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In the Pesticide Risk Reduction Programme Ethiopia the evaluation of risks of pesticides present in drinking water for man and cattle was selected as a priority protection goal. In cooperation with the Plant Health Regulatory Department of the Ministry of Agriculture of Ethiopia and other Ethiopian stakeholders Alterra developed a procedure to assess the risks for drinking water caused by pesticides, used according to Good Agricultural Practices (GAP). To do so, 'realistic worst case' scenarios were developed, that intend to protect man and cattle in 99% of all possible situations in Ethiopia. For groundwater three scenarios representing wells in aquifers in the Ethiopian highlands or Rift Valley margins were developed and for surface water three scenarios representing small rivers in the highlands or temporay stagnant ponds were developed. The scenarios were linked to crops on which pesticides are used that score high on acute, chronic or local chronic risk for man. In addition other agro-environmental conditions were defined, such as precipitation, soil, and land use management. The groundwater scenarios were parameterised in the EuroPEARL metamodel to calculate leaching concentrations to groundwater, whereas the surface water scenarios make use of the runoff model PRZM, the EU-FOCUS spray drift deposition table and the surface water model TOXSWA to calculate the concentration in the small river or pond scenarios. The concentration calculations use 33 years of meteorological data for the selected scenario sites of both groundwater and surface water. Example calculations for seven high risk compounds (dimethoate, endosulfan, deltamethrin, 2,4-D, malathion, atrazine and chlorothalonil) on e.g. barley, wheat, teff, maize, cotton, potatoes (Irish and sweet) and faba beans indicated that for the considered application schemes risks exist for drinking water produced from groundwater for atrazine. For surface water no acute toxicity risks exist, but for dimethoate used on barley and faba beans chronic toxicity risks exist.

Keywords: pesticide registration, Ethiopia, risks for drinking water, groundwater scenarios, surface water scenarios, EuroPEARL metamodel, FOCUS_PRZM model, FOCUS_TOXSWA model

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List of abbreviations

Abbreviation	Explanation
a.i.	Active ingredient
ADI	Acceptable Daily Intake
ARfD	Acute Reference Dose
CSA	Central Statistical Agency of Ethiopia
Ctgb	Dutch Board for the Authorization of Plant Protection Products and Biocides
dw	Drinking water
ECAE	Ethiopian Conformity Assessment Enterprise
ECMWF	European Centre for Medium-Range Weather Forecasts
EFSA	European Food Safety Agency
EHNRI	Ethiopian Health and Nutrition Research Institute
EPA	Environmental Protection Agency
ERA	Environmental Risk Assessment
ETR	Exposure Toxicity Ratio
EU	European Union
EuroPEARL	PEARL model for use on European scale
EIAR	Ethiopian Institute for Agricultural Research
FAO	Food and Agricultural Organisation
FOCUS	FOrum for Co-ordination of pesticide fate models and their USe
GAP	Good Agricultural Practice
IBC	Institute for Biodiversity Conservation
IEDI	International Estimated Daily Intake
IESTI	International Estimated Short Term Intake
IFPRI	International Food Policy Research Institute (Washington, DC, USA)
ITMDI	International Theoretical Maximum Daily Intake
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	FAO/WHO Joint Meeting on Pesticide Residues
LP	Large Portion
LSF	Large Scale Farms
MoA	Ministry of Agriculture
PEARL	Pesticide Emission Assessment at the Regional and Local scale
PEC	Predicted Environmental Concentration
PHRD	Plant Health Regulatory Directorate (of the Ministry of Agriculture)
PNEC	Predicted No Effect Concentration
PPP	Plant Protection Product
PRIMET	Pesticides Risks in the tropics to Man, Environment and Trade
PRZM	Pesticide Root Zone Model
PRRP	Pesticide Risk Reduction Program (Ethiopia)
SEARCH	Southern and Eastern Africa Regulatory Committee for Harmonization of Pesticide Registration
sw	Surface water
ToIU	Table of Intended Uses
TOXSWA	TOXic substances in Surface WAters
US EPA	United States Environmental Protection Agency
WHO	World Health Organisation

Preface

The Pesticide Risk Reduction Programme (PRRP)-Ethiopia ran from the beginning of 2010 up to the end of 2014. It is funded by the State of The Netherlands (Ministry of Foreign Affairs/Development Cooperation), the Food and Agriculture Organisation of the United Nations (Technical Cooperation Programme) and the Federal Republic of Ethiopia (Ministry of Agriculture).
Its main objectives were:

1. To develop a legal framework for the registration and post-registration of pesticides (regulation, directives and guidelines);
2. To develop a proper pesticide registration system for Ethiopia and capacity building on dossier evaluation;
3. To develop a well-functioning post-registration system (including monitoring, procurement guideline, inspection, storage of pesticides, capacity building and training);
4. To develop a formal consultation platform that will support the Plant Health Regulatory Department (PHRD) with advice on (post-)registration issues and
5. To execute an impact assessment of the new (post-)registration system.

The PRRP project intends to serve as a pilot project for other African countries and regions.
This report has been written as part of the Work Package B2.1 of the PRRP project. The goal of WP B2.1 of PRRP Ethiopia is to further develop the technical and scientific evaluation capacity to ensure sound pesticide management in Ethiopia at the pesticide registration stage, focussing on plant protection products.

Within WP B2.1 a total of fourteen workshops and training sessions were organized. In six workshops with the aid of Linge Agroconsultancy, improved guidelines for efficacy testing and statistical analysis of the trials were developed, which were incorporated into the new Directive on Pesticides of Ethiopia (developed within another Work Package of the PRRP project). In addition, twenty crop-pest specific protocols were developed for the evaluation of efficacy.

In a further series of seven workshops with representatives of the PHRD of the Ministry of Agriculture of Ethiopia and other stakeholders, the dossier evaluation system has been expanded with the aid of Alterra and representatives of the Dutch Board for the Authorisation of Crop Protection Products and Biocides (Ctgb). Protection goals were set and prioritized, and risk assessment procedures were developed, according to procedures applied in the EU or elsewhere in the world. Moreover, capacity building and specific training sessions on dossier evaluation were organized (see www.prrp-ethiopia.org, Activities and Outputs, Dossier Evaluation).

Drinking water produced from groundwater and surface water was selected as the protection goal having the highest priority. Therefore, specific Ethiopian scenarios for groundwater and surface water were developed within WP B2.1. The aim of these scenarios is to protect 99% of all possible situations in time and space in Ethiopia. This aim is very strict, because human toxicological end points are used in the risk assessment. The surface water scenarios consist of vulnerable water bodies such as small streams and temporay stagnant ponds. These water bodies are also relevant for the environmental risk assessment for the aquatic ecosystem and therefore the same scenarios are also used for this purpose. However, scenarios representing 90th and not 99th percentile overall probability in time and space are selected for the aquatic risk assessment, in accordance with EU standards.

The human health and environmental risk assessment procedures have been implemented in a software tool, PRIMET_Registration_Ethiopia_1.1, that enables the PHRD to perform the risk evaluation in a reproducible, user-friendly and transparent way. Details of this tool are given in a separate manual which can be freely downloaded, together with the software, from www.pesticide.models.eu. The final training on dossier evaluation, held in September 2014, was specifically aimed at the use of PRIMET_Registration_Ethiopia_1.1.

Major Ethiopian contributions to the development of the groundwater and surface water scenarios for drinking water production were made by Dr Engida Zemedagegenhu of the Water Works Design and Supervision Enterprise-Ethiopia, as well as the late Dr Dereje Gorfu of the Ethiopian Institute of Agricultural Research (Hawassa). We thank Martin Mulder of Alterra for writing a number of computer programmes to process data from the PRZM and TOXSWA models and to encode the FOCUS stream metamodel. Finally, the authors would like to thank the colleagues of the PHRD in Addis Ababa for their continuing kind help and support, whenever we needed this during the process of development and parameterisation of the scenarios.

This report documents the development of the groundwater and surface water scenarios in order to make the drinking water risk assessment in the Ethiopian pesticide registration procedure transparent and traceable. The remaining part of the human health and environmental risk assessment procedures, the efficacy guidance and the developed software tool PRIMET_Registration_Ethiopia_1.1. have been documented in the two reports mentioned below.

Related reports of PRRP-Ethiopia

Deneer, J.W., P.I. Adriaanse, P. de Boer, M. Busschers, J. Lahr, C. Van der Schoor, P. Van Vliet, A. Woldeamanuel, 2014. A scientific evaluation system for the registration of pesticides in Ethiopia. Alterra report 2547, 185 pp. Alterra, Wageningen University and Research centre (WUR), Wageningen, The Netherlands.

Wipfler, E.L., P.I. Adriaanse, M.M.S. Ter Horst, J. Vlaming, P.J. Van den Brink, F.M. Peeters, J.W. Deneer, J.J.T.I. Boesten and J.G. Groenwold, 2014. PRIMET_Registration_Ethiopia_1.1, technical description and manual. Alterra report 2573, 133 pp. Alterra, Wageningen University and Research centre (WUR), Wageningen, The Netherlands.

Summary

In the Pesticide Risk Reduction Programme Ethiopia the evaluation of risks of pesticides present in drinking water for man and cattle was selected as a priority protection goal. In cooperation with the Plant Health Regulatory Department (PHRD) of the Ministry of Agriculture of Ethiopia and other Ethiopian stakeholders Alterra developed a procedure to assess the risks of pesticides present in drinking water for man and cattle, when used according to Good Agricultural Practices (GAP) and before they are admitted on the market. To do so, ‘realistic worst case’ estimates of pesticide concentrations are to be compared to the ADI, Acceptable Daily Intake during a lifetime, or to the ARfD, the Acute Reference Dose, i.e. the total acceptable intake in one day. Scenarios were developed to calculate these ‘realistic worst case’ concentrations, intending to protect man and cattle not in the average situation, but in more vulnerable situations, and chosen to be protective for 99% of all possible situations in Ethiopia.

Scenarios are defined as fixed combinations of agro-environmental conditions, such as precipitation, soil, land use management, crops with their cropping calendar and the surface water or groundwater body to be protected. Thus, by selecting a scenario with a crop and a water body and specifying the compound and its application pattern on the selected crop the ‘realistic worst case’ concentrations can be calculated.

The scenarios were developed in a stepped procedure. First, data on agro-environmental characteristics of Ethiopia were gathered, e.g. soils, crops, elevation, meteorological data, land use management practices. Data on imported volumes of pesticides (2010) were combined with their acute and chronic toxicity properties (ARfD and ADI) and local use rates, while the physico-chemical properties of sorption (K_{om} and *pKa*) and degradation ($DT_{50,soil}$) were used to estimate leaching to groundwater. In this way we intended to focus the scenario development on compounds and cropping systems that are relevant for drinking water risk assessment within the pesticide registration procedure.

The next step was to divide Ethiopia into two scenarios zones, one above 1500 m, encompassing the traditional agro-ecological zones Woina Dega, Dega and Wurch and one below 1500 m, encompassing the traditional zones Bereha and Kolla. This was a compromise between the stakeholders’ wish to account for the great variety in agro-environmental conditions of Ethiopia and the limitations within the project concerning the number of scenarios to develop. In addition, having two scenario zones introduces some flexibility in the registration procedure, because the risks are assessed for each scenario zone separately.

Protection goals were defined in detail (what and where was to be protected) and coupled to the scenario zones. For surface water, small rivers in the Ethiopian highlands (above 1500 m elevation), as well as temporary stagnant ponds (for cattle watering) were selected and conceptually described. For groundwater, wells in alluvial aquifers along small rivers or in volcanic aquifers in the Ethiopian highlands were selected and conceptually described, along with wells in alluvial aquifers in the Rift Valley margins (up to 2000 m elevation) or in lowlands (below 1500 m elevation and having minimally 500 mm annual rain).

The next steps in the scenario development procedure were to (i) choose models for the calculation of concentrations, (ii) develop a procedure to select ‘realistic worst case’ scenarios and (iii) apply this for drinking water produced from surface water and from groundwater, (iv) parameterise the models and finally (v) design and construct a user-friendly software tool to perform all calculations in a robust, reproducible and transparent way.

Groundwater
For leaching to groundwater the EuroPEARL metamodel (Tiktak *et al.,* 2006) was selected, because it is process-based, relatively simple and only needs data that are often available from general soil and climate databases. It was used with the regression parameters fitted on the warm and wet climatic zone of Europe, best representing Ethiopian conditions. To select the 'realistic worst case' scenarios, locations were sought where the leaching concentration corresponds to the 99th percentile probability of occurrence in time and space for each scenario zone. Combining the long term (33 years) annual average percolation from the climate database at a 80*80 km grid with the organic carbon content and bulk density of the upper 30 cm at a 5*5 km grid leaching concentrations were calculated for all relevant grids of the scenario zone. After ranking the 99th spatial percentile was selected. As leaching concentrations depend strongly on the pesticide properties sorption and degradation, the calculations were repeated for 49 fictitious compounds with K_{om} and $DegT_{50,soil}$ ranging between 10 and 480 L/kg and 10 and 480 d, resp. The (80*80 km) grid with most 99th (spatial) percentile rankings was selected as the best scenario location. This selection procedure was repeated for the four groundwater protection goals, defined for Ethiopia. In this way the following three groundwater scenarios were selected: (i) grid 219 near Bichena (Amhara region), representing both alluvial aquifers along small rivers and volcanic aquifers on shallow wells in areas above 1500 m, with an organic matter content of 0.34%, annual precipitation of 1786 mm and percolation of 879 mm and located at 2190 m altitude, (ii) grid 346 approx. 100 km southwest of Jimma (SNNPS region), representing alluvial aquifers in the Rift Valley margins and lowland areas below 1500 m, with an organic matter content of 0.72%, annual precipitation of 2078 mm and percolation of 888 mm and located at 1363 m and (iii) grid 323 at Abala Kulito (SNNP region), representing alluvial aquifers in the Rift Valley margins between 1500 and 2000 m, with an organic matter content of 0.57%, annual precipitation of 1418 mm and percolation of 700 mm and located at 2056 m altitude. For each of these three scenarios the EuroPEARL metamodel needs to be applied. However, as this metamodel results in 80th temporal percentile leaching concentration instead of the desired 99th temporal percentile, a correction factor (with a value of 3) is needed to obtain the 99th percentile probability of occurrence in time and space of the leaching concentration at 1 m depth.

Surface water
For concentrations in surface water the FOCUS surface water scenarios models applied in the European Union were adapted for use in Ethiopia. The EU_FOCUS_PRZM model was changed to include Ethiopian crops and cropping calenders, irrigation gifts, their Runoff Curve Numbers and the available 33 years of meteorological data, such as daily precipitation, temperature and pan evaporation. This model calculates runoff water and associated pesticide fluxes as well as pesticide-free subsurface drainage water fluxes on an hourly basis. The EU_FOCUS spray drift deposition tables were adapted for use in Ethiopia, taking the application technique into account: knapsack spraying or tractor-mounted spraying and adopting the distances from the last row of the crop to the edge-of-water for identical crops or FOCUS crops that are equivalent to the Ethiopian crops. The EU-FOCUS_TOXSWA model for behaviour in surface water was applied and its output was adapted to calculate concentrations in the Ethiopian pond scenarios for 33 years, while a simple metamodel was designed to calculate concentrations in the Ethiopian stream scenario on the basis of the adapted EU_FOCUS_PRZM entries for 33 years. The selected target concentration is the yearly maximum concentration in both scenarios.

To select 'realistic worst case' scenarios, locations were sought where the target concentrations in the small stream or pond correspond to the 99th percentile probability of occurrence in time and space within each relevant scenario zone. First, the 99th percentile in space is determined and next, by ranking the target concentrations of the 33 years' calculation and selecting the 99th percentile (so, in time), the overall 99th percentile probability of occurrence in space and time is selected. To determine the percentile in space (corresponding to a scenario location) spatially-variable 'driving factors' for the target concentration in surface water need to be identified. Back-of-the-envelope calculations showed that runoff entries are the main driving factor for the target concentration; mole drainage is not applied near the small streams or temporary ponds in Ethiopia and pesticide entries by spray drift are not taken into account, as (i) the back-of-the-envelope calculations demonstrated that their peak concentrations are generally lower than those caused by runoff and (ii) runoff entries are seldom stacked on top of drift entries into the small streams. Precipitation amounts above 20 mm/day are a good indicator for the occurrence of runoff (Blenkinsop *et al.,* 2008) and therefore the selection of the scenario locations was done by considering the distribution in time and space of the number of days with a daily precipitation of 20 mm or more. This was done by: (i) selecting the relevant 80*80 km grid cells for each of the protection goals (above 1500 m or below 1500 m elevation) (ii) counting the number of days with daily rainfall above 20 mm for each grid cell and each of the 33 years, (iii) selecting the 99th percentile (so, in time) by ranking the 33 numbers for each of the grid cells, (iv) plotting this single number on the map for each of the grid cells, and finally (v) ranking all grid cells and selecting the 99th percentile (so, in space). For the selected grid cells the models were run for 33 years and the 99th temporal percentile of the calculated annual peak concentration was selected. For the protection goal of the temporary pond below 1500 m an additional selection criteria for the relevant grids of (i) was that there should be a minimum of 500 mm rainfall (long term annual average), while for the temporary pond above 1500 m the elevation should remain below 2000 m. Before the scenario location was finally selected from the candidate locations a plausibility check was done with the aid of Google maps and Ethiopian experts, e.g. whether the protection goal (streams or temporary pond) were present in the grid cell, as well as villages and intensive cultivation.

Three surface water scenarios were selected: (i) grid 191, southwest of Lake Tana, representing the protection goal of small streams above 1500 m, having a long term annual average precipitation of 2581 mm, 46 days with a daily rainfall above 20 mm and being located at 1682 m altitude, (ii) grid 373, near Arba Minch representing temporary ponds below 1500 m, but with more than 500 mm annual rain, having a long term annual average rainfall of 1702 mm, 46 days with a daily rainfall above 20 mm and being located at 1288 m altitude and (iii) grid 217, farther southwest of Lake Tana than grid 191, representing temporary ponds between 1500 and 2000 m altitude, having a long term annual average rainfall of 2779 mm, 21 days with a daily rainfall above 20 mm and being located at 1705 m altitude.

For the selected scenario locations the 'realistic worst case' annual peak concentrations can now be calculated for a selected crop, compound and application pattern. First, the adapted FOCUS_PRZM model is run for 33 years. Next, for the small stream scenario the water and pesticide runoff fluxes calculated by PRZM plus part of the pesticide-free subsurface drainage fluxes are fed into the stream metamodel. This metamodel also accounts for a constant, pesticide-free base flow and it assumes that 20% of the area of the upstream catchment feeding the stream is treated with pesticides. This implies that the pesticide concentration in the runoff water is diluted by a factor of at least five in the Ethiopian stream scenario. For each of the 33 years the annual peak concentration is selected and the 99th percentile, i.e. the highest ranked year is retained. Runoff fluxes are calculated on an hourly basis by PRZM, and therefore the concentrations of the stream metamodel are concentrations at an hourly basis. Thus the retained target concentration is an hourly, annual peak concentration.

For the Ethiopian temporary, stagnant pond scenarios the runoff fluxes and part of the subsurface drainage fluxes from a surrounding cropped area of 4500 m^2 are fed into the slightly adapted R4 EU-FOCUS pond of 30*30 m. A small constant pesticide-free baseflow is assumed to enter the pond as well. After complete mixing, excess water flows out of the pond over a over a 1-m wide and 1-m high weir. Spray drift deposition (according to the adapted EU-FOCUS deposition tables) from treatment of the Ethiopian crops around the pond also ends up in the pond. Repeated applications may stack up, because of the very low flow in the pond. The TOXSWA model is run for 33 years and for each of the 33 years the annual peak concentration is selected and the 99th percentile, i.e. the highest ranked year is retained. As the flow dynamics are low in the pond daily peak concentrations are calculated. Thus the retained target concentration is a daily, annual peak concentration.

Example calculations were performed to test whether the outcome of the risks of drinking water produced from groundwater and surface water are plausible. For seven high risk compounds (dimethoate, endosulfan, deltamethrin, 2,4-D, malathion, atrazine and chlorothalonil) used on barley, wheat, teff, maize, cotton, cabbage, sugarcane, potatoes (Irish and sweet) and faba beans for application schemes compiled by the PHRD and local experts, concentrations were calculated and evaluated first. The resulting risks were determined with the aid of the ADI and a daily intake of 2L or the ARfD and a large portion intake of 6 L, and a body weight of 60 kg. For drinking water produced from groundwater risks exist for atrazine, while for surface water no acute toxicity risks exist, but for dimethoate used on barley and faba beans chronic toxicity risks exist.

A user-friendly software tool, PRIMET_Registration_Ethiopia_1.1, was developed to enable a robust, transparant and reproducible calculation of the risks of pesticide use in agriculture by the PHRD of the Ethiopian Ministry of Agriculture. Next to risks for drinking water produced from groundwater and surface water other risks are evaluated as well in this tool, such as risks for operators in greenhouses and workers indoor or outdoor, as well as risks for the environment, e.g. for birds, bees or the aquatic ecosystem (see www.pesticidemodels.eu).

1 Introduction

1.1 Country of Ethiopia

The Federal Democratic Republic of Ethiopia is located in the north-eastern part of Africa, commonly known as the Horn of Africa (Figure 1.1.1). Neighbouring countries include Djibouti and Somalia in the east, Kenya in the south, Sudan in the west and south-west and Eritrea in the north and north-east. The country covers 1 112 000 square kilometres making it roughly five times the size of the UK. The country has a high central plateau that varies from 1800 to 3000 meters above sea level, with some mountains reaching 4620 meters. Elevation is generally highest just before the point of descent to the Great Rift Valley, which splits the plateau diagonally. A number of rivers cross the plateau, notably the Blue Nile flowing from Lake Tana which is the biggest lake in the country. The plateau gradually slopes to the lowlands of the Sudan on the west and the Somali-inhabited plains to the southeast.

Figure 1.1.1 *Location of Ethiopia in Africa.*

Ethiopia constitutes nine regional governments which are vested with authority for self-administration (Figure 1.1.2) namely Afar, Amhara, Benishangul/Gumuz, Gambella, Harari, Oromiya, Southern Nations Nationalities and Peoples State (SNNPS), Somali and Tigray; the two chartered cities are Addis Ababa and Dire-Dawa.

Figure 1.1.2 *Regional states and chartered cities of the Federal Democratic Republic of Ethiopia (Source: http://www.ethioembassy.org.uk/about_us/regional_states.htm).*

Ethiopia has a population of about 88 million inhabitants, which makes it the second-most populated nation on the African continent. It is a multilingual society with around 80 ethnic groups, with the two largest being the Oromo and the Amahara. A majority of the population is Christian and a third is Muslim. Ethiopia has it own calendar, which is seven years and about three months behind the Gregorian calendar. It is the origin of the coffee bean.

1.2 Pesticide registration in Ethiopia

In recent years Ethiopian agriculture has increased in acreage and it has intensified using more external inputs such as pesticides and fertilisers. The use of pesticides may cause negative effects on human beings as well as the environment. The Government of Ethiopia recognises this and it has the overall responsibility to regulate the manufacture, formulation, import, transport, storage, distribution, sale, use and disposal of pesticides in line with the International Code of Conduct on the distribution and use of pesticides, international conventions and local legislations. It has developed policies and legal instruments to regulate the use and management of pesticides. In cooperation with the FAO and the PRRP project a Regulation has been finalized in 2013, detailing the Pesticide Registration and Control Proclamation No. 674/2010 of August 2010.

The Plant Health Regulatory Department (PHRD, part of the Ministry of Agriculture) is the responsible body for the registration of pesticides in Ethiopia. It requests data from the applicants according to the SEARCH (Southern and Eastern Africa Regulatory Committee for Harmonization of Pesticide registration) data requirements for the registration of chemical pesticides. This form has been updated by Work Package B2.1 of the PRRP project. However, no assessment of risks for human health or the environment is done, because the tools to do so, lack. The PRRP project intends to fill in this gap and has developed procedures in accordance with those in the European Union or elsewhere in the world. For some protection goals (a.o. drinking water produced from groundwater and surface water) Ethiopia-specific exposure assessments were developed to account for typical Ethiopian crops and (agricultural) practices, pathways and hydrological conditions. The procedures are described in an evaluation manual for Ethiopia that has been written, in cooperation between Alterra, the Dutch Board for the Authorization of Plant Protection Products and Biocides (Ctgb) and the PHRD (Deneer *et al.,* 2014). In this report the science behind the risk assessment, especially the Ethiopia-specific exposure assessment for drinking water produced from groundwater or surface water is explained.

1.3 Structure of the report

After a short introduction on Ethiopia, this report starts with the outline of the scenario development procedure in Chapter 2: a roadmap with a stepped procedure consisting of two parts, i.e. the protection goal definition and next, the scenario selection and parameterization. It also describes which decisions have been made to operationalize the exposure assessment in the protection goals. The stepped procedure is based upon the experience of the Environmental Risk Assessment team of Alterra in the development of scenarios for risk assessment in The Netherlands, the EU and beyond. In Chapter 3 the principles of the assessment of risks for drinking water produced from groundwater and surface water are given and the approach considering the vulnerability of the scenarios is explained. From Chapter 4 onwards the steps of the roadmap are followed: data on agro-environmental characteristics are gathered and the most relevant pesticides and crops are identified. In Chapter 5 the scenario zones are defined, the protection goals are identified, conceptually defined and combined with the scenario zones. In Chapter 6 the models used for calculating leaching concentrations to groundwater and concentrations in surface water are presented, while in Chapter 7 the vulnerability drivers for the concentrations are identified and used in the design of the scenario selection procedure for groundwater and surface water. In Chapter 8 the scenario selection procedure is applied, resulting in the location of three groundwater and three surface water scenarios. Chapter 9 gives a brief overview of the calculation procedure for calculation of both the leaching concentrations and the surface water concentrations and in the Chapters 10, 11 and 12 the parameterisation of the used models is described in more detail. Chapter 13 presents some calculation examples for high-risk pesticides and crops, while Chapter 14 presents the software developed to evaluate the risks for drinking water produced form groundwater and surface water. The final Chapter 15 summarizes the main conclusions and recommendations for further improvement of the presented methodology.

2 Outline of the exposure scenario development procedure

2.1 Roadmap for developing scenarios for drinking water produced from groundwater and surface water

An exposure scenario can be defined as a unique combination of agronomic and environmental conditions (such as climate, hydrogeology, surface water characteristics, soil and topography), that realistically represents significant areas within which conditions are relatively homogeneous with respect to modelling input parameters (FOCUS, 1996). Exposure scenarios are used in the environmental risk assessment during pesticide registration procedures. They characterise the exposure in the environment and are compared to ecotoxicological effect concentrations to predict risks for the considered organisms.

Based on experiences in scenario development at national (Dutch) and European Union level as well as in China (Ter Horst *et al.,* 2014), Alterra designed a structured and simplified procedure to develop exposure scenarios within projects with a limited time span. The procedure employs ten steps, forming three main steps (Figure 2.1.1 and 2.1.2):

1. Definition of the protection goals and specification of the scenario zones in which the protection goal does or does not exist;
2. Design and application of the scenario selection procedure and
3. Parameterization of the scenarios, in order to be able to perform simulations for combinations of pesticides, application pattern and possibly crops.

The stepped procedure seems linear, but in reality retracing to earlier steps is sometimes necessary. The first step consists of making an inventory of agro-environmental conditions and pesticide use data for Ethiopia relevant for the protection of groundwater and surface water, such as climate, soils, land use, crops and agricultural practices, depth of groundwater level, surface water systems, size of catchment and the pesticide use and application techniques. If possible and relevant we gather geographically distributed data, e.g. for climate and soils.

The second step consists of identifying the number and extent of the scenario zones. Should one scenario cover the entire country or do we divide the country into several zones to account for its diverse agro-environmental conditions? The choice for scenario zones has consequences for the registration system, so, next to scientists, risk managers should be involved. If there is only a single scenario and the compound fails to pass it, there will be no registration. If there are multiple scenarios, the compound may fail some scenarios and pass some others and this means that in some zones registration would be possible, while in others not, or only with restrictions. Therefore, using multiple scenario zones, some flexibility is introduced in the registration procedure. It is important to decide upon the number of scenario zones in an early stage of the project, because this determines the definition of the scenarios: if there is one zone there is only one scenario that represents e.g. the 90^{th} percentile worst case situation of the entire country. When using several zones, the scenario should represent the 90^{th} percentile worst case situation for each scenario zone separately. Different types of criteria may exist for dividing the country, e.g. adhere to the division of the nine regional states in Ethiopia, or use the traditional agro-ecological zones, or the modern agro-environmental zones.

In the third step options for protection goals are defined, such as drinking water produced from groundwater, drinking water produced from surface water, the aquatic ecosystem birds, bees. What should be protected, where and how strict ? In this step the emphasis is upon the spatial component, the ’what’ and ‘where’ questions. It is the role of scientists to draw the list of protection goals options. Examples for drinking water produced from groundwater are: (i) village wells at shallow depth across the entire country, implying that surface areas of a couple of 100 m^2 around the wells need protection, or (ii) deep water wells in villages in Afar and Somali regional states, requiring protection of surface areas of several km^2 around the wells. Examples for drinking water produced from surface water are: (i) rivers with a description of the dimensions, discharge and its variation, the number and location of abstraction points along the river, their location with respect to the treated fields, or (ii) lakes with a description of their dimensions, water depth, entrance and discharge of water, presence of drainage or runoff entries, and the location of the abstraction points with respect to the treated fields around the lake or along the incoming water flow.

In the fourth step policy makers select protection goals from the list with options. Next, it is determined which protection goals are valid for each of the scenario zones. The scenario zones may be identified into further detail in this step by considering especially the overlap of areas where the protection goal is relevant and where agriculture uses pesticides. If the protection goals focus (indirectly) on human health, it may be an intelligent, pragmatic choice to consider especially areas where the most toxic compounds are used, e.g. insecticides, instead of herbicides. In this way, some crops may turn out to be more relevant than others. In a similar way, it may seem to be more relevant to focus either on smallholder farms, or on Large Scale Farms (Figure 2.1.1). Policy makers may also set priorities in the operationalisation of the protection goals. The reason is that each protection goal needs its own assessment method. Considerations for setting priorities may include the balancing of economic versus environmental issues, or pragmatic reasons like considering only areas where pesticides are currently used, neglecting areas where pesticides may also be used in the future.

The fifth step consists of the definition of the conceptual model for the protection goals. A conceptual model consists of an explanatory picture or drawing plus a description of the protection goal. Relevant elements may be:

- lay out of the protection goal, e.g. dimensions of surface water body, size of surrounding fields, fields treated, catchment size;
- entry routes of pesticides;
- farm types (smallholders or Large Scale farms), characteristics of the farm types, such as e.g. land preparation, size of fields;
- application techniques used (with links to types of farms or crop management);
- relevant crops (on which pesticides are used), e.g. crop calendar with main crop management activities and
- relevant pesticide processes (focussing on exceptional or country-specific aspects).

The conceptual model should contain all relevant information for determining the exposure. If two fundamentally different situations exist for one protection goal, and it is a priori not evident which situation represents the ‘realistic wost case’ situation, then it may be necessary to design two conceptual models, e.g. surface water can originate from a river, but also from a lake with nearby intensive horticulture.

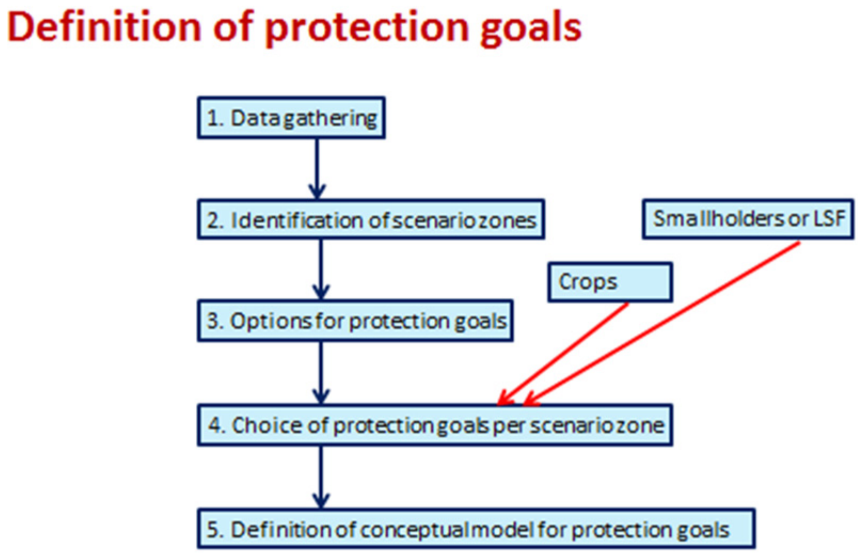


Figure 2.1.1 *First part of the roadmap for the development of scenarios for drinking water produced from groundwater and surface water in Ethiopia (LSF = Large Scale Farms).*

In the sixth step we select the models we want to use to calculate the exposure concentrations. Selection criteria may include the availability of needed input parameters (e.g. soil profiles), the need to model a certain entry route of pesticide, the access to the source code of the model, thus enabling adaptation of the model to the specific needs of the project, the use of the model elsewhere in the world, the user-friendliness, etc.

In the seventh step the vulnerability drivers are determined and the scenario selection procedure is designed. Ideally the exposure concentrations can be calculated as a function of time and space across the relevant geographic areas by a fate model incorporating all relevant processes and which is supplied with a comprehensive data set of input data, that expresses the variability in time and space. A chosen percentile of vulnerability may be obtained by statistical manipulation of the exposure concentrations. In reality a simplified procedure is often used, where variability in time and space are considered separately. First, sensitivity drivers are identified, i.e. model input having a large effect on the selected model output. Next, a limited set of vulnerability drivers are selected from among the sensitivity drivers. Vulnerability drivers define part of the agro-environmental conditions of the scenario and are strongly spatially variable. Next the probability in space of the vulnerability driver can be determined and this is combined with the probability in time (by including time series of the most important sensitivity and vulnerability drivers in the model calculations). In this way a simplified scenario selections procedure is designed. As sensitivity and vulnerability drivers may not only consist of agro-environmental data, but also be model-specific as well as interact with compound properties, expert judgement is necessary in the design of the scenario selection procedure.

Step number eight consists of the application of the scenario selection procedure. For each specific protection goal and scenario zone the designed scenario selection procedure need to be worked through and this results in the final location of each specific protection goal in each scenario zone.

In the ninth step the scenarios are parameterised in the selected models. To do so, data need to be gathered for the selected scenario locations and in addition to the geographically distributed data used in step seven more detailed data are sometimes needed as input for the models. Sometimes also time series are needed for additional input data, not considered in the scenario selection procedure. Once the scenarios are ready, it is advisable to perform a number of example simulations to check the correctness of the calculations as well as the plausibility of the results.

Finally, we strongly advise to include a tenth step, aimed at the design and construction of a user-friendly software tool. In this way all simulations can be executed in a robust, transparent and reproducible way, which is important in pesticide registration procedures.

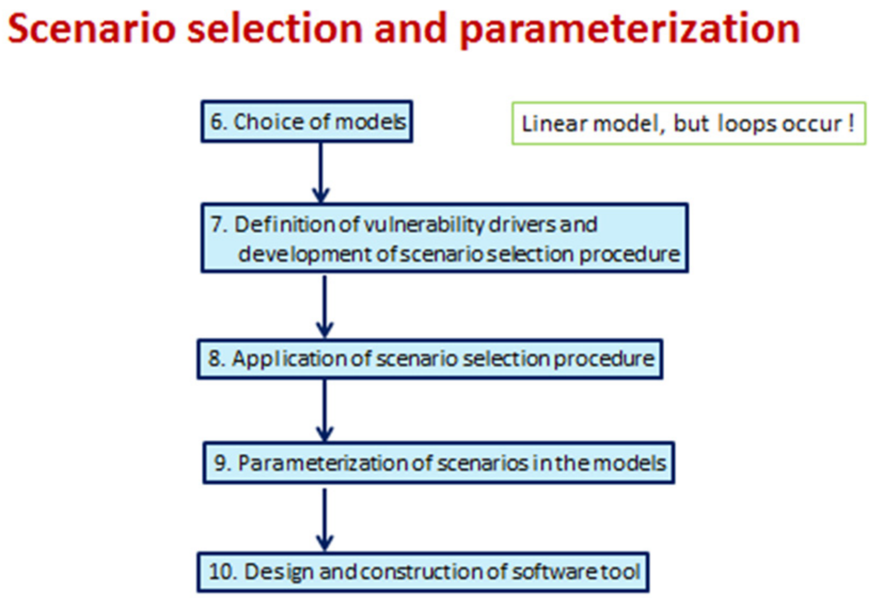


Figure 2.1.2 *Second and last part of the roadmap for the development of scenarios for drinking water produced from groundwater and surface water in Ethiopia.*

2.2 Target variables of the exposure assessments

2.2.1 Protection goals

During a workshop in November 2011 in Ethiopia the PHRD and other stakeholders selected drinking water for cattle and man, produced from groundwater or surface water, as the protection goal with the highest priority. Therefore, the scenarios described in this report aims to represent situations where drinking water is produced for cattle or for man.

Because in many places in Ethiopia groundwater or surface water is used as drinking water without purification, it was decided that groundwater and surface water needed to be protected from pesticide pollution in such a way that it is safe to drink it without prior purification.

In contrast with the situation in the EU, where 0.1 µg/L is used as the drinking water standard, a choice for using human toxicological criteria for drinking water was made in Ethiopia. This implies that there is no single cut off value, but that the standard is pesticide-dependent. In general the human toxicologically based standard is considerably less strict than the 0.1 µg/L standard. Realising that exceeding these human toxicologically based standards may lead to human health problems, the Ethiopian project partners PHRD and other stakeholders decided to compensate this by adopting very vulnerable scenarios, i.e. 99th percentile probability of occurrence situations instead of the 90th percentile applied in the EU.

In consecutive workshops vulnerable conditions for sources for drinking water produced from groundwater and surface water were defined. For surface water this resulted in streams in the highlands, being the only closeby sources of water and used even after the rains have stopped already for months when the streams have shrinked to really small streams of only 1 to 2 m wide. Stagnant, temporary ponds, mostly used for drenching cattle but sometimes also used by humans, was identified as another vulnerable source of drinking water. Often vegetables are grown around these retreating ponds and part of the pesticides used on these crops may easily end up in the pond due to surplus irrigation water running back into the pond.

The most vulnerable groundwater sources were identified by the Ethiopian expert, Dr Engida Zemedagegenhu during the November 2012 workshop. Based upon his thorough knowledge of the hydro-geological structure of Ethiopia and his long experience in identifying well locations all over the country of Ethiopia, three specific groundwater protection goals were defined: (i) alluvial aquifers along small rivers, (ii) volcanic aquifers of shallow wells (generally found in the vicinity of (i)) and (iii) alluvial aquifers at the Rift Valley margins and lowlands.
In Chapter 5 the protection goals has been defined into more detail and their conceptual models have been designed.

2.2.2 Risk management decisions

During a workshop in November 2011 in Ethiopia the PHRD and other stakeholders selected drinking water for cattle and man, produced from groundwater or surface water, as the protection goal with the highest priority. Therefore, the scenario development, described in this report aims to represent situations where drinking water is produced for cattle or for man.

In the same workshop the PHRD and other stakeholders decided that risk for drinking water should be assessed on the basis of a 99th percentile target exposure concentration. This implies that a 99th percentile of occurrence in time and space of the total population of target exposure concentrations should be used as the exposure concentration in risk estimates, opting to protect 99% of all possible situations in time and space. This protection level is higher than the 90th percentile approach, common in the EU (FOCUS, 2001). This more strict exposure assessment is is evaluated against human toxicological criteria, which are less strict than the European drinking water criterion of 0.1 µg/L for pesticides.

In view of the highly variable agro-environmental conditions in Ethiopia, the PHRD and other stakeholders deliberately opted to represent the country by two scenario zones, one located above 1500 m altitude and one located below 1500 m altitude. This is in accordance with the delimitation between the lowlands and highlands, consisting of the traditional Ethiopian agro-ecological zones Bereha and Kolla versus Woina Dega, Dega, and higher (above 3200 m). In his way there is some flexibility in the registration procedure, e.g. a compound-crop combination may pass the risk assessment in one zone, but fail in the other zone, thus being registered for one zone, but not (or with restrictions) for the other zone.

The PHRD and other project partners decided to limit the scenario development to three types of drinking water produced from groundwater protection goals, i.e. (i) alluvial aquifers along small rivers, (ii) volcanic aquifers on shallow wells and (iii) alluvial aquifers in the Rift Valley margins and lowlands, and to two types of drinking water produced from surface water protection goals, i.e. small rivers and (ii) temporary ponds. Combined with the two scenario zones (in which not every protection goal occurs) this results in three groundwater scenarios and three surface water scenarios. The PHRD and other stakeholders thus chose to increase the degree of realism in the scenarios, thereby increasing the public support for the risk assessment procedure in Ethiopia.

Although it was recognised that the pesticide-intensive cultivation of e.g. flowers or vegetables in greenhouses may result in contamination of groundwater and surface water in Ethiopia the project partners decided not to develop a specific exposure scenario for this type of cultivation, because of lack of readily available instruments (e.g. models or scenarios in EU registration) and Ethiopian-specific data.

Representatives of the PHRD decided not to consider pesticide entries via drainage canals into surface waters, since this occurs only in very specific cases. Moreover, it would render the calculation of exposure concentrations too complex within the framework of the PRRP project.

For drinking water produced from surface water the target exposure concentrations were defined as the 99th percentile of probability in time and space of the yearly maximum daily concentration of the simulated 33 years. The 99th percentile of probability in time and space of all daily maximum concentrations of the 33 years was judged not to be acceptable (even after eliminating all days with a daily maximum concentration of zero), because each year the acceptable 99th percentile exposure concentration would be exceeded for a number of days. Details are given in Chapter 9.2.1.

2.2.3 Operational decisions

Drinking water produced from groundwater and surface water for cattle and humans was selected as the protection goal with the highest priority. In this report risks from drinking water are evaluated for humans only, i.e. based upon exposure and toxicological criteria valid for humans, thus not for cattle. We did so, because toxicological criteria (e.g. ADI, ARfD) for humans are available from the standard pesticide registration dossiers, while this is not the case for cattle. We presume that the risk assessment for humans also covers the risks for cattle, i.e. when risks for humans are negligible, the risks for cattle are negligible as well. As cattle is a highly appreciated asset in Ethiopia, the Ethiopian project partners stressed the importance of mentioning cattle explicitly in the protection goal.

In the PRRP project risks for the aquatic ecosystem are also assessed. For reasons of simplicity the surface water scenarios, developed to assess the risks for drinking water produced from surface water, are also used to assess the risks for the aquatic ecosystem. However, not the 99th percentile but the 90th percentile target exposure concentration is used for the risk assessment, in accordance with EU guidance.

Although the need was recognised by all project partners to include metabolites, these are not considered in the drinking water risk assessment, due to time restraints and complexity.

Spray drift deposition numbers as a function of e.g. crops were not available for Ethiopian conditions, not allowing for differentiation between various types of spraying equipment, spraying practices (e.g. spot spraying by smallholders), nozzle type, spray pressure, spraying height, distance between last row of crops and edge of water surface, humidity, wind speed etc. Therefore, use was made of the FOCUS (2001) curves, developed for a range of European crops under European conditions.

Although the reliability of the data are relatively low (pers. comm. T. Hengl-ISRIC) we had to use the Harmonised World Soil Database, because this was the only readily available source of soil data covering the entire country of Ethiopia at the time of scenario selection. ISRIC World Soil Information provided soil organic matter and bulk density data of the upper 30 cm soil on an approximate 5 * 5 km grid for Ethiopia.

We assessed the risks for drinking water produced from groundwater by considering the leaching concentration at 1 m depth. Usually groundwater from greater depth is used as drinking water. However, by adopting the leaching concentrations at 1 m depth, we followed the line of FOCUS (2000), which is a protective approach for groundwater, and eliminates the need for additional soil data below 1 m depth.

Within the PRRP project it was judged to be feasible to develop scenarios for the three groundwater protection goals, ranked highest for their vulnerability. These were (i) alluvial aquifers along small rivers, (ii) volcanic aquifers of shallow wells and (iii) alluvial aquifers at the Rift Valley margins and lowlands. Surface water scenarios could be developed for the two highest ranked protection goals, (i) small rivers in the highlands and (ii) temporary, stagnant ponds used for cattle or man.

No sufficiently detailed soil data and no Runoff Curve Numbers (RCN) were available for Ethiopian conditions. Therefore, it was decided to parameterise the selected EU runoff model, FOCUS_PRZM, with the soil and RCN data of the worst-case scenario (R4) of the four EU runoff scenarios. However, Ethiopian data were used for weather, irrigation and crops.

The Ethiopian protection goal of small streams was simulated by adapting the EU FOCUS stream scenario with respect to (i) stream dimensions, (ii) incoming types of water flow in the stream (runoff water, constant uncontaminated base flow and uncontaminated subsurface drainage flow) and (iii) configuration of the upstream catchment (size and pesticide treatment ratio). A FOCUS_stream metamodel was made for this project, thus avoiding running FOCUS_TOXSWA for a series of 33 years.

The Ethiopian protection goal of a temporary, retreating pond was schematised into the (permanent) FOCUS runoff R1 pond. As the FOCUS pond is smaller (less wide and deep), the exposure concentration in the FOCUS ponds generally is more worst-case than in the Ethiopian temporary pond. Therefore, the PRRP project experts judged that it was defensible to use the FOCUS R1 pond (using runoff from Ethiopian crops and Ethiopian weather) for the assessment of risks for the registration in Ethiopia.

2.3 Position in the tiered assessment scheme

Tiered approaches form the basis of environmental risk assessment schemes used in the registration of plant protection products (EFSA, 2010). EFSA defines a tier as a complete exposure or effect assessment, resulting in an appropriate endpoint (in this report PEC_{sw_99} or PEC_{gw_99}). The rationale of tiered approaches is to start with a simple, conservative assessment and to carry out additional, more complex and realistic assessments only if necessary. These higher tiers are less conservative than the lower tiers. In this way the procedure aims to be cost-effective for both notifiers and regulatory agencies.

The general principles of tiered exposure approaches are (EFSA, 2010):
- Lower tiers are more conservative than higher tiers;
- Higher tiers are more realistic than lower tiers;
- Lower tiers usually require less effort than higher tiers;
- In each tier all available scientific information is used and
- All tiers aim to assess the same exposure goal.

In short, the tiered exposure assessment needs to be internally consistent and cost-effective and to address the problem with increasing accuracy and precision, going from lower to higher tiers. These principles permit moving directly to higher tiers without performing the assessments for all lower tiers (EFSA, 2010 and summarised by Tiktak *et al.,* 2012).

The scenarios for risks for drinking water produced from groundwater and surface water, described in this report are intended to be the first-tier in the registration procedure of Ethiopia. Although the risk assessment procedure is relatively detailed and complex (comparable to the EU_FOCUS 3rd tier, i.e. higher-tier assessments), it is relatively easy to use, because (i) Ethiopia has all the required basic data at its disposal in the so-called updated SEARCH (Southern and Eastern Africa Regulatory Committee for Harmonization of pesticide registration) data requirement forms and (ii) the entire exposure calculation and risk assessment method has been implemented in a user-friendly software tool, specifically designed for Ethiopia, PRIMET_Registration_Ethiopia_1.1. The SEARCH-based data requirements forms have been updated and completed within the PRRP project, and thus all required information is available for the PHRD in future registration dossiers. The PRIMET_Registration_Ethiopia tool and its documentation (Wipfler *et al.,* 2014) is freely available at www.pesticidemodels.eu) and eight representatives of the PHRD were trained in using it during a specific training course in September 2014. Higher-tier options were not developed within the PRRP project.

3 Approach to estimate risks for drinking water produced from surface water and groundwater

3.1 Introduction and general principles

The first step in risk assessment is to define what one wants to protect, i.e. setting protection goals. Three questions need to be answered to define the protection goals in sufficient detail: (i) what do we want to protect, (ii) where do we want to protect and (iii) when and how strict do we want to protect. Figure 3.1.1 presents the example of the aquatic ecosystem and explains which types of answers are needed.

