameter	Would need to be adjusted in case new soil profiles are implemented	indirectly sensitive
Crop parameters			
Model parameter/variable	Transpiration rate/Evapo-transpiration rate (ET)	The key factors affecting ET in response to climate change include: temperature, precipitation, humidity & solar radiation	indirectly sensitive
Model parameter/variable	Emergence Date	Shifts in temperature and precipitation can alter when crops emerge, affecting growth and productivity and harvest date ==> see above for Application Dates; relevant for FOCUS scenarios and also NEU-specific GW scenarios	yes
Model parameter/variable	Harvest Date		yes

Model parameter/variable	Leaf Area Index (LAI)	Variations in temperature and precipitation influence LAI, which in turn affects plant growth and productivity. Impact on PEC calculations expected to be small (see section 4.2.2.6).	yes
Model parameter/variable	Crop Factor	Crop factor modifies the standard reference potential evapotranspiration (PET) into PET for the simulated crop. Variations in temperature and precipitation influence Kc. Impact on PEC calculations expected to be small (see section 4.2.2.6).	yes
Model parameter/variable	Rooting depth	Temperatures can influence root growth rates and depths, changes in precipitation affect soil moisture levels, which can influence root development. Impact on PEC calculations expected to be small (see section 4.2.2.6).	yes

Ecotoxicology

Ecotox Testing	Details	Test media parameters	Temperature	Light	Climate Sensitive (yes/no/maybe)
Aquatic organism testing:					
OECD Guideline 203 (2019)	Fish (acute)	Water: Oxygen content, pH, hardness, salinity etc.	water temp 21–25 °C species specific	Lux 540–1000 species specific and intensity 10–20 μE m^2 s^{-1}	yes
OECD Guideline 211 (2011)	Aquatic invertebrates (Daphnia reproduction)	Water: Oxygen content, pH hardness, salinity etc.	water temp 18–22 °C	Lux 1000–1500 and intensity 15–20 μE m^2 s^{-1}	yes

OECD Guideline 239 (2014)	Aquatic plants (Myriophyllum, rooted macrophyte)	Water and sediment characteristics; pH between 7.5 - 8.0 for water media, peat/clay/sand content of sediment + nutrient medium.	water temp 20 ± 2 °C	wavelength 400–700 nm at water surface and intensity 140 +/- 20 µE m^2 s^{-2}	yes
Soil organism testing:					
OECD Guideline 222 (2016)	Earthworm reproduction	Artificial soil composition; OMC, clay, calcium carbonate, sand etc.	ambient air temp 20±2 °C	Lux 400–800	yes
OECD Guideline 216 (2000)	Soil micro-organisms	Natural soil composition; OMC, sand content, pH, microbial biomass, water holding capacity, moisture content (40-60%)	ambient air temp 20 ± 2 °C	carried out in the dark	yes
Terrestrial organism testing:					
OECD Guideline 223 (2016)	Avian (acute oral)	-	ambient air temp 15–27 °C	photoperiod 8hrs light : 16hrs dark	yes
OECD Guideline 213 (1998)	Pollinators (Honeybee acute oral)	-	ambient air temp 25 ± 2 °C and 50–70% humidity	carried out in the dark	yes

IOBC - SETAC	NTA - Aphidius extended lab	suitable plant for fecundity phase	ambient air temp 20 ± 3 °C and 50–90% RH	400–3000 Lux for mortality phase 4000–20 000 Lux for fecundity phase	yes
OECD 227 Guideline (2006)	Terrestrial plants: vegetative vigour	Artificial soil composition; OMC, clay, sand etc.	ambient air temp 22 ± 10 °C and humidity 70% ± 25%	wavelength 400–700 nm and intensity 350 +/- 50 µE m^2 s^{-2}	yes
Risk assessment:	**details**				**Climate Sensitive (yes/no/ maybe)**
Considerations regarding ecotox risk assessment	Ecotox testing involves measurement of survival, rate of reproduction, biomass, weight etc., to determine endpoints for use in the risk assessments; EC50,20,10, NOEC .				maybe
	Impact of climate changes on biodiversity				yes
	Potential change in species sensitivity				maybe
	Risk assessment: NEU specific avian species to consider at specific BBCH growth stages of crop (Willow warbler etc.). Flowering stages of crop specific to bee exposure.				maybe
	Short cut values used in the avian and mammal assessments (EFSA GD).				maybe
	Potential change in PECsoil and PECsw values.				yes

Toxicology

Method/Model	Deta	Parameter name (if possible)	Climate Sensitive (yes/no/maybe)	Considerations on how to update/refine parameter values
Toxicology			no climate sensitive parameters were identified	
EFSA online calculator (https://r4eu.efsa.europa.eu/).			no climate sensitive parameters were identified However pay attention that some changes may appear due to climate change: Outcomes of DFR or exposure studies might be influenced by climate parameters and bridging approaches between zones might change.	
Relevance assessment of metabolites in groundwater			Indirectly affected by PECgw calculations. Further tox studies are potentially needed but still covered by current method	No changes, covered by current method

Chemistry

Method/Model	Deta	Parameter name (if possible)	Climate Sensitive (yes/no/maybe)	Considerations on how to update/refine parameter values
Phys/Chem			no (not relevant for risk assessment)	
Analytical methods			no climate sensitive methods are used; therefore no changes are required	
Storage stability			Testing of shelf-life is dependent on ambient temperature which is defined for moderate/temperate, hot, and very hot climate. Potentially for some regions a shift to hotter climates for this test would need to be considered.	Review by member states

Residues

Method/Model	Detail	Parameter name (if possible)	Climate Sensitive (yes/no/maybe)	Considerations on how to update/refine parameter values
Metabolism in plants and animals			no climate sensitive methods are used; therefore no changes are required However pay attention that metabolism can be influenced by the temperatures/CO2/stress in plants (Zandalinas S. et al., JEB, 2022) and may lead to additional metabolites or a shift in the relevant metabolites for the residue definition	
Residues in plants			no climate sensitive methods are used; therefore no changes are required However pay attention that some changes may appear due to climate change: shift of the geographical zones for residue trials, change of typical crops growing areas, change of major/minor crops status in northern zone	
MRL calculator		Mean/SD	no However due to more extreme conditions (drought/flooding, higher temperatures, local thunderstorm, plant stress), a higher variance in local plant growth and herewith residues levels within the northern zone may influence the estimation of the MRL (Mean+4SD))	
pesticide_mrl_guidelines_animal_model(Dietary burden calculation)		animal diets	maybe Since crops that were typically growing in the southern zone may become easier available/grown in northern zone, a change in the animal feeding pattern may appear	Parameter "animal diet" should be updated, new animal diet data should be collected

fish dietary burden calculator	fish diet	no	
Processing		no climate sensitive methods are used; therefore no changes are required	
Rotational crops		no climate sensitive methods are used; therefore no changes are required However parameters DT90 and PECs used for the design of rotational crop studies may be influenced by changed E-fate models	
PRIMo (Consumer risk assessment)	consumption data	maybe A change of the "typical" consumption may change due to climate change (higher temperatures, change of local grown/available crops)	Parameter "consumption data" should be updated, new consumer survey data should be collected

About this publication

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