Figure 3.1.1 *Questions to define the environmental protection goals for the pesticide registration procedure.*

In Ethiopia the PHRD of the Ministry of Agriculture will be responsible for the assessment of risks for the environment and the drinking water production from surface water and groundwater as part of the registration procedure of pesticides in Ethiopia. During a workshop with representatives from the PHRD, several ministries, the Ethiopian Institutes of Agricultural Research (EIAR), the Federal Environmental Protection Agency (EPA), the Ethiopian Conformity Assessment Enterprise (ECAE), the Institute of Biodiversity Conservation (IBC) and the Addis Ababa University highest priority was given to the protection goal of risk assessment of drinking water production. To be able to assess this protection goal it needs to be translated into a target parameter. In this case the target parameter consists of a parameter that expresses the risks of pesticides in drinking water, based upon a predicted concentration in drinking water and a human toxicological endpoint. Pesticide concentrations can be expressed as dissolved phase pesticide concentrations or total pesticide concentrations (i.e. dissolved + sorbed to suspended solids). As is usually done, we use the dissolved phase concentrations in the risk assessments for drinking water produced from groundwater or surface water in this report.

Principles of risk assessment for drinking water
The assessment of risks is based upon the comparison of (eco)toxicological effect concentrations to exposure concentrations. For drinking water Figure 3.1.2 gives an overview of the risk assessment procedure. Pesticide concentrations in water are predicted with the aid of environmental baseline data, characterising the agro-environmental conditions in which the pesticide is used. Fixed sets of these agro-environmental conditions are called exposure scenarios and these will be derived in the Chapters 5 to 8. Combined with physico-chemical data and use data of the pesticide a fate model (or combination of several fate models) will result in a PEC, Predicted Environmental Concentration, in the water.

Toxicity studies, performed according to agreed test protocols for the pesticide concerned, result in a human toxicological endpoint, such as e.g. the ADI, Acceptable Daily Intake, i.e. 'the estimated amount of active substance, expressed per kg body weight, that can be consumed daily over a lifetime without appreciable health risks', or the ARfD, Acute Reference Dose, i.e. 'the estimate of the amount of a substance in food or drinking water, normally expressed on a body weight basis, that can be ingested in a period of 24 h or less without appreciable health risks to the consumer on the basis of all known facts at the time of the evaluation'. A data base of food additive specifications with their current ADI status, the year of their most recent JECFA (Joint FAO/WHO Expert Committee on Food Additives) evaluation, their assigned INS numbers, etc. are available in English at the JECFA website at FAO http://www.fao.org/ag/agn/jecfa-additives/search.html?lang=en. The database has a query page and background information in English, French, Spanish, Arabic and Chinese. The reports of JECFA are available at the JECFA website at WHO http://www.who.int/ipcs/food/jecfa/en/. Considering the acute reference dose, ARfD, there is a Guidance Document of the European Commission and a JMPR (FAO/WHO Joint Meeting on Pesticide Residues) Guidance on setting of the ARfD for pesticides. These documents provide a guideline on how the ARfD should be derived, which studies can be used as a starting point, and which effects are relevant for acute exposure. (See http://ec.europa.eu/food/plant/protection/resources/7199_vi_99.pdf and http://www.who.int/entity/foodsafety/chem/jmpr/arfd_guidance.pdf). Monographs and evaluations of the FAO/WHO Joint Meeting on Pesticide Residues (JMPR) can be found at: http://www.inchem.org/pages/jmpr.html

The human toxicological endpoint is compared to the intake of the pesticide based upon the water concentration and water consumption, resulting in an estimate of the risk. Next, this estimate is compared to a registration criteria, indicating which risk is judged acceptable. The decision on which risks are acceptable is a political decision, based upon considering various societal interests by e.g. the Ministry of Environment, Ministry of Agriculture, Ministry of Economic Affairs, farmers, pesticide industry or consumers.

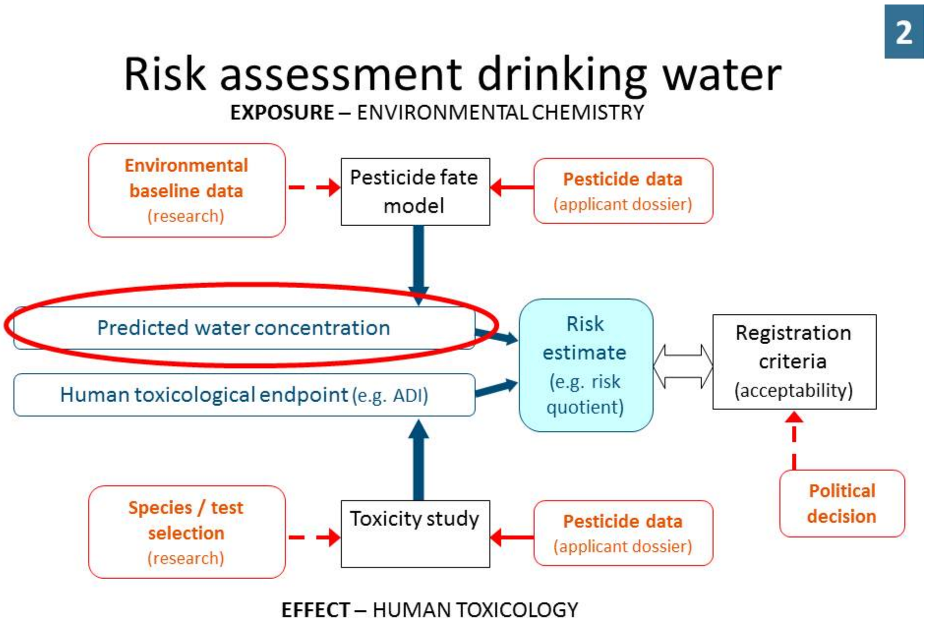


Figure 3.1.2 *Overview of the risk assessment procedure for drinking water.*

So, there are two distinctive parts in the risk assessment: an exposure part and a toxicological part. The exposure depends on local agro-environmental conditions and pesticide use, so it is country-specific and thus, it needs to be derived specifically for Ethiopian conditions. For the toxicological endpoints we use the internationally accepted standards, such as the ADI or ARfD. Therefore, the remainder of this report will mainly focus on deriving Ethiopian exposure concentrations.

3.2 Acute and chronic risks for drinking water produced from groundwater and surface water

Acute risks of drinking water produced from small streams and temporary ponds
The acute risk for drinking water consumption from Ethiopian surface water was calculated with the aid of a Large Portion (*LP*) of contaminated water, drawn from the small stream or from the temporary ponds, the acute human toxicity standard, i.e. the Acute Reference Dose (*ARfD*) and 99th percentile exposure concentrations:

$$IESTI = \frac{LP \times PEC\_99}{ARfD \times BW}\ 100\% \qquad \text{(eqn. 3.2.1)}$$

in which I*ESTI* = internationally Estimated Short Term Intake, expressed in % of the total acceptable intake of the pesticide during one day (-), *LP* = Large Portion (L.d^{-1}), *PEC_99* = 99th percentile concentration in the selected surface water (μg.L^{-1}), *ARfD* = Acute Reference Dose, expressed in μg pesticide per kg *BW* per day (μg.kg^{-1}.d^{-1}) and *BW* = Body Weight (kg). The Body Weight is set at 60 kg and the Large Portion intake at 6 L.d^{-1} for Ethiopia. Hourly peak concentrations in the diluted runoff water coming out of the catchment feeding the small stream for all runoff events during 33 simulated years and daily peak concentrations in the pond receiving runoff and spray drift were used for selecting 99th percentile exposure concentrations.

Acute risks for drinking water produced from groundwater are not assessed, as the exposure to pesticides by drinking groundwater is chronic. The reason is that the groundwater concentration is rather stable without sharp increases or decreases due to mixing by dispersion/diffusion during the relatively long travel times during leaching to groundwater.

Chronic risks of drinking water produced from surface water or groundwater
The chronic risk for drinking water consumption from Ethiopian surface water or groundwater was calculated with the aid of the daily intake (DI) of contaminated water, drawn from the surface water or groundwater, the chronic human toxicity standard, i.e. the Acceptable Daily Intake (*ADI*) and 99th percentile exposure concentrations:

$$IEDI = \frac{DI \times PEC\_99}{ADI \times F_{dw} \times BW}\ 100\% \qquad \text{(eqn. 3.2.2)}$$

in which I*EDI* = Internationally Estimated Daily Intake, expressed in % of the total acceptable intake of the pesticide during a lifetime (-), *DI* = Daily Intake ($L.d^{-1}$), *PEC_99* = 99th percentile concentration in the selected surface water or groundwater ($\mu g.L^{-1}$), *ADI* = Acceptable Daily Intake, expressed in μg pesticide per kg *BW* per day ($\mu g.kg^{-1}.d^{-1}$), F_{dw}= fraction of *ADI* allocated to drinking water (-) and *BW* = Body Weight (kg). The Body Weight is set at 60 kg, the Daily Intake at 2 $L.d^{-1}$ and the Fraction of *ADI* allocated to drinking water at 0.1 for Ethiopia. Annual average leaching concentrations at 1 m depth as calculated by the EuroPEARL metamodel for the Ethiopian groundwater scenarios were used as the 99th percentile exposure concentrations for drinking water produced from groundwater. Hourly peak concentrations in the diluted runoff water coming out of the catchment feeding the small stream for all runoff events during 33 simulated years and daily peak concentrations in the pond receiving runoff and spray drift were used for selecting 99th percentile exposure concentrations for drinking water produced from surface water.

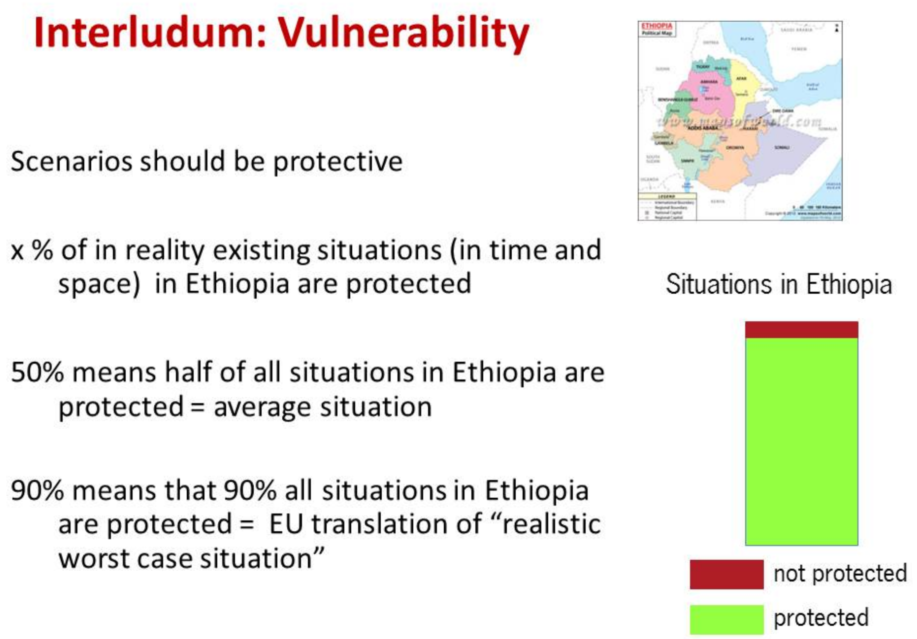
3.3 Definition of exposure scenarios and probability in time and space

Probability in time and space for exposure concentrations and vulnerability drivers
Exposure concentrations are calculated in (exposure) scenarios, fixed sets of agro-environmental conditions, such as precipitation, soil, land use management, crops with their cropping calendar and the surface water body or groundwater body to be protected. In agreement to what is internationally accepted the new Proclamation of Ethiopia now includes a phrase stating that risks should be assessed in 'realistic worst case' conditions. The scenarios need to represent 'realistic worst case' conditions for which the risks of normal agricultural use of pesticides are evaluated (the so-called GAP, Good Agricultural Practice), before the pesticide is admitted on the market. Not the average situation is to be protected, but a more vulnerable situation, covering e.g. 90% or 99% of all possible situations in Ethiopia with respect to the defined protection goals (Figure 3.3.1). In order to be able to evaluate the vulnerability of exposure situations, statistics expressing variability in time and space are needed. Ideally the exposure could be calculated as a function of time and space across the relevant geographic area, e.g. Ethiopia, by a fate model incorporating all relevant processes and being fed by a comprehensive set of input data, that expresses the variability in time and space. Next, a comprehensive set of exposure concentrations as function of time and space would have been obtained, which could be manipulated statistically to obtain e.g. an overall 90th percentile exposure.

In reality however, a simplified procedure often needs to be followed. In this simplified procedure variability in time and space are considered separately. First it is assessed which sensitivity drivers determine the exposure, a sensitivity driver being defined as a model input that has a large effect on the selected model output, i.e. the exposure concentration. From the array of sensitivity drivers a very limited set of drivers need to be selected, that determines the vulnerability of the exposure scenario. A vulnerability driver is defined as a sensitivity driver that has been selected to represent the vulnerability of an exposure scenario. A sensitivity driver is selected as a vulnerability driver if (i) it defines part of the scenario, i.e. defines a part of the fixed agro-environmental conditions that make for the scenario and (ii) is strongly spatially variable. E.g. if rainfall is a sensitivity driver for the pesticide concentration, it will only become a vulnerability driver if it strongly varies across the scenario zone, and not if the rainfall is of a similar size everywhere across the scenario zone. Once the vulnerability drivers have been selected, their probability of occurrence in space can be determined and these will be combined into one overall probability in space which can be next combined with the probability in time by simple calculation rules into an overall probability in time ánd space for the target parameter. An example of such a calculation rule = 90th +90th = overall 90th percentile (see Figure F1 and explanatory text for more details).

The variability in time can be accounted for by including time series of the most important sensitivity and vulnerability drivers in the model calculations, e.g. for rainfall or temperature.

Main sensitivity and vulnerability drivers may not only be formed by physical features, such as climatic data, soil properties, slope, land use or pesticide entry routes (e.g. spray drift, runoff, or drainage into surface water), but they may also depend on the model used. Moreover, their importance may depend on their interaction with compound properties. Therefore the selection of the main vulnerability drivers should be based on a combination of knowledge on main drivers for pesticide losses, importance of pesticide physico-chemical processes, selected pesticide models and possible interaction with compound properties. In the simplified scenario selection procedure expert judgement, next to relevant local data on spatial heterogeneity thus play an important role.



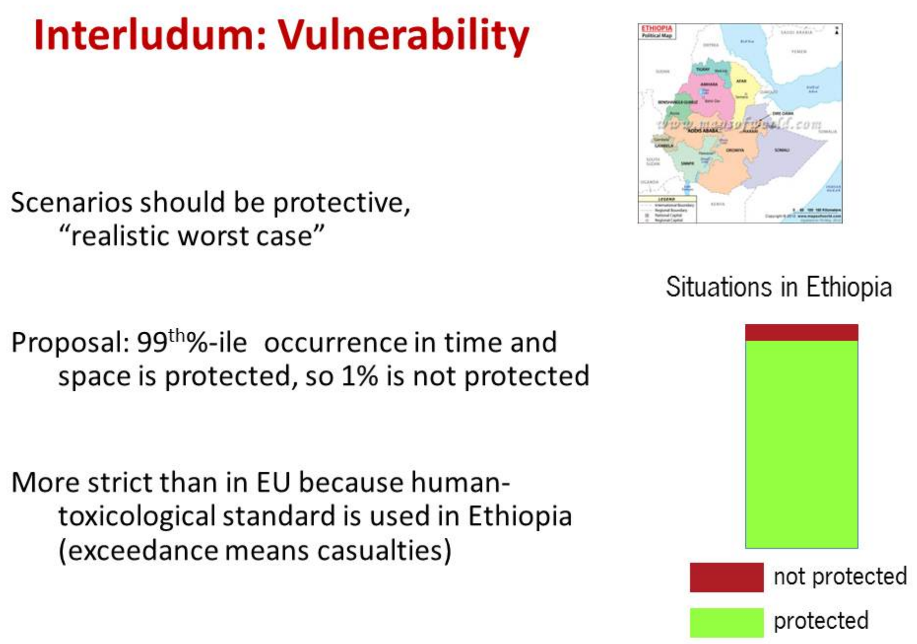


Figure 3.3.1 *Explanation of the vulnerability concept, used for assessing the protection goal of drinking water in Ethiopia.*

Percentiles for surface water and groundwater used for drinking water (and for the aquatic ecosystem)
After discussions with representatives of the Ethiopian Plant Health Regulatory Directorate (PHRD), Ethiopian Institutes of Agricultural Research (EIAR), the Federal Environmental Protection Agency (EPA), the Ethiopian Conformity Assessment Enterprise (ECAE), the Institute of Biodiversity Conservation (IBC), the Addis Ababa University and PAN-Ethiopia a choice was made to evaluate the environmental protection goals using a 90th percentile probability in time and space and to be more strict for drinking water production (because human health is involved), by using the 99th percentile probability. The concentrations in both surface water and groundwater, used for drinking water, should represent a 99th percentile probability in time and space, while for the risk assessment of the aquatic ecosystem 90th percentile concentrations in surface water are needed.

Division between probability in time and space of the overall 90th and 99th percentiles
In the text box below we intend to explain how the overall probability can be obtained by a combination of probability in time and in space.

The aim of the scenario selection procedure is e.g. to obtain an overall 90th percentile exposure concentration considering both variability in space and time. The problem is then which combination of space and time percentiles will give an overall 90th percentile. Let us assume that the percentiles of the exposure concentration are a continuously increasing function of the percentiles in space and time (see Figure F1). Let us consider the exposure concentration for a combination of a 90th percentile in time and a 90th percentile in space. For this case it is certain that 81% of the exposure concentrations are lower than this value (0.9 × 0.9 × 100%, i.e. the green plane in Figure F1). It is also certain that 0.1 × 0.1 × 100% = 1% (i.e the red plane in Figure F1) of the exposure concentrations are higher than this value. The areas of the question marks in Figure F1 sum up for this case to 2 × 0.1 × 0.9 × 100% = 18%. Without having more information on the relationship between the exposure percentile and the space and time percentile, the best guess is to assume that half of this 18% is above the value of the exposure concentration for the 90th percentiles in time and space and half is below this value. So the result is that the exposure concentration at the 90th percentiles in time and space corresponds to the 90th percentile (81% + 9%) of the population of exposure concentrations. The same reasoning can be set up for the 99th percentiles in time and space which then correspond to the 99th percentile of the exposure concentration.

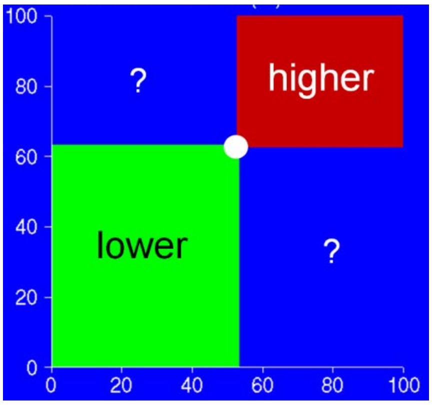


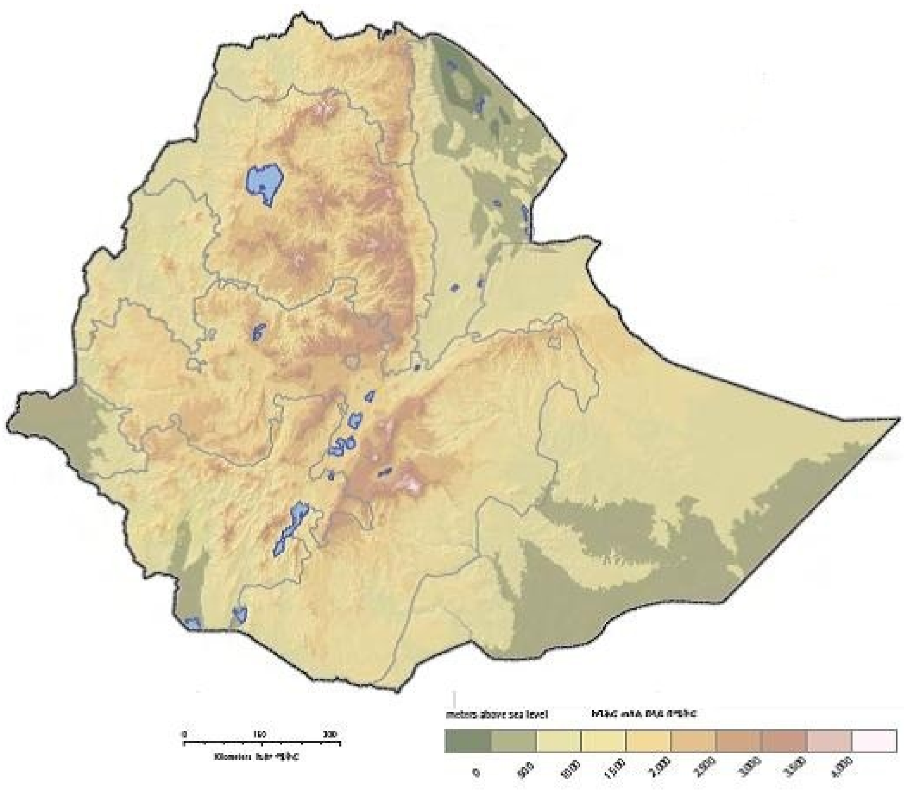
Figure F1 *Diagram of the percentile of a stochastic variable z which is a function of two variables x and y. The horizontal axis consists of percentiles of x and the vertical axis consists of percentiles of y. It is assumed that z increases continuously as a function of x and y. The point in the plane is an arbitrary combination of x and y percentiles.*

4 Agro-environmental characteristics and identification of the most relevant pesticides and crops

4.1 Geography, crops, soils, meteorology and agro-ecological zones in Ethiopia

In an early stage of the PRRP project an inventory was made of the geography, crops, soils, meteorology and agro-ecological zones in Ethiopia (Assefa *et al.,* 2011). The Atlas of Rural Economy of Ethiopia (IFPRI and CSA, 2006) of the Central Statistical Agency (CSA), the Ethiopian Development Research Institute (both located in Addis Ababa) and the International Food Policy Research Institute (IFPRI, Washington, DC, USA) provided a wealth of easily accessible information and a significant number of their maps plus associated texts were incorporated in the PPRP Inventory report of Assefa *et al.* (2011) and are reproduced below.

Elevation is an important determinant of climate, having a strong influence on temperature and rainfall. As such, elevation is a fundamental dimension of the geographical context in which agriculture and other rural activities take place. The most basic understanding of Ethiopian land use and agricultural practices is defined by a distinction between highlands and lowlands, traditionally defined at 1500 meters above sea level. Elevation ranges from 110 meters below sea level in the Danakil Depression to 4620 m above sea level at Ethiopia’s highest mountain, Ras Dashen. Addis Ababa is located at approximately 2300 m (IFPRI and CSA, 2006). Figure 4.1.1 shows the elevation in different parts of Ethiopia.



Data source: Shuttle Radar Topographic Mission, NASA.

Figure 4.1.1 *Elevation in Ethiopia (source: IFPRI and CSA, 2006).*

Land cover refers to the vegetative coverage of the earth's surface, as well as to the observable evidence of land use for economic activities. According to IFPRI and CSA (2006), most of the natural forest that once covered much of the temperate highlands is now seriously reduced, converted to agriculture and grazing land. At the year 2006, only 21 percent of the country is classified as cultivated. At present this figure is expected to have risen, owing to the vast recent intensification of agricultural investment in Ethiopia.

Much of the grassland and shrub land shown in Figure 4.1.2 is used for grazing, but it is either too poor for crop cultivation, supporting only limited cultivation (for example, in ravines or small irrigated areas), or was in fallow when the data were collected. Much of the highland woodland areas are non-native Eucalyptus plantations, often planted on steep slopes where other crops are infeasible or non-economic (IFPRI and CSA, 2006).

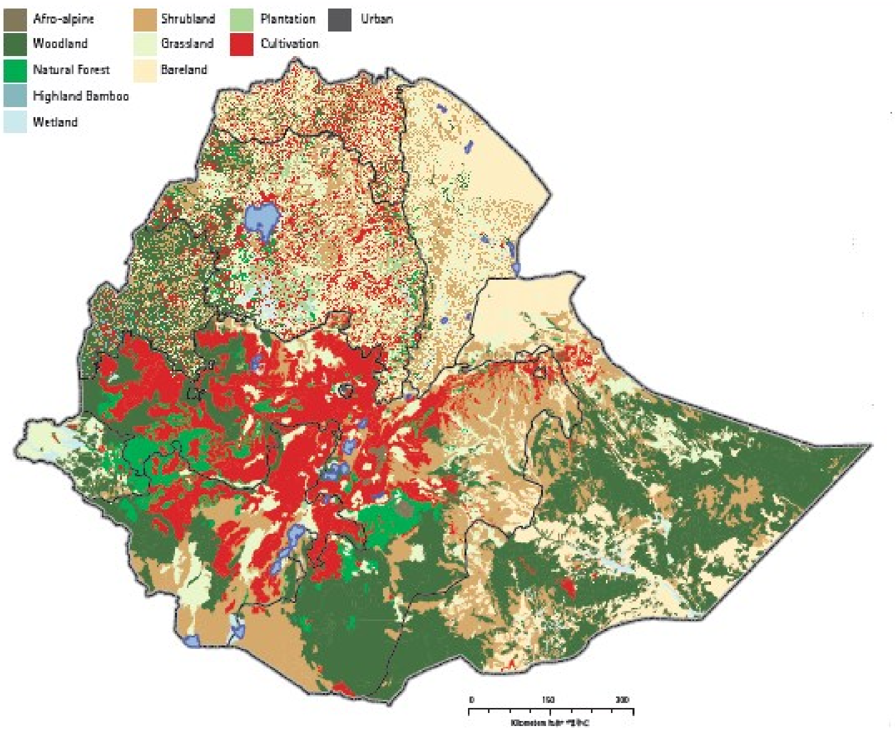


Figure 4.1.2 *Land cover in Ethiopia (Source: IFPRI and CSA, 2006).*

From a biophysical perspective, soil conditions, together with climate and terrain, are major determinants of what agricultural production is possible in a given area. Major soil associations are classified on the basis of predominant chemical and physical properties, derived from parent geological material and modified by weathering and other transformative processes.

Leptosols are the most abundant types of soils in Ethiopia (29.8 percent of total land area). They are mostly found in the north, are very shallow (< 30 cm) and have somewhat limited agricultural potential (Figure 4.1.3). Nitosols (12.5 percent) are mostly found in the west and are deep, well-drained soils. Despite low pH and low levels of phosphorus, they have relatively good agricultural potential. Vertisols (10 percent) have a wider distribution. They are heavy, black clay soils that are difficult to work and have poor drainage. Although they have good chemical properties, their use is limited due to water-logging. Other soils, including Cambisols (9.4 percent), Calcisols (9.3 percent), and Luvisols (7.8 percent), have relatively good physical and chemical properties for agricultural production. Gypsisols (7.6 percent) in the eastern lowlands have limited agricultural potential (IFPRI and CSA, 2006).

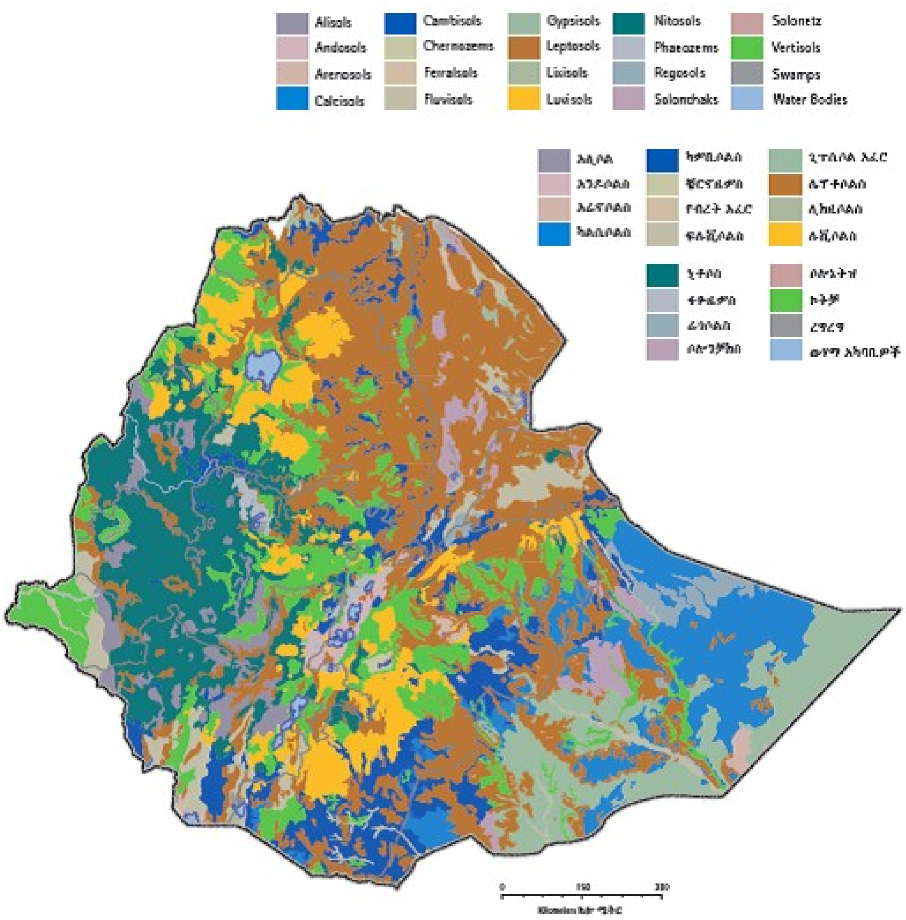


Figure 4.1.3 *Major soil types in Ethiopia (Source: IFPRI and CSA, 2006).*

Rainfall is essential for the non-irrigated agriculture practiced across most of Ethiopia. The western highlands have particularly high rainfall, averaging more than 1200 millimeters annually in many areas. Rainfall is lower with loss of elevation, especially toward the east. Most of the eastern lowland areas of Afar and Somali are unsuitable for crop production because of lack of rainfall (Figure 4.1.4). Figure 4.1.5 shows the variability of annual rainfall for each location, its coefficient of variation ranged from 14 to 44% during the past 35 years. High variability in annual rainfall represents increased risk for farmers who depend on rainfall for crop production.

The major growing seasons in Ethiopia are associated with annual rainfall patterns. The long rains occur roughly from June to September (Kiremt); the short rains occur from March to May (Belg). Most areas in the country experience both the Kiremt and Belg rains with the exception of some areas in the northwest. In the north, Kiremt rains tend to fall earlier, around the end of June, while in the south, they start as late as October (Figure 4.1.6). Although most crop production in the highlands is associated with the Kiremt rains, many communities depend on the Belg season to meet their food needs. Figure 4.1.7 shows the number of months with more than 100 mm of rainfall. Note that the south western highlands get more than seven months of heavy rainfall, while the eastern lowlands get less than two months.

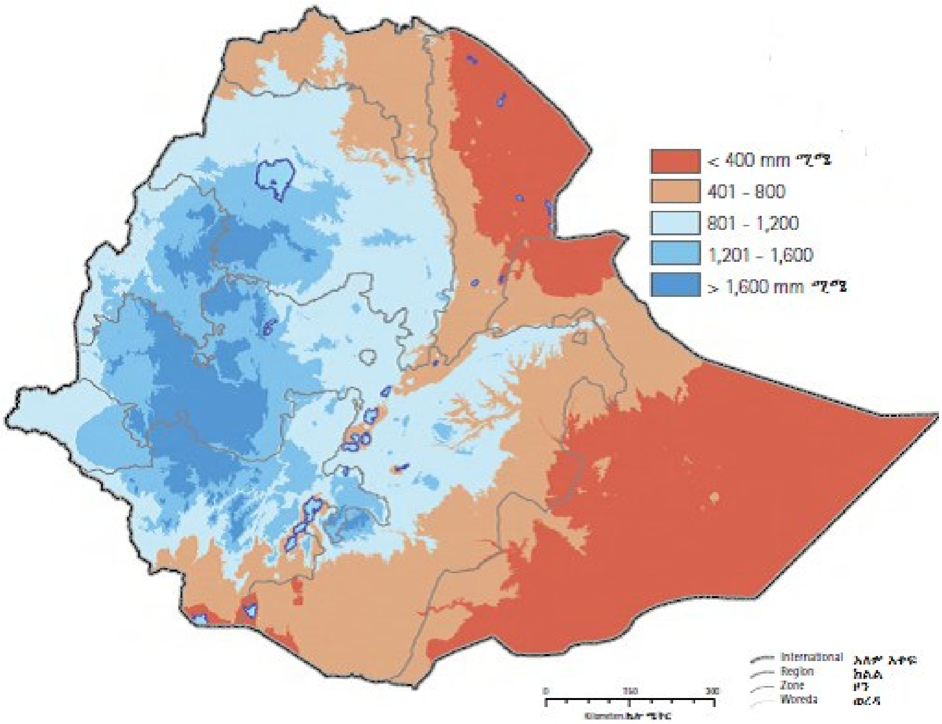


Figure 4.1.4 *Annual rainfall distribution in Ethiopia (Source: IFPRI and CSA, 2006).*

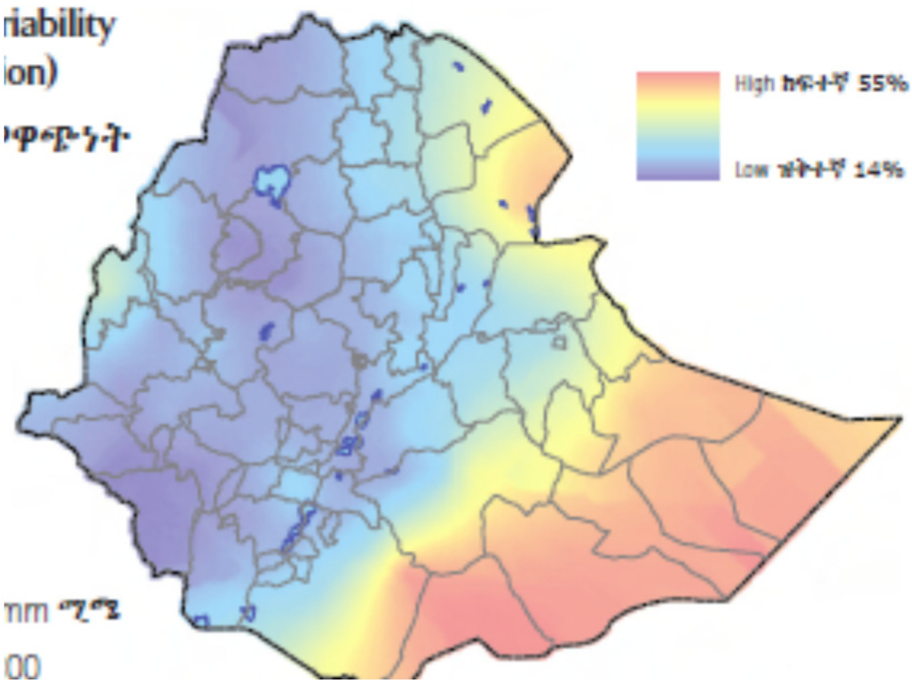


Figure 4.1.5 *Annual precipitation variability (coefficient of variation) in Ethiopia (Source IFPRI and CSA, 2006).*

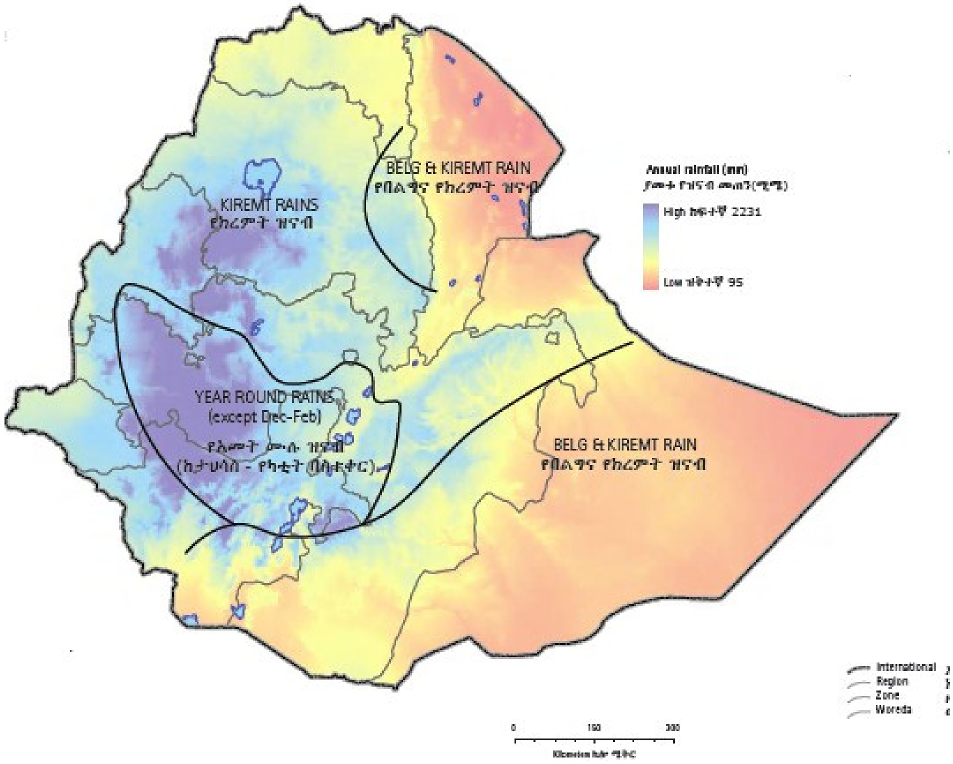


Figure 4.1.6 *Seasonality of rainfall in Ethiopia (Source: IFPRI and CSA, 2006).*

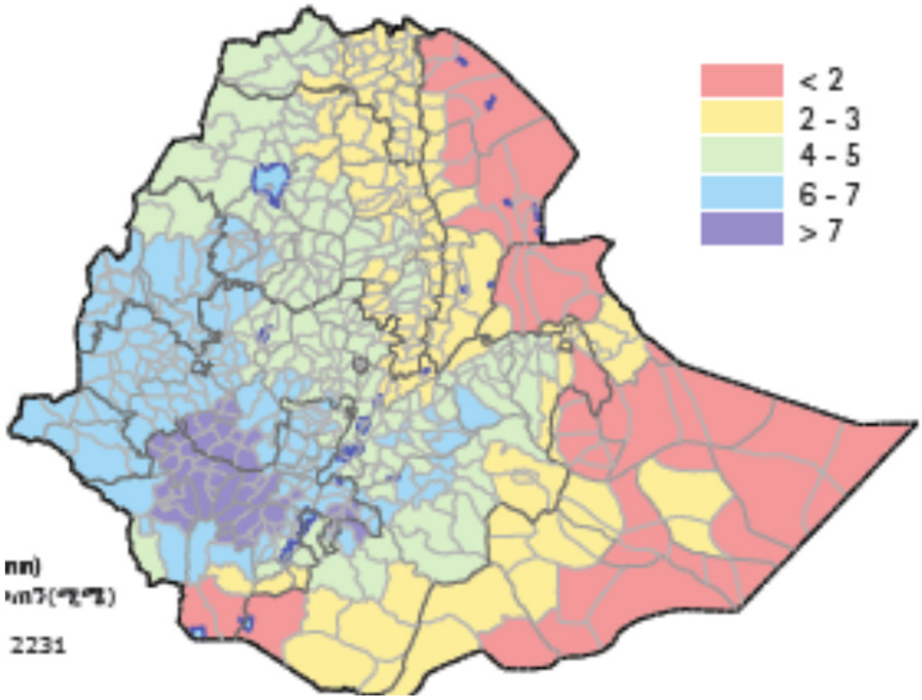


Figure 4.1.7 *Number of months per year with more than 100 mm of rainfall in Ethiopia (Source: IFPRI and CSA, 2006).*

Meteorological data to run the models were taken from the ERA Interim Dataset (Dee *et al.,* 2011). It contained all parameters at a geographically distributed level for model calculations: daily precipitation, evapotranspiration and runoff. In this way we could obtain the percolation flux for the EuroPEARL metamodel, and the daily precipitation and temperature for the PRZM and TOXSWA models. Moreover, this data set had the advantage of being a full data set without gaps, which we were not able to obtain in Ethiopia itself.

Figure 4.1.8 shows the long-term average daily temperatures for the 12 Gregorian calendar months over the past 35 years. It is immediately apparent that variation between different parts of the country at any one time is likely to be much greater than variation over monthly averages for a single location. Variation in temperature is driven mostly by elevation. Because of Ethiopia's location near the equator, seasonal changes in day length and incoming solar radiation are minimal and, consequently, have little impact on average temperatures. The upper parts of Rift Valley and the west and east lowlands have a mean maximum monthly temperature of >25^0C almost throughout the year, while some places in the central highlands have an average temperature of <10^0C.

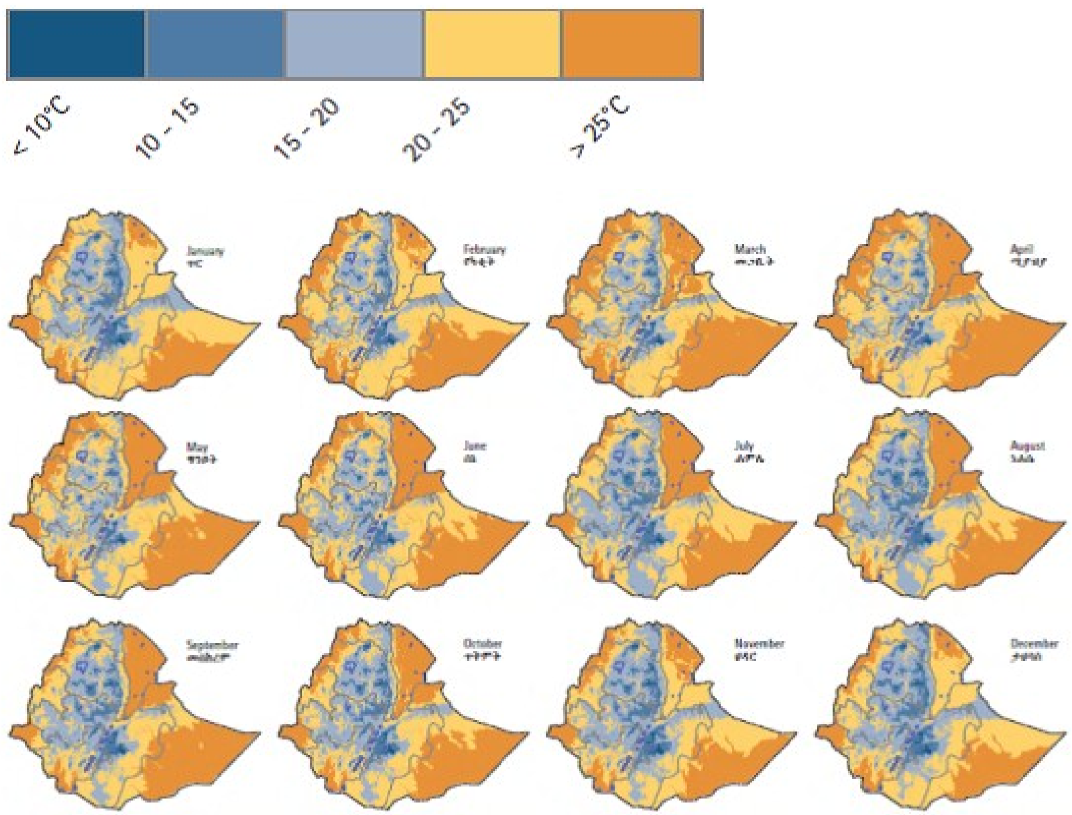


Figure 4.1.8 *Distribution of mean monthly temperature in Ethiopia (Source: IFPRI and CSA, 2006).*

Agro-ecologies can be defined differently in different parts of the world. According to IFPRI and CSA (2006) agro-ecological zones are areas where predominant physical conditions guide relatively homogeneous land use options. Since Ethiopia is located near the equator elevation has a stronger impact on the temperature of an area than rainfall. The traditional agro-ecological classification made elevation as its basis for classification and resulted in six distinct zones (Figure 4.1.9). These zones are widely used by local farmers to classify different localities based on the climatic variations (especially temperature) due to change in elevations (Table 4.1.1).

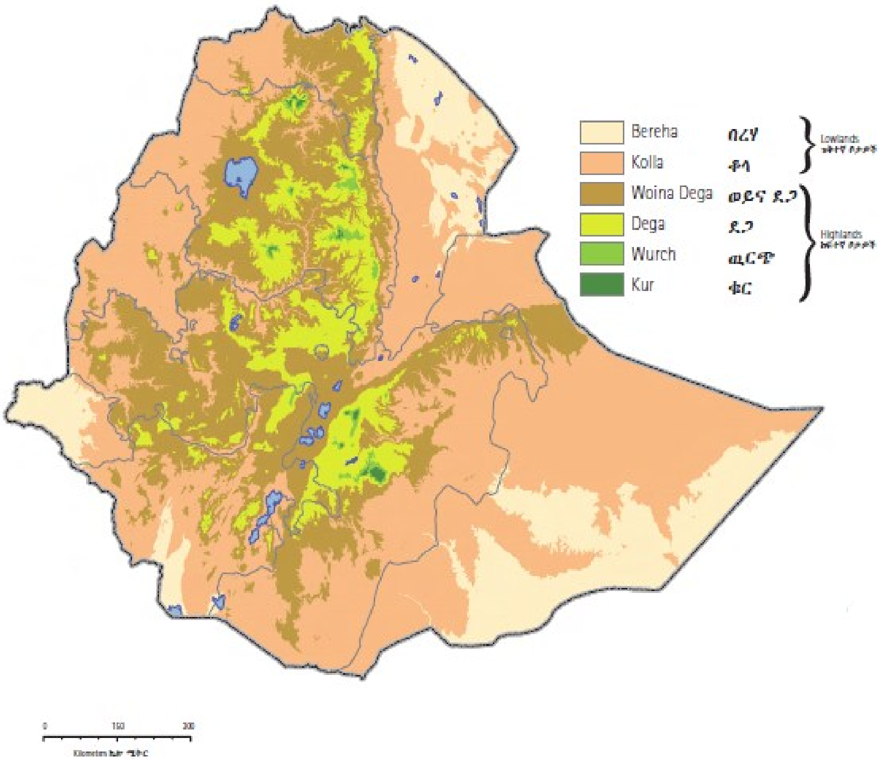


Figure 4.1.9 *Traditional agro-ecological zones in Ethiopia (Source: IFPRI and CSA, 2006).*

Table 4.1.1
Summary of the description of the traditional agro-ecological zones in Ethiopia (Source: IFPRI and CSA, 2006).

Traditional agroecological zone	Description
Bereha	Refers to hot lowlands of less than 500 meters above sea level. In the arid east, Bereha crop production is very limited. In the humid west, mixed root crops and maize are grown.
Kolla	Refers to lowlands between 500 and 1500 meters. Predominant crops here are sorghum, finger millet, sesame, cowpeas, and groundnuts.
Woina Dega	Refers to highlands between 1500 and 2300 meters. Predominant crops here are wheat, teff, barley, maize, sorghum, and chickpeas.
Dega	Refers to highlands between 2300 and 3200 meters. Predominant crops here are barley, wheat, oilseeds, and pulses.
Wurch	Refers to highlands between 3200 and 3700 meters. Barley is common here.
Kur	Refers to highland areas above 3700 meters. These areas are primarily used for grazing animals.

The Ministry of Agriculture and Rural Development of Ethiopia divides the country into 18 major agro-ecological zones, which is often referred to as the modern agro-ecological classification (Figure 4.1.10). Temperature and moisture regimes are used in this classification, reflecting the most important local conditions in determining agricultural options (besides the soil). Each of these zones has characteristic crops found within its boundaries. Some crops are found within several zones; others are restricted to only one or two. In addition to showing the complex mosaic of temperature and moisture patterns across the country, this may highlights fundamentally different production environments across the arid eastern and humid western lowlands and across highlands which are moister in the west than in the north. Water bodies are considered as a single agro-ecological zone in this classification (IFPRI and CSA, 2006).

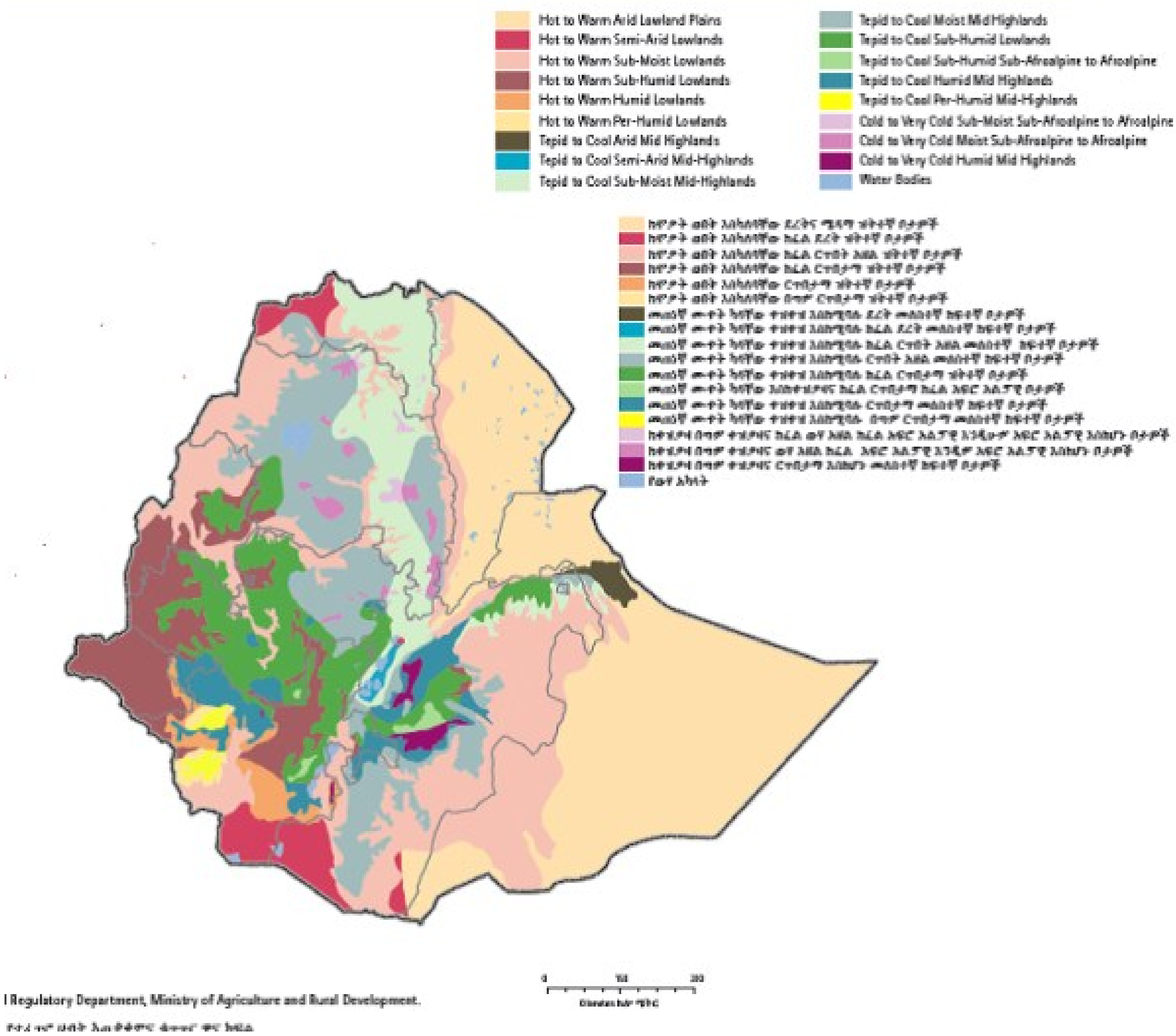


Figure 4.1.10 *Modern agro-ecological zones of Ethiopia (Source: IFPRI and CSA, 2006).*

Based on the inventory above and discussions with the crop expert of the EIAR (Dr D. Gorfu) a first selection of relevant crops for the surface water scenarios was made (Table 4.1.2) and main features of crop cultivation and harvesting have been summarized (aided by Mr Zebdewos Salato Amba of the PHRD). This information may be helpful in establishing e.g. crop calendars or the Runoff Curve Numbers, needed for the runoff calculations by the PRZM model.

Table 4.1.2

Harvesting practices and some other cultivation practices of relevant crops (featuring in the surface water scenarios).

Crops	Practices for harvest and other cultivation activities	Remarks
Tomato (=veg.fruiting)	Tomatoes are picked by hand, 1st time, 2nd time 5-7 d later, sometimes 3rd time. Plant remainings left in the field (no cattle grazing)	Can also be grown in greenhouse
Onion (=veg.bulb)	Whole plant is taken out, bulb is taken, remainder left on the field, no cattle grazing	Can also be grown in greenhouse
Cabbage (=veg.leafy)	Leafy cabbage, stick is remaining in the field; head cabbage: only head is removed, remainder left in the field. After harvest cattle come in for grazing	Can also be grown in greenhouse
Potato	Tubers and plants are taken out, but plant remainings are left on the field until ploughing at first rains. No cattle grazing.	
Teff	Cut by hand with aid sickle, gathered in bunches on the arm and next laid down on field with remaining stubbles. Cattle come in to graze stubbles. Ploughing at first rains	
Wheat	See teff	
Maize	Immediately after harvesting the cobs, the entire stick is taken (roots remain in soil)	
Barley	See teff	
Faba bean (=pulses)	Crop is 80 cm to 1-1.5 m high. Beans picked by hand, crop remainder left in the field, but can be collected: for cattle (threshed pods) or for firewood (sticks). Some remainders are left in the field until ploughing at first rains	
Sweet potato	Tubers and plants are taken out. Leafy parts are collected and fed to cattle. Soon after harvest the field is fallow	
Cotton	Is a perennial crop grown as an annual. Picked several times by hand. Thereafter plant remainders left in the field. For ploughing: first remainder removed, then real ploughing.	
Sugarcane	Crop up to 2 m high. Cut by hand	Pesticides used ? sometimes
Banana	Bunch with bananas cut when nearly ripe	Pesticides used ? no
Citrus (lemon)	Fruits picked by hand	Pesticides used ? sometimes
Coffee	Berries picked by hand	
Pome/stone fruit (represented by mango)	(Large) tree with fruits. Peak harvest: April-June. After harvest older leaves drop during the dry season. At first rains new shoots and leaves are formed. Mango is a strictly perennial crop growing mid to lowlands in Ethiopia, it grows at altitudes b/n 1000-1500 masl, well managed tree stays up to 100 years, it gives yield up to 40 years flowering every two years	
OTHERS (Not in scenarios)		
Chat (chataedulis) (include ??)	Permanent crop, fresh sprouts (leaves) (to chew) during rainy season. Grown widely in highlands. Not picked after pesticide spraying, stays on farm for several years while first harvest is done four years after planting.	Heavy pesticide user, also illegal use of DDT
Flowers (greenhouses)	Picked by hand, bundles gathered on arms worker ?? harvested after planting every two months for several times before the old plant is uprooted and replaced with a new one	

Figure 4.1.11 illustrates the harvesting of the typical Ethiopian crop teff by hand with a sickle and shows its grains.

Figure 4.1.11 *Harvesting of the Ethiopian cereal teff.*

4.2 Ranking of pesticide risk for surface water

The analysis in this section 4.2 as well as in the next section for groundwater was performed to ensure a focus on the relevant crops and cropping systems. In the PRRP-Ethiopia project a risk assessment of pesticides is set up for use in registration, addressing a.o. risks for drinking water produced from surface water and groundwater. The PRRP project limits itself to the agricultural use of pesticides, used according to Good Agricultural Practices. This use of pesticides according to the GAP is evaluated in so-called scenarios during the registration procedure. Scenarios are intended to represent realistic worst case situations of agricultural cropping systems influencing the selected protection goal, which here is drinking water produced from surface water.

The goal of the assessment was to identify the most relevant crops and cropping systems by determining those crops in which the active ingredients with the highest hazard to humans and cattle, using surface water as drinking water, are predominantly used.

Pesticides/actives used for migratory pests (locusts, army worm, quelea bird) were excluded from the analysis, since their use is considered to be non-agricultural, and exposure through surface water after agricultural use is considered unlikely. For the same reason some types of formulations like pellets (aluminium phosphide) and baits (brodifacoum), and actives for indoor use against mosquitoes, cockroaches and flies (DDT, dichlorvos) are not considered to be relevant for the scenarios under development, which do not deal with domestic use or situations in storage warehouses.

The approach consisted of the following steps:

- For each pesticide (uniquely identified by tradename) the total amount of imported or locally produced volume was calculated. These volumes for individual pesticides (products) were available separately for commercial farms, flower farms and locally produced pesticides from data received from the PHRD. Although volumes over 2006 – 2010 were available, only the most recent volumes, i.e. the volumes over 2010, were considered in the calculations. Often a product is mentioned several times in the information available, an example is the product/tradename Zura, which in 2010 was imported by KMS Egga 3 times, with amounts of 69120, 138240 and 207360 liters resp., and imported by KMS Egga Trad and Industry PLC with an amount of 69120 liters. Calculation of the total amount of the pesticide (identified by tradename) was done by constructing pivot tables. The result (totals per product/pesticide) are given in Appendix 4.2.

- For each pesticide the fraction/content of active ingredient is known. This information was originally provided by Berhan Teklu, partly using information provided by the FAO. Since the information was not complete (the content was not known for each pesticide), the information was updated by Deneer by searching the internet for product information for pesticides for which Berhan Teklu had not previously given information. The result is given in Appendix 4.3.
- By multiplying the amount of imported/locally produced pesticide/product by its content of active ingredient, the amount of active ingredient (in kg for 2010) is calculated for each of the pesticides/products. By again constructing pivot tables, but now over the active ingredients, the total sum of each of the active ingredients is calculated over all products (and over commercial/flower/locally produced products). The table below, 3.2.1, gives an overview of the actives with the highest volumes of import/production in 2010. Information about pests and crops in which the actives were used was provided by Berhan Teklu, and mostly taken from FAO's Pesticide Stock Management System (PSMS) form compiled by the PHRD.

Table 4.2.1 gives an overview of the actives with highest volume, and their acute and chronic toxicity (Acute Reference Dose, ARfD, and Acceptable Daily Intake, ADI, resp.) for humans (data taken from Appendix 4.2).

Table 4.2.1
Imported or locally produced actives with highest volumes in 2010.

Active ingredient	Acute toxicity ARfD (mg/kg bw/day)	Chronic toxicity ADI (mg/kg bw/day)	Volume of import/production in 2010 (tons)
2,4-D	0.62[a]	0.05	1823
Glyphosate	3.69[a]	0.30	195
Malathion	0.3	0.03	193
Mancozeb	0.6	0.05	148
Aluminium phosphide	0.032	0.019	110
Endosulfan	0.02	0.006	84.2
Dimethoate	0.01	0.001	57.7
Thiram	0.6	0.01	52.1
Diazinon	0.025	0.0002	46.9
Atrazine	0.1	0.02	39.7
Deltamethrin	0.01	0.01	30.2
Fenitrothion	0.013	0.005	21.6
S-Metolachlor	1.23[a]	0.1	20.2
Carbaryl	0.01	0.0075	19.9

[a] ARfD is estimated from ADI and is relatively uncertain.

The actives contained in the list vary from relatively low toxicity compounds like 2,4-D and glyphosate, which are used as herbicides, to highly toxic compounds like endosulfan, dimethoate and other insecticides. Remarkably, 3 of the chemicals in this list of actives with high volume (diazinon, fenitrothion and carbaryl) are actives used against migratory pests, and are therefore excluded from the analysis. These actives are quite toxic chemicals with relatively high volumes of use in 2010, but in view of their use against migratory pests they are not considered in the process of scenario construction. However, evaluation of the risk of other, agricultural, uses of these actives using the relevant scenario remains feasible. Further compounds removed from Table 4.2.1 were aluminium phosphide, which is used against storage pests, and thiram, which is used as a seed treatment, i.e. not sprayed, resulting in Table 4.2.2 giving relevant actives with the highest volumes in 2010.

Table 4.2.2

Imported or locally produced actives with agricultural use with highest volumes in 2010.

Active ingredient	Crop	Pest	Volume of import/production in 2010 (tons)
2,4-D	Cereals, wheat, maize, teff	Broad leaf weeds	1823
Glyphosate	Coffee (weeds under trees)	Broad leaf weeds	195
Malathion	Sweet potato	Sweet potato butterflies	193
Mancozeb	Potato[a]	Blight	148
Endosulfan	Cotton	African bollworm	84.2
Dimethoate	Barley	Aphids	57.7
Thiram		Seed treatment	52.1
Atrazine	Maize	Complex weeds	39.7
Deltamethrin	Cotton	African bollworm, leafhoppers	30.2
S-Metolachlor	Haricot beans	Broad leaf weeds	20.2

[a] 'Potatoes' denotes 'Irish potatoes', distinguishing them from 'sweet potatoes'.

- The next step in the analysis, establishing a ranking according to toxicity for humans/cattle, was performed by dividing the imported/produced volume (2010) by either the Acute Reference Dose (ARfD) for an evaluation of acute toxicity, or by dividing the volume by the Acceptable Daily Intake (ADI) for an evaluation of chronic toxicity. For many of the compounds the acute toxicity (ARfD) was not readily available, and was estimated from their ADI by using the average ratio between ARfD and ADI from all compounds for which both were available. Compounds rapidly degrading in water (with a half-life of 2 or less days) were considered to be irrelevant for chronic risk evaluation. Since they rapidly disappear from water, chronic exposure resulting from agricultural use is considered unlikely. The data contained only four compounds with an ADI above 3 mg/kg/day, and a priori exclusion of compounds of low chronic toxicity, irrespective of their volume, was therefore considered infeasible and all compounds except irrelevant formulations and actives used against migratory pests, were therefore included in the analysis. Properties of the actives (ARfd, ADI, DT50 in laboratory water/sediment systems) are given in Appendix 4.4.

The ranking according to acute risk is given in Table 4.2.3, whereas Table 4.2.4 gives the ranking according to chronic risk, i.e. based on the ratio between imported volume and ADI.

Table 4.2.3

The 10 active ingredients with highest acute risk, based on the ratio of 2010 volume and acute reference dose (ARfD).

Active ingredient	Volume 2010 (tons)	ARfD (mg/kg bw/day)	Volume / ARfD (10^3 units)	Remarks
Dimethoate	63	0.01	6247	
Endosulfan	84	0.02	4208	
Deltamethrin	30	0.01	3024	
2,4-D (amine)	1824	0.62[a]	2964	Estmtd ARfD
Malathion	193	0.3	642	
λ-Cyhalothrin	3	0.0075	403	
Atrazine	40	0.1	397	
Abamectin	1.4	0.005	285	
Mancozeb	148	0.6	247	
Oxamyl	0.23	0.001	232	

[a] Estimated from ADI, and possibly too high.

Table 4.2.4

The 10 active ingredients with highest chronic risk, based on the ratio of 2010 volume and acceptable daily intake (ADI).

Active ingredient	Volume 2010 (tons)	ADI (mg/kg bw/day)	Volume / ADI (10^3 units)	Remarks
Dimethoate	63	0.001	62471	
2,4-D (amine)	1824	0.05	36471	High ADI
Endosulfan	84	0.006	14025	
Malathion	193	0.03	6422	
Deltamethrin	30	0.01	3023	
Mancozeb	148	0.05	2959	High ADI
Atrazine	40	0.02	1983	
Dicofol	2	0.002	947	
Clodinafop	3	0.003	938	
Chlorpyrifos	8	0.01	801	

Apart from a number of relatively non-toxic herbicides and fungicides with high volumes (2,4-D, atrazine, mancozeb), the actives with highest acute risks are highly toxic insecticides. In view of their high toxicities, the most interesting actives are dimethoate, endosulfan and deltamethrin, which are predominantly used in barley (dimethoate) and cotton (endosulfan and deltamethrin).

The actives with highest chronic risks are, apart from the high-volume 2,4-D herbicide, the same insecticides that scored highest on acute risk (dimethoate, endosulfan, deltamethrin), with the addition of malathion, which is predominantly used in sweet potatoes.

An alternative analysis of chronic risk was performed by not using the national volume of actives as a measure of use/risk, but by dividing the application rate of an application (calculated as the rate of a single application multiplied by the number of applications) by the ADI. Application rates were taken from Berhan Teklu's list of registered pesticide, or from the website www.fytostat.nl, which gives details about Dutch registrations. This measure of 'local chronic risk' gives slightly different information, since it is directly related to the use of the active during a single application of the pesticide in the field. Table 4.2.5 presents the results of this analysis.

Table 4.2.5

The 10 active ingredients with highest local chronic risk, based on the ratio of application rate (kg/ha) and Acceptable Daily Intake (ADI).

Active ingredient	Application rate (kg/ha)	ADI (mg/kg bw/day)	AR / ADI	Remarks
Metam-sodium	153	0.001	153000	Soil desinfectant, greenhouse use?
Oxamyl	4	0.001	4000	Nematicide, greenhouse use?
Dimethoate	0.4	0.001	400	
Propineb	1.425	0.007	204	
Endosulfan	0.78	0.006	131	
Beta-cyfluthrin	0.31	0.003	104	
Thiophanate-methyl	0.75	0.08	94	
Chlorothalonil	1.24	0.015	82	
Propyzamide	1.5	0.02	75	
Acephate	1.88	0.03	63	

Oxamyl, dimethoate, endosulfan, beta-cyfluthrin rank high on this list because of their relatively high toxicity, whereas metam-sodium and propineb rank high because of the combination of high application rate and high toxicity.

The actives scoring high on either acute, chronic and local chronic risk, or a combination thereof, are given in Table 4.2.6, together with the crops they are mostly associated with.

Table 4.2.6
Active ingredients with highest acute, chronic and/or local chronic risk.

Active ingredient	Crops	Volume (2010, tons)	ADI (mg/kg bw)	Criterion
Dimethoate	Barley, french beans	63	0.001	Acute, chronic, local
Endosulfan	Cotton	84	0.006	Acute, chronic, local
Deltamethrin	Cotton, flowers, cereals, maize, potato[a], cabbage	30	0.01	Acute (chronic)
2,4-D	Wheat cereals, maize, teff	1824	0.05	Acute, chronic
Metam-sodium	? Soil disinfectant	0.9	0.001	Local
Oxamyl	? Nematicide	0.23	0.001	Local
Beta-cyfluthrin	? Similar to deltamethrin	0.02	0.003	Local
Propineb	Flowers	0.51	0.007	Local

[a] 'Potatoes' denotes 'Irish potatoes', distinguishing them from 'sweet potatoes'.

For metam-sodium and oxamyl no specific information with regard to crops could be retrieved. Similarly, for beta-cyfluthrin no information was found with regard to the crops in which it is used, but it is assumed that these crops will be very similar to the crops relevant for deltamethrin.

Overall, insecticides (dimethoate, endosulfan, deltamethrin, beta-cyfluthrin) appear in the list because of their high toxicity, whereas the herbicide 2,4-D is in the list because of its high volume. The fungicide propineb is in the list because of the combination of high application rate and high toxicity.

The main crops associated with these actives are barley, cotton, wheat, maize, teff, flowers, potatoes and French beans. As already stated previously, some high toxicity actives are not considered and do not appear in this list because of their use against migratory pests. Flowers are often cultivated in greenhouses and within the PRRP project no environmental risk assessment for cultivation in greenhouses was developed.

These crops, possibly amended by crops with high acreage (horticulture and floriculture) can serve as a basis for identifying the most relevant cropping systems, and the development of scenarios for risk of surface water used as drinking water by humans and cattle.

The analysis is summarized in Appendix 4.5.

4.3 Ranking of pestide risk for groundwater

Apart from surface water, large amounts of ground water are used in the production of drinking water. Therefore leaching of pesticides into ground water may pose a risk for humans in situation where this ground water is used as a basis for drinking water.

Similar to the assessment performed for surface water, the present goal was to identify the active ingredients with the highest possibility of leaching into ground water, and to identify the crops in which these actives are predominantly used. Moreover, the suitability of the method used to estimate leaching potential is addressed, possible pitfalls are identified, and the feasibility of integrating leaching into risk assessment is discussed.

As in the risk assessment for surface water, pesticides/actives used for migratory pests (locusts, army worm, quelea bird) were excluded from the analysis, since their use is considered to be non-agricultural. For the same reason some types of formulations like pellets (aluminium phosphide) and baits (brodifacoum), and actives for indoor use against mosquitoes, cockroaches and flies (DDT, dichlorvos) are not considered to be relevant for the scenarios under development, which do not deal with domestic use or situations in storage warehouses.

The analysis is based on the list of actives, previously derived for the ranking of risk in surface water. For each of these actives physico-chemical properties (K_{om}, pKa, DT50 in soil) were obtained from the Pesticides Properties Database (http://sitem.herts.ac.uk/aeru/footprint/en/). For the estimation of leaching potential the EuroPEARL meta-model for leaching (Tiktak *et al.,* 2006, described in more detail in the scenario development section) was used, choosing coefficients appropriate for a wet and warm meteorological scenario. The calculation resulted in leaching concentrations which were then compared to the chronic toxicity (assuming that a person of 50 kg body weight consumes 5 litres of ground water contaminated with the pesticide), and to the threshold level of 0.1 μg/L used in European legislation with regard to ground water.

A substantial drawback of the EuroPEARL meta-model is that it was devised to deal with European soils, which tend to carry a negative charge at low pH. Tropical soils, however, tend to be charged positive at lower pH, and this positive charge will result in increased leaching of bases. The net result is that the leaching of bases, i.e. compounds charged positive at low pH, will be underestimated. There is currently no suitable method to correct for this in an acceptable way. The only practical way to circumvent this shortcoming of the EuroPEARL meta-model is:

- For bases always demand sorption studies with Ethiopian/tropical soils;
- Or use a conservative approach by assuming no sorption at all and demanding sorption studies for cases where the risk thus estimated is not acceptable.

However, to effectively use this approach, there should be a reliable procedure in place to identify bases, i.e. to be able for a given compound to categorize it as a basic, acidic or neutral compound.

Of the 165 compounds in the list of actives 35 were considered to be bases, using expert judgement appraising their chemical structure, and values for pKa given by Tomlin (2003). Of the 35 bases, 24 are expected to be charged to a substantial part at soil pH between 4 and 7. For these 35 bases a K_{om} of 0 was assumed, i.e. assuming no sorption at all. For all other compounds, i.e. the non-basic compounds, the calculation of the leaching concentration using the PEARL meta-model was performed using values K_{om} and DT50 as found in the Pesticides Properties Database (see Appendix 4.4; K_{om} was calculated from K_{oc} as $K_{om} = K_{oc} / 1.724$).

The calculation assumed a yearly precipitation of 1500 mm/year, and an average soil temperature of 20°C. A relatively low organic matter content of the soil (4.5% OM) and soil moisture at field capacity of 0.25 l/kg were assumed. For each of the actives a net soil deposition of 1 kg/ha was assumed. A conservative estimate of daily intake of the active from ground water was calculated by assuming that a person of 50 kg daily consumes 5 litres of contaminated water. Hence, the amount of active contained in 5 litres of water was compared to the acceptable daily intake for a person of 50 kg body weight (ADI_50kg, equal to 50 * ADI). Appreciable risk is assumed when the daily intake exceeds 0.1 * ADI_50kg. Detailed results for all actives are given in Appendix 4.6.

The calculations indicated that of the 24 partly charged bases, 10 exceeded the threshold level of appreciable risk corresponding to 10% of the ADI when assuming no sorption of these basic compounds. This indicates that a better estimate of K_{om} is needed for such compound to avoid overestimation of their leaching potential.

In view of the high uncertainty in the outcome of the leaching concentrations for bases, it was decided to exclude these compounds from the assessment, and to limit the assessment to non-bases only. For the remaining compounds, leaching concentrations were estimated using the same conditions of annual rainfall, soil temperature, soil organic matter content and soil moisture at field capacity as previously given. Several compounds showed severe leaching potential, some even having concentrations in ground water potentially rendering it hazardous as drinking water; three compounds were found to exceed the threshold of 0.1 ADI_50kg: flutriafol, omethoate and myclobutanil (Table 4.2.7). There were however several more compounds with a leaching concentration above

0.1 µg/L and a volume (in 2010) above 1 ton/year (Table 4.2.7). Concentrations in ground water used for drinking water may thus be significant and it is certainly worthwhile to consider leaching to ground water in regulatory scenarios.

Table 4.2.7
Active ingredients with high (> 0.1 µg/L) leaching concentrations.

Active ingredient	Leaching concentration for 1 kg/ha net soil deposition (µg/L)	Volume (2010, kg)	ADI (mg/kg bw)	Daily Intake / ADI_50kg
Flutriafol	86.2	75	0.01	0.86
Omethoate	0.89	148	0.0003	0.30
Myclobutanil	55.3	15	0.025	0.22
Thiamethoxam	24.4	21	0.026	0.094
Atrazin	4.24	39652	0.02	0.021
Triadimenol	9.85	7500	0.05	0.020
Dinotefuran	39.7	2	0.22	0.018
Metamitron	4.70	25	0.03	0.016
Imidacloprid	7.97	312	0.06	0.013
Methoxyfenocide	10.8	50	0.1	0.011
Oxamyl	0.105	232	0.001	0.010
Propiconazole	1.13	6379	0.04	0.003
Fenarimol	0.187	83	0.01	0.002
Cyproconazole	0.374	5	0.02	0.002
Oxycarboxim	0.933	285	0.15	0.001
Flumetasulam	14.3	180	-	-

The leaching concentrations were calculated assuming a net soil deposition of 1 kg/ha. If an active is in practical situations used in scenarios with several applications, the calculated risk given will underestimate the actual risk because multiple applications are not accounted for in the calculation. For applications with a lower application rate, and hence a lower net soil deposition, the actual risk is overestimated.

Constant values for yearly rainfall (1500 mm/year), a soil temperature of 20^{o}C, soil organic matter (4.5%) and soil moisture at field capacity of 0.25 l/kg were used in the calculations, and the choice of these values has a noticeable effect on the outcome of the calculations. Choosing 800 mm/year rainfall, combined with an average soil temperature of 10^{o}C will result in the same rank of compounds, but leaching concentrations are approximately 3-fold lower. Similarly, lowering soil organic matter to 2.5% will also result in the same rank of compounds, but with 2.5-fold higher leaching concentrations. Changing soil moisture content from 0.25 l/kg to 0.40 l/kg will result in the same rank for top-10 compounds, with compounds in ranks 11 – 20 having slightly changed order.

The analysis is summarized in Appendix 4.7.

5 Identification of scenario zones and drinking water protection goals

5.1 Choice for scenario zones

A scenario can be defined as a unique combination of agronomic and environmental conditions (such as climate, hydrogeology, surface water characteristics, soil and topography), that realistically represents significant areas within which conditions are relatively homogeneous with respect to modelling input parameters (FOCUS, 1996). A scenario zone corresponds to a geographic area, that is represented by the scenario. As explained in Chapter 3 scenarios represent 'realistic worst case' exposure situations, and these may relate to the entire country or parts of it. It is a political decision to opt for one scenario representing the entire country, or to divide the country into more scenario zones. Having more than one scenario zone in the country creates more flexibility in the registration procedure, compared to using only one scenario covering the entire country. E.g. in the Netherlands there is only one 90th percentile leaching concentration representing the entire Netherlands, implying that if this 90th percentile leaching concentration of a compound does not meet the required standard, the compound will not be admitted in the Netherlands. At EU level a deliberate choice was made for 10 surface water scenarios to avoid creating a rigid system: at present if a compound fails to fulfil the standard at 8 scenarios, but does full the required standard at 2 scenarios, the active ingredient will still be placed at Appendix I (and next, the individual Member States of the EU may decide upon the registration of the formulated product of the active ingredient concerned). On the other hand, having more than one scenario zone introduces more complexity into the registration procedure and the procedure may be more difficult to uphold, e.g. a compound may be registered for use in some parts of the countries, but not in others, or it may be registered with restrictions on its use.

Awaiting the approval of the Pesticide Advisory Board representatives of the PHRD of the Ministry of Agriculture, the Federal Environmental Protection Authority, the Ethiopian Institute for Agricultural Research, the Addis Ababa University, the Ethiopian Conformity Assessment Enterprise and the Institute of Biodiversity Conservation opted for two scenario zones: below and above 1500 m altitude. This division corresponds to a well-known division in the definition of the traditional agro-ecological zones: below 1500 m the agro-ecological zones Bereha and Kolla feature while above 1500 m the zones Woina Dega, Dega, Wurch and Kur feature. Moreover, this division is consistent with the division used in the PRRP project for Efficacy testing under various climatic conditions. In this way the large variation in agro-environmental conditions in Ethiopia was accounted for, while keeping efforts necessary for scenario development within reasonable limits.

It is important to make a choice for the scenario zones in an early stage of the scenario development procedure, because the scenario zones define implicitly the population of scenarios out of which the scenario has to be selected that represents the e.g. 99th %ile probability of occurrence in time and space across each scenario zone. E.g. if there is one scenario zone only one 99th-%ile situation represents the entire country, while in case of more scenario zones, a 99th-%ile situation need to be developed for each scenario zone. So, more scenario zones require also more work.

Description of types of farms and associated spraying and irrigation practices and crops in the two scenario zones
Smallholders may be found both in the scenario zone above 1500 m altitude and below 1500 m altitude (Figure 5.1.1). Smallholders mostly use knapsack spraying, whereas ultra-low-volume (ULV) spraying is becoming less common. Smallholders often spray pesticides in the form of spot application instead of treating the entire field. Vegetable farmers in the Rift valley are known to apply such spot applications many times (up to 20 times) within a growing season. Typically, knapsack sprayers are used with nozzles 30 – 50 cm above the crop, but sometimes spraying underneath leaves is applied.

Large scale farms occur in both scenario zones, above and below 1500 m, but mostly below 1500 m (Figure 5.1.1). In the lowlands they are installed along the major rivers, which they may use for irrigation, sometimes with the aid of a well-established irrigation infrastructure. So, the rivers are usually the major sources of irrigation water. Furrow irrigation is very widespread. Water runs through furrows over fields. In nitosoils often closed furrow irrigation, using relatively narrow plant beds, is employed, whereas vertisols typically use broad bed drainage. For obvious reasons irrigation is usually not employed during the rainy seasons. Irrigation is employed on a large scale in arid and semi-arid areas. In the areas close to the large rivers, alluvial, fertile soils are present and because the area is flat mechanization may be achieved relatively easily.

In the highlands above 1500 m large scale farms are less common and in general rain-fed cereals are cultivated. They may use knapsack, aerial and tractor-mounted spraying devices. In orchards motorized sprayer equipment is used.

Types of farming in scenario zones

Smallholders
- these are evenly distributed across scenario zone >1500 m,
- these are evenly distributed in zone 1000-1500 m in scenario zone < 1500 m

Large Scale Farms (LSFs)
- these occur in both scenario zones, irrigated, along major rivers (4, 5 up to max 10 km away)
(dominant < 1500 m because big rivers, flat, fertile alluvial, less >1500 m, may be irrigated, mostly rain fed, mostly cereals)

Figure 5.1.1 *Type of farming systems in the two scenario zones in Ethiopia.*

Exposure calculations in the scenario zones are not only dependent on meteorological data, but may also be influenced by the crop for which the calculation is performed (i.e. the crop in which the pesticide is intended to be used). Therefore it is important to establish realistic combinations of scenario zones and crops grown in these zones. So, once the scenario zones were established, a selection of relevant crops was made. The following combinations of scenarios, zones and crops were established:

- For large scale farms above 1500 m elevation, the most relevant crops are considered to be cereals (wheat, barley, maize) and also pulses (faba beans, field pea, French beans, chick pea), coffee, citrus and vegetables (onions, tomato, pepper, cabbage, French beans). Below 1500 m elevation the most relevant crops are sorghum, sesame, French beans, sugar cane, cotton, maize, citrus, sweet potatoes for planting material and vegetables (onions, tomato, pepper, cabbage, French beans) (Figure 5.1.2).
- For small-holder farms above 1500 m elevation, the most relevant crops are all vegetables, teff, maize, wheat, barley, potatoes, pulses and lentils and pome/stone fruits. Below 1500 m elevation (specifically between 1000 and 1500 m) the most important crops are teff, wheat, maize, barley, vegetables, bananas and mango. Coffee is grown as well, but in view of low pesticide consumption is not considered very relevant (Figure 5.1.3).

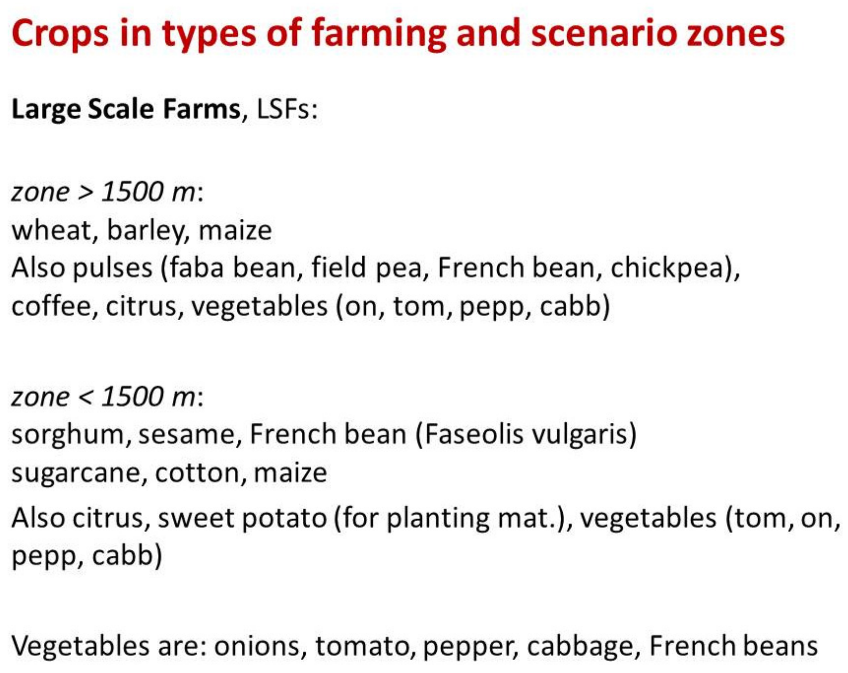


Figure 5.1.2 *Crops in the two scenario zones in Ethiopia for Large Scale Farms.*

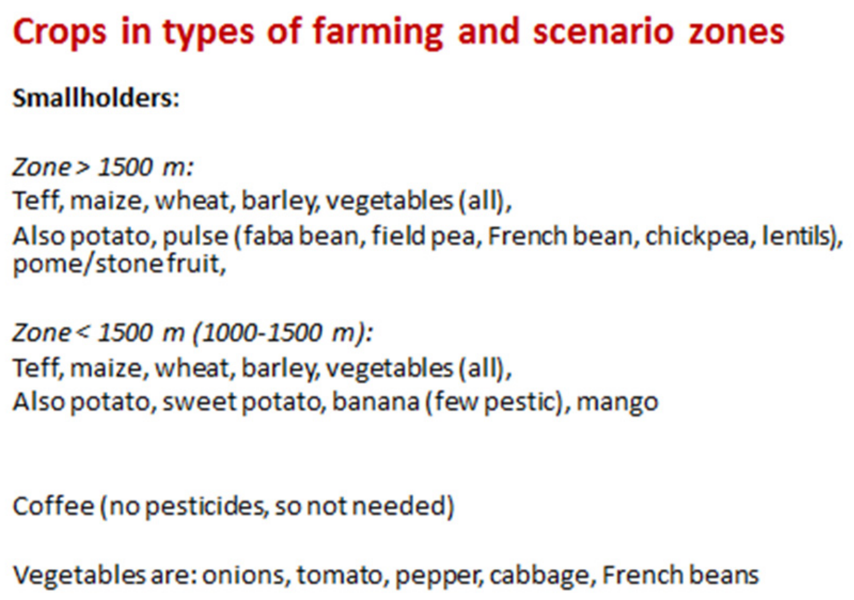


Figure 5.1.3 *Crops in the two scenario zones in Ethiopia for smallholders.*

5.2 Groundwater

5.2.1 Options for protection goals and selection

The Ethiopian population might be exposed to pesticides via contaminated groundwater used for drinking water production. Therefore groundwater used for the production of drinking water was identified as one of the protection goals for Ethiopia, tolerating no human toxicological effects in any groundwater in Ethiopia used for drinking water production. Next to defining what to protect and how strict (see Chapter 3) it is important to define where (i.e. which groundwater system; type of aquifer or hydrogeological system and at which depth) to protect the groundwater. With respect to the 'where question' we identified four options for groundwater protection goals in Ethiopia with the aid of Mr. Engida Zemedagegenhu of the Water Works Design and Supervision Enterprise of Ethiopia:

1. Alluvial aquifers along small rivers
2. Volcanic aquifers of shallow wells
3. Alluvial aquifers at the Rift Valley margins and lowlands
4. Fractured basement rocks of shallow wells

These four options are ranked according to their vulnerability; i.e. Alluvial aquifers along small rivers is the most vulnerable protection goal. In the PRRP-Ethiopia project scenarios are developed and parameterized for options 1, 2 and 3.

As target variable the annual average leaching concentration at 1 m depth was selected. This is in line with the operational definition for the concentration in groundwater used in FOCUS (2000).

The protection goals defined above are restricted to the problem of groundwater contamination due to the use of pesticides according to Good Agricultural Practices (GAP). Problems of contaminated groundwater because of construction errors in groundwater wells, or insufficient protection against point sources (cleaning pesticide application equipment) cannot be tackled by registration authorities and are therefore not considered for defining the groundwater protection goals.

5.2.2 Conceptual models for protection goals and association to scenario zones

Conceptual models of the three protection goals selected for scenario development are discussed below. The groundwater system i.e. the hydrogeological situation is described and landscape characteristics and main cropping systems are given.

5.2.2.1 Alluvial aquifers along small rivers

Figure 5.2.1 gives a graphical representation of the groundwater protection goal Alluvial aquifers along small rivers. Groundwater is pumped up from hand-dug wells with a minimum depth of 3 m and an average depth of approx. 15 m. The wells are located in alluvial deposits next to small rivers. These alluvial deposits with usually at least 3 m of clay on top of the alluvial layer are found in depressions in the landscape. The underlying rocks are fractured basaltic and volcanic rocks and this same type of rock is found in the higher areas surrounding the depression with the alluvial deposits. Most of the water supplying the rivers flows through these fractured rocks from the higher areas to the alluvial deposits. During the dry season from January to May/June the wells will often fall (almost) dry (5-10 L/s remaining). Agricultural fields (dominant crop is cereals) are found near the rivers and the wells. There is also some agriculture found in the higher areas. Groundwater production from the wells is approx. 1-2 m^3/d, corresponding to about 50 people using 20 L/d. This means that the intake area is approx. 800 m^2, so there is no dilution of infiltrating clean water from non-treated fields outside the intake area. This protection goal is mainly found above elevations of 1500 m and therefore only relevant for the scenario zone above 1500 m.

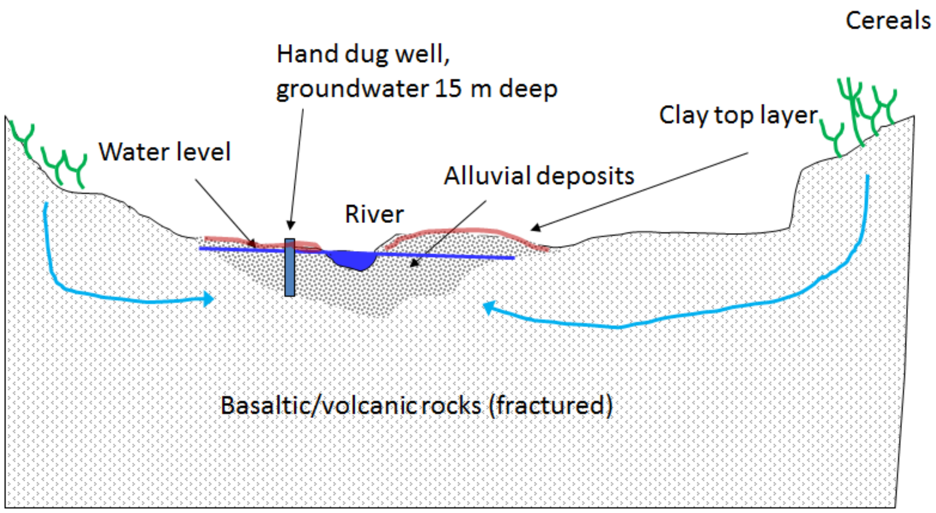


Figure 5.2.1 *Conceptual model of groundwater protection goal Alluvial aquifers along small rivers.*

5.2.2.2 Volcanic aquifers with shallow wells

Figure 5.2.2 gives a graphical representation of the groundwater protection goal Volcanic aquifers with shallow wells. This protection goal is often found in the vicinity of the protection goal Alluvial aquifers along small rivers. Groundwater is pumped up from drilled wells with a minimum depth of 50 m and up to 100 m deep. The wells are located in lower laying areas and the aquifers in which they are found consist of fractured volcanic rocks. Filters are placed near a fault line. Water flows from the higher laying areas (same aquifer type) to the wells. These higher grounds are usually cropped with agricultural crops (cereals are the dominant crop), but they may also be barren where the top soil is rocky. In cases where these areas are cultivated, crops might grow on terraces. This is probably the most vulnerable situation and becomes more commonplace, however not yet in the Rift Valley. The wells are motorized and supply groundwater for approx. 500 to 1000 people with groundwater. Assuming a consumption of 20 L/d per person, the total yield of the well is about 20 m^3/d (10 000 m^3/yr). This yield corresponds to an intake area of approx. 2 ha (500 mm infiltrating excess water per year). This implies that there is no dilution of infiltrating clean water from non-treated fields outside the intake area. Cereals are the dominant crop, but pulses (faba bean) are also found. The wells are almost found exclusively above 1500 m and they are therefore only relevant for the scenario zone above 1500 m.

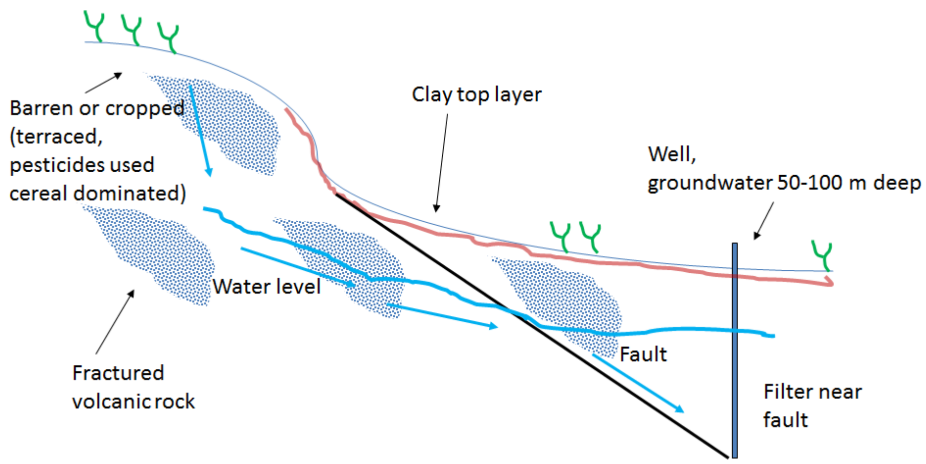


Figure 5.2.2 *Conceptual model of groundwater protection goal Volcanic aquifers on shallow wells.*

5.2.2.3 Alluvial aquifers at Rift Valley margins and in lowlands

Figure 5.2.3 gives a graphical representation of the groundwater protection goal Alluvial aquifers at the Rift Valley margins and lowlands. Groundwater comes from artesian wells (2-3 m deep) or is pumped from up from wells from 3 m depth (hand-dug) up to 230 m deep (drilled), with water levels up to 200 m depth. The most vulnerable wells are the shallow hand-dug wells nearby surface water bodies. The wells are found in alluvial aquifers in large lower areas. Towards the margins of these lower grounds higher areas with volcanic rocks are found. The aquifers consist of a clay layer on top of sand and gravel layers. Towards the higher areas, the clay layer on top becomes less thick and the sand and gravel layers come to the surface. The groundwater in the aquifer is recharged by runoff from volcanic rocks at the higher grounds, percolated rain or infiltration from rivers and/or spate irrigation. The intake area may be very large, up to thousands of hectares, with the entire area cultivated. However, a lot of variation is possible. Dominant crops are cotton, sugar cane, vegetables and teff. The wells are found both below 1500 m and between 1500 – 2000 m. Therefore scenarios for this protection goal were developed for the scenario zone below 1500 m and the scenario zone above 1500 m.

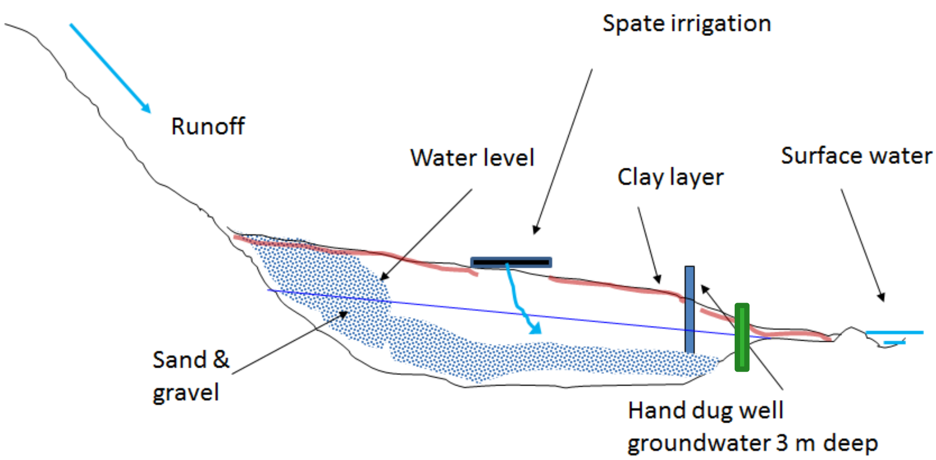


Figure 5.2.3 *Conceptual model of groundwater protection goal Alluvial aquifers at Rift Valley margins and in lowlands.*

5.3 Surface water

5.3.1 Options for protection goals, selection and association to scenario zones

Drinking water produced from surface water was selected as a priority protection goal. No human toxicological effects are to be tolerated by obtaining drinking water produced from surface water from the following types of surface water located across Ethiopia.

Types of surface water bodies and their location

Relevant types of surface water bodies used for drinking water production as well as the location where they can be found were assessed.

The following five types of surface water were listed as sources of drinking water at risk for contamination by pesticides:

1. River type: streams or small rivers near villages in rural areas. These streams are widespread in Ethiopia, except in the drier eastern part of the country. When no groundwater wells are present for drinking water production, these streams are used by the population as a source of drinking water. Agriculture or horticulture using pesticides may result in contamination of the stream. As the streams are small, they are relatively vulnerable for pesticide contamination.
2. Pond/lake type: temporary stagnant ponds are formed during the rainy season which are used for cattle drenching during the dry season. These types of ponds occur in eastern parts of Ethiopia,

but also in the Rift Valley. It is less likely to find these types of ponds in western parts of Ethiopia as rainfall is abundant there, so streams and small rivers do not dry out after the main rainy season. As horticulture or agriculture may be close to these ponds they are vulnerable to pesticide contamination. Sometimes the ponds are also used for human consumption.

3. Rift Valley lakes: The population density is relatively high in the Rift Valley, but in most areas its groundwater is brackish, and unsuitable for drinking water production. Therefore the lakes may be used as source of drinking water. Because of their size, the Rift Valley lakes are judged to be less vulnerable than the streams or temporary ponds.
4. River Awash. This river is increasingly used for production of drinking water in the Rift Valley.
5. Dammed lakes. Lake Koka and Lake Ziway are at present the only two dammed lakes used for the production of drinking water. The Tandaho dam near Dupti is now under construction and is near a cotton growing area.

Selection and coupling to scenario zones
Priorities were set regarding the types of surface water bodies for which risks should be assessed. It was feasible to work out the risks for two types of surface water bodies only and it was decided to consider the small rivers/streams as well as the temporary ponds, because they were judged to be more vulnerable than the other three surface water bodies with their higher volumes and consecutive dilution.

It was established in which scenario zones the streams/small rivers and the temporary ponds occur. Based on expert judgement of representatives of especially Water Work Design and Supervision Enterprise Ethiopia and the Ethiopian Institute of Agricultural Research streams/small rivers were judged to occur only in the scenario zone above 1500 m, while the temporary ponds occur in both scenario zones: (i) the scenario zone above 1500 m, but not above 2000 m and (ii) the scenario zone below 1500 m, but receiving more than 500 mm rainfall per year.

Detailed exposure scenarios will therefore be developed for:
1. Streams/small rivers in areas above 1500 m altitude and
2. Temporary ponds in
   a. areas below 1500 m altitude, receiving at least 500 mm rain (long-term annual average value) and
   b. areas between 1500 and 2000 m.

For the streams/small rivers and the temporary ponds conceptual models were drawn (Figure 5.3.1 and 5.3.2). For the Rift Valley lakes a simple conceptual model was also made (Figure 5.3.3), whereas for the two remaining types of water bodies no conceptual models were made.

5.3.2 Conceptual models for protection goals

The conceptual model of the surface water bodies consist of a description plus a sketch. Ideally the conceptual model should contain all information relevant to determine the exposure to the pesticides. If two fundamentally different situations exist for one protection goal and it is a priori not evident which situation represents the ‘realistic worst case’ situation, then it may be necessary to design two conceptual models for this single protection goal.

A conceptual model for a surface water body may contain the following components:
lay out of the situation, e.g. catchment size, size of adjacent field or surrounding fields, dimensions of water body, which fields treated;
farm types (smallholders of large-scale investment farms) and their characteristics such as size or cultivation techniques;
land use: cultivated crops with their crop calendar and main crop management activities
entry routes of pesticides;
application techniques used and
relevant pesticide processes, especially those that are exceptional or country-specific.
As the risk assessment at the pesticide registration stage is based upon Good Agricultural Practice (GAP) the description of the conceptual model should also be based upon GAP.

5.3.2.1 Streams/small rivers above 1500 m elevation

The conceptual model for the streams/small rivers is presented in Figure 5.3.1. This surface water protection goal consists of small rivers (1 - 2 m wide) which are widespread in the Ethiopian highlands and which are the first source of drinking water for villages closeby. They may be depleted just before the start of the rainy season Kremt. Their upstream catchment is often cultivated with cereals (>50% of area) on which pesticides may be used. The water may also be used for cattle, and is sometimes used for small scale irrigation of horticultural crops. The distance between the last row of crops and the edge of the water surface often ranges between 2 and 5 m. Pesticide residues may enter the stream by surface runoff and erosion, by spray drift deposition and sometimes also by contaminated drainage water originating from irrigation schemes. This latter route has not been considered in the calculation of exposure concentrations for the streams/small rivers scenario.

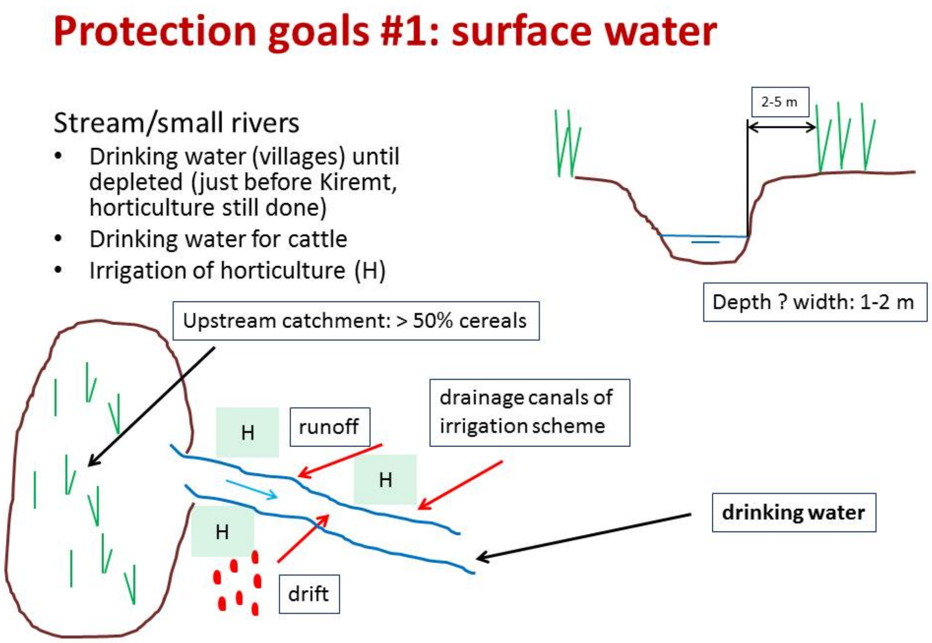


Figure 5.3.1 *Conceptual model for the streams/small rivers.*

5.3.2.2 Temporary, stagnant ponds

The conceptual model for the temporary ponds is presented in Figure 5.3.2. The temporary ponds are formed in depressions during the rainy season. During the rainy season there are no crops close to the edge of the ponds. The ponds are located downstream of farm fields and are formed by the runoff water of these cropped fields, especially during the last rains. Sometimes water is drained from the crops into the depression. In the dry season there are often no crops anymore, except on some parts close to the temporary ponds, from which they are often irrigated with the aid of pumps. The main crops during dry season are vegetables and potatoes, which therefore have more than one crop cycle (because they may also already have been cultivated during the rainy season). E.g. they may be planted once in November and once in February/March.

At the end of the rainy season (Kremt) the ponds have their maximum size and they shrink thereafter. The temporary ponds may differ in size, they are circular. Selecting realistic worst case dimensions with respect to their exposure concentrations they are on average 20* 20 m^2 at the end of the Kremt and up to 2 m deep in the centre (due to their bowl shape they are considered to be on average 1 m deep). The contributing area around the pond (contributing its runoff water into the pond) is often planted around November and its size is approximately 5 * 5 km down to 2 * 2 km.
Spray drift, mainly from knapsack sprayers, and runoff from the contributing area are considered to be the main entry routes of pesticides into the pond water.

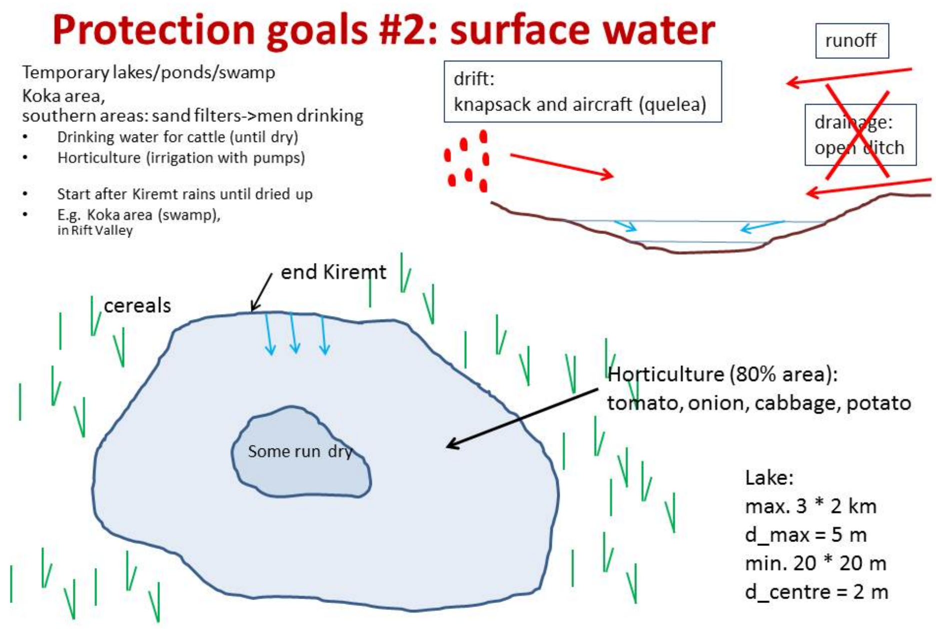


Figure 5.3.2 *Conceptual model for the temporary ponds.*

5.3.2.3 Rift Valley lakes (not selected)

The conceptual model for the Rift Valley lakes is presented in Figure 5.3.3. These lakes may be used as source for drinking water for humans as well as for cattle. On their edges, or farther around crops may be cultivated on which pesticides may be used. Pesticides may enter the lake via spray drift deposition, runoff and erosion or dranage canals. Non-agricultural pests, such as the Quelea birds may be sprayed, which may also lead to pesticides entering the lake. As these lakes are generally larger and deeper than the temporary ponds, these Rift Valley lakes are less vulnerable for pesticide contamination than the temporary ponds, and thus no surface water scenarios are made for these types of lakes.

Figure 5.3.3 *Conceptual model for the Rift Valley lakes.*

Some pictures were taken in order to illustrate the actual occurrence of the protection goals across Ethiopia (Appendix 5.1).

6 Selected models/modules

6.1 EuroPEARL metamodel for leaching to groundwater

Introduction

The EuroPEARL metamodel of Tiktak *et al.* (2006) was selected for calculating leaching concentrations for both the scenario selection procedure and for use in the PRIMET software tool for the registration procedure. This model was selected for its simplicity (easy to understand and use by non-expert users) and limited need of data. For Ethiopia we were unable to obtain a systematic overview of existing spatially distributed soil profiles and all relevant soil data needed for complex models like PEARL (Leistra *et al.,* 2001). The metamodel was calibrated against leaching concentrations predicted with the spatial distributed EuroPEARL model. The metamodel explained 90% of the variation of the original data using only four independent spatially distributed parameters that are often available from general soil and climate databases (Tiktak *et al.,* 2006). For the first tier calculations for Ethiopia the process-based EuroPEARL metamodel was therefore considered to be an attractive alternative to the more complex transient leaching models.

The EuroPEARL meta-model

Tiktak *et al.* (2006) rewrote the original metamodel of Van der Zee and Boesten (1991; see eqn. 5 in Tiktak *et al.* 2006) as a multiple linear regression model (eqn. 1) and fitted the leaching concentration in this regression model (C_L) to the leaching concentration obtained by simulations with the spatially distributed EuroPEARL model over a 20-years period. Regression parameters a_0, a_1, a_2 in eqn. 6.1.1 are determined by this regression. Tiktak *et al.* (2006) established the regression parameters for four major climate zones in the EU: i) temperate and dry, ii) temperate and wet, iii) warm and dry and iv) warm and wet. Out of these four, climate zone iv) warm and wet (annual average precipitation > 800 mm/yr and annual average temperature > 12.5 °C) was expected to be the most representative climate zone for Ethiopia and therefore the regression parameters of this zone were used for Ethiopia.

$$Ln\ (C_L) = a_0 - a_1 * X_1 - a_2 * X_2 \qquad \text{(eqn. 6.1.1)}$$

where C_L is the leaching concentration at 1 m depth, a_0, a_1, a_2 are the regression coefficients and where X_1 (unitless) and X_2 (unitless) are independent regression variables defined as follows:

$$X_1 = k_s\ \Theta\ D_{gw} / q \qquad \text{(eqn. 6.1.2)}$$

where, Θ is the volume fraction of water, averaged over the top 1 m soil and the simulation period (default value set at 0.25 m^3/m^3 for Ethiopia), D_{gw} is the depth at which the leaching concentration is calculated (default set at 1 m for Ethiopia), q is the volume flux of water percolating to the groundwater, calculated as the excess precipitation over evapotranspiration and runoff (m/d) and k_s is the degradation rate coefficient in soil at 20 °C (1/d), with

$$k_s = ln(2)/DegT50_{soil} \qquad \text{(eqn. 6.1.3)}$$

where $DegT50_{soil}$ is the transformation half-life of the substance in soil.

$$X_2 = k_s\ \rho_b\ f_{om}\ \Theta\ K_{om}\ D_{gw} / q \qquad \text{(eqn. 6.1.4)}$$

where ρ_b is the dry bulk density of the soil (kg/dm^3), f_{om} is the fraction organic matter content (kg/kg) and K_{om} is the coefficient for distribution over organic matter and water (dm^3/kg). Tiktak *et al.* (2006) calculated f_{om} as an average over the top 1 m, using the horizon thickness as a weighing factor, based upon the EuroPEARL input files. They calculated the bulk density ρ_b as a function of the organic matter content by a continuous pedotransfer function.

Values of a_0, a_1, a_2 are taken from Table 1 in Tiktak *et al*. (2006), using the results of Model III of a spring application in maize for climate zone iv) warm and wet: a_0 = 4.81, a_1 = 0.58, a_2 = 0.46. Note that the metamodel has been calibrated on the 80th percentile of the annual average leaching concentration (in time, *i.e.* 20 years of climatic data). We expect that the ranking of leaching concentrations calculated by the metamodel is also valid for more worst case situations, e.g. for the 95 or 99th percentile probability of occurrence for leaching concentrations.
Figure 6.1.1 shows the validity area of the EuroPEARL metamodel for a) organic matter, b) soil texture, c) annual rainfall and d) mean annual temperature. Appendix 6.1 gives more information about the validity of extrapolating the EuroPEARL metamodel to Ethiopia.

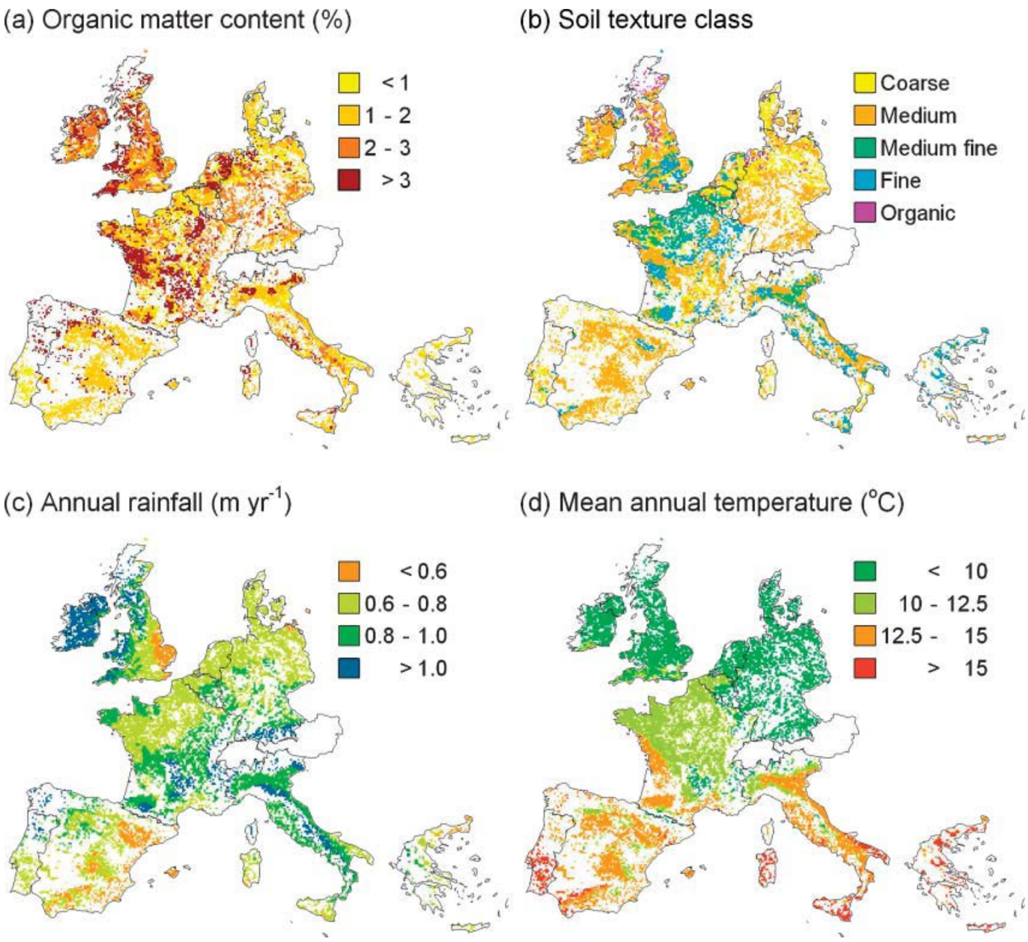


Figure 6.1.1 *Validity area of the EuroPEARL metamodel.*

6.2 Models and modules for calculation of concentrations in surface water

Pesticides may enter the streams or the temporary ponds by runoff/erosion. In the ponds spray drift deposition also occurs. Entry through open drainage canals or by drain pipes has not been taken into account in Ethiopia, because in most situations surface runoff is expected to be the dominant process for removal of the surplus of rainfall.

6.2.1 Spray drift deposition: EU_FOCUS tables

Spray drift deposition is a function of the type of application equipment (e.g. knapsack sprayers or tractor-mounted sprayers), nozzle types, pressure used and atmospheric conditions such as wind velocity and direction, air humidity and temperature. The distance between the last nozzle and the

edge of the water surface also is important for the size of the deposition. In the PRRP project a pragmatic choice was made to use the Step 3 FOCUS Drift Calculator of the EU FOCUS Surface Water Scenarios. For all Ethiopian crops and for tractor-mounted as well as knapsack sprayers 70th percentile spray drift deposition values were derived in order to avoid stacking two extreme situations (99th percentile runoff entry plus the EU_FOCUS 90th percentile spray drift deposition) for the Ethiopian ponds (See Appendix 6.2). For the Ethiopian streams only peaks caused by runoff have been taken into account, so no spray drift deposition values were determined.
The figures for knapsack sprayers are relevant for smallholders, while tractor-mounted sprayers are most often used on the Large Scale Farms in Ethiopia.

6.2.2 Runoff, erosion and subsurface drainage: FOCUS_PRZM_SW model

Runoff entries are calculated with the aid of the FOCUS_PRZM_SW_3.1.1 model (see FOCUS website: (http://viso.ei.jrc.it/focus/sw/), as is done for the EU Surface Water Scenarios (FOCUS, 2001). The Pesticide Root Zone Model (PRZM) (Carsel *et al.,* 1998) is a one-dimensional, dynamic, compartmental model that can be used to simulate pesticide movement in unsaturated soil systems within and immediately below the plant root zone. It has been used extensively in the USA (e.g. Carsel *et al.,* 1985 and 1998; Singh and Jones, 2002; Carbone *et al.,* 2002) and accepted as a FOCUS model for use in the registration procedure in the EU in 2003. The PRZM model has two major sub models: hydrology and pesticide transport.

The hydrological sub model describes water flow in the soil, including runoff of water and erosion of soil. The downward water flow in the soil is described by the tipping bucket approach. This means that infiltrating water fills up all soil layers to field capacity from the top layer going to downward layers. PRZM simulates also upward flow due to evaporation and describes uptake of water by plants using a sink term. It has a changing root zone and changing foliage during the growing season and simulates also crop interception of water. PRZM uses daily weather data to calculate daily soil moisture and a daily moisture-adjusted runoff curve number (*RCN*) to express the runoff potential. The *RCN* ranges between 0 and 100, the higher the curve number, the greater the runoff. The *RCN* is a function of soil type, soil drainage properties, crop type and land use management practice. For the FOCUS runoff scenarios these constant daily fluxes were converted to hourly fluxes by distributing the daily values linearly over a number of hours. This was done to match the time resolution in the TOXSWA model, which receives the runoff flux and describes the pesticide behaviour in the surface water. Moreover, by using hourly fluxes the runoff process is simulated in a more realistic way.

The sub model for pesticide behaviour in PRZM includes the following processes in soil (Carsel *et al.,* 1998): (i) distribution over the solid, liquid and gas phases, using Henry's law for the gas/liquid partitioning and the Freundlich equation for instantaneous distribution between the liquid and solid phases, (ii) degradation using a first-order rate equation with a rate coefficient that is a function of soil moisture content, soil temperature and soil depth, (iii) transport in the liquid phase due to convection and diffusion/dispersion, (iv) transport in the gas phase due to diffusion.

Creation of multiple year PRZM output files for runoff, erosion and subsurface drainage (p2t files)
For the Ethiopian stream and pond scenarios the FOCUS_PRZM_SW model was used to calculate the runoff water and associated pesticide fluxes, the pesticide-free subsurface drainage water (of which only a fraction enters the stream or pond) as well as the eroded soil and associated pesticide fluxes. However, the FOCUS_PRZM_SW model only prepares a TOXSWA-specific input file with the runoff (and subsurface drainage + erosion) fluxes for one single year, while for Ethiopia an input file with 33 years of runoff (and subsurface drainage + erosion) fluxes was needed. For this purpose a specific post-processing program was written (Appendix 6.3).

6.2.3 Behaviour in streams: FOCUS_stream metamodel

For the Ethiopian stream scenarios a simplified metamodel (Appendix 6.4) was designed to calculate the daily peak concentrations entering the Ethiopian stream scenario for the 33 years of meteorological data at the selected scenario location (grid 191). This was done in order (i) to decrease the run time of the software system developed for registration by the PHRD (FOCUS_TOXSWA_3.3.1

runs for streams last 1 to a few minutes per simulated year) and (ii) to avoid potential problems in the FOCUS_TOXSWA software by applying it to non-tested stream dimensions and runoff sizes. This stream metamodel was incorporated in the same post-processing program described in Appendix 6.3. The FOCUS_stream metamodel is based upon the FOCUS stream scenarios, consisting of a so-called FOCUS stream of 1 m wide and minimally 30 cm deep, fed by a 100 ha upstream catchment of which 20 ha are treated with pesticides. Runoff (water) fluxes and associated pesticide fluxes and a subsurface drainage water flux flow into the FOCUS stream. Aim of the metamodel is to calculate the pesticide concentration flowing into the FOCUS stream. Input in the metamodel are: i) pesticide mass fluxes (of 20 treated ha) across the upper boundary of the FOCUS stream and ii) discharge across the upper boundary of the FOCUS stream, consisting of a small constant base flow and the runoff fluxes and subsurface drainage water fluxes from the 100 ha catchment. The pesticide concentration entering the FOCUS stream is calculated as the pesticide mass fluxes divided by the discharge (see Appendix 6.4 for more details).

Selection of overall 99th (and 90th) percentile of stream concentrations
Finally, ranking of the stream concentrations for the 33 years and selection of the desired target concentrations, the overall 99th and 90th percentile concentrations in the stream water, was also incorporated in the post-processing program described in Appendix 6.3.

6.2.4 Behaviour in ponds: slightly adapted FOCUS_TOXSWA model

For the Ethiopian pond scenarios the FOCUS_TOXSWA_3.3.1 model was used (see FOCUS website: (http://viso.ei.jrc.it/focus/sw/), as is done for the EU Surface Water Scenarios (FOCUS, 2001), but using the 33-year runoff and erosion fluxes p2t input file. TOXSWA is the acronym of TOXic substances in Surface WAters. It is a pseudo-two-dimensional numerical model describing pesticide behaviour in a water layer and its underlying sediment at the edge-of-field scale (Adriaanse, 1996). Pesticides may enter the water by spray drift, atmospheric deposition, surface run-off, drainage or leaching through the soil. Entries can be instantaneous or distributed over a certain period, and they can be point source type or distributed over a certain length of the water course.
In the water layer, pesticides are transported by advection and dispersion. In the sediment, diffusion is included as well. The degradation rate covers the combined effects of hydrolysis, photolysis and biodegradation. Degradation depends on temperature. Sorption to suspended solids and to sediment is described using the non-linear Freundlich equation. Sorption to macrophytes is described using a linear isotherm, but this feature is not used for the Ethiopian scenarios. Pesticides are transported across the water-sediment interface by upward or downward seepage (not for the Ethiopian scenarios) and by diffusion.

Selection of overall 99th (and 90th) percentile of pond concentrations
So, the first part of the post-processing program described in Appendix 6.3 produces p2t files for 33 years. For the Ethiopian pond scenarios this 33-year input file is read by TOXSWA. A second post-processing program (Appendix 6.5) has been written to read, rank and select the pond concentrations for the 33 years, thus obtaining the wished target concentrations: the overall 99th and 90th percentile concentrations in the pond water.

7 Design of scenario selection procedure

7.1 Drinking water produced from groundwater

The selection procedure for groundwater scenario locations was based upon the procedure described in section 4.2.6 of EFSA (2012). The basic idea is to find those locations which yield an approx. 99-percentile leaching concentration and which are therefore suitable for use as a scenario location. To do so, we used spatial distributed data and the simple analytical EuroPEARL metamodel (Chapter 6.1).

Vulnerability drivers for groundwater
A vulnerability driver is defined as a sensitivity driver for the target output parameter, i.e. the pesticide exposure concentrations. A vulnerability driver is strongly spatially variable and needs to be part of the scenario definition, i.e. defining part of the fixed agro-environmental conditions for which the risk assessment is done (Chapter 3).The vulnerability drivers for leaching are the parameters of the metamodel: the organic matter content, f_{om}, the dry bulk density, ρ_b and the long term annual average percolation, q.

Scenario selection procedure
The scheme in Figure 7.1.1 shows the procedure to select scenario locations for the groundwater protection goal.
A complication is that the scenario selected based on calculations for one certain substance will probably be different from the scenario selected based on calculations for another substance. Analogous to EFSA (2012) the scenario selection procedure is based on calculations with the EuroPEARL metamodel using 49 different substances with varying $DegT_{50}$,soil and K_{om} values (Table 7.1.1).

Table 7.1.1
Substances included in the calculation of the target temporal percentile. The numbers in the table are the substance IDs.

	K_{om} (L/kg)						
$DegT_{50,soil}$ (d)	10	20	30	60	120	240	480
10	1	8	15	22	29	36	43
20	2	9	16	23	30	37	44
30	3	10	17	24	31	38	45
60	4	11	18	25	32	39	46
120	5	12	19	26	33	40	47
240	6	13	20	27	34	41	48
480	7	14	21	28	35	42	49

Leaching concentrations were calculated for each relevant spatial unit (pixel) in Ethiopia using spatial data of the organic matter content, f_{om}, the dry bulk density, ρ_b and the long term annual average percolation, q and for each of the 49 substances. This resulted in a concentration map for each substance (49 in total). Each concentration map was subsequently transformed into a vulnerability map by assigning to each spatial unit (pixel) the percentile corresponding to its leaching concentration (EFSA, 2012). From each vulnerability map, those spatial units (pixels) with a percentile between 98 and 100 were selected. Like in EFSA (2012), in the last step the 98-100 percentile vulnerability maps of all substances were overlain and those spatial units (grids, containing pixels vulnerable for leaching) that were common in all maps were considered candidate scenario locations.

As explained in Chapter 3 the aim of the scenario selection procedure is to obtain a location with an overall 99th percentile exposure concentration considering both variability in space and time. The procedure described above results in a 99th percentile in space only (i.e. the 5 x 5 km grids). However, in the risk assessment (using the software tool PRIMET for Ethiopia) for each scenario location one simulation is done with the EuroPEARL metamodel to calculate *cL*; using the long term annual average percolation, *q* in m/d (one value, average of 33 years of weather data) and the organic matter content and dry bulk density of the scenario location as input. This calculated *cL* value corresponds to a 80th temporal percentile because the EuroPEARL metamodel was based on the 80th percentile of 20 annual average leaching concentrations and on the 20-year average of the water flux percolating at 1 m depth. So leaching concentrations calculated with the metamodel for a 99th percentile spatial unit, are temporal 80th percentile values for a 99th spatial percentile.

This 80th temporal percentile is an underestimation of the 99th temporal percentile opted for. For the scenario selection procedure we assumed that the probability density function for the leaching concentration as a function of time and space based on 80th temporal percentiles do not differ from the probability density function using the 99th temporal percentile. So, using an 80th temporal percentile does not affect the scenario selection procedure. However, the value of the final target variable, the leaching concentration, does depend on the temporal percentile, and therefore, we designed a procedure to estimate a correction factor needed to convert leaching concentration given by the metamodel, so, based upon the 80th temporal percentile, into a leaching concentration representing the 99th temporal percentile required. Our procedure resulted in a correction factor of 3. More information on this procedure is given in Appendix 7.1.

Summarizing: the EuroPEARL metamodel calculates 80th temporal percentile leaching concentrations, whereas we opted for the use of a higher 99th temporal percentile in the risk assessment. Therefore, a correction factor was estimated, which is used to convert the leaching concentration given by EuroPEARL into the concentration to be used in the risk assessment (99th percentile). The details of estimation of this factor, which is equal to 3.0, are given in Appendix 7.1.

Step 1. Calculation of the spatial 99th percentile vulnerability

Selection of 'n' relevant 80x80 km^2 grids in Ethiopia (relevant for the selected protection goal; e.g. all grids with altitude > 1500 m)

↓

For all 5x5 km^2 pixels in each relevant 80x80 km^2 grid in Ethiopia model simulations with the EuroPEARL meta model using the long term annual average percolation, *q*, (one value, average of 33 years of weather data) to calculate *cL* (leaching concentration) for 49 different substances with varying $DegT_{50soil}$ and K_{om} values.

Result: Concentration map for each substance

↓

For each substance ranking of the *cL* values of all pixels in each relevant grid in Ethiopia and assigning to each pixel the percentile corresponding to its leaching concentration.

Result: Vulnerability map for each substance

↓

For each substance selection of those pixels with *cL* values between the 98th and 100th percentile

↓

Determine for each pixel the number of substances (x out of 49) resulting in 98-100 percentile leaching concentrations.

Result: Overlay of vulnerability maps of all 49 substances

↓

Determine per grid the number of pixels (y out of max 225) resulting in 98-100 percentile concentrations for x out of 49 substances.

Candidate locations: those grids with the highest number of pixels cells for the highest number of substances, preferably the maximum of 49.

↓

Spatial vulnerability

Selection of the most suitable candidate location as scenario location by the Ethiopian project partners according defined criteria

Figure 7.1.1 *Schematic overview of the steps needed for selecting scenario locations for the groundwater protection goals.*

7.2 Drinking water produced from surface water

The selection procedure for surface water scenario locations was based upon expert judgement combining knowledge on the main vulnerability drivers for the exposure concentration and the simulation models intended to be used for calculating the exposure concentrations in the Ethiopian streams and ponds.

Vulnerability drivers for streams/small rivers and for temporary ponds

A vulnerability driver is defined as a sensitivity driver for the target output parameter, i.e. the pesticide exposure concentrations. A vulnerability driver is strongly spatially variable and needs to be part of the scenario definition, i.e. defining part of the fixed agro-environmental conditions for which the risk assessment is done (Chapter 3). Both for the streams and for the ponds major vulnerability drivers for the pesticide concentration in the water are formed by the entry routes of pesticides into the water as well as by the dimensions of the receiving water body. In order to get insight in their relative importance some back-of-the envelope calculations were used.

For the temporary, stagnant ponds concentrations caused by spray drift and by runoff were estimated (Appendix 7.2). For spray drift 5% of the application rate of 1 kg/ha was assumed to be deposited on a strip of 10 m wide. This represents a rather high, i.e. conservative, deposition for bare soil and for most crops (excluding trees with upward or sideward spraying) (FOCUS, 2001; Van der Zande and Ter Horst, in prep). For a pond of 20 x 20 m and a water depth of 1 m, this corresponds to an aqueous concentration of 2.5 μg/L (Table 7.2.1). For a pond of 100 x 100 m and a water depth of 1 m, this corresponds to 0.5 μg/L. For comparison: in case of overspray (100% of applied mass deposited) the concentration would be 100 μg/L.

Table 7.2.1

Concentration in pond (after complete mixing) as a function of spray drift deposition, expressed as a percentage of the application rate of 1 kg/ha.

Spray drift deposition (% of 1 kg/ha)	Pond (length*width*depth, in m)	Concentration (μg/L)
5% on 10 m wide strip	20*20*1	2.5
5% on 10 m wide strip	100*100*1	0.5
100% overspray	100*100*1	100

For runoff the entries are estimated with the aid of calculations performed for the worst case EU-FOCUS Runoff scenario, R4, for 20 mm of rain, resulting in 4 mm runoff with a concentration of 500 μg/L for a tracer compound and for 50 mm of rain, resulting in 30 mm runoff with a tracer concentration of 200 μg/L (P.I. Adriaanse, pers.comm., 2014). Assuming that the pond is fed by a 10 ha surrounding, pesticide-treated area, the 4 mm runoff corresponds to 400 m^3 water, i.e. a 20 x 20 x 1 m water body. So, the volume of a 20 x 20 m pond with a water depth of 1 m would be doubled and thus, the incoming concentration of 500 μg/L would be halved when running into the pond with pesticide-free water, i.e. 250 μg/L (Table 7.2.2). If the pond would be 100 x 100 m with a 1 m water depth the 400 m^3 having 500 μg/L would be diluted into the original 10 000 m^3 pond water, resulting in a concentration of approximately 20 μg/L. If the 100 x 100 m pond would be fed by a 100 ha of treated area, the 4000 m^3 having a concentration of 500 μg/L would be diluted into the original 10 000 m^3 pond water, resulting in a concentration of approximately 150 μg/L. Runoff entries of 30 mm with a concentration of 200 μg/L would result in lower concentrations for the three cases described above.

Table 7.2.2

Concentration in pond (after complete mixing) as a function of size of runoff contributing area for the EU-FOCUS-R4 scenario. Concentrations result from a runoff event of 4 mm having a concentration of 500 μg/L.

Pesticide-treated surface area delivering runoff in pond		Pond (with initial pesticide-free water)			
Size (ha)	Runoff volume (m^3)	Initial size (length*width*depth, in m)	Initial volume (m^3)	Volume after runoff (m^3)	Concentration after runoff (μg/L)
10	400	20*20*1	400	800	250
10	400	100*100*1	10 000	10 400	approx. 20
100	4000	100*100*1	10 000	14 000	approx. 150

So, comparing concentrations caused by spray drift deposition to those caused by runoff, and excluding 100% overspray, it is clear that concentration caused by runoff are one to two orders of magnitude greater than those caused by spray drift deposition and thus, that runoff is a far more important entry route into surface water than spray drift for the temporary, stagnant Ethiopian ponds. Thus the main vulnerability driver for the concentration in the pond is the runoff. The dimensions of the pond are less important: the concentration is a linear function of its depth, width and length and so, the dimensions are a less important vulnerability driver for the size of the pesticide concentration than the presence and size of runoff flow.

For the streams/small rivers concentrations were also estimated, caused by spray drift and by runoff (Appendix 7.2). The assumed situations were: a spray drift of 5% of the application rate of 1 kg/ha was deposited on a 2 m-wide stream with a water depth of 0.5 m, this results in a concentration of 10 µg/L. Overspray would result in a concentration of 200 µg/L. For runoff the assumption was that the entire runoff contributing area would be treated with pesticides, so, the runoff event would replace all water in the stream. Thus, the 4 mm runoff event would result in a concentration of 500 µg/L and the 30 mm runoff event in a concentration of 200 µg/L. So, excluding the overspray situation, runoff is the main vulnerability driver for the concentration in the stream, and the spray drift entry route is a less important entry route.

Next, the probability in space of the runoff need to be established for each protection goal in its relevant scenario zones. As no runoff maps were available for Ethiopia the number of days with a daily precipitation amount of 20 mm or more was used as an indicator for the occurrence of runoff events, which was shown to be a relevant indicator in Europe (Blenkinsop *et al.,* 2008). Daily rainfall amounts were available from the ERA Interim Dataset for 33 years, from 1979 to 2011 (Dee *et al.,* 2011). This database includes also runoff data, but these data were judged to be insufficiently reliable, because they also include deep soil drainage, moreover the used soil-water concept was very simple and based upon a single soil.

The drainage entry route was not taken into account. Considerations for this decision were: (i) in Ethiopia drainage pipes or drainage channels are not common in Ethiopian agriculture, (ii) operationalizing a third model (next to runoff and behaviour in surface water) is not possible within the limited time and budget of the PRRP project and (iii) this approach was also used in the EU-FOCUS Surface Water Scenarios.

Other possibly relevant vulnerability drivers are soil properties, land use or slope. Soil profiles across Ethiopia were not available in a structured and easy-to-stochastically-manipulate way, so a pragmatic choice was made to use EU-FOCUS selected soil properties and to select the most conservative soil, i.e. most protective with respect to runoff, of the 4 EU-FOCUS Runoff scenarios. For pesticide leaching and runoff the soil organic matter content is the most relevant property. Land use is taken into account by considering the most important crops in the scenarios, i.e. covering substantial areas, and where pesticides are applied. Contrary to general beliefs, slope is not an important vulnerability driver determining runoff, because it is the soil infiltration rate that determines whether any runoff may occur and not a slight or steep slope. Soil infiltration rate is an important factor in the soil classification used in the runoff PRZM model and in selecting the most conservative of the 4 EU-FOCUS Runoff scenarios this factor was also considered, next to the organic matter content.

For runoff entries the Runoff Curve Number may be considered a model-specific vulnerability driver, because it determines to a large extent the runoff water and pesticide fluxes. It was decided to use the RCNs of the EU-FOCUS crops as much as possible as a reference RCN values and to define the RCNs for the Ethiopian crops as much as possible in agreement with the EU-FOCUS values.
No analysis was done to quantify the influence of compound-specific properties on the concentration in the streams or temporary ponds.

Scenario selection procedure
The scheme in Figure 7.2.1 presents the procedure to select scenario locations for the surface water protection goals. The procedure needs to be followed for each combination of detailed protection goal and scenario zone, i.e. for the streams/small rivers in the zone above 1500 m, for the temporary

ponds in the zone between 1500 and 2000 m and for the temporary ponds in the zone below 1500 m, but with more than 500 mm annual rain. The following steps are presented in the scheme: first, all relevant spatial units are selected, i.e. all spatial units belonging to the scenario zone where the selected protection goal is present. In the second step for each spatial unit and for each available year the number of days with 20 mm or more are counted and the numbers are ranked for each spatial unit (N values if there are N years). Next the year corresponding to the desired cumulative percentile is selected. At this point the desired *temporal* percentile (here 99th percentile) is obtained. In the third step the selected value (i.e. numbers of day with daily rain above 20 mm) is plotted on the map for all spatial units of the relevant scenario zone and these values are ranked. E.g. if there are M spatial units, then the cumulative spatial percentile is calculated on basis of M values. A few spatial units with percentiles close to the desired cumulative percentile are selected, so now the chosen *spatial* cumulative percentile (the 99th percentile) has been obtained. The remaining locations are the candidate scenario locations from which in step 4 the most suitable spatial unit, i.e. scenario location, can be selected.

Cumulative percentiles (P_{cum}) are calculated according to:

$$P_{cum} = 100\% \frac{(i-0.5)}{N} \qquad \text{(eqn. 7.2.1)}$$

where *i* is the rank number of the individual observation and *N* is the number of ranked observations.

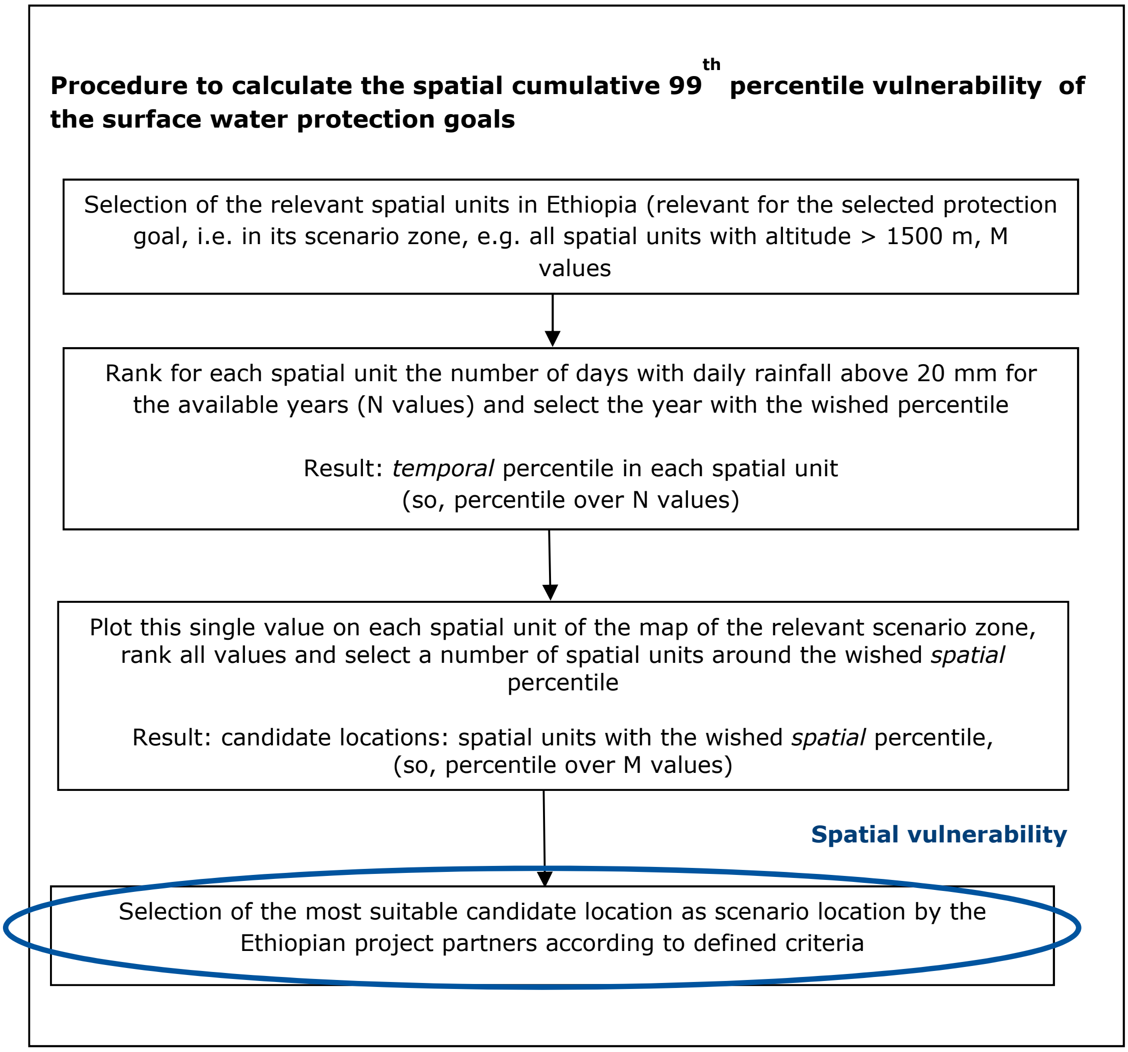


Figure 7.2.1 *Schematic overview of the steps needed for selecting the scenario locations for the surface water protection goals.*

As explained in Chapter 3 the aim of the scenario selection procedure is to calculate overall 99th percentile exposure concentrations, considering variability both in time and space. The scenario selection procedure presented in Figure 7.1.1 and 7.2.1 result in the 99th percentile locations, i.e. in spatial percentiles. In these scenarios exposure concentrations will be calculated for a series of years, out of which the 99th percentile in time will be selected, resulting in the wished overall 99th percentile probability of occurrence in time and space for the exposure concentration.

The details of implementing the selection of the 99th percentile for pond and stream scenarios are given below.

Temporary ponds
The protection goal for drinking water produced from Ethiopian ponds was defined in first instance as: 'in 99 percent of all days during which pesticide is present in the pond, the pond water should fulfil the required standard'. This implied that all days with a pesticide concentration (e.g. above 10^{-10} g/L) need to be ranked and the 99th (temporal) percentile to be selected. A post-processing program (Appendix 6.5) performed this selection for the two scenario locations (grids 373 and 217) corresponding to the spatial 99th percentile, resulting in an overall 99th percentile probability of occurrence (see Chapter 3). The two pond scenarios are also used to evaluate the risks for the aquatic ecosystem and for this purpose the 90th temporal percentile concentrations were also calculated. However, after analysing the first calculation results we formulated another protection goal: 'in 99 percent of all years, the pond water should fulfil the required standard'. This implied that the 33 yearly peak concentrations (instead of daily peak concentrations) were ranked and the 99th (temporal) percentile was selected. The 90th percentile exposure for the aquatic ecosystem protection goal was selected according to the same procedure. The reason for this change in definition of protection goals is explained in more detail in Section 9.2.1.

Streams/small rivers
The protection goal for drinking water produced from Ethiopian streams was formulated in first instance as 'in 99 percent of all runoff events the stream water should fulfil the required standard'. A software program was written to calculate the daily peak concentrations into the Ethiopian streams for the series of 33 years at the selected scenario location, which were next ranked to select the peak concentration that represents the 99th percentile probability of occurrence in time (Appendix 6.3). Only one concentration value per day was ranked and only for days when there was a runoff event. Combined with the 99th spatial percentile (the selected scenario location) this results in an overall 99th percentile probability of occurrence (see Chapter 3). The stream scenario is also used to evaluate the risks for the aquatic ecosystem and for this purpose the 90th temporal percentile concentrations was also calculated and written as output. However, after analysing the first calculation results we formulated another protection goal: 'in 99 percent of all years, the stream water should fulfil the required standard'. This implied that the 33 yearly peak concentrations (instead of daily peak concentrations) were ranked and the 99th (temporal) percentile was selected. The 90th percentile exposure for the aquatic ecosystem protection goal was selected according to the same procedure. The reason for this change in definition of protection goals is explained in more detail in Section 9.2.1.

8 Selection of scenarios for specific protection goals in Ethiopia

In this chapter the scenario selection procedure will be described for the drinking water produced from groundwater and surface water protection goals. So, in this chapter, we describe how we have operationalised the selection of the percentile of occurrence in space (for more details, see Chapter 3). This chapter describes how the general principles described in Chapter 7 are applied to Ethiopian data and result in the selection of scenario locations for use in the Ethiopian procedures for the registration of pesticides.

8.1 Groundwater scenarios for Ethiopia

8.1.1 Introduction

This chapter describes the selection of the scenario locations of Chapter 7.1 using the Ethiopian meteorological and soil data available. This procedure is complicated because the meteorological data and soil data are available for different spatial scales (see Chapter 4). Meteorological data (Appendix 4.1) is available on a scale of approx. 0.75°x.75°; this corresponds roughly to 80x80 km^2 spatial units. The soil data is available on a scale of 5x5 km^2 (Appendix 4.1). For simplicity we refer to the 80x80 km^2 spatial units of the meteorological data as 'grids' and to the 5x5km^2 spatial units of the soil data as 'pixels'. ISRIC provided for each grid 225 pixels with soil data (note that a grid would contain 256 pixels if the scale of the grid would be exactly 80x80 km^2 and the scale of the pixel would be exactly 5x5 km^2; however these grid and pixel scales are only approximations of the true scales used).

The scheme of Figure 7.1.1 explains i) how we used the data with the different spatial scales for calculations with the EuroPEARL metamodel and ii) how we dealt with these different spatial scales in the selection procedure of the candidate locations and the final scenario selection.

First the calculations and modifications needed to get the necessary input data for the EuroPEARL metamodel are described. This is followed by a section discussing the application of the scenario selection procedure of Chapter 7.1 using the scheme given in Figure 7.1.1. For each protection goal the results of the application of the scenario selection procedure are given in Chapter 8.1.4.

8.1.2 Input for the EuroPEARL metamodel

Spatial distributed data of the volume flux of water percolating to the groundwater (referred to as percolation), q, the dry bulk density soil, ρ_b and the organic matter content, f_{om} are needed as input for the EuroPEARL metamodel.

Tiktak *et al.* (2006) parameterised the EuroPEARL meta model using 20-yr averages of the dynamic properties, like the percolation. Therefore, we followed this same procedure and calculated the total percolation per year followed by calculating the annual average percolation of the 33 years used. The percolation flux, q, was calculated using the ERA interim data of precipitation, evapotranspiration and runoff. Firstly, percolation, q_{day}, was calculated on a daily basis for period 1 January 1979 – 31 December 2011 as follows:

$$q_{day} = P - ET - R \quad \text{(eqn. 8.1.1)}$$

where P is the precipitation in mm/d (Appendix 4.1: parameter ID 228 in Table A4.1.1.), ET is the reference evapotranspiration in mm/d and R is runoff in mm/d (Appendix 4.1: parameter ID 205 in Table A4.1.1.). The q_{day} values were summed for each of the 33 years, resulting in a total percolation flux in mm/yr. Subsequently, the average of 33 years of the total percolation flux was calculated and this average in mm/yr was converted to q, the long term annual average percolation in m/d. Note that ET is calculated for a reference crop (see Appendix 4.1), not short of water, which means that q_{day} might be underestimated. However, for the scenario selection procedure q_{day} is only of importance in a relative sense as the goal is to determine the 99th percentile of the annual average leaching concentration via ranking. The metrological data is available for 80x80 km^2 spatial units (grids), consequently q is available for the same spatial scale.

Other input for the metamodel are soil properties fraction organic matter content, f_{om} (-) and dry bulk density, ρ_b (kg/kg). The fraction of organic matter content is calculated from the fraction of organic carbon content, f_{oc}, (-) as follows:

$$f_{om} = 1.724\ f_{oc} \qquad \text{(eqn. 8.1.2)}$$

Because organic matter content, f_{om} and dry bulk density, ρ_b for the top 1m soil, (that Tiktak *et al.* (2006) used in his calibration of the metamodel) were not available, the values of the Harmonised World Soil Database, which represent the top 30 cm soil (Appendix A4.1.6) were used.

The properties f_{om} and ρ_b are both available for 5x5 km^2 spatial units (pixels). These pixels were linked to the grids with meteorological data. Calculations with the metamodel were performed for each pixel using the q value of the corresponding grid and for each substance defined in Table 7.1.1 (Note that the calculations are only done for a particular selection of grids; *e.g.* those above 1500m. Consequently calculations are only done for the pixels corresponding to the grids selected). Pixels with organic carbon contents of 0 were omitted from the selection and pixels with unrealistic combinations of ρ_b and f_{oc}[1] were omitted from the selection as well. Both features were found to be unrealistic and probably caused by artefacts of the geo-statistical interpolation procedure for preparation of the maps of dry bulk density and organic content.

In principle, only pixels should be included from locations where agriculture and horticulture take place. However, it was impossible to select these pixels because no appropriate land use map was available. The pixels located in areas without agriculture and horticulture will lead to an error in the scenario selection procedure, but it is not clear whether this leads to too high or too low concentrations, because these pixels may generate both concentrations at the high and the low end of the probability of occurrence distribution.

8.1.3 Application of the scenario location selection procedure

The first step in the procedure (Figure 7.1.1) was the selection of those grids relevant for the specific groundwater protection goal. For the protection goals 1 (Alluvial aquifers along small rivers in areas above 1500 m altitude) and 2 (Volcanic aquifers on shallow wells in areas above 1500 m altitude) all grids within the Ethiopian area with an altitude above 1500 m were selected.

Protection goal 3 (Alluvial aquifers in Rift Valley margins and lowlands) is only found in specific areas of Ethiopia (see Appendix 8.1). For protection goal 3a (protection goal 3 in areas below 1500 m altitude) only relevant grids in the specific areas and with an altitude below 1500 m altitude were selected. For protection goal 3b protection goal 3 in areas between 1500 m – 2000 m altitude) only relevant grids in the specific areas and with an altitude between 1500 m and 2000 m altitude were selected.

The second step in the procedure was to perform simulations with the metamodel for all pixels in the relevant grids for 49 different substances with varying $DegT_{50soil}$ and K_{om} values according to the sets in Table 7.1.1 and using the input data as described in Chapter 8.1.2. This resulted in a concentration map for each substance. For each substance the cL values of all pixels in each relevant grid were ranked and each pixel was assigned the percentile corresponding the its cL value. This step resulted in vulnerability maps for each substance. Then for each substance those pixels with cL values between the 98th and 100th percentile were selected. This was followed by calculating for each pixel the number

[1] Unrealistic sets of ρ_b and f_{oc} were defined as sets where ρ_b values < 800 kg/m^3 unless f_{oc} > 20% and ρ_b > 250 kg/m^3

of substances (*x* out of 49) resulting in 98-100 percentile leaching concentrations. Subsequently, for each grid the number of substances (*x* out of 49) resulting in 98-100 percentile concentrations for *y* pixels (*y* out of max 225) was determined. After this step the candidate locations were selected; i.e. those grids with the highest number of substances (preferably all 49 substances tested) resulting in 98-100 percentile concentrations for the highest number of pixels. This results in the selection of locations which are vulnerable for as many pesticides (i.e. all 49 tested substances) as possible. This implies that it is more favourable to find a few pixels in a grid that are vulnerable for all tested substances then to find many pixels in a grid which are only vulnerable for a few of the tested substances.

The final step was that the Ethiopian project partners identified those locations from the pool of candidate locations that are suitable to be scenario locations, according to pre-defined criteria, which were:

- Sufficient number of pixels resulting in 98-100 percentile concentrations for all 49 substances.
- Hydrogeological situation such that the aquifers of the protection goal are present
- Does the water supply for the population come from the aquifers of the protection goal?
- Is this water used for drinking water for man?
- Presence of agriculture; relevant crops treated with pesticides grown there?
- Is the area populated?

8.1.4 Results for the groundwater protection goals

8.1.4.1 Alluvial aquifers along small rivers and volcanic aquifers on shallow wells above 1500 m

The groundwater protection goals 1 (alluvial aquifers along small rivers in areas above 1500 m) and 2 (volcanic aquifers on shallow wells in areas above 1500 m) may occur at a distance of a few kilometres apart. Therefore they may occur in the same grid and because the meta model calculation is identical for both protection goals, the scenario selection procedure for both was applied in one go. Details about the candidate locations can be found in Appendix 8.2. A suitable scenario location was selected from the pool of candidate locations. Grid 219 (see Figure 8.1.1 for location on map) was selected because both protection goals are present in this area. In the alluvial aquifers along small rivers the water supply is from springs (discharged from shallow groundwater at low areas) or from hand-dug wells, while in the areas with alluvial and fractured volcanic rocks with intermittent or perennial small streams shallow wells are found along the alluvial or fractured volcanic rocks. The higher situated recharge area in this grid is intensively cultivated and grid 219 is selected because relevant crops treated with pesticides are grown here.

Figure 8.1.1 *Selected scenarios locations for the three groundwater protection goals. Grid 219 for goals 1 and 2: alluvial aquifers along small rivers and volcanic aquifers on shallow wells in areas above 1500 m; grid 346 for goal 3a: alluvial aquifers in the Rift Valley margins and lowlands below 1500 m altitude; grid 323 for goal 3b: alluvial aquifers in the Rift Valley margins and lowlands between 1500 -2000 m altitude.*

8.1.4.2 Alluvial aquifers at Rift Valley margins below 1500 m

Details about the candidate locations can be found in Appendix 8.2. A suitable scenario location was selected from the pool of candidate locations. Because groundwater protection goal 3a (alluvial aquifers at Rift Valley margins and in lowlands in areas below 1500 m altitude) is only found in a limited area of Ethiopia (see Appendix 8.1.) the pool of candidate locations is rather small. Of this pool grid 346 was chosen. This grid has a sufficient number of pixels for which all 49 tested substances resulted in 98-100 percentile concentrations. Both the Kolla and Woina Dega agro-ecological zones (i.e. below 1500 m and above 1500 m, resp.) are found within grid 346. Relevant crops grown are coffee, faba beans, banana and some cereals and maize. The dominant aquifers in the area are shallow volcanic aquifers, but there are also areas with shallow alluvio-lacustrine aquifers which correspond to protection goal 3a.

8.1.4.3 Alluvial aquifers at Rift Valley margins between 1500 and 2000 m

Details about the candidate locations can be found in Appendix 8.2. A suitable scenario location was selected from the pool of candidate locations. Because groundwater protection goal 3b (alluvial aquifers at Rift Valley margins in areas between 1500 and 2000 m altitude) is only found in a limited area of Ethiopia (see Appendix 8.1.) there were no suitable scenario locations among the set of candidate locations when using the altitude between 1500 - 2000 m as selection criterion. The altitude of each grid, is the altitude valid for the center of the grid. This means that the surrounding area might have somewhat lower or higher altitudes. We therefore decided to relax the altitude selection criterion to the range 1500 – 2500 m. From the resulting pool of candidate locations grid 323 was selected because this grid covers the areas west of Lake Ziway and Lake Koka where groundwater is known to be extracted from shallow wells, while the Rift Valley margins as well as the nearby plains are intensively cultivated with a high use of pesticides. Grid 323 is considered to some extent vulnerable with only 28 out of 49 substances resulting in 98-100 percentile concentrations for 5 pixels and 21 out of 49 substances resulting in 98-100 percentile concentrations for 6 pixels. However, the other more vulnerable candidate locations were judged not to represent the Rift Valley margins very well.

8.1.4.4 Overview of selected groundwater scenarios

The application of the scenario selection procedure described in section 8.1.3 resulted for each protection in several candidate locations. Selected locations should be vulnerable for as many pesticides (i.e. all 49 tested substances) as possible. It is thus more favourable to find a few pixels in a grid that are vulnerable for all tested substances then to find many pixels in a grid which are only vulnerable for a few tested substances. Candidate locations were ranked according to their vulnerability for leaching. The candidate locations ranked first represent the grid with the highest number of substances resulting in 98-100 percentile concentrations for the highest number of pixels, and therefore the most vulnerable location with respect to leaching. Table 8.1.1. shows the selected scenario locations and for each location the number of substances resulting in 98-100 percentile concentrations (*x* out of 49) for *y* pixels (y out of maximum 225). Grid 219 is the third ranked grid out of five candidate locations (Table A8.2.1). Grid 346 is the third ranked grid out of four (Table A8.2.2) and Grid 323 is the fifth ranked grid out of six (Table A8.2.3b). For none of the three protection goals the most vulnerable location was selected, because next to vulnerability other considerations also influence the selection (see 8.1.3).

Table 8.1.1
Selected locations for the groundwater protection goals for Ethiopia.

Grid	Longitude	Latitude	Number of relevant pixels in grid*	Number of substances resulting in 98-100 percentile concentrations for y pixels**
219	38.25	10.5	225	49 substances for 22 pixels
346	36	6.75	225	49 substances for 13 pixels
323	38.25	7.5	209	28 substances for 5 pixels + 21 substances for 6 pixels

* The maximum number of pixels in a grid in 225. The number of relevant pixels in a grid varies due to the selection criteria of organic matter content > 0 and realistic sets of organic matter content and dry bulk density.

** Indicating that *x* substances out of 49 had 98-100 percentile concentrations for *y* (unique) pixels out of maximal 225 in the corresponding grid.

Tables 8.1.2 to 8.1.4 present an overview of the main characteristics of the selected groundwater protection goals, grids 219, 346 and 323.

Table 8.1.2
Groundwater specific protection goals for Ethiopia.

No	Protection goal	Grid no.	Name location
1.	Alluvial aquifers along small rivers in areas above 1500 m	219	Bichena (Amhara region)
2.	Volcanic aquifers on shallow wells in areas above 1500 m	219	Bichena (Amhara region)
3a.	Alluvial aquifers in the Rift Valley margins and lowland areas below 1500m	346	Ca. 100 km SW of Jimma (SNNP)
3b.	Alluvial aquifers in the Rift Valley margins between 1500 and 2000m	323	Abala Kulito (SNNP)

Table 8.1.3
Organic matter content, f_{om} (kg kg^{-1}), and dry bulk density, ρ_b (kg dm^{-3}), and annual average volume flux of percolating water to groundwater, q (mm yr^{-1}), for the specific groundwater protection goals.

Protection goal	Grid no	fom (kg kg^{-1})	ρb(kg dm^{-3})	q (mm yr^{-1})
1 + 2	219	0.0034	1.528	879
3a	346	0.0072	1.375	888
3b	323	0.0057	1.390	700

Table 8.1.4
Altitude (m) and long-term annual precipitation (mm) for the specific groundwater protection goals.

Protection goal	Grid no	Altitude (m)	Annual precipitation (mm)
1 + 2	219	2190	1786
3a	346	1363	2078
3b	323	2056	1418

8.2 Surface water scenarios for Ethiopia

8.2.1 Introduction

This chapter describes the selection of the scenario locations for surface water, using data on elevation and meteorological data for the 80x80 km^2 spatial units, called 'grids', specific to Ethiopia. Locations for exposure scenarios are selected to assess the risks of contamination of surface water used as source of drinking water for humans and cattle. Two protection goals for surface water were selected:
1. Small streams in areas above 1500 m altitude
2. Temporary ponds
   a. Below 1500 m altitude and with more than 500 mm rain (long term, annual average)
   b. Between 1500 – 2000 m altitude

The procedures result in a number of candidate scenario locations out of which the most suitable locations have to be selected, one for each of the three surface water protection goals. Finally one, most suitable location is selected for each exposure scenario. Criteria to select the most suitable locations are:
1. The protection goal should be present in the selected grid, i.e. within the 80*80 km area and preferably in a considerable number or extent.
2. Agricultural activity should be present within at least a part of the 80*80 km area of the grid.
3. Preferably a number of crops on which high risk pesticides are being used, are cultivated within the 80*80 km area of the grid.
4. The area should be well populated.
5. If several locations are suitable, the final location is selected such that all exposure scenario locations are distributed as much as possible across the country, thus avoiding that all scenarios are located close to each other.

8.2.2 Application of the scenario selection procedure

The main driver for exposure of pesticides in the Ethiopian temporary pond is runoff. Spray drift and drainage are not considered to be drivers, because i) preliminary calculations demonstrated that the amount of pesticide transferred into the pond via spray drift is small compared to amounts involved in runoff (Chapter 7.2) and ii) mole drainage is not applied around temporary ponds.

Precipitation amounts above 20 mm/day are a good indicator for the occurrence of runoff events (Blenkinsop *et al.,* 2008). The procedure for the selection of surface water scenarios for Ethiopia therefore considered the distribution in time and space of the number of days with runoff, i.e. with P_{day}>20 mm.

Protection goal 1 Small streams is only found above 1500 m. Altitude was available for the 80x80 km^2 grid cells. Firstly all 80x80 km^2 grid cells above 1500 m and those grid cells fully confined within the Ethiopian area were selected. For these grid cells and for each of the 33 years of meteorological data the number of days with more than 20 mm of rain per day was determined. For each grid cell the 33 values of the number of days with more than 20 mm of rain per day were ranked and the 99^{th} percentile (number 33 rank) was selected. Cumulative percentiles were calculated according to the procedure of Appendix 6.4 (Eqn A6.4.7). This resulted for each grid cell in one value of the 99^{th} percentile number (in fact the 98.5^{th} percentile) of days with more than 20 mm of rain per day. The next step was to rank the grid cells using the value of the 99^{th} percentile number of days with more than 20 mm of rain per day. We now obtained the 99^{th} percentile as a combination of 99^{th} percentile in space (Ethiopia, 57 grids > 1500 m) and the 99^{th} percentile in time (33 years). The three grid cells with the highest spatial percentiles (95.6, 97.4 and 99.1) were selected and it was checked whether they were located in agricultural areas where small streams are present.

For protection goals 2a and 2b temporary ponds we used the same scenario selection procedure as used for protection goal 1, with the exceptions of i) a small difference considering the first step: the selection of the relevant 80x80 km^2 grid cells and ii) plausibility criteria for the final selection. For protection goal 2a (temporary ponds below 1500 m) all 80x80 km^2 grid cell below 1500 m and those grid cells fully confined within the Ethiopian area were selected. Additionally only those 80x80 km^2 grid cells with more than 500 mm precipitation (long term, annual average) were selected. This resulted in a total of 47 selected grids. For protection goal 2b (temporary ponds above 1500 m) all 80x80 km^2 grid cell between 1500 – 2000 m and those grid cells fully confined within the Ethiopian area were selected. This resulted in a total of 34 selected grids. The following steps of the scenario selection procedure are similar to those described for protection goal 1. However, when choosing from the grid cells with the highest percentiles (in time and space) it was checked whether they were located in agricultural areas where temporary ponds are present. The following criteria were used:

i) Area with streams far apart (10 km or more)
ii) Flat area
iii) Cultivated area

8.2.3 Results of the scenario selection procedure for the surface water protection goals

8.2.3.1 Small streams above 1500 m

Out of the three candidate locations (for details, see Appendix 8.3) grid 191 was selected. This grid represents the 97.4-99.1 percentile in space and has 46 days with 20 mm of rain or more for the selected year. Its long term annual average precipitation equals 2581 mm. The grid was selected because it fitted the selection criteria of presence of small streams and intensive agriculture best. Its elevation is 1682 m and its location is presented in Figure 8.2.1.

Figure 8.2.1 *Selected scenario locations for the surface water protection goals. Grid 191 for protection goal 1: Small streams above 1500 m, grid 373 for protection goal 2a Temporary ponds below 1500 m and with more than 500 mm rain and grid 217 for protection goal 2b Temporary ponds between 1500 m and 2000 m.*

8.2.3.2 Temporary ponds below 1500 m with more than 500 mm rain

Out of the eleven candidate locations (for details, see Appendix 8.3) grid 373 was selected. This grid represents the 72.4 percentile in space and has 21 days with 20 mm of rain or more for the selected year. Its long term annual average precipitation equals 1702 mm. The grid was selected because grids with higher percentiles of occurrence in time and space were not suitable, either because of lack of ponds, or because of lack of intensive agriculture. Grid 373 is located near Arba Minch in the Rift Valley and is densely populated and there are cattle. Agriculture is intensive with high pesticide use, a large variety in crops is cultivated and temporary ponds are present in this area. Its elevation is 1288 m and its location is presented in Figure 8.2.1.

8.2.3.3 Temporary ponds between 1500 m and 2000 m

Out of the twelve candidate locations (for details, see Appendix 8.3) grid 217 was selected. This grid represents the 95.6-98.5 percentile in space and has 46 days with 20 mm of rain or more for the selected year. Its long term annual average precipitation equals 2779 mm. The grid was selected because it fitted the selection criteria of presence of temporary ponds best, there is agriculture with pesticide used and a number of different crops are cultivated in the area. Its elevation is 1705 m and its location is presented in Figure 8.2.1.

8.2.3.4 Overview of selected surface water scenarios

The spatial percentiles of the selected grids have been combined with the selected temporal percentiles (for details see Appendix 8.3) to obtain the overall probability of occurrence for the concentrations calculated for the small stream and in the ponds. This approach has been explained in Figure F1 of section 3.3. and it was applied in Appendix 8.3 for the three selected grids 191, 373 and 217.
Finally, Table 8.2.1 presents an overview of the main characteristics of the locations selected for the surface water scenarios, grids 191, 373 and 217.

Table 8.2.1
Overview of selected surface water protection goals.

Protection goal number	Description	Grid	Name location	Elevation m	Percentile for overall probability of occurrence	Number of days with P>20 mm	Long term annual average precipitation mm
1	Small streams above 1500 m	191	SW Lake Tana	1682	97.4-99.1	46	2581
2a	Temporary ponds below 1500 m, and more than 500 mm rain	373	Near Arba Minch	1288	72.4	46	1702
2b	Temporary ponds between 1500 and 2000 m	217	Farther SW Lake Tana	1705	95.6-98.5	21	2779

9 Calculation of concentrations in groundwater and surface water

9.1 Groundwater

For groundwater the exposure target concentrations are calculated using the EuroPEARL metamodel described in Chapter 6.1. The metamodel estimates the leaching concentration for a standard application of 1 kg a.i./ha ($CL_{gw,1kg/ha}$). To estimate the leaching concentrations from multiple applications, all applications in one year in kg a.i./ha have to be added. The metamodel generates temporal80th percentile leaching concentrations, which have to be multiplied by a constant correction factor, cf_{gw}, of 3 to yield the desired overall 99th percentile leaching concentrations used in Ethiopian risk assessment (Chapter 7.1).

The leaching concentration to be used as exposure target concentration in the leaching assessment (CL^{n}_{gw}) is calculated as follows:

$$CL^{n}_{gw} = CL_{gw,1kg/ha} \cdot AR \cdot n \cdot cf_{gw} \qquad \text{(eqn. 9.1.1)}$$

with,

$CL_{gw,\ 1\ kg/ha}$	=	Leaching concentration, annual average concentration leaching from the soil profile at 1 m depth. This concentration is valid for a standard application of 1 kg/ha (µg/L).
CL^{n}_{gw}	=	Leaching concentration of *n* applications within one year, annual average concentration leaching from the soil profile at 1 m depth (ug/L).
AR	=	Application Rate (kg a.i./ha)
n	=	number of applications (-)
cf_{gw}	=	correction factor to account for the difference in calculated PEC between a 80th percentile and a 99th percentile (target concentration). The correction factor is a constant, i.e. 3 (-).

$CL_{gw,\ 1\ kg/ha}$ is calculated using eq. 6.1.1. Input parameters of eq. 6.1.1. k_s and k_{om} are pesticide specific properties. The parameterisation of eq. 6.1.1. with respect to scenario specific properties *q*, the volume flux of water percolating to the groundwater, fraction organic matter content, f_{om} and dry bulk density, ρ_b is described in Chapter 10.

9.2 Surface water

9.2.1 Type of concentration and percentiles

Risk assessment on the basis of peak concentrations
For the risk assessment exposure concentrations are compared to toxicological effect concentrations. For drinking water produced from surface water peak concentrations, and not time-weighted average concentrations over several days, are used, as often the total daily water consumption is abstracted from the pond or the river in one go. For streams the peak concentration corresponds to an hourly concentration value, as the concentration in the stream varies at an hourly basis due to hourly runoff entries. For the ponds the peak concentration corresponds to a daily concentration value, as the variation in concentration in the pond is relatively small: after a runoff event the concentration increases within the day, but thereafter only slowly decreases during a couple of days or weeks, depending on other runoff water entries.
The peak concentrations were used to perform an acute risk assessment on the basis of an accidental incidental large portion water intakes, as well a chronic risk assessment on the basis of a life time daily (see Chapter 3 for more details).

Within PRRP surface water is associated with risks for humans as well as risks for the aquatic ecosystem, and both were selected as protection goals. The combination of two protection goals with two different types of water body (small streams and temporary ponds) results in different procedures for calculating the necessary exposure target concentrations. Table 9.2.1 gives an overview of the surface water protection goals defined within PRRP, their scenario locations and their exposure target concentrations.

Selection of 99th percentile in time

In principle a 99th temporal percentile can be obtained in several ways, e.g. obtaining all daily maximum concentrations of the 33 available years, ranking these and selecting the 99th percentile. Another possibility is to determine for each year the maximum daily concentration, thus obtaining 33 values, and next, to rank these 33 values and to select the 99th percentile. In the PRRP project we considered both types of 99th temporal percentiles and finally opted for selecting the 99th percentile of the ranked 33 values. However, we did not select the highest ranked value, i.e. number 33, because this value corresponds to the most extreme day of all days during the 33 years, but we opted for the last-but-one value, i.e. number 32, thus avoiding the most extreme day. This approach was followed for the small stream (grid 191) as well as for the two ponds (grids 373 and 217).

Our considerations for this choice were as follows:
For small streams the runoff water entering the stream is assumed to have a constant concentration during the runoff event (EU-FOCUS assumption for PRZM output) and so, each day has a maximum daily value. Two approaches are possible: (i) selecting the 99th percentile of all days with runoff and (ii) selecting the 99th percentile of all days, not considering whether there was runoff or not. During the 33 years approximately 3400 runoff events happen, i.e. around 100 events per year; thus at approximately 70% of the days there is no runoff. Following even the most strict option (option (i), only ranking days with runoff), selection of the 99th percentile would correspond to ranking number 35-40 (the highest ranked 35-40 days of all 3400 days with runoff) and thus, in the 33 years considered 1 to 2 days per year the selected 99th percentile concentration is exceeded. These 1 to 2 concentrations per year are up to a factor of 100 higher than the 99th percentile. We considered this to be insufficiently protective and therefore we opted for ranking the 33 yearly maximum daily incoming concentrations and selecting the last-but-one value. In this option we expect only very few days with higher concentrations than the last-but-one value we selected, namely the yearly maximum concentration of the highest ranked year, plus, maybe one or two other high concentrations of that same year (depending on the runoff events in that year).

For the ponds we observed that the concentrations in the simulated ponds remain high over a relatively long time as a result of the very low flow-through. Taking the 99th percentile of all daily concentrations of the 33 years corresponds to ranking number 120-140 (the highest ranked 120-140 days of all approximately 12050 days of the 33 years) and thus each year, there are around 4 days (120-140 d / 33 years) with concentrations higher than the selected percentile in the ponds. Again we considered this to be insufficiently protective and therefore we opted for ranking the 33 yearly maximum daily concentrations in the pond and selecting the last-but-one value. In this option we expect only one runoff event with a higher pond concentration than the last-but-one value we selected, namely the event of the highest ranked year. As the concentrations in the pond lower slowly, the pond concentration in the highest ranked year may remain higher than the pond concentration of the last-but-one ranked year for a number of days, depending on e.g. the difference in peak concentrations of the two years, the size of the flow-through and the degradation rate of the compound in water.

Due to the use of different models it was necessary to develop different procedures for (i) the small stream (section 9.2.2) and (ii) the temporary ponds (section 9.2.3) to select the temporal percentile concentrations. These are explained in the following section.

Table 9.2.1

Surface water protection goals and their scenario locations and aimed exposure target concentrations.

Protection goal		Scenario	Aimed exposure target
Surface water for drinking water	1.Small streams in areas above 1500 m altitude	191 (W of Lake Tana); 1682 m altitude; 2581 mm rain (long term annual average)	99th percentile of the 33 yearly maximum runoff concentrations delivered in the stream
	2a.Temporary ponds below 1500 m altitude and with more than 500 mm rain (long term, annual average)	373 (W of Arba Minch); 1288 m altitude; 1702 mm rain (long term annual average)	The 99 percentile of the 33 yearly maximum daily concentrations in the pond
	2b. Temporary ponds between 1500 – 2000 m altitude	217 (SE of Bure); 1705 m altitude; 2779 mm rain (long term annual average)	The 99 percentile of the 33 yearly maximum daily concentrations in the pond
Aquatic ecosystem	1.Small streams in areas above 1500 m altitude	191 (W of Lake Tana); 1682 m altitude; 2581 mm rain (long term annual average)	90th percentile of the 33 yearly maximum runoff concentrations delivered in the stream
	2a.Temporary ponds below 1500 m altitude and with more than 500 mm rain (long term, annual average)	373 (W of Arba Minch); 1288 m altitude; 1702 mm rain (long term annual average)	The 90 percentile of the 33 yearly maximum daily concentrations in the pond
	2b. Temporary ponds between 1500 – 2000 m altitude	217 (SE of Bure); 1705 m altitude; 2779 mm rain (long term annual average)	The 90 percentile of the 33 yearly maximum daily concentrations in the pond

9.2.2 Procedure for small streams

As described in Chapter 6.2, the runoff water and associated pesticide fluxes and the fraction of pesticide-free subsurface drainage water into the Ethiopian small stream are calculated with the FOCUS_PRZM_SW model. For the Ethiopian stream scenarios a simplified metamodel (Appendix 6.4) was designed to calculate the daily peak concentrations entering the Ethiopian small stream scenario for the 33 years of meteorological data at the selected scenario location. This metamodel uses the output of the FOCUS_PRZM_SW model as input and its program is shown in Appendix 6.3. Figure 9.2.1. gives a schematic representation of the procedure. Both the 99th and 90th percentile concentrations are generated.

9.2.3 Procedure for temporary ponds

As described in Chapter 6.2, the runoff water and associated pesticide fluxes, the fraction of pesticide-free subsurface drainage water and the eroded soil and associated pesticide fluxes into the Ethiopian temporary pond are calculated with the FOCUS_PRZM_SW model. These fluxes are input into the FOCUS_TOXSWA model which is run for 33 years to calculate concentrations in the pond water. It is necessary to post-process the PRZM output to make a suitable input file for TOXSWA. Therefore a post-processing program was created (see Appendix 6.3) which served two goals: i) calculating daily peak concentrations entering the Ethiopian small stream and ii) converting PRZM output to an input file for TOXSWA). Subsequently, the TOXSWA output needs post-processing as well, which is achieved by using a second post-processing program (Appendix 6.5). The entire procedure is depicted in Figure 9.2.1. Both the 99th and 90th percentile concentrations are generated.

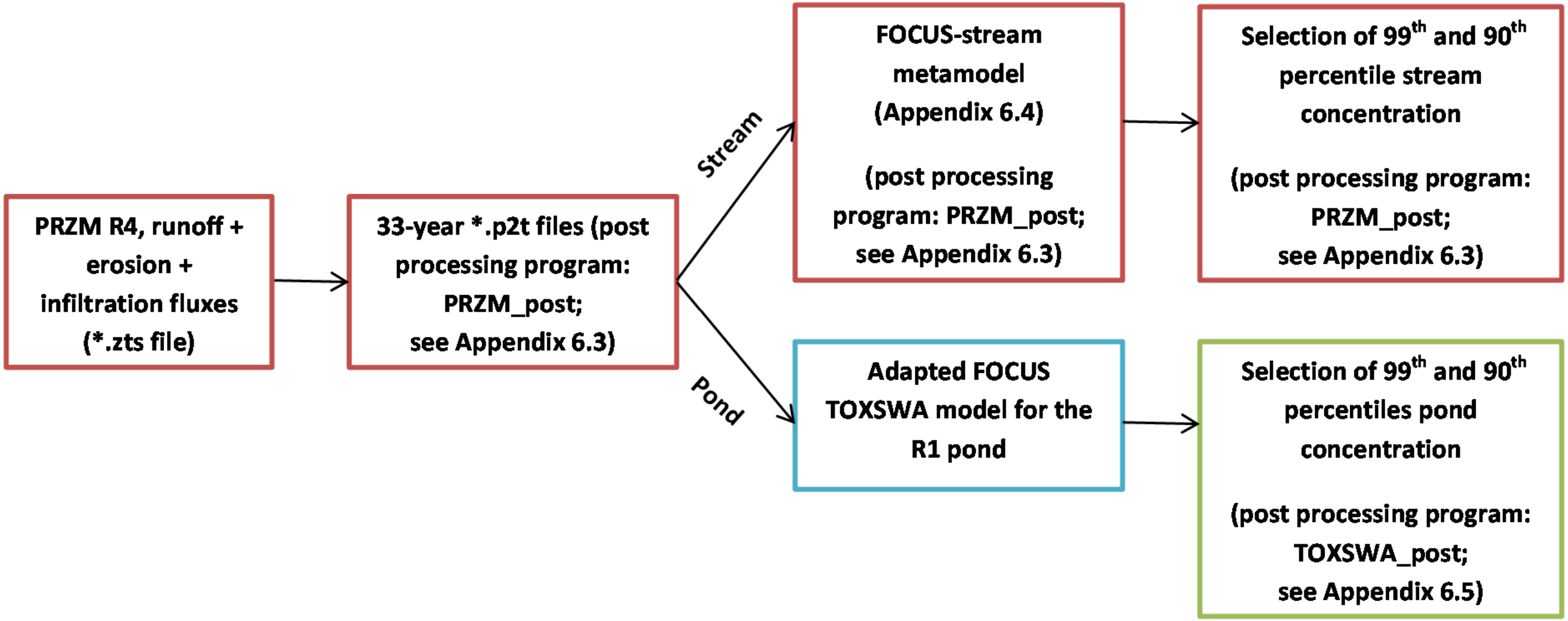


Figure 9.2.1 *Procedure for calculating the exposure target concentrations in the small stream and the temporary pond.*

10 Ground water scenarios: Parameterisation of the EuroPEARL model

For the groundwater for drinking water protection goals, the exposure target concentrations are calculated using the EuroPEARL metamodel described in Chapter 6.1.

The scenario specific parameters in this metamodel (excluding those with default values; see Chapter 6.1) are: the organic matter content, f_{om} (kg kg^{-1}), the dry bulk density, ρ_b (kg dm^{-3}) and the volume flux at 1 m depth of water percolating to the groundwater, q (m d^{-1}). Values of the scenario specific properties are given in Table 10.1 for each of the groundwater protection goals.

Table 10.1
Organic matter content, dry bulk density and the annual average volume flux of percolating water to the groundwater for the groundwater specific protection goals.

Protection goal	Grid	Location	Organic matter content, f_{om} (kg kg^{-1})	Dry bulk density of the soil, ρ_b (kg dm^{-3})	The annual average volume flux at 1 m depth of percolating water to groundwater, q (mm yr^{-1})
1 + 2*	219	Bichena (Amhara region)	0.0034	1.528	879
3a	346	*Ca*. 100 km SW of Jimma (SNNP)	0.0072	1.375	888
3b	323	Abala Kulito (SNNP)	0.0057	1.390	700

* Note that the exposure target concentrations calculated for scenario 1 and 2 are the same.

Pesticide specific properties are $DegT_{50,soil}$ and K_{om}. Both are user input into the models.

The volume flux of water percolating to the groundwater, q (m d^{-1}), represents the annual, average percolation of the 33 years 1979 up to 2011 included. It is calculated as the excess precipitation over evapotranspiration and runoff on a daily basis (for details, see Chapter 8.1.2).

Because we did not have at our disposal data for the soil properties fraction organic matter content, f_{om} and dry bulk density, ρ_b for the top 1m soil, (that Tiktak *et al.* (2006) used in his calibration of the metamodel) we used the values of the Harmonised World Soil Database, which represent the top 30 cm soil (Appendix A4.1.6). For the three groundwater scenario locations the organic matter content, f_{om}, and the dry bulk density, ρ_b, for this top 30 cm soil are calculated as follows.

Appendix 10.1 gives for each location (grid) the soil data of all relevant pixels (i.e. organic matter content > 0 and realistic sets of organic matter content and dry bulk density). Appendix 8.2 gives for each grid the number of substances resulting in 98-100 percentile concentrations for y (unique) pixels. For grid 219, y = 22 for 49 substances; for grid 346, y = 13 for 49 substances and for grid 323, y = 5 for 28 substances and y = 6 for 21 substances. The ids of these y pixels were easily identified by sorting all relevant pixels of the grid by fraction organic matter (sort from smallest to largest) and selecting those pixels with the smallest fractions of organic matter (note that it was checked whether the pixels identified in this way did correspond to 98-100 percentile leaching concentrations). From these 'y' pixels it was decided to take the fraction organic matter and dry bulk density from the pixels with the smallest fraction organic matter.

For grid 219 the values of the organic matter content and the dry bulk density were taken from the 22 pixels with the smallest identical organic matter content; these pixels had an identical dry bulk density also (the pixel ids are highlighted in Table A10.1 in Appendix 10.1).

For grid 346 the values of the organic matter content and the dry bulk density were taken from pixels 77337, 77338 and 77340 (three of the 13 pixels with the smallest identical fraction of organic matter). Data for the other ten pixels with the same organic matter content was not included because of the probable lack of agricultural activity in these pixels (based on Google Earth).

For grid 323 the values of the fraction organic matter and the dry bulk density were taken from pixels 71533, 71534, 71535, 71922, 72312 (identical values of f_{om} and ρ_b for all five pixels).

11 Surface water scenarios: Parameterisation of the FOCUS_PRZM model

11.1 Introduction

Chapter 9 explains the procedures for calculating concentrations in the Ethiopian small stream and the Ethiopian temporary ponds. For both scenarios the PRZM model was parameterised. Full parameterisation of the PRZM model for the Ethiopia situation (soil and runoff curve numbers) was not possible within the PRRP project because of limited available data. For all three Ethiopian surface water scenarios use was made of the standard PRZM input of the EU FOCUS surface water R4 scenario (the worst case scenario in the EU), but to use Ethiopian weather data (daily rainfall, pan evaporation, temperature, wind speed and solar radiation), Ethiopian irrigation data and Ethiopian crop data. Details about these scenario specific input data are given below.

11.2 Soil and Runoff Curve Numbers (FOCUS R4 scenario)

The soil and site parameters of the R4 FOCUS Surface Water scenario can be found in FOCUS (2001). For completeness they are given in Tables A11.1.1. and A11.1.2. in Appendix 11.1.
Runoff Curve Numbers (*RCN*) are input in PRZM and determine the amount of runoff water entering the stream (i.e. the higher the curve number, the greater the runoff). The *RCN* values are not only scenario specific but also crop-specific and depend on crop development stage-specific. Table A11.1.3. specifies the runoff curve numbers for the FOCUS SW R4 scenario for the specific FOCUS crops during different stages of crop development. For Ethiopia a translating table was developed to link the crops specific for Ethiopia to the FOCUS crops (Table 11.2.1).

Table 11.2.1
Ethiopian crops, corresponding FOCUS crops and RCN numbers for various crop development stages.

Ethiopian crop	FOCUS crop	Runoff curve number (antecedent moisture condition II)			
		Emergence (cropping)	Maturation (cropping)	Harvest (residue)	Fallow
Tomato	Vegetables, fruiting	82	82	87	91
Onion	Vegetables, bulb	82	82	87	91
Cabbage	Vegetables, leafy	82	82	87	91
Potato	Vegetables, root	82	82	87	91
Teff	Cereals, spring	81	81	86	91
Wheat	Cereals, spring	81	81	86	91
Maize	Maize	82	82	87	91
Barley	Cereals, spring	81	81	86	91
Faba bean	Field beans	82	82	87	91
Sweet potato	Vegetables, root	82	82	87	91
Cotton	Sunflowers	82	82	87	91
Mango	Pome/stone fruit [a]	70	70	70	70
Sugar cane	Maize	82	82	87	91
Banana	Citrus [a]	70	70	70	70
Citrus	Citrus [a]	70	70	70	70
Coffee	Olive [a]	70	70	70	70

[a] Perennial crops

11.3 Meteorological data

Meteorological data on daily rainfall, pan evaporation, temperature, wind speed and solar radiation are input into the PRZM model. Data was found in the ERA Interim dataset (Dee *et al.,* 2011) which could be extracted from the ECMWF (**E**uropean **C**entre for **M**edium-Range **W**eather **F**orecasts) MARS (**M**eteorological **A**rchival and **R**etrieval **S**ystem) archive (Appendix 4.1). All meteorological data was either directly extracted from this archive or it was calculated using the data extracted from the ECMWF MARS archive. Table A.11.3.1 specifies for each meteorological input parameter in PRZM its unit, the source from which the data was taken and, where appropriate, the needed calculation/conversion method.

Table 11.3.1
Meteorological input parameters in PRZM: its unit, the source from which the data was taken including if needed the calculation/conversion method.

Parameter PRZM	description	Unit	Source of data
MMDDYY	time	12 106 (note day 1 is written as ‘ 1’ and not as ‘01’)	-
PRECIP	precipitation	cm/day	Extracted from ECMWF MARS parameter ID 228 in the ECMWF MARS archive (Table A4.1.1. Appendix 4.1); generating daily values using eqn. A.1.2. in Appendix 4.1.
PEVP	Pan evaporation	cm/day	Calculated according eqn. A.1.3 – A.1.10 in Appendix 4.1 using data extracted from ECMWF MARS
TEMP	Air temperature at 2 m height	C	Extracted from ECMWF MARS parameter ID 167 in the ECMWF MARS archive (Table A4.1.1. Appendix 4.1); generating daily values using eqn. A.1.1. in Appendix 4.1.
WIND	Wind speed at 10m height	cm/sec	Calculated according eqn. A.1.6 – A.1.7 in Appendix 4.1 using data extracted from ECMWF MARS
SOLRAD	Total daily solar radiation	Langley	Extracted from ECMWF MARS parameter ID 149 in the ECMWF MARS archive (Table A4.1.1. Appendix 4.1); generating daily values using eqn. A.1.2. in Appendix 4.1. Unit in ECMWF MARS is Jm^{-2} and thus converted to Langley using: 1 Langley [Ly] = 48140 Jm^{-2}

Meteorological data in the ECMWF MARS archive is given from 1 January 1979 to 31 December 2011. PRZM cannot handle the transition to another century. Therefore it was decided to change the year numbers to year numbers in the 20th century. We start at 1903, to assure that the converted years run parallel to the original years in the ECMWF MARS data with regard to leap years.

11.4 Crop data

PRZM needs the following general cropping parameters: Pan Evaporation factor, canopy interception and USLEC factors for fallow, cropping and residue. These parameters are crop dependent, but scenario independent and their values are listed for all FOCUS crops in Table A.11.1.4 in in Appendix 11.1. For these general cropping parameters a conversion table was used to link the crops specific for Ethiopia to the FOCUS crops; the same crop conversion scheme was used as applied for establishing RCN numbers (Table 11.4.1).

Table 11.4.1
Ethiopian crops and their corresponding FOCUS crops considering the general cropping parameters specified in Table A.11.1.4 in Appendix *11.1.*

Ethiopian crop	FOCUS crop
Tomato	Vegetables, fruiting
Onion	Vegetables, bulb
Cabbage	Vegetables, leafy
Potato	Potatoes
Teff	Cereals, spring
Wheat	Cereals, spring
Maize	Maize
Barley	Cereals, spring
Faba bean	Field beans
Sweet potato	Potatoes
Cotton	Sunflowers
Mango	Pome/stone fruit
Sugar cane	Maize
Banana	Tobacco
Citrus	Citrus
Coffee	Olive

We also determined where the Ethiopian crops can be cultivated twice per year. Table 11.4.2 gives an overview of the scenario locations where the scenario crops are cultivated and whether more than one crop per year can be cultivated. The second crops of tomato (representing all fruity vegetables), onion (all bulb vegetables), cabbage (all leafy vegetables) and potato are cultivated after the main rainy season and they require irrigation (see section 11.5).

Table 11.4.2
Association of crops with surface water scenario locations (gridpoint+approximate location, altitude and annual precipitation).' Yes' indicates that it is possible to grow the crop there from an agronomic point of view (mainly meteorology and altitude).

Crops	191 (W of Lake Tana)	217 (SE of Bure)	373 (W of Arba Minch)
	1682 m	1705 m	1288 m
	2581 mm	2779 mm	1702 mm
Tomato#	Yes, 2 crops/yr	Yes, 2 crops/yr	Yes, 2 crops/yr
Onion#	Yes, 2 crops/yr	Yes, 2 crops/yr	Yes, 2 crops/yr
Cabbage#	Yes, 2 crops/yr	Yes, 2 crops/yr	Yes, 2 crops/yr
Potato#	Yes, 2 crops/yr	Yes, 2 crops/yr	Yes, 2 crops/yr
Teff	Yes	Yes	Yes
Wheat	Yes	Yes	No
Maize	Yes	Yes	Yes
Barley	Yes	Yes	No
Faba bean	Yes	Yes	No
Sweet potato	No	No	Yes
Cotton	No	No	Yes
Mango (pome/stone representative)	No	No	Yes
Sugarcane	No	No	Yes
Banana	No	No	Yes (few pesticides)
Citrus (lemon)	Yes	Yes	Yes
Coffee	Yes	Yes	Yes

these 4 crops are cultivated twice: once in the rainy season Kremt and once with irrigation in Bega.

Furthermore PRZM needs the following scenario dependent crop parameters: maximum rooting depth, maximum cropping height, emergence date, maturation date, harvest date and fallow date. For these inputs we gathered Ethiopian specific data (Table 11.4.3 for annual crops and Table 11.4.4 for perennial crops).

Information on the crop calendar has been obtained from Mr. Aweke Nigatu, irrigation agronomist at the Ministry of Agriculture (MoA), Ethiopa, working for the IFAD/irrigation project as well as from the Crop Variety Register of the Plant Health Regulatory Department (PHRD) of the Ministry of Agriculture (MoA) of Ethiopia, issue numbers 14 (2011), 13 (2010), 12 (2009), 11 (2008), 10 (2007) and 9 (2006). In collaboration with Mr Zebdewos Salato Amba of the PHRD, MoA it has been subdivided by Paulien Adriaanse into the crop development stages that are required for the PRZM model (Appendix 11.2).

Table 11.4.3

(Julian) dates of crop development stages (date/month) for annual crops cultivated in the highlands (H, above 1500 m altitude) and low/midlands (M, below 1500 m altitude). For simplification, the crop development cycle of a single scenario zone is used: i.e. the zone where the crop is most commonly grown (bold).

Crop	Altitude	Max crop height (cm)[1]	Max. rooting depth (cm)[1]	Crop development stage (date/month)			
				Emergence	Crop maturation	Harvest	Fallow
Tomato*	H, 1st	110	80	1 June	8 Aug	27 Sep#	15 Oct
	2nd			15 Nov	22 Jan	13 Mar#	30 Apr
	M, 1st			**1 June**	**8 Aug**	**27 Sep#**	**15 Oct**
	2nd			**15 Nov**	**22 Jan**	**13 Mar#**	**30 Apr**
Onion*	H, 1st	60	40	1 June	4 Aug	3 Oct	10 Oct
	2nd			15 Nov	18 Jan	19 Mar	26 Mar
	M, 1st			**1 June**	**4 Aug**	**3 Oct**	**10 Oct**
	2nd			**15 Nov**	**18 Jan**	**19 Mar**	**26 Mar**
Cabbage*	**H, 1st**	30	60	**1 June**	**23 Aug**	**27 Sep**	**20 Oct**
	2nd			**15 Nov**	**27 Jan**	**13 Mar**	**10 May**
	M, 1st			1 June	23 Aug	27 Sep	20 Oct
	2nd			15 Nov	27 Jan	13 Mar	10 May
Potato*	**H, 1st**	100	60	**25 June**	**27 Aug**	**11 Oct**	**18 Oct**
	2nd			**1 Jan**	**5 Mar**	**19 Apr**	**26 Apr**
	M, 1st			25 June	27 Aug	11 Oct	18 Oct
	2nd			1 Jan	5 Mar	19 Apr	26 Apr
					Flowering till		
Teff	**H**	70	40	**5 July**	**22 Aug**	**6 Oct**	**30 May**
	M			5 July	22 Aug	6 Oct	30 May
Wheat	**H**	110	120	**10 July**	**29 Aug**	**18 Oct**	**30 May**
	M			10 July	29 Aug	18 Oct	30 May
Barley	H	110	120	10 July	29 Aug	18 Oct	30 May
Maize	H	250	100	10 Mar	24 May	7 Aug	30 Jan
	M			**10 Mar**	**24 May**	**7 Aug**	**30 Jan**
Faba bean	H	150	60	5 July	24 Aug	2 Nov	30 Apr
Sweet potato	M	40	40	10 July	8 Sep	2 Nov	20 Nov
Cotton	M	70	150	8 July	27 Aug	8 Nov	30 May

[1] based on EU FOCUS R4 scenario (Appendix D, Tables D1 and Tables D12, potato rooting depth based on D9) except for teff, sweet potato and cotton.

* 2 crops per calendar year (with PRZM simulations performed separately for 1st and 2nd crop), the first crop during the rainy season (Kiremt) and the second crop with irrigation.

2nd harvest of tomatoes 10 d after the 1st harvest.

Table 11.4.4
Maximum crop height (cm), maximum rooting depth (cm) and (Julian) dates of crop development stages (date/month) for perennial crops cultivated in the highlands (H, above 1500 m altitude) and low/midlands (M, below 1500 m altitude). For simplification, the crop development cycle of a single scenario zone is used: i.e. the zone where the crop is most commonly grown (bold).

Crop	Altitude	Max crop height (cm)	Max. rooting depth (cm)	Crop development stage (date/month)			
				Emergence	Maturation	Harvest	Fallow
Sugarcane*	M	200	150	2 Jan	3 Jan	30 Dec	31 Dec
Banana*	M	200	75	2 Jan	3 Jan	30 Dec	31 Dec
Citrus* (lemon)	H	290	150	2 Jan	3 Jan	30 Dec	31 Dec
	M	290	150	**2 Jan**	**3 Jan**	**30 Dec**	**31 Dec**
Coffee*	**H**	290	150	**2 Jan**	**3 Jan**	**30 Dec**	**31 Dec**
	M	290	150	2 Jan	3 Jan	30 Dec	31 Dec
Mango* (Pome/stone fruit)	M	290	150	2 Jan	3 Jan	30 Dec	31 Dec

***** All crops are perennial, bearing leaves permanently. Therefore they are parameterised as covering the soil during the entire year (see R4 scenario with citrus, Appendix D, Table D12).

N.B. In reality sugarcane and banana harvested after 18 months only ! So, the crop development stages (i) sprouting/new leaves, (ii) flowering, (iii) harvest are: 15 Feb, 15 Oct, 15 Aug (sugarcane) and 1 Apr, 1 Dec and 1 Oct (bananas). Sugarcane is taken as ratoon crop, i.e. never fallow, crop sprouts on remains after harvest; bananas are permanent crops developing underground lateral sprouts forming new banana trees.

11.5 Irrigation

Information on the crop irrigation has been obtained from Mr. Aweke Nigatu, irrigation agronomist at the Ministry of Agriculture (MoA), Ethiopia, working for the IFAD/irrigation project in collaboration with Mr Zebdewos Salato Amba of the PHRD, MoA and has been processed by Paulien Adriaanse for inclusion in the PRZM model.

During the dry season some crops are cultivated with the aid of irrigation. The most common crops thus cultivated are tomatoes, onions, cabbage and (Irish) potato. These four crops are often cultivated twice during the year: one rain fed crop cycle and one irrigated crop cycle.

More background on the crop irrigation data is given in Appendix 11.2 and the irrigation schedules for the crops of tomato, onion, cabbage and potato at the three surface water scenario locations are given in Appendix 11.3.

Standard procedure for PRZM is to add irrigation (as given in Appendix 11.3) to the precipitation data in the meteorological input file for PRZM.

11.6 Remaining PRZM input

Pesticide application method + Dissipation rate at foliage and foliar wash-off coefficient
PRZM offers eight different options for pesticide application methods. For Ethiopia this option is fixed to 'application to the crop canopy, default soil incorporation depth for non-foliar intercepted chemical is 4 cm, linearly decreasing with depth' (CAM = 2) as this seemed the most realistic option. In FOCUS (2001) a CAM=1 is used, i.e. 'default soil incorporation depth for non-foliar intercepted chemical is 4 cm, linearly decreasing with depth'. Crop interception values used were those reported in Table D.1 of Appendix D of FOCUS (2001), where the Ethiopian crops correspond to the FOCUS crops as stated in Table 11.4.1 above.

Setting the application method to CAM = 2 requires input on the pesticide dissipation rate of pesticide deposited on foliage (d^{-1}; PLDKRT) this value is set to 0.0693 d^{-1} (i.e. a DT_{50} of 10 days) conform EFSA (2012). Furthermore input of the foliar wash-off coefficient (FEXTRC) is needed in case the of setting the application method to CAM = 2. FEXTRC is set to 0.5 cm^{-1} (Appendix H of FOCUS, 2001).

Soil adsorption and degradation
For Ethiopia the option for soil adsorption is default set to 'normalised Freundlich equation' (KDFLAG =2) and a layer specific partition coefficient K_d (L/kg) needs to entered by the user (NB this is different from the EU FOCUS SWS procedure where the software tool SWASH is used to prepare input for the PRZM model).

Considering degradation in soil, the input of biphasic degradation half-life is not allowed (DKFLG2 = 0) and the half-life value entered is corrected for temperature and soil moisture (ITFLAG = 2).

No metabolites
It was decided to disregard metabolites for the moment and therefore NCHEM was set to 1 in the PRZM input files, implying simulations for the parent only.

11.7 PRZM example input file

Appendix 11.5 gives a set of example input files of PRZM for the crop maize, the pesticide 2,4-D and an application pattern of 1.44 kg/ha applied each year on 10 March. The record numbers in Appendix 11.5 follow those used in Annex K of FOCUS (2001).

12 Surface water scenarios: Parameterisation of the FOCUS_stream metamodel and the adapted FOCUS_TOXSWA model

12.1 FOCUS_stream metamodel

12.1.1 Variable water and pesticide fluxes

For each of the 16 possible crops the FOCUS_PRZM_SW model, parameterized for Ethiopian weather and crop conditions, calculates the runoff water and pesticide fluxes, as well as a downward infiltration (water) flux at 1 m depth. These fluxes are variable and expressed on an hourly basis. They originate from a 100-ha upstream catchment, from which 20 ha are assumed to be treated with pesticide. So, the water fluxes originate from 100 ha and the pesticide fluxes originate from 20 ha only, i.e. the fraction of upstream catchment treated is 0.2. Of the downward infiltration flux at 1 m depth, only a fraction enters the small stream, this fraction has been set at 0.1, similar to the EU-FOCUS R4 scenario. (For more details, please refer to Appendix 6.4.)

12.1.2 Base flow

The base flow equals a fraction of the long-term annual total flow in the catchment. It has a constant value and has been estimated at 10 $m^3.h^{-1}$ for the Ethiopian small streams, i.e. the average value for the FOCUS Runoff stream scenarios (Appendix 6.4). This corresponds to a flow of 2.78 $L.s^{-1}$ In the stream.

12.2 The adapted FOCUS_TOXSWA model

12.2.1 Introduction

Parameterisation of the TOXSWA model was only done for the Ethiopian temporary pond scenarios. A conceptual model of the Ethiopian temporary pond was developed in PRRP (see Chapter 5). However, parameterisation of TOXSWA for this conceptual model was too ambitious for the PRRP project, because it would require among others expansion of the TOXSWA model with a concept for the specific hydrology of the temporary pond. It was therefore decided to take the parameterisation of the EU FOCUS R1pond scenario, the only pond in the EU-FOCUS Runoff scenarios (FOCUS, 2001). Ethiopian data for temperature were used and the base flow corresponded to the FOCUS R4 scenario. Note that the runoff entries into the Ethiopian temporary pond are calculated using the PRZM model with a parameterisation based upon the EU FOCUS R4 scenario (the worst case EU-FOCUS Runoff scenario), plus Ethiopian weather and crop data.

12.2.2 The EU FOCUS R1 pond

Figure 12.1 gives the conceptual outline of the EU FOCUS pond scenario. The parameterisation of the R1 pond scenario in TOXSWA was used for the Ethiopian temporary pond scenarios.

The dimensions of the pond are fixed (in time). The pond has a rectangular internal cross-section (vertical side slope) with a width and a length of 30 m. The water depth in the pond is maintained by a weir and its minimum depth is 1 m. Base flow without pesticides enters the pond. The pond is surrounded by 0.45 ha of fields which are treated with pesticides. Runoff fluxes (water and pesticides) from 0.45 ha and eroded sediment (including pesticides) from a 20 m contributing margin around the pond enter the pond.

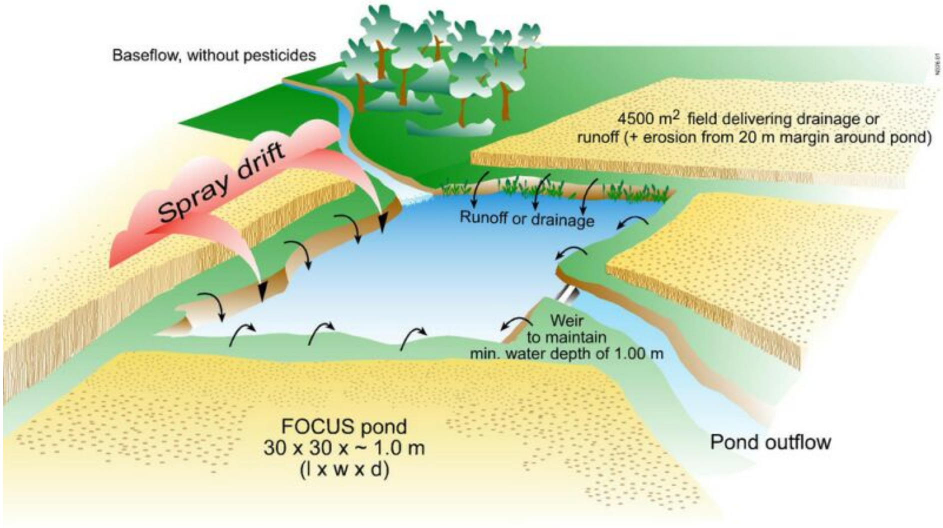


Figure 12.1 *Conceptual outline of the EU FOCUS pond scenario.*

The sediment layer of the EU FOCUS ponds represents relatively vulnerable sediments in European agricultural areas (FOCUS, 2001) with properties based upon experimental data. Characteristics of sediment and suspended solids are fixed (in time and with sediment depth) and defined in Table 12.1.

Table 12.1
Sediment and suspended solid characteristics of the EU FOCUS R1 pond scenario.

Characteristic	Value
Concentration of suspended solids in the water layer	15 g m^{-3}
Mass fraction of organic matter in suspended solids	0.090 kg kg^{-1}
Sediment layer depth	0.1 m
Mass fraction of organic matter in sediment	0.090 kg kg^{-1}
Bulk density of the sediment	800 kg m^{-3}
Porosity	0.60 m^3 m^{-3}
Tortuosity	0.60 (-)

Identical to the FOCUS pond we assumed that the Ethiopian temporary pond does not contain macrophytes. This is a conservative approach because macrophytes tend to absorb pesticides.

12.2.3 Water temperatures

Values of the water temperature are needed for the calculation of volatilisation and transformation of pesticides. Monthly average water temperatures are input in the TOXSWA model. For the locations of the two temporary pond scenarios minimum and maximum air temperatures at 2 m height are available (Appendix 4.1). They are converted to daily average air temperatures (eqn. A.1.5 in Appendix 4.1) and subsequently these data are converted to monthly average air temperatures. We assumed that these monthly average air temperatures are representative for the monthly average water temperatures of the Ethiopian temporary ponds. The factor for the effect of temperature on the rate coefficient of transformation in water and sediment is calculated with the Arrhenius equation (see Eqn. A1 in Appendix 1 of Beltman *et al.,* 2006) and applied over the entire range of mean monthly temperatures used as input in TOXSWA.

12.2.4 Base flow

Because runoff entries into the Ethiopian temporary pond are calculated using the PRZM model with a parameterisation partly based upon the EU FOCUS R4 scenario, we decided to alter the base flow that feeds the pond such that it is in line with the base flows of the FOCUS R4 scenario.

The base flow of the FOCUS R4 scenario (1.927 m^3 d^{-1} ha^{-1}; Table 4.3.3-2 in FOCUS, 2001) were multiplied with 3 ha, similar to FOCUS (2001, p102), resulting into a base flow of 5.781 m^3 d^{-1}. This figure is used in the parameterisation of the Ethiopian temporary pond for the TOXSWA model.

12.2.5 Spray drift deposition

Spray drift deposition is assumed to occur over the entire length of 30 m by wind perpendicular to the pond length. The TOXSWA pond is modelled as a completely mixed reservoir and an average value of spray drift deposition is therefore applied to the entire 30 m width of the pond. The average drift value is calculated taking into account that drift decreases exponentially with distance from the sprayer boom. These width-averaged numbers are shown in Appendix 6.2.
For the Ethiopian pond scenarios spray drift deposition in % of application rate is calculated with the aid of the EU-FOCUS Drift Calculator. Their values are given in Table 6.2.2 in Appendix 6.2. In case the Ethiopian crop is not found in the list of FOCUS crops the Ethiopian crop has been replaced by a FOCUS crop with characteristics as similar as possible to the Ethiopian crop. The 70^{th}%ile deposition corresponds to 6 applications in the FOCUS Drift Calculator. These FOCUS drift deposition values are assumed to correspond to Large Scale Farming practices in Ethiopia. Figures of spray drift deposition from knapsack sprayers are listed separately as applications, hand (Table 6.2.3 in Appendix 6.2). These figures are based upon the EU_FOCUS data as well (based upon crop stage averaged deposition and crop height).

12.2.6 Pesticide properties

Most substance parameters are assumed to be substance dependent and should be supplied by by the user. However, some parameters are assumed to be substance independent, and their values have been taken from the literature. These substance independent data for input in TOXSWA and their values for Ethiopia are listed below.

- Molar enthalpy for degradation in sediment (MolEntTraSed): 65.4 kJ/mol (EFSA, 2007)
- Molar enthalpy for degradation in surface water (MolEntTraWat): 75 kJ/mol (Tiktak *et al.,* 2012)
- Molar enthalpy of vaporisation (MolEntVap): 95 kJ/mol (FOCUS, 2000)
- Molar enthalpy of dissolution (MolEntSlb): 27 kJ/mol (FOCUS, 2000)
- Coefficient for linear sorption on macrophytes (CofSorMph): 0 L/kg (no macrophytes assumed)
- Reference diffusion coefficient in water (CofDifWatRef): 0.43×10^{-4} m^2 d^{-1} (FOCUS 2000).

12.2.7 Sediment segmentation

The sediment is assumed to be 10 cm thick. In principle, the model user should select a sediment segmentation in such a way that a converging solution for the mass balance equation for the sediment is obtained. In practice, a standard segmentation is often used. The standard FOCUS segmentation with 14 numerical segments is used in this project where the smallest numerical segments are found in the top of the sediment (Beltman *et al.,* 2006). However, if an assessment is done for a substance with a sorption coefficient $K_{om\_Sediment}$ > 3000 L/kg (corresponding to $K_{oc\_sediment}$ > 5172 L/kg) the preliminary, rough analysis presented in Appendix 12.1 suggests that the FOCUS – HighKoc sediment segmentation results in an improved concentration calculation (lower value, i.e. less conservative). It remains, however, the responsibility of the user to check that a converging solution is obtained with this proposed segmentation. Table 12.2 gives the details of the different sediment segmentations proposed for the Ethiopian pond, based upon the preliminary findings of Appendix 12.1. Note that the characteristics given in Table 12.1 are valid for each numerical sediment segment.

Table 12.2
Proposed numerical sediment segmentation for the Ethiopian pond.

FOCUS sediment segmentation (for substances with $K_{om\_sediment}$ ≤ 3000 L/kg)	**FOCUS high KOM sediment segmentation (for substances with $K_{om\_sediment}$ > 3000 L/kg)**
Number of sediment segments = 14	Number of sediment segments = 23
Thickness of the sediment segments from top to bottom of the sediment (m) =	Thickness of the sediment segments from top to bottom of the sediment (m) =
4 x 0.001	8 x 0.00003
3 x 0.002	2 x 0.00006
2 x 0.005	2 x 0.00012
2 x 0.01	3 x 0.0003
1 x 0.02	2 x 0.00075
1 x 0.03	2 x 0.002
	1 x 0.003
	2 x 0.005
	3 x 0.01
	1 x 0.02
	1 x 0.03

13 Example calculations

13.1 Selection of compounds

In order to test whether the outcome of the groundwater and surface water assessments is plausible, example calculations were performed for some selected pesticides.

The pesticides were selected with the aid of the analysis which active ingredients pose the highest hazards to humans and cattle, using surface water as a source of drinking water, described in Chapter 4.2. We selected those active ingredients that scored high on either acute, chronic or local chronic risk, or a combination thereof and that were used on crops relevant for the three surface water scenarios. (For groundwater scenarios the crop is only used to derive the application scheme that is assessed.) Within the PRRP project no drinking water risk assessment for cultivation in greenhouses was developed, so, active ingredients used on flowers, or on horticultural crops mainly grown inside greenhouses, were excluded. Also some high toxicity actives were excluded, because of their use against migratory pests. Table 13.1.1 presents the final selection of active ingredients, together with the crops they are used on, the volumes used in 2010 in Ethiopia, their ADI and the criterion for which they had a high score causing their selection. The main crops associated with these active ingredients are barley, cotton, wheat, maize, teff, potatoes (irish and sweet) and french beans.

Table 13.1.1
Active ingredients with highest acute, chronic and/or local chronic risk.

Active ingredient	Crops	Volume (2010, tons)	ADI (mg/kg bw)	Criterion
dimethoate	Barley, french beans	63	0.001	Acute, chronic, local
endosulfan	Cotton	84	0.006	Acute, chronic, local
deltamethrin	Cotton, flowers, cereals, maize, sweet potato, cabbage	30	0.01	Acute (chronic)
2,4-D	Wheat cereals, maize, teff	1824	0.05	Acute, chronic
malathion	Sweet potato	193	0.03	Acute. Chronic
atrazine	Maize	39.7	0.02	Acute, chronic
chlorothalonil	Irish potato, coffee	1.0	0.015	Local

Overall, insecticides (dimethoate, endosulfan, deltamethrin) appear in Table 13.1.1 because of their high toxicity, whereas the herbicide 2,4-D is in the table because of its high volume. To increase the number of compounds we added the insecticide and acaricide malathion combining a relatively high volume to a moderate toxicity, the herbicide atrazine and the fungicide chlorothalonil. As the calculations are used to assess risks at registration level, we assume that the compounds are used according to Good Agricultural Practice, GAP.

Table 13.1.2 lists the combination of compounds and crops for which the example calculations have been performed. The crops of cotton, sugar cane and sweet potatoes only grow under tropical conditions, therefore they do only figure in the scenarios below 1500 m altitude, i.e. the groundwater scenario of grid 373 and the surface water scenario of grid 346. Barley and faba bean crops need temperate conditions, so they do not grow in the scenarios below 1500 m altitude. All other crops are associated with all three groundwater scenarios as well as all three surface water scenarios.

Table 13.1.2
Combination of compounds and crops for which the example calculations have been performed.

Compound	Crops
dimethoate	barley, faba beans
endosulfan	cotton, maize
deltametrin	cotton, maize, sweet potato, cabbage
2,4-D	wheat, maize, teff, sugarcane
malathion	sweet potato
atrazine	maize, sugar cane
chlorothalonil	potato

Application rates of the compounds on the crops were taken from the FAO's Pesticide Stock Management System (PSMS) form compiled by the PHRD, while the number of applications were determined with the aid of local experts. (Table 13.1.3).

Table 13.1.3
Overview of crops, application rates and number of applications considered in the example risk calculations for drinking water produced from groundwater and surface water.

Compound	Crop	Rate kg. ha^{-1}	Number of applications
2-4D	Maize	1.44	1
	Sugar cane	1.44	1
	Teff	1.44	1
	Wheat	1.44	1
atrazine	Maize	2.5	1
	Sugar cane	2.5	1
chlorothalonil	Potato 1st	1.5	3
	Potato 2nd	1.5	3
deltamethrin	Cabbage 1st	0.025	5
	Cabbage 2nd	0.025	5
	Cotton	0.18	5
	Maize	0.021	1
	Sweet potato	0.09	4
dimethoate	Barley	0.6	2
	Faba bean	0.48	2
endosulfan	Cotton	1.05	6
	Maize	0.7	2
malathion	Sweet potato	1	7

The relevant pesticide properties were taken from the FOOTPRINT database (FOOTPRINT, 2006). The FOOTPRINT database often offers slightly different types or values of pesticide properties which might all be suitable to use for the one single pesticide property in the model. For instance for the model input parameter $DegT_{50soil}$, three different properties in FOOTPRINT database might be suitable (see Table A13.1 in Appendix 13.1). In such situations a choice is needed. We therefore developed a protocol that specifies which FOOTPRINT database property should be used for which pesticide property in the models (Appendix 13.1, Table 13.2). This protocol was based upon several criteria:

i) PHRD staff should be able to evaluate the studies used to determine the pesticide property (e.g. evaluation of a water-sediment experiment and its kinetic study is too complex), so, it should be easy to use;
ii) the FOOTPRINT database property should be valid for the model, e.g. the half-life in water for the process of photolysis is not suitable as input for the TOXSWA model, because TOXSWA uses an overall half-life (degradation due to the sum of hydrolysis, photolysis and microbial degradation in water) as input and
iii) use the most conservative option in case the two criteria above are not met.

The protocol also contains guidelines on how to deal with possibly unreliable data or data measured at for instance different temperatures or pH levels.
The main pesticide properties used in the simulations are listed in Table 13.1.4. Appendix 13.1 gives all pesticide properties needed for the simulations and more information on the procedure used to select the pesticide properties from the FOOTPRINT database.

Table 13.1.4
Main physico-chemical and human toxicological properties used in the example calculations, taken from the FOOTPRINT database.

Pesticide	**Main properties**				
	K_{om} L.kg^{-1}	**$DegT_{50,soil}$ day**	**$DegT_{50,water}$ day**	**ARfD mg/kgBW,day**	**ADI mg/kgBW,day**
2-4D	51.3	14	1000	0.05	0.05
atrazine	58	75	86	0.1	0.02
chlorothalonil	493	15.7	1000	0.6	0.015
deltamethrin	5939675	26	1000	0.01	0.01
dimethoate	16.4	2.6	68	0.01	0.001
endosulfan	6670.5	39	20	0.02	0.006
malathion	1044.1	0.17	10.4	0.3	0.03

13.2 Groundwater: exposure and risks for drinking water

For groundwater risk assessments the calculation of leaching concentrations does not depend on the crop type (see Chapter 6.1), but application rate and number of applications are relevant, which in their turn are determined by crop type.

Table 13.2.1 presents for the most risky active ingredients the crops in which they are used, the corresponding application scheme and the groundwater concentrations as calculated by the EuroPEARL metamodel. Next, the chronic daily intake is calculated (Chapter 3.2) by multiplying the PEC_{gw} with the daily intake from drinking water originating from groundwater, set at 2 L/d. This is compared to the acceptable chronic daily intake, estimated as 0.1 times the total acceptable daily intake of the specific compound for an Ethiopian adult of 60 kg, i.e. 0.1 * ADI * 60 kg. The ETR of Table 13.2.1 equals the ratio of chronic daily intake and the acceptable chronic daily intake. A value above 1 indicates there is a risk for humans and cattle by drinking this groundwater daily.

Only the ETR of atrazine is above 1, so this active ingredient in combination with the selected crop and application scheme poses risks to humans and cattle using groundwater as source of drinking water.

The risk is due to the relatively large application rate (2.5 kg/ha), the high toxicity (ADI = 0.02 mg/kgBW,day) and because atrazine is a very mobile substance (K_{om} = 58 L/kg).

For all other compounds the ETR is below 1, so the chronic risk from daily use of the groundwater as drinking water is low. For chlorothalonil, endosulfan, deltamethrin and malathion the PECs and ETR values are even close to zero or zero. The ETR for deltamethrin is zero: it has a large sorption capacity (K_{om} = 5939675 L/kg), so, the substance accumulates in the top layers of the soil and the risk of leaching is negligible The ETR of malathion is also zero: it has a very small degradation half-life ($DegT_{50,soil}$ = 0.17 d), causing the substance to degrade before is has time to leach to the groundwater. Chlorothalonil and endosulfan both have a relatively high K_{om} (493 and 6670.5 L/kg, respectively), combined with a relatively rapid degradation in soil ($DegT_{50,soil}$ of 15.7 and 39 d, respectively), resulting in very low ETR values.

Table 13.2.1

Groundwater concentrations and ETR values for the combination of the most risky active ingredients, crops and application pattern used in the example simulations for the three groundwater scenarios.

Substance	Crop	Rate	Number	Scenario					
		kg. ha^{-1}	of applications	219		346		323	
				$PEC_{n,gw}$	$ETR_{dw,gw,chronic}$	$PEC_{n,gw}$	$ETR_{dw,gw,chronic}$	$PEC_{n,gw}$	$ETR_{dw,gw,chronic}$
				(mg.m-3)	(-)	(mg.m-3)	(-)	(mg.m-3)	(-)
2-4D	Maize	1.44	1	2.16E+00	1.44E-02	2.39E-01	1.59E-03	1.01E-01	6.70E-04
	Sugar cane	1.44	1	a	a	2.39E-01	1.59E-03	a	a
	Teff	1.44	1	2.16E+00	1.44E-02	2.39E-01	1.59E-03	1.01E-01	6.70E-04
	Wheat	1.44	1	2.16E+00	1.44E-02	2.39E-01	1.59E-03	1.01E-01	6.70E-04
atrazine	Maize	2.5	1	3.10E+02	5.17E+00	1.95E+02	3.24E+00	1.65E+02	2.75E+00
	Sugar cane	2.5	1	a	a	1.95E+02	3.24E+00	a	a
chlorothalonil	Potato 1st	1.5	3	4.84E-08	1.07E-09	2.41E-16	5.36E-18	6.39E-17	1.42E-18
	Potato 2nd	1.5	3	4.84E-08	1.07E-09	2.41E-16	5.36E-18	6.39E-17	1.42E-18
deltamethrin	Cabbage 1st	0.025	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cabbage 2nd	0.025	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cotton	0.18	5	a	a	0.00E+00	0.00E+00	a	a
	Maize	0.021	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Sweet potato	0.09	4	a	a	0.00E+00	0.00E+00	a	a
dimethoate	Barley	0.6	2	6.16E-07	2.05E-07	a	a	1.92E-10	6.39E-11
	Faba bean	0.48	2	4.93E-07	1.64E-07	a	a	1.53E-10	5.12E-11
endosulfan	Cotton	1.05	6	a	a	1.00E-20	1.00E-20	a	a
	Maize	0.7	2	1.00E-20	1.00E-20	1.00E-20	1.00E-20	1.00E-20	1.00E-20
malathion	Sweet potato	1	7	a	a	0.00E+00	0.00E+00	a	a

a no simulation result since the crop is not expected to be grown on the specified location.

* all PEC_{gw} and ETR values smaller than 1.00E-20 have been set to 1.00E-20.

13.3 Surface water: exposure and risks for drinking water

Simulations have been done for the combinations of active ingredients and crops for the three Ethiopian surface water scenarios parameterized in the models PRZM and TOXSWA (Table 13.3.1.).

Table 13.3.1
Overview of the combination of most risky active ingredients and crops used in the example simulations for the three surface water scenarios.

Scenario/crop	191 (west of Lake Tana)	217 (SE of Bure)	373 (W of Arba Minch)
Altitude	1682 m	1705 m	1288 m
Precipitation (av/yr)	2581 mm	2779 mm	1702 mm
Active ingredient			
dimethoate	barley, faba beans	barley, faba beans	-
endosulfan	maize	maize	cotton, maize
deltametrin	maize, cabbage*	maize, cabbage*	cotton, maize, sweet potato, cabbage*
2,4-D	wheat, maize, teff	wheat, maize, teff	wheat, maize, teff, sugarcane
malathion	-	-	sweet potato
atrazine	maize	maize	maize, sugar cane
chlorothalonil	potato*	potato*	potato*

* two crop cycles in a year, of which one with irrigation.

Application patterns used in the simulations are given in Table 13.3.2. The application dates were determined by local experts. More background information on the application patterns used are given in Appendix 13.2.

Table 13.3.2
Pesticides, crops and application patterns used in the example simulations for the three drinking water produced from surface water scenarios.

Pesticide	Crop	Rate kg. ha^{-1}	Number of applications	Application dates Highland + midland*
2-4D	Maize	1.44	1	10 March
	Sugar cane	1.44	1	2 January
	Teff	1.44	1	5 July
	Wheat	1.44	1	10 July
atrazine	Maize	2.5	1	10 March
	Sugar cane	2.5	1	2 January
chlorothalonil	Potato 1st	1.5	3	12, 19 and 26 July,
	Potato 2nd	1.5	3	19 and 26 January, 1 February
deltamethrin	Cabbage 1st	0.025	5	4, 14 and 24 June, 4 and 14 July
	Cabbage 2nd	0.025	5	21 November, 1, 11, 21 and 31 December
	Cotton	0.18	5	12, 19 and 26 July, 2 and 9 August
	Maize	0.021	1	17 April
	Sweet potato	0.09	4	19 and 29 July, 2 and 9 August
dimethoate	Barley	0.6	2	29 July and 5 August
	Faba bean	0.48	2	23 and 30 July
endosulfan	Cotton	1.05	6	12, 19 and 26 July, 2, 9 and 16 August
	Maize	0.7	2	10 and 17 April
Malathion	Sweet potato	1	7	10, 20 and 30 July, 9, 19 and 29 August, 8 September

* For reasons of simplification we selected the application dates corresponding to the crop development in only one of the two scenario zones (highland or midland): the scenario zone where the crop is most commonly grown.

Table 13.3.3 gives the simulation results (99th overall percentile) of the three surface water scenarios. Active ingredients 2,4-D, atrazine, chlorothalonil and dimethoate are the compounds with the highest PEC99th results (Table 13.3.3), whereas the PEC99th concentration for deltamethrin is calculated to be very low (negligible) both in the stream and the pond scenarios.

Table 13.3.3
PRZM, TOXSWA and TOXSWA metamodel simulation results, the Predicted Environmental Concentrations (µg/L) for the small stream (grid 191) and the two ponds (grid 217 and 373) for the aimed overall 99th probabilities of occurrence.

Pesticide	Crop	Predicted Environmental Concentration, PEC (99 percentile concentration, µg/L)		
		191	217	373
2,4-D	Maize	6.1	0.4	0.5
	Sugar cane	a	a	0.6
	Teff	61.3	19.3	0.6
	Wheat	57.6	21.8	0.9
Atrazine	Maize	27.8	0.5	0.5
	Sugar cane	a	a	0.3
Chlorothalonil	Potato (cycle 1)	30.8	40.5	2.7
	Potato (cycle 2)	34.8	15.5	17.1
Deltamethrin	Cabbage (cycle 1)	1.9E-04	7.9E-04	8.8E-04
	Cabbage (cycle 2)	1.9E-04	8.4E-04	8.4E-04
	Cotton	a	a	6.6E-03
	Maize	4.1E-05	2.9E-04	2.9E-04
	Sweet potato	a	a	2.9E-03
Dimethoate	Barley	27.4	21.7	a
	Faba beans	22.6	15.6	a
Endosulfan	Cotton	a	a	0.5
	Maize	1.40	0.9	1.6
Malathion	Sweet potato	a	a	0.2

a: no simulation result since the crop is not expected to be grown on the specified location.

Table 13.3.4 gives the estimated acute risks for humans. These risks are estimated from the International Estimated Short Term Intake (IESTI). An IESTI below 100% means that the daily intake from consuming a large portion (6L) of drinking water per day is below the acceptable total daily intake for the compound considered. For all scenarios and associated compound-crop combinations the IESTI is less than 100%, indicating that for the investigated combinations of compounds and crops, direct surface water consumption is associated with low acute health risks for humans in Ethiopia.

Table 13.3.4
Summary of risk assessment results for humans for grids 191, 217 and 373.

Pesticide	Crop	IESTI (%) 191	IESTI (%) 217	IESTI (%) 373	Risk category 191	Risk category 217	Risk category 373
2,4-D	Maize	1.22	0.08	0.1	low	low	low
	Sugar cane	a	a	0.12	a	a	low
	Teff	12.26	3.86	0.12	low	low	low
	Wheat	11.52	4.36	0.18	low	low	a
Atrazine	Maize	2.78	0.05	0.05	low	low	low
	Sugar cane	a	a	0.03	a	a	low
Chlorothalonil	Potato (cycle 1)	0.51	0.68	0.05	low	low	low
	Potato (cycle 2)	0.58	0.26	0.29	low	low	low
Deltamethrin	Cabbage (cycle 1)	0.00019	0.00079	0.00088	low	low	low
	Cabbage (cycle 2)	0.00019	0.00084	0.00084	low	low	low
	Cotton	a	a	0.01	a	a	low
	Maize	0.0000415	0.00029	0.00029	low	low	low
	Sweet potato	a	a	0.0029	a	a	low
Dimethoate	Barley	27.4	21.7	a	low	low	a
	Faba beans	22.6	15.6	a	low	low	a
Endosulfan	Cotton	a	a	0.25	a	a	low
	Maize	0.70	0.45	0.8	low	low	low
Malathion	Sweet potato	a	a	0.0067	low	low	low

a no simulation result since the crop is not expected to be grown on the specified location.

The exposure simulations of the compound-crop combination 2,4-D – Maize are analysed in more detail as an example given below.

In the small stream scenario, grid 191, located in the highlands southwest of Lake Tana, the long term annual average precipitation is 2581 mm. The main rainy season is June- September (Figure 13.3.1).

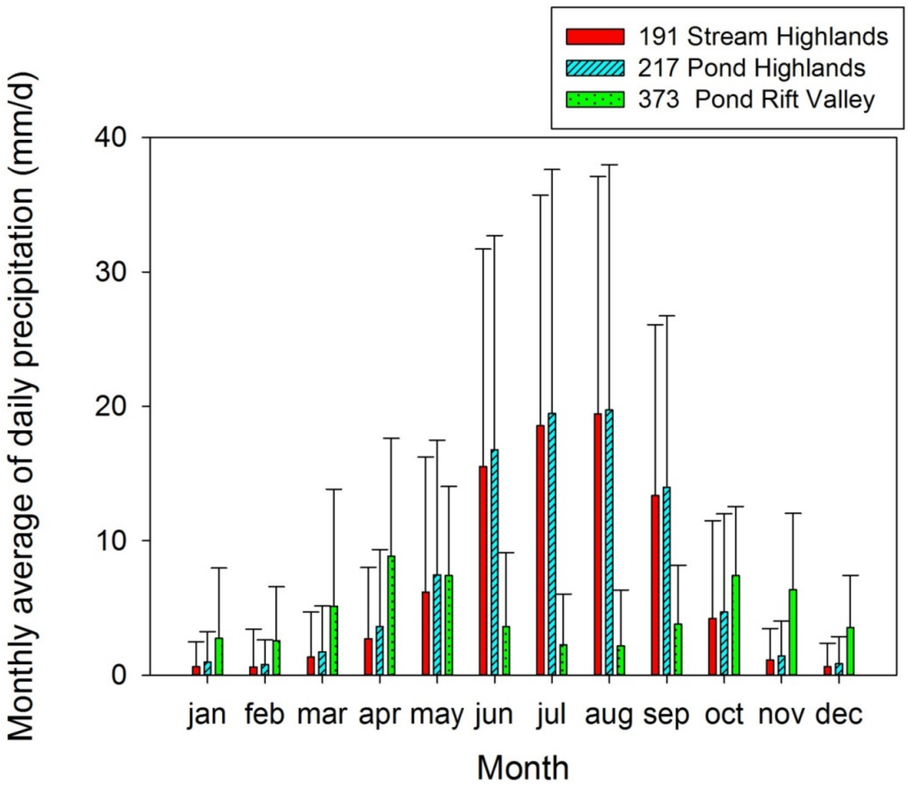


Figure 13.3.1 *Daily precipitations averaged per month over 33 years plus their standard deviation (error bars) for the three surface water scenarios in Ethiopia (non-irrigated crops).*

Figure 13.3.2 presents the daily precipitation, runoff size and concentration as well as the amount of discharge in the small stream plus its concentration of 2,4-D as a function of time for the selected year, 1920, being the 95.5 temporal percentile for this grid (for details on temporal, spatial and overall percentiles, see Appendix 8.3). There are approx. 100 smaller and larger runoff events per year that feed the small stream (e.g. Figure 13.3.2 C for 1920). Runoff, occurring immediately after the application of 2,4-D (10 March) results in relatively elevated concentrations in the runoff water, up to approximately 100 µg/L, depending on the size of the runoff (Figure 13.3.2 B). In 1920 the concentration in the stream increases due to a runoff event in the period 21-24 March. The very small runoff amount of 0.039 mm/d on March 21st (due to a precipitation event of about 11 mm/d) leads to the highest concentration in the stream of the year (approximately 6 µg/L, Figure 13.3.2 D) after which the concentration decreases within the following three days, despite more runoff events during these days. The metamodel calculates the concentration of the water flowing into the stream by diluting the runoff water from treated fields with (i) the clean baseflow, (ii) part of the subsurface drainage flow into the stream and (iii) the uncontaminated runoff water from untreated fields (Appendix 6.4). In 1920, the next runoff event leading to an elevated discharge in the stream is found on April 15th. However, concentrations are at this point negligible.

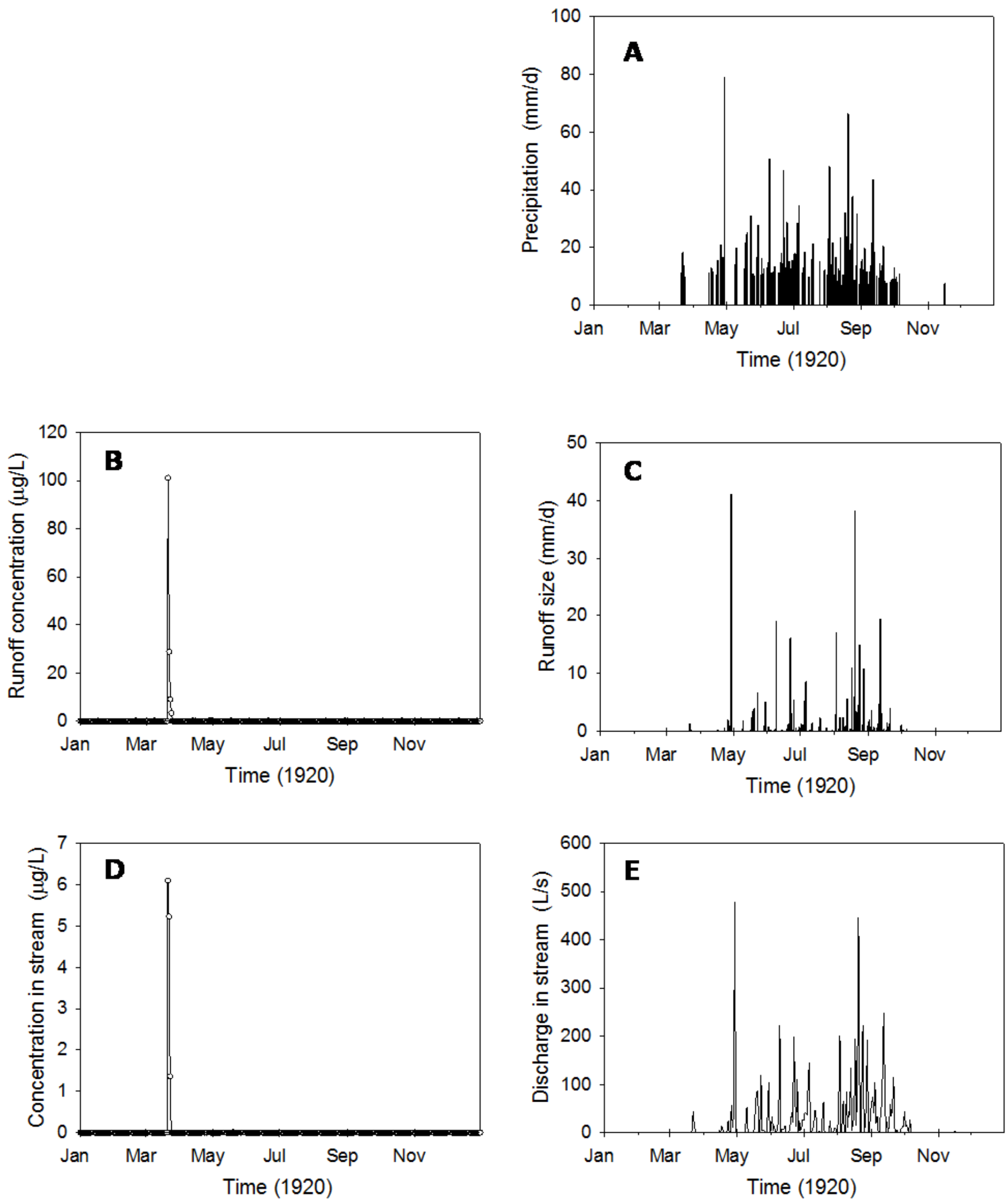


Figure 13.3.2 *Precipitation (A), runoff concentration (B), runoff size (C), concentration in the stream (D) and discharge in the stream (E) of grid 191 in the selected year 1920; results of simulations for one annual application of 1.44 kg/ha of 2,4-D in maize on 10 March.*

Figure 13.3.3 presents the concentration 2,4-D in the small stream for the 33 years simulated. For each year concentrations are highest for runoff events occurring immediately after application on March 10. During subsequent runoff events the amounts of 2,4-D available diminish and runoff concentrations decrease.

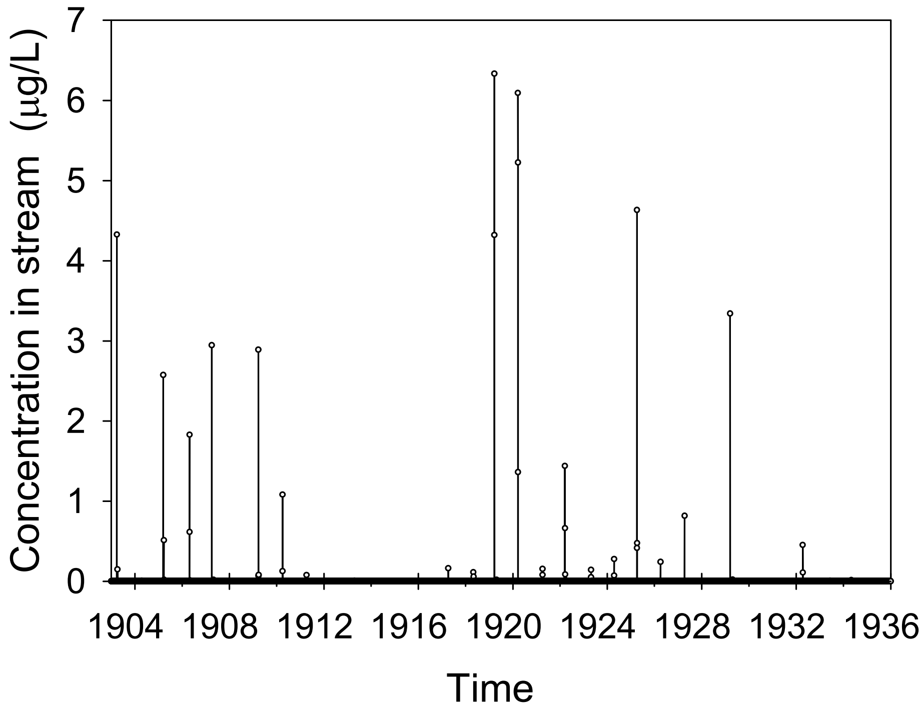


Figure 13.3.3 *Concentration 2,4-D in the highland small stream (grid 191) for one annual application of 1.44 kg/ha in maize on 10 March.*

Table 13.3.5 presents the yearly maximum concentrations in the stream, their associated discharge and date as well as the corresponding runoff event with its 2,4-D concentration for the 33 years simulated. The second highest ranked concentration, i.e. a c_{stream} of 6.09 µg/L in 1920, is selected to represent the overall 99^{th} percentile of occurrence (See Appendix 8.3).

Table 13.3.5 shows that the two highest maximum yearly concentrations in the stream (1919 and 1920) originate from relatively small runoff events. These small runoff events (0.01936 and 0.03873 mm/d) result in very high concentrations in the runoff water (133 and 101 µg/L), because the 2,4-D mass is dissolved in a small amount of runoff water. The runoff events last for 6 hours, both in 1919 and 1920 [data from *.p2t file, not shown], implying that during six hours the runoff equals 0.003227 and 0.006455 mm/h. Only 20 of the 100 ha upstream catchment have been treated with 2,4-D, so e.g. for 1919 20 ha * 0.003227 mm/h * 133 µg/L= 85838 µg/h, so 85838 µg 2,4-D leaves the catchment per hour during runoff. For 1920 this amounts to 130391 µg/h. The mass is dissolved in (i) the clean, constant base flow of the catchment (10 m^3/h, see Appendix 6.4), (ii) some clean subsurface drainage flow of the 100 ha catchment (0.0003558 and 0.00497 mm/h for 1919 and 1920, [from *.p2t file, not shown]) and (iii) the runoff water of the 100 ha upstream catchment (0.003227 and 0.006455 mm/h for 1919 and 1920, [from *.p2t file, not shown]). This results in concentrations in the stream of e.g. for 1919 85838 µg/h in a water volume of 10 000L/h + (100 ha * 0.0003558 mm/h * 10^4) + (100 ha * 0.003227 mm/h * 10^4) = 13582.8 L/h, equalling 6.32 µg/L, which corresponds well to the stream concentration of 6.33 µg/L presented in Table 13.3.5. For 1920 there is 130391 µg/h dissolved into 21425 L/h, resulting in 6.09 µg/L, corresponding to the stream concentration of 6.09 µg/L presented in Table 13.3.5. (See Appendix 6.4 for more details on the calculations.)

Table 13.3.5 also shows that the highest concentration in the runoff water does not automatically result in the highest concentration in the stream. In 1905 the concentration in the runoff water is 142 µg/L, which is higher than the ones cited above for 1919 and 1920, but this concentration occurs within the very small runoff event of 0.008094 mm/d, (in a five hours lasting runoff event, i.e. 0.001619 mm/h runoff flow). So, the 2,4-D mass is only 142 µg/L * 0.001619 mm/h * 20 ha = 45980 µg/h. This is dissolved in(i) the clean, constant base flow of the catchment (10 m^3/h, see Appendix 6.4), (ii) some clean subsurface drainage flow of the 100 ha catchment (0.006292 mm/h, [from *.p2t file, not shown]) and (iii) the runoff water of the 100 ha upstream catchment (0.001619 mm/h, [from *.p2t file, not shown]), totalling to 17911 L/h. This results in concentrations in the stream of 45980 µg/h divided by 17911 L/h, equal to 2.57 µg/L, which corresponds to the number shown in Table 13.3.5. Although the concentration in the runoff water is the highest of the 33 years, the corresponding concentration flowing into the stream is not the highest, because the relatively small contaminated amount of runoff water is diluted into a large amount of uncontaminated water.

In 1918, the first runoff event after application of 2,4-D on 10 March is found on May 1st. This very small runoff event (0.0063 mm/d) results in a concentration of 8.19 µg/L in the runoff water, which is much lower than the concentration of 142 µg/L after the slightly higher runoff event of 0.0081 mm/d in 1905. Between application and May 1st the 2,4-D concentration in the upper layers of the soil decreased due to degradation ($DegT_{50,soil}$ = 14 days).(The precipitation is in this period was zero, so the substance did not leach to deeper layers, so, this did not contribute to a low concentration in the runoff water.) The resulting concentration in the stream was about 0.1 µg/L.

In conclusion, Table 13.3.5 shows that the maximum yearly concentration is lower than 0.1 µg/L for 14 of the 33 years, while for the other 19 years the maximum yearly concentration is above the 0.1 µg/L, thus, above the EU standard for drinking water.

Table 13.3.5
Ranked, maximum yearly concentrations 2,4-D in the small streams at grid 191.

Rank nr	C_{stream} µg/L	$Q_{stream,in}$ during runoff L/s	C_{runoff} µg/L	Runoff size mm/d	Date*	Precipitation mm/d
1	6.33E+00	3.77	1.33E+02	0.01936	21-3-1919	11.7
2	6.09E+00	5.95	1.01E+02	0.03873	21-3-1920	11.3
3	4.63E+00	118.93	2.39E+01	8.303	5-4-1925	39.9
4	4.33E+00	9.20	3.10E+01	0.1387	28-3-1903	12.9
5	3.34E+00	4.22	4.89E+01	0.0259	16-3-1929	10.7
6	2.95E+00	154.39	1.50E+01	10.35	4-4-1907	37.6
7	2.89E+00	283.28	1.47E+01	24.05	25-3-1909	57.6
8	2.57E+00	4.98	1.42E+02	0.008094	15-3-1905	10.2
9	1.83E+00	17.76	1.08E+01	0.5933	25-4-1906	21.2
10	1.44E+00	5.88	4.34E+01	0.01759	18-3-1922	10.5
11	1.08E+00	108.78	5.58E+00	5.314	3-4-1910	28.4
12	8.17E-01	3.88	1.44E+01	0.02787	12-4-1927	13.6
13	4.53E-01	61.32	2.38E+00	2.098	11-4-1932	20.7
14	2.76E-01	23.75	1.59E+00	0.5918	17-4-1924	15.2
15	2.40E-01	4.57	3.06E+00	0.03881	5-4-1926	11.1
16	1.61E-01	38.36	8.67E-01	1.153	9-4-1917	17.6
17	1.54E-01	5.50	4.21E+00	0.02166	6-4-1921	11.3
18	1.41E-01	8.99	1.13E+00	0.1213	26-4-1923	12.2
19	1.12E-01	4.25	8.19E+00	0.006281	1-5-1918	11.6
20	7.51E-02	3.97	1.25E+00	0.02575	7-4-1911	11.9
21	1.36E-02	69.50	7.09E-02	2.882	2-5-1934	23.5
22	5.92E-03	24.83	3.70E-02	0.572	9-6-1933	15.1
23	5.77E-03	22.26	3.52E-02	0.4597	16-4-1904	14.5
24	5.09E-03	84.94	2.63E-02	3.846	19-4-1913	25.2
25	2.94E-03	15.16	2.23E-02	0.2161	18-5-1935	12.9
26	2.94E-03	10.09	2.88E-02	0.1485	13-5-1912	16.5
27	2.26E-03	21.02	1.30E-02	0.4597	9-5-1915	14.5
28	1.05E-03	6.96	8.76E-03	0.09045	30-4-1928	11.7
29	1.00E-03	4.69	1.23E-02	0.04128	27-4-1916	11
30	1.63E-04	15.54	1.34E-03	0.2037	4-5-1930	12.8
31	2.27E-05	18.01	2.30E-04	0.1917	2-6-1914	12.7
32	2.00E-05	92.96	1.08E-04	4.02	18-5-1908	25.6
33	5.52E-06	24.34	6.62E-05	0.2554	3-6-1931	13.2

* The years 1903-1935 correspond to the years 1979-2011; they have been numbered 1903-1935, because the PRZM model cannot handle year numbers above 1999.

Next, results of the exposure simulations of the compound-crop combination 2,4-D – Maize for the pond scenarios of grids 373 and 217 are analysed in more detail.

At the selected grids 373 and 217, located respectively near Arba Minch in the midlands in the southern part of the Rift Valley and in the highlands SW of Lake Tana, the long term annual average precipitation is 1702 and 2779 mm. Near Arba Minch the months with main rains are March to May (Belg, short rains) and October/November (Kremt, long rains), while the main rainy season is June-September (Kremt) in the highlands SW of Lake Tana (Figure 13.3.1). At grid 373 there are on average approx. 83 smaller and larger runoff events per year that feed the pond and in grid 217 there are on average approx. 113 events per year. Runoff, occurring immediately after the application of 2,4-D (10 March) results in relatively elevated concentrations in the runoff water (depending on the size of the runoff). Later on concentrations in the runoff water decrease and after half of April in grid 373 and after end of April in grid 217, the concentrations become negligible to zero. Figure 13.3.4 and Figure 13.3.5 present the daily precipitation, runoff size and concentration as well as the water depth in the pond plus the concentration of 2,4-D as a function of time for the selected year, 1935, for grid

373 and 1930 for grid 217 both being the 95.5 temporal percentile for this grid (See Appendix 8.3 fore more details on percentiles probability).

For both grids the concentration in the pond increases sharply due to runoff events shortly after the application of 2,4-D on March 10th. Although the runoff events themselves are not particularly large (Figure 13.3.4 C and Figure 13.3.5. C, 0.39 and 0.76 mm/d respectively, Table 13.3.6, 2nd ranked year) concentrations in the runoff water are large. Concentrations in the pond are much lower (roughly a factor of 500) due to dilution mainly by the pond water. The flow velocity in the pond is rather slow, so disappearance of the substance in water is mainly explained by the transformation and sorption characteristics of the substance. The sorption capacity of 2,4-D is low and degradation half-life in water is large (1000 d). This, in combination with the low flow velocity, results in a slow concentration decrease and thus large residence times of the substance in the pond. For grid 217 the discharge of the pond increases from June onwards due to repeated runoff into the pond in the rainy season. The increased discharges cause greater water depths and higher flow velocities and lead to a quicker disappearance of 2,4-D from this pond than seen for the pond of grid 373.

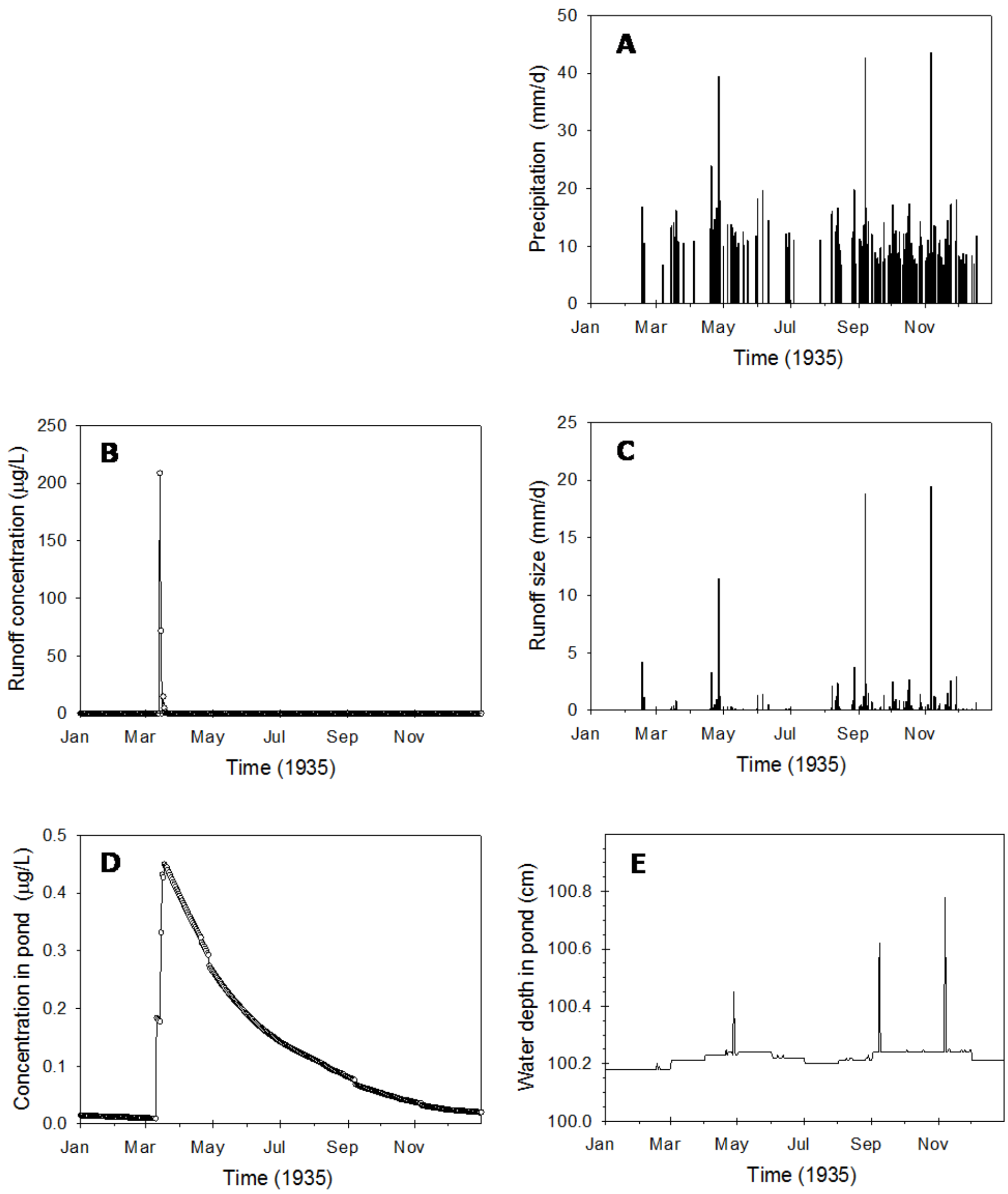


Figure 13.3.4 *Precipitation (A), runoff concentration (B), runoff size (C), concentration in the pond (D) and water depth in the pond (E) of grid 373 in the selected year 1935; results of simulations for one annual application of 1.44 kg/ha of 2,4-D in maize on 10 March.*

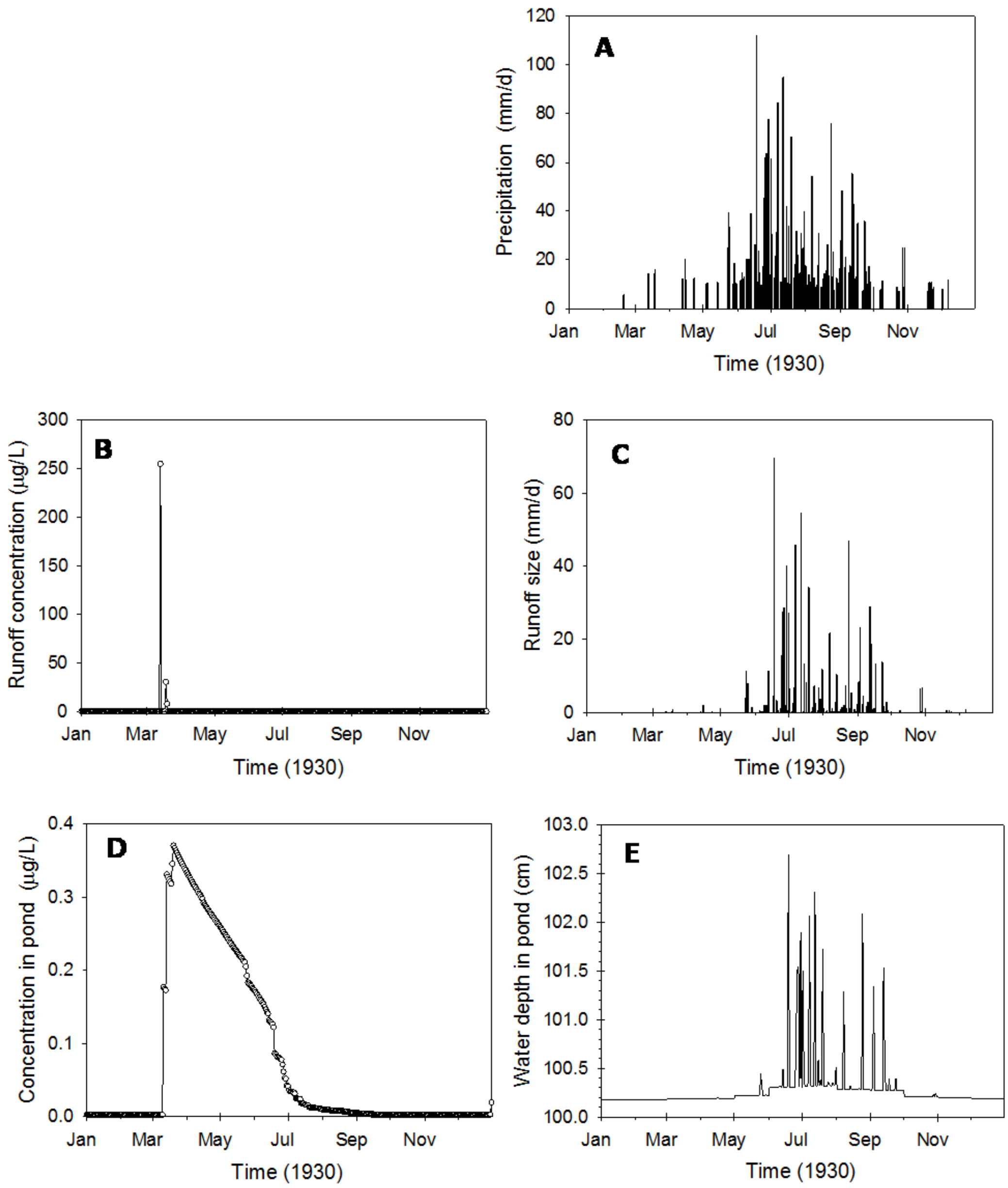


Figure 13.3.5 *Precipitation (A), runoff concentration (B), runoff size (C), concentration in the pond (D) and water depth in the pond (E) of grid 217 in the selected year 1930; results of simulations for one annual application of 1.44 kg/ha of 2,4-D in maize on 10 March.*

Figure 13.3.6 presents the concentration 2,4-D in the two ponds for the 33 years simulated. The second highest concentration has been selected for the assessment of risks for drinking water, being 1935 for grid 373 and 1930 for grid 217. Scrutiny of the data behind these graphs (data not shown) demonstrate that the concentrations in the ponds are highest at the moments of runoff events occurring immediately after the application of 10 March; thereafter the concentrations lower gradually in the course of the year, due to the very low flow velocities and corresponding long hydraulic residence times. At the fields surrounding the pond of grid 373 and 217 multiple runoff events occur. After a few runoff events 2,4-D has run off and it has leached out of the upper 2 cm soil into deeper layers, so no more 2,4-D mass can run off (data not shown).

Table 13.3.6 presents the yearly maximum concentrations in the ponds, their associated water depth h, outgoing discharge Q_{out}, concentration in runoff c_{runoff}, runoff size, precipitation and date ranked according to c_{pond} of 2,4-D for the 33 years simulated.

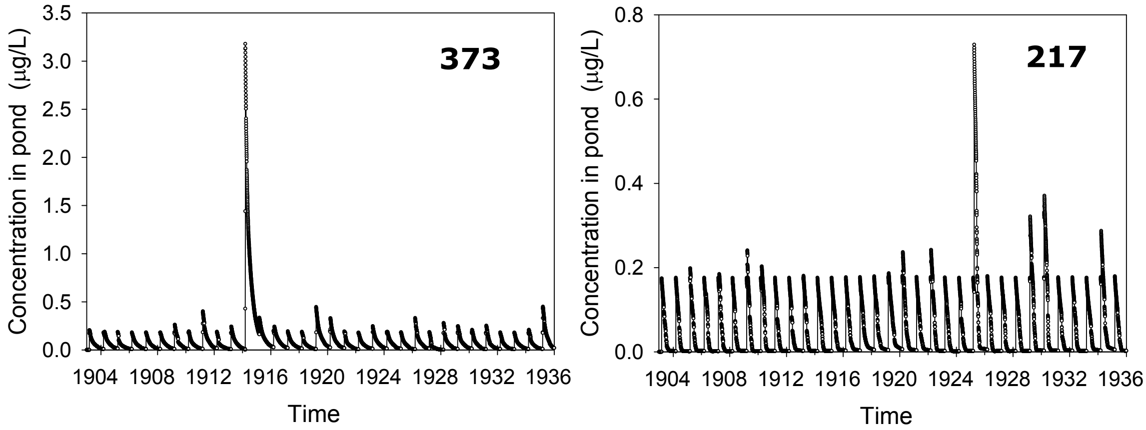


Figure 13.3.6 *Concentration 2,4-D in the water of the Rift Valley pond (grid 373) and of the Highland pond (grid 217) for one annual application of 1.44 kg/ha in maize on 10 March for the period 1903-1935 (representing 1979-2011).*

As the water volume in the pond is virtually constant (water depth of 100.0-100.8 cm in grid 373 and 100.0-102.8 cm in grid 217), the maximum concentration in the pond is predominantly determined by the 2,4-D mass in the pond, entering at the day itself and possibly stacked on top of 2,4-D mass already present before the entry causing the maximum concentration.

For instance for grid 373 the first ranked yearly maximum concentration in the pond on 14 March 1914 (see the note ** below Table 13.3.6: this is the actual concentration on March 13th end of the day) is determined mostly by the runoff events of the three preceding days with runoff concentrations of 571, 178 and 33 µg/L in the corresponding runoff sizes of 0.0905, 1.18 and 11.45 mm/d at 10, 11 and 12 March (data not shown). The concentration in the pond on March 12th end of the day is 3.127 µg/L. With an average pond volume of 30*30*1.0047 m^3 at 12 March this means that a mass of about 2827.5 mg is present in the pond on March 12th end of the day (Table 13.3.7). Next, on 13 March a runoff mass of 2,4-D of 201.8 mg enters the pond. (This mass is calculated by considering that the runoff entry of 7.588 mm/d with a concentration of 5.909 µg/L, see Table 13.3.6, corresponds to 5.909 µg/L * 7.588 mm* 4500 m^2 (i.e., the surrounding area delivering runoff water into the pond) = 201.8 mg, so, a 2,4-D mass of 201.8 mg entering the pond) (Table 13.3.7). Therefore, at the end of March 13th, a concentration of approximately 3.2 µg/L is present in the pond, corresponding to a mass of 3029.3 mg (= 2827.5 + 201.8 mg) divided by a water volume of 944 m^3 at 13 March (this is the pond volume of 30*30*1.0047 (water depth on 13 March) m^3 + incoming runoff water of 7.588.10^{-3} m* 4500 m^2 + the base flow of 5.8 m^3/d). Note that we neglected the incoming subsurface drainage flow, but even so, the calculated 3.2 µg/L concentration in the pond corresponds well to the number of 3.179 µg/L mentioned in Table 13.3.6 for grid 373, rank number 1. For the calculation example above the first ranked yearly maximum concentration in the pond of grid 373 is used. However, the aimed 99th overall probability of occurrence in time and space is represented by the <u>second</u> ranked yearly maximum concentration in the pond (so for grid 373 this is the concentration of 0.450 µg/L on 18 March 1935).

In grid 217 the first ranked yearly maximum concentration in the pond on 6 April 1925 (see the note ** below Table 13.3.6: this is the actual concentration on 5 April end of the day) is predominantly determined by the large amount of 2,4-D mass in the runoff entry of 10.66 mm with a concentration of 11.67 µg/L on 5 April, corresponding to 559.8 mg (i.e. 11.67 µg/L * 10.66 mm * 4500 m^2) (Table 13.3.7). Before the runoff entry on April 5th, the pond already contained 128.1 mg (i.e. the pond concentration of 0.142 µg/L on April 4th end of the day times the average pond volume of 30*30*1.002 m^3). So, on April 5th end of the day the total mass in the pond is 128.1 + 559.8 = 687.9 mg. This results in a pond concentration of approximately 0.72 µg/L (corresponding to 687.9 mg divided by the pond volume 30*30*1.002 m^3 + the runoff water 10.66 10^{-3} m * 4500 m^2 + the base flow of 5.8 m^3/d) (Table 13.3.7). Again, we neglected the incoming subsurface drainage flow, but even so, the calculated 0.72 μg/L concentration in the pond corresponds well to the number of 0.729 μg/L mentioned in Table 13.3.6 for grid 217, rank number 1.

Furthermore Table 13.3.6 contains yearly maximum pond concentrations on days without a runoff event. (Note that the date of these days are all 11 March in Table 13.3.6. The reason is that the TOXSWA model provides the concentrations in the pond on March 10 at end of the day on time 11 March 00:00 in its output file.) These concentrations are caused by the spray drift deposition accompanying the application on March 10th. The spray drift deposition on the surface area of the pond corresponds to 0.1229% of the application rate (0.1229% corresponds to the lineic average deposition from 3.50 to 33.50 m distance from the crop for Large Scale Farms), i.e. 0.1229% * 1.44 kg/ha * 30 m* 30 m =159.3 mg deposited on the pond, resulting in a pond concentration of approximately 0.1758 μg/L (i.e. 159.3 mg divided by the pond volume of 30 m*30 m*approximately 1 m water depth+ the base flow of 5.8 m^3/d). This value of 0.1758 μg/L corresponds well to the values shown for the pond in grid 217 (Table 13.3.6), where the mass of the former year has flowed out due to the relatively high rainfall (Figure 13.3.1) and consecutive numerous runoff events in June-September (see e.g. Figure 13.3.5 C). For grid 373 Table 13.3.6 contains many yearly maximum concentrations in the order of magnitude of 0.181 μg/L (rank number 33) to 0.194 μg/L (rank number 18). These concentrations are slightly higher than the 0.1758 μg/L calculated above, because mass of spray drift deposition and runoff events of former years was still present in the pond before the application on 10 March, due to a low flow through rate in the pond of grid 373. E.g. for ranking numbers 18. 20, 21 and 23 the concentrations at the start of 10 March were 0.019442, 0.018499, 0.01584 and 0.014356 μg/L. An addition reason is that 2,4-D with its $DegT_{50,water}$ of 1000 d degrades very slowly in water.

For grid 373, the concentration in the pond for rank number 5 is higher than for rank number 6 (Table 13.3.6). Both maximum yearly concentrations are found on 11 March 00:00 and partly due to spray drift deposition accompanying the application on March 10th. Although there is also a runoff event on March 10th for rank number 6, the maximum yearly concentration is lower than for rank number 5. This is due to the difference in mass of spray drift deposition and runoff events of former years still present in the pond. For rank number 5 the concentration in the pond just before the drift event on March 10th 1915 is 0.1616 μg/L while this concentration is 0.006272 μg/L just before the drift event on March 10th 1926 (rank number 6).

Table 13.3.6

Ranked, maximum yearly concentrations 2,4-D in the two ponds at grids 373 and 217, as well as water depth h, outgoing discharge Q_{out}, concentration in runoff c_{runoff}, runoff size, precipitation and date.

Grid 373	c_{pond}	h	Q_{out}	c_{runoff}	Runoff size	Date*,**	Precipitation
Rank nr	μg/L	cm	L/s	μg/L	mm/d		mm/d
1	3.179	100.47	0.699846	5.909	7.588	14/03/1914	32.8
2	0.450	100.21	0.080801	14.65	0.3911	18/03/1935	14.1
3	0.447	100.2	0.077361	267	0.2037	12/03/1919	12.8
4	0.402	100.21	0.084605	9.033	0.242	15/03/1911	13.1
5	0.335	100.19	0.06893	0	0	11/03/1915	0
6	0.332	100.23	0.178584	578.5	0.05345	11/03/1926	11.2
7	0.331	100.22	0.091778	17.21	1.403	18/03/1920	18.5
8	0.281	100.19	0.07116	189.9	0.1171	13/03/1928	12
9	0.262	100.2	0.07636	85.23	0.2289	21/03/1909	13
10	0.253	100.2	0.0739	1.392	15	20/03/1931	44.9
11	0.248	100.21	0.082597	16.69	0.9235	18/03/1929	16.7
12	0.247	100.22	0.090597	127.1	0.008094	13/03/1923	10.2
13	0.244	100.18	0.06699	8.507	1.849	01/04/1916	22.7
14	0.243	100.22	0.08522	77.62	0.1917	16/03/1913	12.7
15	0.210	100.21	0.084991	24.89	0.3586	21/03/1934	13.9
16	0.209	100.22	0.08622	11.75	0.6739	19/03/1930	15.6
17	0.206	100.21	0.08227	178.5	0.04128	13/03/1903	11

Grid 373	c_{pond}	h	Q_{out}	c_{runoff}	Runoff size	Date*,**	Precipitation
Rank nr	µg/L	cm	L/s	µg/L	mm/d		mm/d
18	0.194	100.18	0.06691	0	0	11/03/1917	0
19	0.194	100.2	0.082663	6.347	0.1267	19/03/1910	12.1
20	0.193	100.19	0.06946	0	0	11/03/1921	0
21	0.190	100.21	0.08407	0	0	11/03/1912	0
22	0.190	100.21	0.08275	3.487	2.902	08/04/1904	23.5
23	0.189	100.19	0.07202	0	0	11/03/1918	0
24	0.188	100.19	0.073057	18.14	0.03064	27/03/1924	10.8
25	0.188	100.22	0.08605	0	0	11/03/1905	0
26	0.186	100.22	0.08572	0	0	11/03/1927	0
27	0.186	100.2	0.076269	0	0	11/03/1925	0
28	0.184	100.2	0.07693	0	0	11/03/1932	0
29	0.183	100.18	0.06691	0	0	11/03/1908	0
30	0.183	100.18	0.06691	0	0	11/03/1907	0
31	0.182	100.18	0.06691	0	0	11/03/1906	0
32	0.181	100.2	0.0756	0	0	11/03/1933	0
33	0.181	100.2	0.074726	0	0	11/03/1922	0
Grid 217	c_{pond}	h	Q_{out}	c_{runoff}	Runoff size	Date*,**	Precipitation
Rank nr	µg/L	cm	L/s	µg/L	mm/d		mm/d
1	0.729	100.19	0.07213	11.67	10.66	06/04/1925	43.9
2	0.371	100.19	0.079482	7.918	0.7607	20/03/1930	16
3	0.321	100.19	0.10133	9.479	1.074	18/03/1929	17.3
4	0.287	100.18	0.0676	73.12	0.3586	23/03/1934	13.9
5	0.242	100.19	0.073139	15.12	0.4248	21/03/1922	14.3
6	0.241	100.2	0.087826	2.7	0.3429	28/03/1909	13.8
7	0.237	100.2	0.087117	8.284	0.3747	24/03/1920	14
8	0.203	100.23	0.33537	0.5279	1.898	05/04/1910	20.1
9	0.199	100.21	0.08043	123.9	0.05345	16/03/1905	11.2
10	0.187	100.18	0.068537	51.58	0.03577	23/03/1919	10.9
11	0.185	100.19	0.081838	0.8893	10.53	05/04/1907	37.9
12	0.181	100.18	0.06701	156.9	0.01403	15/03/1913	10.4
13	0.180	100.19	0.06767	0	0	11/03/1926	0
14	0.180	100.18	0.06691	0	0	11/03/1935	20.4
15	0.179	100.18	0.06691	0	0	11/03/1918	0
16	0.178	100.18	0.06691	0	0	11/03/1921	0
17	0.178	100.18	0.06691	0	0	11/03/1917	0
18	0.177	100.18	0.06691	0	0	11/03/1916	0
19	0.177	100.18	0.06691	0	0	11/03/1931	0
20	0.177	100.18	0.06691	0	0	11/03/1932	0
21	0.177	100.18	0.06691	0	0	11/03/1923	0
22	0.176	100.18	0.06699	0	0	11/03/1927	0
23	0.176	100.19	0.068641	0	0	11/03/1911	0
24	0.176	100.18	0.06691	0	0	11/03/1915	0
25	0.176	100.18	0.06691	0	0	11/03/1933	0
26	0.176	100.18	0.06691	0	0	11/03/1906	0
27	0.176	100.18	0.06691	0	0	11/03/1928	0
28	0.176	100.18	0.06691	0	0	11/03/1914	0
29	0.176	100.18	0.06691	0	0	11/03/1912	0
30	0.176	100.18	0.075973	0	0	11/03/1924	0
31	0.176	100.18	0.06691	0	0	11/03/1904	0
32	0.176	100.18	0.06691	0	0	11/03/1908	0
33	0.175	100.19	0.06839	0	0	11/03/1903	0

* The years 1903-1935 correspond to the years 1979-2011; they have been numbered 1903-1935, because the PRZM model cannot handle year numbers above 1999.

** Note that the TOXSWA model calculates the pond concentrations at the end of a day (so at 24:00). However in the output of the model these concentrations are allocated to the next day on time 00:00. This means that for example c_{pond} given in this table on 14 March 1914, is in fact the concentration in the pond on 13 March at the end of the day. Therefore, the other parameters in the table are also given for the date preceding the date given in this table, e.g. 13 March 1914. Q_{out} and h are daily averages (e.g. of 13 March). The parameters in this table have been presented in this way to correspond to the dates given in the output of the TOXSWA (and the PRIMET_Registration_Ethiopia_1.1.1.1.1) model(s).

Table 13.3.7

Overview of calculation of pond concentration after runoff event.

	Runoff		Water into pond		Pond		
Date (end of day)	**Size**	**Concen-tration**	**Runoff size (from 4500 m^2)**	**Constant baseflow**	**Volume**	**Mass**	**Concen-tration**
	mm/d	**µg/L**	**m^3**	**m^3**	**m^3**	**mg**	**µg/L**
Grid 373							
12 Mar 1914					904.23 (=30 * 30 * 1.0047)	2827.5	3.127
13 Mar 1914	7.588	5.909	34.1	5.8	944.2 (= 904.2 + 34.1 + 5.8)	3029.3 (= 201.8 + 2827.5)	3.2
Grid 217							
4 Apr 1925					901.8 (=30 * 30 * 1.002)	128.1	0.142
5 Apr 1925	10.66	11.67	48.0	5.8	955.6 (= 901.8 + 48.0 + 5.8)	687.9 (=559.8 + 128.1)	0.72

In Tables 13.3.8 and 13.3.9 the results of all example simulations have been gathered. Table 13.3.8 presents the calculated exposure concentrations (µg/L) for all example compounds and crops. Except for deltamethrin with its high sorption capacity (K_{om} = 5939675 L/kg) the runoff (and for ponds also spray drift entries) result in exposure concentrations that range from 0.217 µg/L (malathion, sweet potato) to 61.30 µg/L (2,4-D, teff). So, these exposure concentrations are above 0.1 µg/L, the European standard for drinking water. For deltamethrin the exposure concentrations are negligible.

Table 13.3.8 demonstrates the impact of the choice for the second largest value of the yearly maximum concentration, i.e. the 95.5th percentile, instead of the largest value of the yearly maximum concentration, i.e. the 98.5th percentile. As the largest value of all 33 yearly maximum concentrations might be an exceptional large or extreme value, the risk assessment is based upon the second largest value. Table 13.3.8 shows that indeed the 98.5th percentile may be significantly higher than the 95.5th percentile (e.g. 2,4-D on maize: 3.18 vs 0.45 µg/L, on teff: 2.40 vs 0.56 µg/L and on wheat: 3.90 vs 0.91 µg/L in grid 373, or chlorothalonil on potato 1st crop: 13.27 vs 2.67 µg/L in grid 373, or atrazine on maize: 1.7789 vs 0.4583 µg/L in grid 217), even up to 8 times (e.g. atrazine on maize with 3.75 vs 0.50 µg/L in grid 373). So, these values confirm that the largest ranked value may be an extreme value. This supports the choice to use the second largest, and not the largest concentration value for the drinking water risk assessment.

Table 13.3.9 presents the IESTI (International Estimated Short Term Intake, expressed as a percentage of the total acceptable intake in one day) and the IEDI (International Estimated Daily Intake, expressed as a percentage of the total acceptable daily intake during a lifetime) of the three surface water scenarios for all example compounds and crops. For all crops and compounds the IESTI is below 100%, indicating that the short term risks from drinking the surface water are acceptable. Except for dimethoate the IEDI is below 100% for all compounds and crops, indicating that the long term risks are acceptable (based upon the assumption that the allocated fraction of ADI allocated to drinking water equals 10% of the total acceptable daily intake during a lifetime). For dimethoate the IEDIs range from 520 to 915% (95.5th percentile), indicating that the long term risks from drinking this type of surface water are not acceptable.

Table 13.3.8

Exposure concentrations (PEC) in the three surface water scenarios for drinking water as a function of the example compounds and crops, plus Acute Reference Dose (ARfD) and Acceptable Daily Intake (ADI) values. (PEC given for both 98.5 and 95.5th temporal percentiles; 95th percentile selected for risk assessment for drinking water, so, 95.5th percentile = PEC_99, i.e. aimed overall 99th probability of occurrence in time and space).

Substance	crop	Scenario							
		191 – highland stream PEC		373 – lowland pond PEC		217 – highland pond PEC			
		98.5th * (mg.m-3)	95.5th ** (mg.m-3)	98.5th * (mg.m-3)	95.5th ** (mg.m-3)	98.5th * (mg.m-3)	95.5th ** (mg.m-3)	ARfD mg/kgBW,day	ADI mg/kgBW,day
2-4D	Maize	6.33	6.09	3.18	0.45	0.7292	0.3709	0.05***	0.05
	Sugar cane	-	-	1.11	0.64	-	-	0.05***	0.05
	Teff	61.79	61.30	2.40	0.56	32.94	19.32	0.05***	0.05
	Wheat	58.51	57.56	3.90	0.91	28.79	21.79	0.05***	0.05
atrazine	Maize	30.94	27.82	3.75	0.50	1.7789	0.4583	0.1	0.02
	Sugar cane	-	-	0.54	0.30	-	-	0.1	0.02
chlorothalonil	Potato 1st	33.16	30.84	13.27	2.67	42.45	40.50	0.6	0.015
	Potato 2nd	34.90	34.75	24.34	17.13	15.59	15.52	0.6	0.015
deltamethrin	Cabbage 1st	0.00019	0.00019	0.00088	0.00087	0.00083	0.00080	0.01	0.01
	Cabbage 2nd	0.00019	0.00019	0.00084	0.00084	0.00084	0.00084	0.01	0.01
	Cotton	-	-	0.0066	0.0066	-	-	0.01	0.01
	Maize	0.000044	0.000041	0.00029	0.00029	0.00029	0.00029	0.01	0.01
	Sweet potato	-	-	0.0029	0.0029	-	-	0.01	0.01
dimethoate	Barley	28.53	27.44	-	-	21.78	21.69	0.01	0.001
	Faba bean	23.03	22.64	-	-	15.83	15.59	0.01	0.001
endosulfan	Cotton	-	-	1.24	0.47	-	-	0.02	0.006
	Maize	1.54	1.40	1.85	1.64	0.9908	0.9056	0.02	0.006
malathion	Sweet potato	-	-	0.218	0.217	-	-	0.3	0.03

98.5th * = 98.5th percentile of the yearly maximum concentration (so the maximum of 33 annual maximum concentration values).

95.5th **= 95.5th percentile of the yearly maximum concentration (so the second largest value of 33 annual maximum concentration values).

0.05*** = no value for ARfD is known, therefore the ADI value is used.

- The crop is not found for this scenario.

Table 13.3.9

IESTI (International Estimated Short Term Intake, expressed as a percentage of the total acceptable intake in one day) and IEDI (International Estimated Daily Intake, expressed as a percentage of the total acceptable daily intake during a lifetime) of the three surface water scenarios as a function of the example compounds and crops. (IESTI and IEDI calculated for both the 98.5th and 95.5th temporal percentiles of occurrence; 95.5th percentile selected for risk assessment).

Substance	crop	Scenario						Scenario					
		191 – highland stream		373 – lowland pond		217 – highland pond		191 – highland stream		373 – lowland pond		217 – highland pond	
		98.5^{th} *	95.5^{th} **	98.5^{th} *	95.5^{th} **	98.5^{th} *	95.5^{th} **	98.5^{th} *	95.5^{th} **	98.5^{th} *	95.5^{th} **	98.5^{th} *	95.5^{th} **
		IESTI	IESTI	IESTI	IESTI	IESTI	IESTI	IEDI	IEDI	IEDI	IEDI	IEDI	IEDI
2-4D	Maize	1.27	1.22	0.64	0.09	0.15	0.07	4.22	4.06	2.12	0.30	0.49	0.25
	Sugar cane	-	-	0.22	0.13	-	-	-	-	0.74	0.43	-	-
	Teff	12.36	12.26	0.48	0.11	6.59	3.86	41.19	40.87	1.60	0.37	21.96	12.88
	Wheat	11.70	11.51	0.78	0.18	5.76	4.36	39.01	38.37	2.60	0.61	19.19	14.52
atrazine	Maize	3.09	2.78	0.37	0.05	0.18	0.05	51.57	46.37	6.25	0.84	2.96	0.76
	Sugar cane	-	-	0.05	0.03	-	-	-	-	0.90	0.49	-	-
chlorothalonil	Potato 1st	0.55	0.51	0.22	0.04	0.71	0.67	73.69	68.53	29.49	5.93	94.33	89.99
	Potato 2nd	0.58	0.58	0.41	0.29	0.26	0.26	77.56	77.22	54.10	38.07	34.64	34.49
deltamethrin	Cabbage 1st	0.00019	0.00019	0.00088	0.00087	0.00083	0.00080	0.00063	0.00063	0.0029	0.0029	0.0028	0.0027
	Cabbage 2nd	0.00019	0.00019	0.00084	0.00084	0.00084	0.00084	0.00062	0.00062	0.0028	0.0028	0.0028	0.0028
	Cotton	-	-	0.0066	0.0066	-	-	-	-	0.022	0.022	-	-
	Maize	0.000044	0.000041	0.00029	0.00029	0.00029	0.00029	0.00015	0.00014	0.0010	0.0010	0.0010	0.0010
	Sweet popotato	-	-	0.0029	0.0029	-	-	-	-	0.0097	0.0097	-	-
dimethoate	Barley	28.53	27.44	-	-	21.78	21.69	951.00	914.67	-	-	725.85	722.84
	Faba bean	23.03	22.64	-	-	15.83	15.59	767.67	754.67	-	-	527.80	519.76
endosulfan	Cotton	-	-	0.62	0.24	-	-	-	-	6.90	2.62	-	-
	Maize	0.77	0.70	0.92	0.82	0.50	0.45	8.56	7.75	10.28	9.11	5.50	5.03
malathion	Sweet popotato	-	-	0.01	0.01	-	-	-	-	0.24	0.24	-	-

98.5^{th} * = 98.5^{th} percentile of the yearly maximum concentration (so the maximum of 33 annual maximum concentration values).

95.5^{th} **= 95.5^{th} percentile of the yearly maximum concentration (so the second largest value of 33 annual maximum concentration values).

IESTI=LP*PEC_99*100%/(ARfD*BW)=
IEDI=DI*PEC_99*100%/(ADI*DF_dw*BW)=

with IESTI= International Estimated Short Term Intake (% of total acceptable intake in one day)
IEDI= International Estimated Daily Intake (% of total acceptable daily intake during a lifetime)
LP=Large Portion drinking water (6L)
DI= Daily Intake drinking water (2L)
DF_dw= Fraction of ADI allocated to drinking water (0.1)
BW = Body weight (60 kg)
PEC_99= 99th percentile of concentration in sw (mg/L)

14 Calculation of risks using the PRIMET_Registration_Ethiopia_1.1 software

The last step of the roadmap for the development of scenarios for drinking water produced from groundwater and surface water consists of the design and construction of a software tool to perform all calculations in an automated way (Figure 2.1.2). Within the PRRP project, Work Package B2.1 on the scientific evaluation of dossiers, has developed a user-friendly software tool to support the PHRD of the Ministry of Agriculture in performing the risk assessments during the registration procedure. This tool, called PRIMET_Registration_Ethiopia_1.1, allows the PHRD to perform all calculations and assessments in a standardised and reproducible way, while also taking care that all data used are consistent between each other. In addition, it enables an easy archiving of input and results per dossier. Four risk aspects are evaluated within this software tool: (i) environmental risks, (ii) drinking water risks, (iii) consumer risks and (iv) occupational risks. The tool and its documentation (Deneer *et al.,* 2014; Wipfler *et al.,* 2014) are freely available at www.pesticidemodels.eu.

So, calculations and risk evaluations for risks for drinking water produced from groundwater or surface water can be easily performed. By creating a so-called project, corresponding to one active ingredient-crop-pesticide dose -application rate- application number combination (as stated in the Table of Intended Use) the risks are calculated for this specific combination (Figure 14.1). The input data on the compound, application pattern can be filled in and stored in a database and details on the results can be looked up and stored in separate sheets, such as the one shown in Figure 14.2).

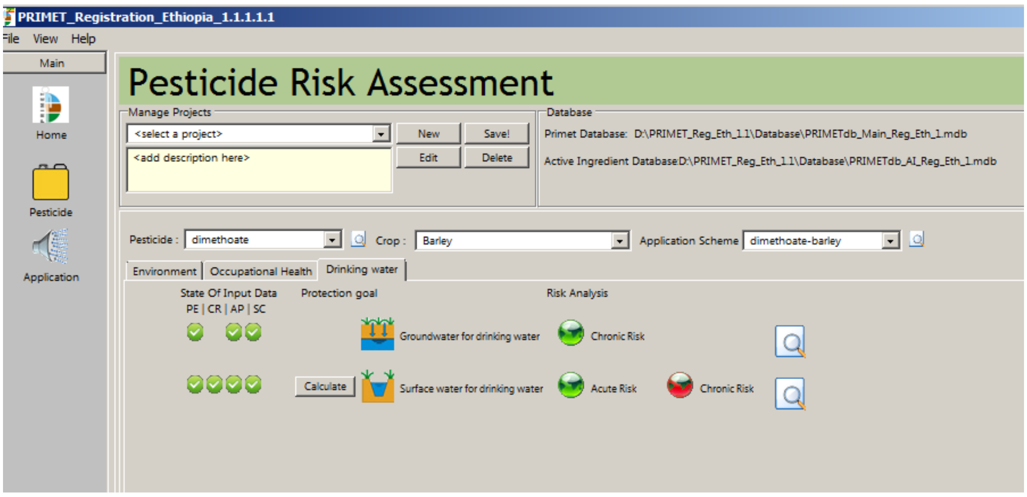


Figure 14.1 *Screen shot of PRIMET_Registration_Ethiopia_1.1 with an example project of dimethoate used on barley on the Drinking water tab, for assessment of risks for drinking water produced from groundwater and surface water.*

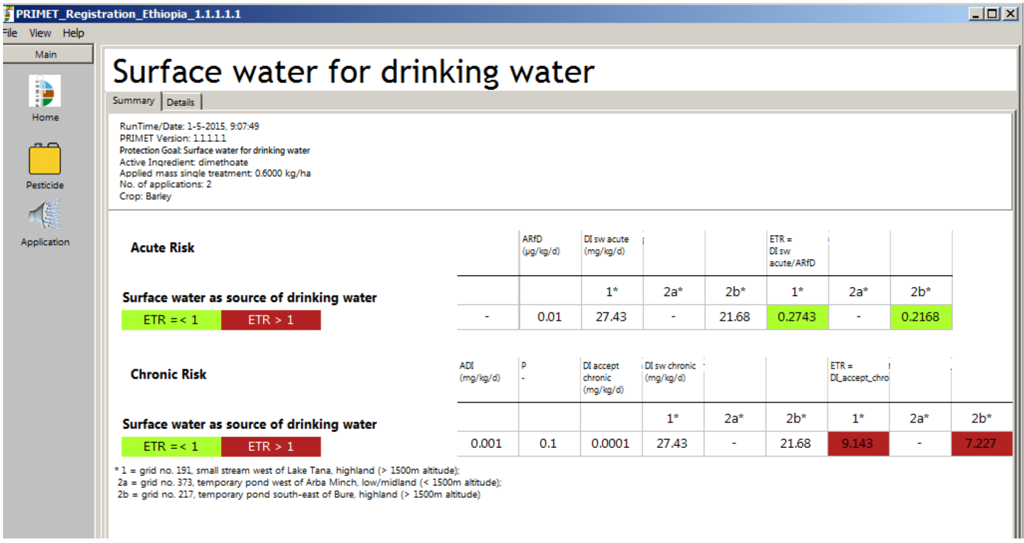


Figure 14.2 *Screen shot of PRIMET_Registration_Ethiopia_1.1 with an example project of dimethoate used on barley on the Drinking water tab. Results of the risk assessment for drinking water produced from surface water are shown for the three specific protection goals: the small streams above 1500 m altitude (1) and the temporary ponds below and above 1500 m altitude (2a and 2b).*

So, in this way the PRIMET_Registration_Ethiopia_1.1 software supports the PHRD in performing robust, transparent and reproducible risk assessments during the registration procedure in Ethiopia.

15 Conclusions and recommendations

15.1 General conclusions

Ethiopia is the first country in Africa able to evaluate risks of agricultural use of pesticides for drinking water produced from groundwater or surface water in its registration procedure with the aid of a tailor-made procedure based upon principles and methods applied in the European Union.

As stated in the new Proclamation on pesticides of Ethiopia, risks need to be assessed in 'realistic worst case' conditions. For the protection goal of drinking water this has been operationalised in this project as 'in 99% of all situations the drinking water should be safe'. This 99th percentile of overall probability in time and space has been split equally between time and space in this project and we demonstrated that, in absence of specific knowledge on frequency distributions, a combination of a 99th percentile in time plus a 99th percentile in space corresponds best to a 99th overall percentile probability.

For the acute and chronic risks for drinking water produced from surface water 99th percentile annual peak concentrations on an hourly basis (small streams) or daily basis (temporary ponds) were used to calculate the Internationally Estimated Short term Intake (IESTI) or Daily Intake (IEDI). By using annual peak concentrations and not time-weighted average concentration for the chronic risk assessment the chronic risks are estimated in a conservative, i.e. protective way.

For drinking water produced from groundwater only chronic risks were judged to be relevant, due to the relatively long residence times of groundwater. By using annual average leaching concentrations at 1 m depth (and not deeper) to calculate the IEDI the chronic risk is assessed in a conservative way.

Four specific protection goals were selected and conceptually defined for drinking water prepared from surface water: (i) alluvial aquifers along small rivers in areas above 1500 m, (ii) volcanic aquifers on shallow wells in areas above 1500 m, (iii) alluvial aquifers in the Rift Valley margins and lowland areas below 1500 m and (iv) alluvial aquifers in the Rift Valley margins between 1500 and 2000 m. The protection goals (i) and (ii) are linked and always located close to each other.

The groundwater scenario selection was based upon a procedure described by the EFSA (2012), but using Ethiopian data for the spatially distributed driving factors for leaching of pesticides: organic matter content, soil bulk density and the long term annual average percolation across Ethiopia. The selection procedure was repeated once for each of the protection goals, and three grid cells were selected as scenario locations and parameterised.

Three specific protection goals were selected and conceptually defined for drinking water prepared from surface water: (i) small streams above 1500 m, (ii) temporary ponds below 1500 m, but with more than 500 mm annual rain and (iii) temporary ponds between 1500 and 2000 m.

The surface water scenario selection and calculation procedure is a slightly adapted and improved version of the current procedure in the European Union, because the overall probability of occurrence of the target variable has been explicitly considered during scenario selection and, moreover, the calculations are done for a series of 33 meteorological years from which the wished 99th temporal percentile is selected instead of using only a single meteorological year as is done in the EU-FOCUS procedure. The selection procedure was repeated three times (once for each of the three protection goals) and three grid cells were selected as scenario locations.

The risks for drinking water produced from groundwater are calculated on the basis of the total mass of applied pesticide, the EuroPEARL metamodel calculation of the leaching concentrations does not explicitly consider crops or detailed daily weather data. The risks for drinking water produced from surface water are calculated on the basis of 16 possible crops, the application rate, number and interval and detailed daily weather data (for runoff even transformed into hourly resolution) in two types of surface water. Calculations for surface water contain more detail than the calculations for groundwater, which reflect increased dynamics in surface water. Differentiation in the level of detail of calculations for different compartments enables the optimal use of project resources.

Example calculations for seven high risk compounds (dimethoate, endosulfan, deltamethrin, 2,4-D, malathion, atrazine and chlorothalonil) on barley, wheat, teff, maize, cotton, potatoes (Irish and sweet) and faba beans indicated that for the considered application schemes and use according to GAP risks exist for drinking water produced from groundwater for atrazine. For surface water no acute toxicity risks exist, but for dimethoate used on barley and faba beans chronic toxicity risks exist.

The models and drinking water scenarios have been incorporated in an user-friendly software tool, PRIMET_Registration_Ethiopia_1.1, to enable a robust, transparent and reproducible calculation of risks, as required for pesticide registration. The tool is freely available at www.pesticidemodels.eu.

The presented scenario selection procedure is demonstrated to be feasible even in countries with relatively few available geographically distributed agro-environmental data.

15.2 Recommendations

Metabolites
At present only risks for parent compounds are evaluated. We recommend to expand the evaluation to metabolites, and to include the formation and degradation of metabolites in the concentration calculations, as metabolites may be more toxic than parent compounds. This is especially relevant for the risk assessment for drinking water produced from groundwater and from surface water with long hydraulic residence times, i.e. long times available for metabolite formation.

Cattle protected ?
We used the IESTI and IEDI standards to assess the acute and chronic risks for humans from drinking water produced from the temporary stagnant ponds, assuming that cattle would thus also be protected. Cattle are an important asset for many Ethiopians. Therefore, we recommend to investigate whether this assumption is correct.

Improved soil data
We recommend to investigate the effect of using alternate information on the organic matter content and bulk density data on the choice of groundwater scenarios and the calculation of leaching concentrations. Using e.g. the Harmonised World Soil Database instead of the available, more accurate Africa soil property maps at 1 km of 2013, may affect the selection of the groundwater scenarios and their calculated leaching concentrations. (See Annex 3.2 for background information on soil data used.)

Validity of models and underlying assumptions
We recommend to look into the validity of the EuroPEARL metamodel, as parameterised in this study (for warm, wet climatic conditions), e.g. by comparing metamodel results with results of the original PEARL model run for Ethiopian conditions. We also recommend to investigate whether the multiplication factor of 3 (Appendix 7.1), used to transform the 80th percentile leaching concentrations of the EuroPEARL metamodel into 99th percentile concentrations is sufficiently protective.

The calculation of spray drift deposition on surface water is based upon the EU-FOCUS drift tables. We recommend to investigate the validity of these tables for Ethiopian meteorological conditions, equipment and spraying practices.

We recommend to compare runoff predictions of the PRZM model to experimental data for runoff under Ethiopian conditions of soils, rainfall, land use and crop management practices.

We recommend to investigate the effect of using rainfall intensities representing Ethiopia, instead of using the relatively low EU-FOCUS value of 2 mm/h on the peak concentration in especially the small streams. Although the concentration in the runoff water will not change, the duration of the runoff event will be shorter and the size of the fluxes larger and therefore, the exact effect on the peak concentration will depend on the size of the pesticide-free base flow and incoming subsurface drainage flow.

We recommend to investigate the effect of choices on size and pesticide treatment ratio in catchments of the small stream scenarios for Ethiopia. These factors are expected to have a relatively large influence on the size of the peak concentrations in the streams.

We recommend to develop improved guidance for users of the TOXSWA model on the sediment segmentation in relation to the wished accuracy of the target variable.

Number of applications in ToIU
We recommend to include the range of numbers of applications in the Table of Intended Uses (ToIU) which is required for registration. The number of applications is a crucial parameter for the calculation of predicted concentrations in the environment, and therefore it is important to make up for this deficiency in the current registration dossiers.

Greenhouse scenarios
Cultivation of flowers and vegetables in greenhouses is increasingly practised in Ethiopia. These cultivation systems are not yet assessed for their impact on drinking water produced from groundwater or adjacent surface waters, but problems have already been reported, e.g. for Lake Ziway. Therefore we recommend to develop specific scenarios for these cultivation systems to evaluate their effect on the environment and drinking water production from groundwater and surface water.

Paddy rice scenario
At present paddy rice cultivation is increasing in Ethiopia. As pesticide use is widespread on paddy rice it is likely that groundwater and surface water may be contaminated by pesticides and therefore we recommend to evaluate risks of pesticides in these cultivation systems by developing specific scenarios for this type of cultivation and using suitable models. The latest research version of the PEARL model is able to simulate leaching of pesticides and runoff flowing over the bunches surrounding the flooded paddy fields and this model may thus be a suitable candidate for such calculations.

Risk assessment for registration versus practices in the field
Finally, we would like to stress that the risk assessments in this study are based upon Good Agricultural Practices and use patterns as requested in the Table of Intended Uses in the registration dossiers. These may not correspond to current practices within the country of Ethiopia and thus risks observed in the field may be very different from the risks calculated. In order to reduce risks in the field we recommend to develop activities aimed at improving the knowledge and pesticide use practices of the farmers in the rural areas of Ethiopia.

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Websites

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Pesticide Risk Reduction Programme www.prrp-ethiopia.org
(for Work Package B2.1: see Activities & Output, Dossier Evaluation)

PRIMET_Registration_Ethiopia_1.1 software: www.pesticidemodels.eu

Appendix 4.1 Background information on the meteorological data used

A.4.1.1 Introduction

Meteorological data for the PRRP project is taken from the ERA Interim dataset (Dee *et al.,* 2011) which is a reanalysis of all available observations from different sources (satellite, ground observations, etc.) made by the ECMWF (**E**uropean **C**entre for **M**edium-Range **W**eather **F**orecasts) to create an analysis field on a regular grid. The ERA Interim dataset runs from 1979 up to present, is available worldwide and the resolution is about 0.75°x0.75° (this corresponds to approximately 80x80 km^2). Necessary ERA Interim data were retrieved from the ECMWF MARS (**M**eteorological **A**rchival and **R**etrieval **S**ystem) archive.

Four times a day (0, 6, 12, 18UTC) an analysis field is available and two times a day (0, 12UTC) forecast fields are available. The analysis fields contain instantaneous variables like temperature, humidity and wind speed. The forecast field contains mostly parameters that cover a time span like precipitation, radiation and minimum and maximum temperature.

To cover the Ethiopia area a rectangular area has been selected between: 0.75°N – 16.50°N and 30.75°E – 49.50°E. In total there are 572 grid points covering the area (Figure A4.1.1).

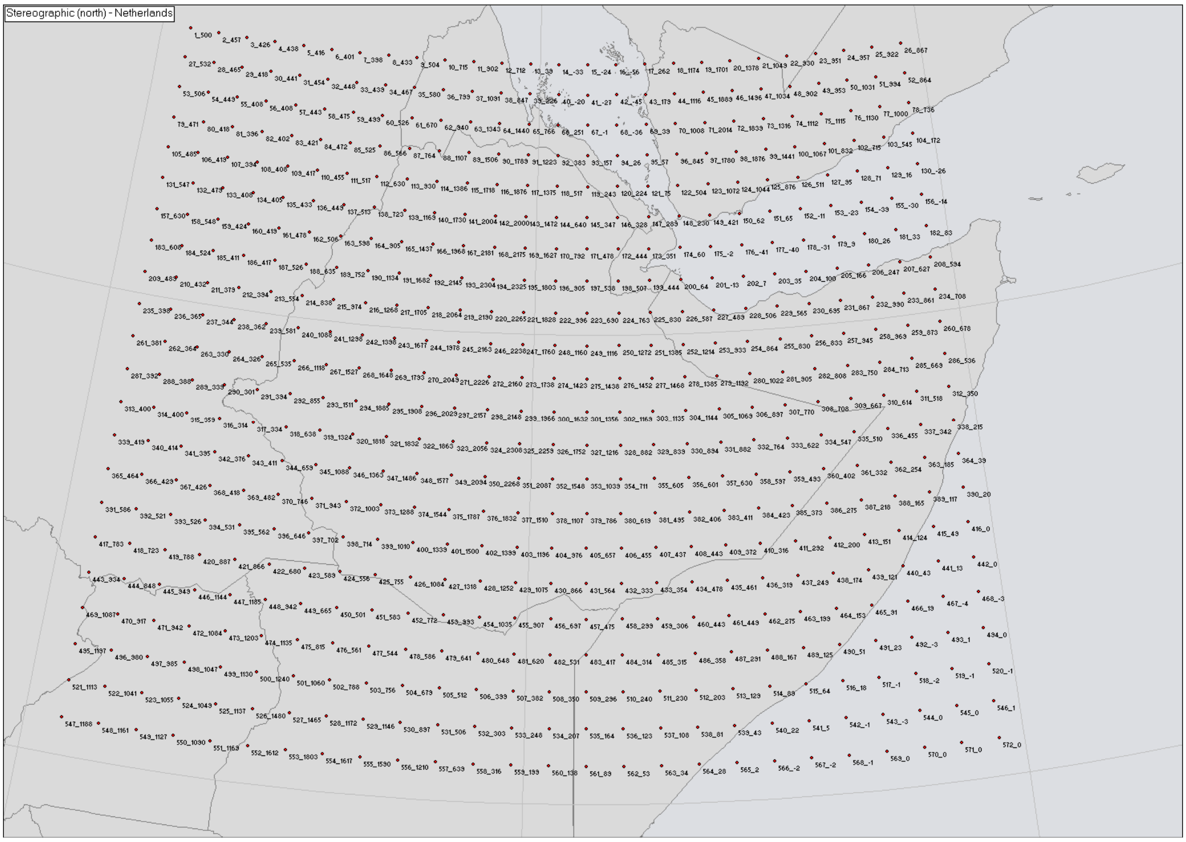

Figure A4.1.1 *Grid point id and the elevation of the location in ERA interim for Ethiopia.*

A.4.1.2 Data collection

Table A.4.1.1. shows the variables that are extracted from the ECMWF MARS archive. The original units and the time period are shown. For future reference the MARS parameter ID's are also given.

Table A.4.1.1
Variables extracted for the ECMWF MARS archive.

Type	Para-meter ID	Name	Description	Unit	Time	Time period	Details
analysis	134	Surface Pressure	Surface Pressure	Pa	0/6/12/18	-	
analysis	165	10 meter U wind component	10 meter U wind component (east-west direction)	m s^{-1}	0/6/12/18	-	
analysis	166	10 meter V wind component	10 meter V wind component (north-south direction)	m s^{-1}	0/6/12/18	-	
analysis	167	2 meter temperature	2 metre temperature	K	0/6/12/18	-	
analysis	168	2 meter dew point temperature	2 metre dew point temperature	K	0/6/12/18	-	
Forecast	149	Surface net radiation	Surface net radiation	J m^{-2}	0/12	0-3 0-6 0-9 0-12	Accumulated field
Forecast	169	Surface solar radiation downwards	Surface solar radiation downwards	J m^{-2}	0/12	0-3 0-6 0-9 0-12	Accumulated field
Forecast	177	Surface thermal radiation	Net thermal radiation at the surface.	J m^{-2}	0/12	0-3 0-6 0-9 0-12	Accumulated field
Forecast	201	Maximum temperature	Maximum temperature at 2 meters since previous post-processing	K	0/12	0-3 3-6 6-9 9-12	Maximum value during period
Forecast	202	Minimum temperature	Minimum temperature at 2 meters since previous post-processing	K	0/12	0-3 3-6 6-9 9-12	Minimum value during period
Forecast	205	Runoff	Amount of water that is lost from the soil through surface runoff and deep soil drainage.	m	0/12	0-3 3-6 6-9 9-12	Accumulated field
Forecast	228	Total precipitation	Convective precipitation + stratiform precipitation*	m	0/12	0-3 3-6 6-9 9-12	Accumulated field

* *Convective* precipitation occurs when air rises vertically through the (temporarily) self-sustaining mechanism of convection. *Stratiform* precipitation occurs when large masses over air rise slant-wise as larger-scale atmospheric dynamics force them to move over each other. *Orographic* precipitation is similar, except the upwards motion is forced when a moving air mass encounters a rising slope (source: http://en.wikipedia.org/wiki/Precipitation_types).

A.4.1.3 Daily values

In the ERA interim dataset all data is stored in Universal Coordinated Time (UTC). As a first step this time was converted to local time (LT) by LT= UTC+3 hour. So, for the analysis field the 0, 6, 12, 18 UTC times correspond to respectively 3, 9, 15, 21 LT times. For forecast fields with accumulated fields first 3-hourly accumulated fields were reconstructed by subtracting two sequential time periods (except for the first period 0-3 which is already a 3-hourly period).

Next daily values are generated for the different parameters with the following formulas:

<u>Analysis fields (example for wind speed):</u>

$$FF_{daily}=\frac{\left(\frac{1}{2}FF_{21LT(prev\ day)}+FF_{3LT}+FF_{9LT}+FF_{15LT}+FF_{21LT}+\frac{1}{2}FF_{3LT(next\ day)}\right)}{5} \qquad \text{(eqn. A.1.1)}$$

where FF_{daily} is the daily wind speed of the present day, $½FF_{21LT(prev\ day)}$ is half the wind speed value at 21 hour local time of the previous day, FF_{3LT}, FF_{9LT}, FF_{15LT}, FF_{21LT}, are the wind speed values are respectively 3, 9, 15 and 21 hours local time at the present day and $½FF_{3LT(next\ day)}$ is half the wind speed value at 3 hour local time of the next day.

<u>Forecast fields (example for Total Precipitation):</u>

$$TP_{daily}=TP_{0-3LT}+TP_{3-6LT}+TP_{6-9LT}+TP_{9-12LT}+TP_{12-15LT}+TP_{15-18LT}+TP_{18-21LT}+TP_{21-24LT} \qquad \text{(eqn. A.1.2)}$$

where TP_{daily} is the total precipitation amount of the present day and TP_{0-3LT}, TP_{3-6LT}, TP_{6-9LT}, TP_{9-12LT}, $TP_{12-15LT}$, $TP_{15-18LT}$, $TP_{18-21LT}$, $TP_{21-24LT}$ are the total precipitation amounts between respectively 0 and 3 hours, 3 and 6 hours, 6 and9 hours, 9 and 12 hours, 12 and 15 hours, 15 and 18 hours, 18 and 21 hours and 21 and 24 hours local time of the present day.

A.4.1.4 Reference evapotranspiration

To calculate the reference evapotranspiration the FAO Penman-Monteith method is used (Allen *et al.,* 1998):

$$\lambda ET=\frac{\Delta(R_n-G)+\rho_a c_p\frac{(e_s-e_a)}{r_a}}{\Delta+\gamma\left(1+\frac{r_s}{r_a}\right)} \qquad \text{(eqn. A.1.3)}$$

Where R_n is the net radiation in MJ m^{-2} day^{-1} (parameter ID 149 in Table A.1.1.), G is the soil heat flux in MJ m^{-2} day^{-1}, $(e_s - e_a)$ represents the vapor pressure deficit of the air in kPa, ρ_a is the mean air density at constant pressure in kg m^{-3}, c_p is the specific heat of the air in MJ kg^{-1} °C^{-1}, Δ represents the slope of the saturation vapour pressure temperature relationship in kPa °C^{-1}, γ is the psychrometric constant in kPa °C^{-1}, and r_s and r_a are the (bulk) surface and aerodynamic resistances in s m^{-1}.

For a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m^{-1} and an albedo of 0.23 the equation can be written as:

$$ET_0=\frac{0.408\Delta(R_n-G)+\gamma\frac{900}{T+273}u_2(e_s-e_a)}{\Delta+\gamma(1+0.34u_2)} \qquad \text{(eqn. A.1.4)}$$

Where u_2 is the wind speed at 2 m height in m s^{-1} and T is the mean daily average temperature in °C. The ground flux, G, is small and therefore neglected.
To calculate the mean daily average temperature, T, we use:

$$T=(T_{max}+T_{min})/2 \qquad \text{(eqn. A.1.5)}$$

Where T_{max} is the daily maximum temperature in °C (parameter ID 201 in Table A.1.1.) and T_{min} is the daily minimum temperature in °C (parameter ID 202 in Table A.3.1.).

The wind speed at 10 m height, u_z, is calculated from the u component, u_{u_10}, (in ms^{-1}; parameter ID 165 in Table A.1.1.) and v component, u_{v_10}, (in ms^{-1}; parameter ID 166 in Table A.1.1.) of the wind speed at 10 height as follows:

$$u_z = \sqrt{{u_{u\_10}}^2 + {u_{v\_10}}^2} \quad \text{(eqn. A.1.6)}$$

To convert the 10 m wind, u_z, to a wind speed at 2 m, u_2, a logarithmic wind profile was assumed:

$$u_2 = u_z \frac{4.87}{ln(67.8z - 5.42)} \quad \text{(eqn. A.1.7)}$$

The psychrometer constant (kPa $°C^{-1}$), depends on the surface pressure with:

$$\gamma = 0.665 \cdot 10^{-3} P \quad \text{(eqn. A.1.8)}$$

Where P is the atmospheric pressure in kPa (parameter ID 134 in Table A.1.1.).

The saturation vapour is calculated from the air temperature by:

$$e(T) = 0.6108 e^{\left[\frac{17.27T}{T+237.3}\right]} \quad \text{(eqn. A.1.9)}$$

Where, *e(T)* is the saturation vapour pressure at the air temperature *T* (kPa) and *T* is the air temperature (°C).

The actual vapour pressure (e_a) is the saturation vapour pressure at the dew point temperature, T_{dew}, in °C (parameter ID 168 in Table A.1.1.). e_a can be calculated by eqn. A.1.9. by filling in the dew point temperature instead of the air temperature:

$$e_a = e(T_{dew}) = 0.6108 e^{\left[\frac{17.27T_{dew}}{T_{dew}+237.3}\right]} \quad \text{(eqn. A.1.10)}$$

A.4.1.5 Open pan evaporation

Open pan evaporation is needed as input in the PRZM model (for the surface water for drinking water and aquatic ecosystem protection goals).

For open pan evaporation the Penman-Monteith equation (A.1.3 – A1.10) is also used but with some adjustments to correct for the properties of the open pan: the albedo is 0.14 and r_s and r_a are described (Roderick *et al.,* 2007) with:

$$r_s = \frac{224}{1+1.35u_2} \quad \text{(eqn. A.1.11)}$$

$$r_a = 1.4 r_s \quad \text{(eqn. A.1.12)}$$

The density of the air in kg m^{-3} is described with:

$$\rho_a = \rho_o e^{-Z/H_p} \quad \text{(eqn. A.1.13)}$$

Where Z is the height of the grid points and H_p is the scale height for density (= 8550 m) and ρ_o is the standard atmospheric density at sea level (1.225 kg m^{-3}).

A.4.1.6 Background information on the soil data used

Soil data was based on the Harmonised World Soil Database (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2012). The data for Ethiopia was provided by Tom Hengl of ISRIC World Soil Information (www.ISRIC.org) on an approximately 5x5 km^2 grid. Although accuracy of the data might be too low for our purpose, more suitable data was not available at the time of performing the scenario selection procedure for Ethiopia (autumn 2012). In 2013 however, a new more accurate map of African soil properties on a 1 x1 km^2 (Hengl *et al.,* 2013) became available and it is advised to use this new map in case the Ethiopian scenarios will be updated in the future.

Figures A.4.1.2 – A.4.2.4 show for Ethiopia the spatial distribution (approximately on 5x5 km^2 scale) of the soil properties dry bulk density, organic matter content and pH_{H2O}. Only the spatial data of dry bulk density and organic matter content are used in the scenario selection procedure.

References

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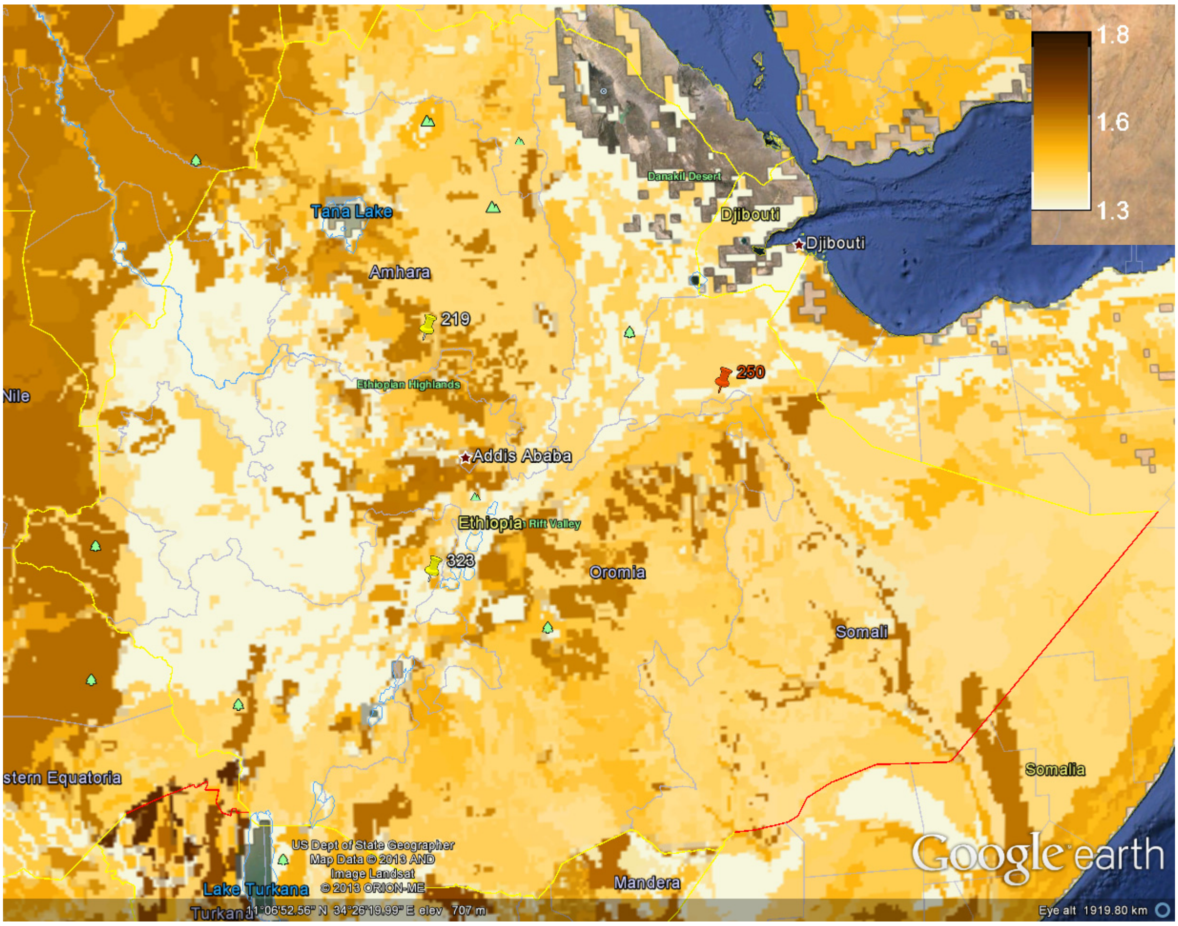


Figure A4.1.2 *Spatial distribution (approximately 5x5 km^2) of dry bulk density (g m^{-3}) of the top 30 cm of the soil in Ethiopia. Source: Harmonized World Soil Database; data provided by Tom Hengl of ISRIC.*

Figure A4.1.3 *Spatial distribution (approximately 5x5 km^2) of the organic carbon content (%) of the top 30 cm of the soil in Ethiopia. Source: Harmonized World Soil Database; data provided by Tom Hengl of ISRIC.*

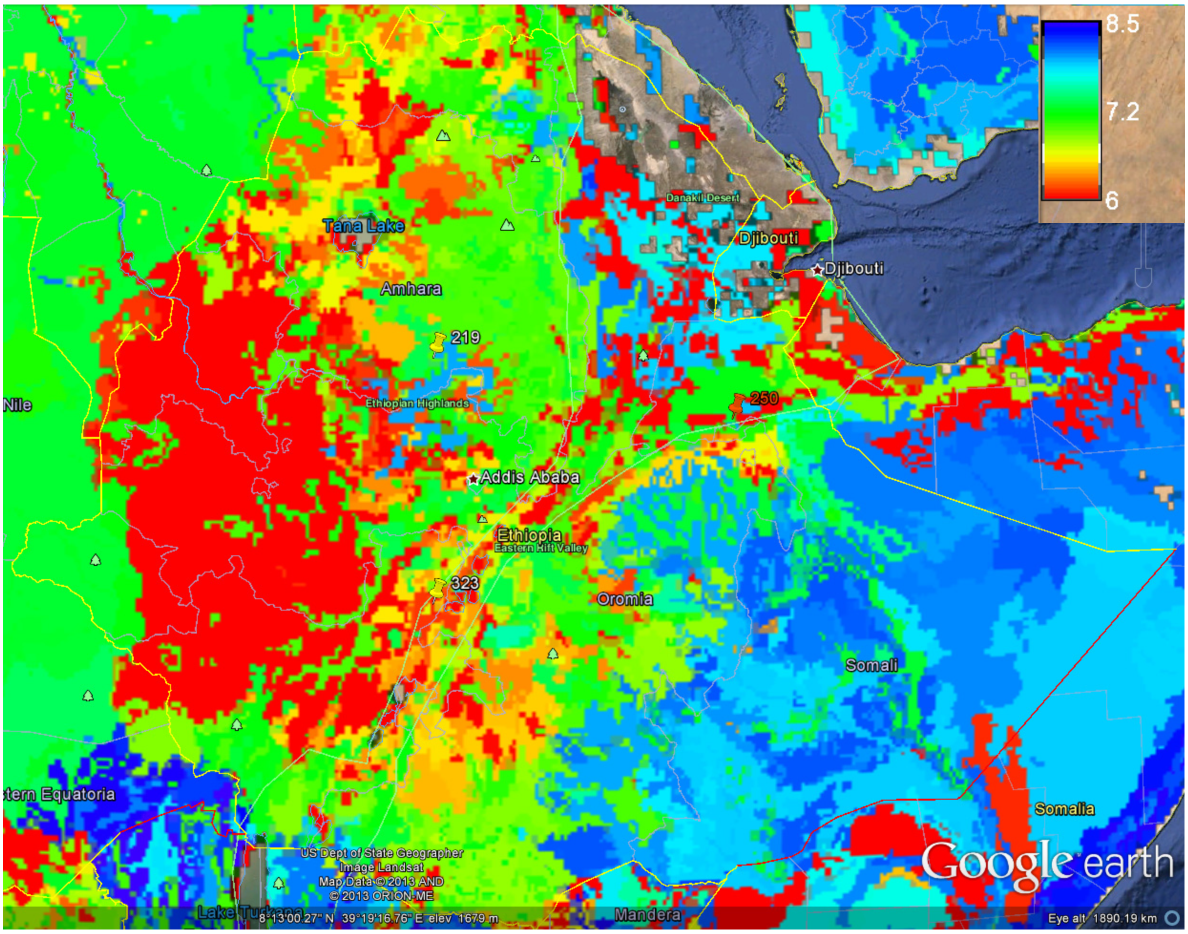


Figure A4.1.4 *Spatial distribution (approximately 5x5 km^2) of the pH$_{H20}$ of the top 30 cm of the soil in Ethiopia. Source: Harmonized World Soil Database; data provided by Tom Hengl of ISRIC.*

Appendix 4.2 Total volumes of imported and locally produced pesticides in 2010, PHRD-Ethiopia

Part I: Pesticides imported for use on commercial farms in 2010
Amounts in liters and amounts in kg were simply added, assuming that 1 l is equivalent to 1 kg.

Product/Pesticide	**Sum of Lt+ Kg**
Row Labels	**Sum of Lt+ Kg**
ACTELLIC 50% EC	4320
AGRO 2,4-D AMINE	399000
AGRO-LAXYL MZ 63.5	13000
AGRO-THIATE 40 EC	24000
AGRO-THOATE	48000
AGRO-THOATE 40 EC	72000
ALAZINE 350/200	6750
ALPHOS 56%	60721.6
AMETRAZINE 500 SL	22000
APPOLLO	600
BAYFIDEN EC250	30000
BAYLETON 25 WP	2000
BEEUP OIL	4000
CELPHOS 56% TAB	47237.3
CHIVAD	514500
CRUZATE R WP	3600
CURZATE R WP	3600
DECIS 2.5 EC	1008
DERBY 175 SC	1800
DICAL	250000
DURSBAAN	5040
FASTAC 7.5 ULV	40000
FLOWSANFS 42%	46464
FOLPAN 50 WP	1920
FULLUNGPHOS	33696
GESAPRIM 500 FW	16800
GLYCEL 41%SL	49200
GLYPHOGAN 480 SL	4620
GLYPHOGAN T	5400
GLYPHOSATE	2825
GRANSTAR 75 DF	999
HELARAT 5% EC	23400
HELOSATE 48 SL	120540
HERBIKILL	48000
HERBKNOCK	83652
INDOFIL M-45	39200
KARATE 5% EC	19200
KARATE 5%EC	9600
KOCIDE 101	4000
LAMDEX 5 EC	8316
LITAMINE 72 SL	52790

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
MABA 360 SL	20400
MALT 50% EC	132000
MAMBA 360 SL	36000
MANCOLAXYL	4620
MANCOLAXYL 72 WP	7000
MATCO	11200
MEGABAN PLUS	9600
MITIGAN 18.5 EC	9636
NIMROD 25 EC	10164
NOBLE 25 WP	15080
PALLAS 45 OD	3000
PHOSTOXIN	1005
PHOSTOXIN	3585.6
PHOSTOXIN 56% /ROUND/ TAB	1005
PHOSTOXIN REGULAR	3585.6
PRIDE 200SL	480
PRIMAGRAM GOLD 660 SL	69600
PYRINEX 48 EC	1848
QUICK PHOSE	9953.28
RIDIMOL 80% WP	20930
RIDIMOL GOLD M2 68 WG	18000
RIDOM 80%	26450
RIDOMIL GOLD MZ 68 WP	10800
RIDOMIL GOLD WZ 68 WG	21600
ROUNDUP	188400
SANAPHEN D 720 SL	259020
SD-TOXIN	5708.696
SEVIN 85 WP	23440
SHENPHOS 57%	28512
STOMP 455 SC	33280
THIONEX 35 EC	11088
THIRAM GRANUFLO 80 WG	33920
TILT 250 EC	18600
TOPIC 080 EC	35160
TOPZOLE 250 EC	6570
TRACER 480 SC	108
Trade name	0
WEED KILLER	441792
ZINC PHOSPHIDE	5000
ZURA	483840
(blank)	
Grand Total	**4145780.076**

Part II: Pesticides imported for use on flower farms in 2010
Amounts in liters and amounts in kg were simply added, assuming that 1 l is equivalent to 1 kg.

Product/Pesticide	**Sum of Lt+ Kg**
Row Labels	**Sum of Lt+ Kg**
A.A TERRA	10
ACET 20 SP	500
ACROBAT8+64% WP	200
ACTELLIC 25%	90
ACTELLIC 50 EC	40
ADONA	1000
ADONA 72 SC	1000
AGRAL	900
AGRAL GOLD	20
AGRIBAT 69 WP	1000
AGRIFOS 600	300
AGRITHANE 80 WP	2000
AGRIXYL	20
AGROTOX /MCPA/	100
ALAR	92
ALIETTE WG 80	1756
ALIETTE WG 80 FLASH	200
ALMECTIN 1.8 % EC	4944
ALTO	51
AMIDIL	620
AMIGUS	186
AMINO GOLD	8880
AMISTAR	220
AMITIR	15
AMITIV	296
ANRACOL	20
ANTISCALANT SGSC	75
ANTRACOL	10
ANTRACOL 70 WP	100
APOLLO 50% SC	913
APPLAUD	584
ARDENT	144
ARROW 25 EC	1000
ASEPTACAREX	16
AVIA	108
AVID	200
AVIMEC 1.8 EC	1000
B NINE	50
BAVESTIN DF	720
BAVISTIN	5
BAYCOR 300 EC	3178
BAYLETON	216
BAYLETON 25 WP	216
BELLIS	963
BENLATE 50%WP	600
BENOCURE 50 WP	500
BENOMYL	1000
BIMATE 25 EC	1000
BIODENW	1000

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
BIOFILM	1820
BIOMECTIN	765
BITOXYBACILLIN	520
BLAD BUFF	500
BLUE COP 61.4 WP	500
BN-3	16940
BOTANIGARD	10
BRAVO 720	20
BRIGADE 25 EC	60
BRODITOP WAX BLOCK	150
BULLDOCK 025 EC	632
BYCOR 300 EC	504
CALyPSO	2
CALYPSO 480 SC	156
CAPTAN	20
CARBOZIM 50 SC	1000
CASCADE	100
CATCH 50 EC	200
CHAMPION	900
CHRYSAL CLEAR CUT FLOWER FOOD	384.7
CHRYSAL SACHET FLOWER FEED	600
CHRYZOPLUS GREY 0.8%	100
CHRYZOTEC BEIGE 0.4%	350
CHRYZOTEK 0.04%	200
CHRYZOTEK 0.4%	300
CLICK 20 SL	500
CLIMATE 50 SC	200
COLLIS	2220
CONFIDOR 200 SL	622
CONGFU	500
CONQUEST	200
CONSERVE	25
CROP GOLD	60
CRUISER	10
CRUISER 350 FS	40
CYLAM	300
CYROZINE 75 WP	200
DACONIL	300
DACONIL 75% WP	200
DANISOROBA	200
DAYNON	10
DECIS 2.5 EC	495
DELAN 500 EC	480
DESOGERM SP VEG	30
DEXONSP	650
DIAFENTHIORON	504
DIMILIN	10
DIVIPAN	1235
DIZICTOL 15%	50
DIZONE 60 EC	500
DOMARK	2744
DOMARK COMBI	40
DOMREX	200

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
DPDI BUFFER	1.5
DPDI REAGENT	0.88
DUKATALON	20
DYGALL	30
DYGALL 160G	4.96
DYNAMEC 1.8% EC	420
EC CONDUCTIVE SOLUTION	15
EC SOLN.1.41 MS CALBIRATION LIQUID EC	15
EFENTAZINE	200
ELPHOS	140
EMTHANE	200
EQUATION PRO	250
ETHREL	3
ETHREL A W6	5
EVISECT	184
FERRAMOL	20
FIBA ZORB	5
FLINT 50 WG	414
FLOCON	400
FLORAMITE	1625
FOLICUR	60
FOLIMAT	185
FOLIO GOLD	304
FOLIO GOLD	300
FOLPAN 500g/kg	493
FONGANIL GOLD	24
FOSTAIL 80 WP	1500
FRUGICO	20
FUNGARAN	300
GAUCHO FS 350	84
GERASOL	200
GIBBEREELIC ACID	4
GIBERLLON	12
GOLAN	306
GOLD STAR	1500
GOLTIX 70 WP	35
GRAMAXONE	25
GRAMOXONE	30
HORMORIL T3	12
HYDROGEN CYANAMIDE 50%	250
HYDROGEN PEROXIDE	2000
IMITATOR PLUS	12000
IMPACT	300
IMPULSE 500 EC	14772
INFINITO	10
IPPON	10
IPRODIONE	40
KARATEZEON	5
KICK BACK 5 GR	20
KILITAC	3100
KILITAC 20%	900
KILITTAC	2000
KNOCKOUT 50 SC	250

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
KODKOD	125
KUMULUS	875
LANNATE	100
LEAF SHINE	46
LQ 215	50
MAGFER	1000
MANCOZEB 80% WP	200
MANIC	6200
MATCH	513
MATCH 050	38
MELTATOX	7487
MERPAN	180
MESUROL	100
MESUROL	20
MESUROL 500 EC	194
METHAMORE	1000
METHOMEX	854
METHRINE	500
ME-TOO-LACHLOR	8000
MILBEKNOCK	670
MILDEW 30 EC	750
MILOR	50
MILPAN	637
MILRAZ 6+70% WP	600
MIRAGE	10
MISSTRESS 72 WP	400
MISTRESS 72%WP	1000
MITIGAN	600
MITOX 20 EC	2000
NEATNESS	200
NEMACURE 400 EC	200
NIMROD	2464
NISAGRA	2750
NISSORUN	216
NISSORUN 10 EC	108
NISSURON 10 EC	1296
NISSURON 5% EC	300
NOMOLT	270
NUSTAR	100
NUSTAR	50
NUSTAR 40% EC	400
OBERON 240 SC	216
OBRON 240 SC	108
OMER	100
ONDAR	350
ORIUS	100
ORTIVA	12
OVERALL 50 SC	800
OVYMETRINE	17
OXYMETRINE 1% SL	400
PEGASES	400
PEGASES 50% WP	340
PETROBAND	2600

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
PH ELECTRODE SOTRAGE SOLN	10
PHYTON 27	804
PIRIMOR	12
PLANT VAX	360
PLANTOC	1000
PLANTOC 722 SC	1000
PLANTVAX	20
POKER 7.5	300
POLAR	511
POLYTRIN	312
PREMPT	220
PRESERVE	150
PREVACUR N 12	204
PREVACURE ENERGY	504
PREVICUR	7
PREVICUR ENERGY 840 SL	312
PREVICUR N	568
PREVICUR N 12	480
PREVICUR SL 840	300
PREVICURE 72% SL	500
PRIMOR	12
PROCLAIM	10
PROFEN 72 WP	2000
PROSPER 44 EC	2000
PROUD	150
PUROGENE	3360
PYRIMEC	500
PYRUS 300	130
QUADRIS	720
REVUS	25
RHIZOLEX	65
RHIZOPHONE	20
RIDOMIL 8+64% WP	100
RIDOMIL GOLD	20
RIDOMIL GOLD PEPITER	5
RIDOMIL GOLD PEPITER 8+64%	200
RONSTAR	10
ROVERAL AQUA FLO	60
ROVRAL 250 SC	40
ROVRAL 50 % AQUAFLO WP	753
ROVRAL AQUA	60
ROVRAL POWDER	75
RUBIGAN	715
RUFAST	318
RUGBY	160
RUGBY 100 ME	1100
RUNNER	210
RVB FLOWER FEED	50
S.T.S	30
SAPROL	200
SCALA	972
SCORE	65
SECURE	400

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
SECURE 24% EC	300
SILWET	260
SILWET GOLD	6193
SKIPPER	85
SODIUM CHLORITE	500
SOLUTION PH-4	10
SOLUTION PH-7	10
SPARTA	10
SPORKILL	250
STARGEM	600
STOMP 455 SC	1000
STRATHENE	200
STRIKER	300
STRIOBIN 25 SC	200
STROBY 50 WG	1320
STS	200
STS 75	480
SULPHUR GOLD	3000
SWITCH	300
SYSTHANE	75
T.O.G.4	20
TALSTAR	20
TALSTAR 10% EC	200
TEDOR	6
TELDOR 50 WG	1120
TEPPEKI WP	10
TEPPIKI	15
THIONEX	165
THIOVET	200
THIRAM 80 WP	300
THIRAM GRANOFLO	10
THUNDER 145 OD	168
TILT	20
TITL	325
TIVAG	206
TOG 3	160
TOG 30	110
TOG3	450
TOG-3	20
TOG6	60
TOPAS	100
TOPNATE 50 SC	200
TOPSIN	240
TOTACH	50
TRACER	8
TRACER 480 SC	179.5
TRACER SUPER	57
TRACER ULTRA	73
TRIBUTE	100
TRIGARD	530
TRISODIUM PHOSPHAT	25
VERITA WG	100
VERTIA	50

Product/Pesticide	Sum of Lt+ Kg
Row Labels	Sum of Lt+ Kg
VIVANDO	505
VYDATE	800
VYDATE 10 G	400
X MITE	50
ZEEMGUARD	10
ZOHAR OC6	10
ZORO	600
(blank)	150
Grand Total	**215541.54**

Part III: Pesticides produced locally in 2010

Amounts in liters and amounts in kg were simply added, assuming that 1 l is equivalent to 1 kg.

Product/Pesticide	Sum of kg/L
Row Labels	**Sum of kg/L**
DDT 75% wdp	455249.8
ethio2,4-D 72% sl	112
ethiodemethrin 2.5% ec	3215
ethiolathion 5% dust	105716.35
ethiolathion 95% ulv	5000
ethiosulfan 5% dust	53803
ethiothoate 40% ec	19378
ethiothoate 40% ulv	4800
ethiotrothion 50% ec	33735
ethiotrothion 95% ulv	5000
ethiozinon 60% ec	69666
vetazinon 60 % ec	86501
amitraz 12.5% ec	2202
deltamthrin 2.5% wdp	1208009.2
ethiolathion 50% ec	233244.5
ethiosulfan 25 % ulv	217717
ethiosulfan 35% ec	65982
ethiozeb 80% wdp	20724
Grand Total	**2590054.85**

Appendix 4.3 Content of active ingredient for the various products/pesticides imported or produced locally in Ethiopia

Data on content was either taken from the spreadsheet provided by Berhan Teklu, which also contained data taken from the FAO Pesticide Stock Management System - PSMS form, or if missing was searched on the internet by J. Deneer. The rightmost column gives the content (as a fraction) actually used to convert kg of product into kg of active ingredient.

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
BIOMECTIN	ABAMECTIN	ABAMECTIN	180			0.18
MELTATOX	DODEMORFACETATE	DODEMORF ACETATE			384	0.384
NIMROD	BUPIRIMATE	BUPIRIMATE		250		0.25
TRACER 480 SC	SPNOSAD	SPINOSAD			480	0.48
TIVAG	GIBBERELLIC ACID	GIBBERELLIC ACID			40	0.04
ALMECTIN 1.8 % EC	ABAMECTIN	ABAMECTIN	180		18	0.18
BULLDOCK 025 EC	BETA-CYFLUTHRIN	BETA CYFLUTHRIN			25	0.025
CONFIDOR 200 SL	IMIDACLOPRID	IMIDACLOPRID	200			0.2
OBERON 240 SC	SPIROMESIFEN	SPIROMESIFEN			240	0.24
IMPULSE 500 EC	SPIROXAMINE	SPIROXAMINE	500			0.5
MATCH	LUFENURON	LUFENURON			500	0.5
STOMP 455 SC	PENDIMETHALIN	PENDIMETHALIN			455	0.455
AMINO GOLD	ORGANOSILICONE	ORGANOSILICONE			1000	1
MISTRESS 72%WP	METALAXYL	METALAXYL	80		80	0.08
MISTRESS 72%WP	MANCOZEB	MANCOZEB	800		640	0.64
PROSPER 44 EC	BENSULFURON-METHYL	BENSULFURON METHYL			440	0.44
ADONA 72 SC	CHLOROTHALONIL	CHLOROTHALONIL	825			0.825
MITOX 20 EC	DODEMORPH	DODEMORF ACETATE			200	0.2
SCALA	PYRIMETHANIL	PYRIMETHANIL	400			0.4
SILWET GOLD	ORGANOSILICONE	ORGANOSILICONE		1000		1
RUGBY 100 ME	CADUSAFOS	CADUSAFOS			100	0.1
KILITAC	AMITRAZ	AMITRAZ	200		200	0.2
FLORAMITE	BIFENAZATE	BIFENAZATE			226	0.226
VYDATE	OXAMYL	OXAMYL			240	0.24
ZORO	ABAMECTIN	ABAMECTIN	180			0.18
APPLAUD	BUPROFEZIN	BUPROFEZIN			440	0.44
LANNATE	METHOMYL	METHOMYL			200	0.2
RUFAST	ACRINATHRIN	ACRINATHRIN	750			0.75
SILWET	ORGANOSILICONE	ORGANOSILICONE		1000		1
BYCOR 300 EC	BITERTANOL	BITERTANOL			300	0.3
MESUROL 500 EC	METHIOCARB	METHIOCARB			500	0.5
PREVICUR N 12	PROPAMOCARB	PROPAMOCARB			600	0.6
IPRODIONE	INSECTICIDE	IPRODIONE			500	0.5
PLANT VAX	OXICARBOXIN	OXYCARBOXIM			750	0.75
APOLLO 50% SC	CLOFENTEZINE	CLOFENTEZINE	500			0.5
MILBEKNOCK	MILBEMECTIN	MILBEMECTIN			9.3	0.0093
TEPPIKI	FLONICAMID	FLONICAMID			500	0.5
MANIC	MANCOZEB	MANCOZEB	800			0.8
GOLD STAR	METALAXYL	METALAXYL	80		80	0.08
GOLD STAR	MANCOZEB	MANCOZEB	800		640	0.64
THIOVET	SULFUR	SULFUR	800			0.8
VIVANDO	METRAPHENOB 500g	METRAFENONE			500	0.5

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
NISSURON 10 EC	HEXYTHIAZOX	HEXYTHIAZOX			100	0.1
PREVICUR ENERGY 840 SL	PROPAMOCARB	PROPAMOCARB			600	0.6
PREVICUR ENERGY 840 SL	F0SETYL	FOSETHYL ALUMINIUM			240	0.24
DIMILIN	DIFLUBENZURON	DIFLUBENZURON			220	0.22
ACTELLIC 25%	PRIMIPHOS METHYL	PIRIMIPHOS METHYL			250	0.25
TRACER SUPER	SPINOSAD	SPINOSAD			480	0.48
ROVRAL 50 % AQUAFLO WP	IPRODIONE	IPRODIONE	500	500		0.5
BENLATE 50%WP	BENOMYL	BENOMYL	500			0.5
RIDOMIL 8+64% WP	METALAXYL	METALAXYL	80		80	0.08
RIDOMIL 8+64% WP	MANCOZEB	MANCOZEB	800		640	0.64
MILRAZ 6+70% WP	CYMOXANIL	CYMOXANIL	300		60	0.06
MILRAZ 6+70% WP	PROPINEB	PROPINEB	600		700	0.7
PREVICURE 72% SL	PROPAMOCARB	PROPAMOCARB			720	0.72
DYNAMEC 1.8% EC	ABAMECTIN	ABAMECTIN	180			0.18
FOLIO GOLD	METALAXYL	METALAXYL	80			0.08
FOLIO GOLD	CHLOROTHALONIL	CHLOROTHALONIL	825			0.825
SECURE 24% EC	CHLORFENAPYR	CHLORFENAPYR	360		240	0.24
PEGASES 50% WP	DIAFETHIURON	DIAFETHIURON			500	0.5
NISSURON 5% EC	HEXYTHIAZOX	HEXYTHIAZOX			50	0.05
OXYMETRINE 1% SL	OXYMATRINE	OXYMATRINE			400	0.4
NUSTAR 40% EC	FLUSILAZOLE	FLUSILAZOLE			400	0.4
THIRAM 80 WP	THIRAM	THIRAM			800	0.8
NUSTAR	FLUSILAZOLE	FLUSILAZOLE			400	0.4
VYDATE 10 G	OXAMYL	OXAMYL			100	0.1
AGROTOX /MCPA/	MCPA	MCPA			500	0.5
PREMPT	PYRIPROXYFEN	PYRIPROXYFEN			100	0.1
NOMOLT	TEFLUBEZURON	TEFLUBENZURON		150		0.15
PEGASES	DIAFETHIURION	DIAFETHIURON			500	0.5
RUBIGAN	FENARIMOL	FENARIMOL			116	0.116
EVISECT	THIOCYCLAM	THIOCYCLAM			500	0.5
DOMARK	TETRACONAZOLE	TETRACONAZOLE			205	0.205
DIVIPAN	DICHLORVOS	DICHLORVOS			760	0.76
POLAR	POLYOXIN	POLYOXIN			1	1
GAUCHO FS 350	IMIDACLOPRID	IMIDACLOPRID	200		350	0.35
TOPAS	PENCONAZOL	PENCONAZOLE			100	0.1
REVUS	MANDIPROPAMID	MANDIPROPAMID	250			0.25
AMITIV	AZOXYSTROBIN 250 g	AZOXYSTROBIN			250	0.25
DACONIL	CHLOROTHALONIL	CHLOROTHALONIL	825	750		0.75
RUGBY	CADUSAFOS	CADUSAFOS			100	0.1
AMIDIL	METALAXY	METALAXYL			80	0.08
KILITAC 20%	AMITRAZ	AMITRAZ	200			0.2
TELDOR 50 WG	FENHEXAMID	FENHEXAMID	500		500	0.5
PREVICUR N 12	PROPAMOCARB	PROPAMOCARB			600	0.6
ANTRACOL	PROPINEB	PROPINEB	600			0.6
ALTO	CRPROCONAZOLE	CYPROCONAZOLE			100	0.1
TITL	PROPICONAZOLE	PROPICONAZOLE	250			0.25
ARDENT	KRESOXIM METHYI	KRESOXIM METHYL			500	0.5
ORIUS	TEBUCONAZOLE	TEBUCONAZOLE	250			0.25
BAYLETON	TRIADIMEFON	TRIADIMEFON	250			0.25
FLINT 50 WG	TRIFLOXYSTROBIN	TRIFLOXYSTROBI N	500			0.5
COLLIS	BOSCAIID	BOSCALID			200	0.2
COLLIS	KEROXYM METHYL	KRESOXIM METHYL			500	0.5
FERRAMOL	FERRIC PHOSPHATE	FERRIC PHOSPHATE			1000	1

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
CHRYZOPLUS GREY 0.8%	CHRYZOPLUS	INDOLE BUTYRIC ACID			8	0.08
T.O.G.4	AMMONIUM CHLORIDE	AMMONIUM CHLORIDE			1000	1
S.T.S	SILVER THIOSULFATE	SILVER THIOSULFATE			10	0.01
AGRAL	PHENOL ETHYLENE	PHENOL ETHYLENE			1000	1
STARGEM	MANCOZEB	MANCOZEB	800			0.8
METHOMEX	METHOMYL	METHOMYL			200	0.2
MILPAN	POLYOXIN	POLYOXIN			1000	1
TOPSIN	THIOPHANATE	THIOPHANATE METHYL			500	0.5
NISAGRA	TRICHODERMA VIRIDE	TRICHODERMA VIRIDE			1000	1
MITIGAN	DICOFOL	DICOFOL	185			0.185
RUNNER	METHOXYFENOCIDE	METHOXYFENOCIDE			240	0.24
BIOFILM	FATTY ACIDE	FATTY ACIDE			1000	1
BIOFILM	GLYCOLETHERS	GLYCOLETHERS			1000	1
AGRIFOS 600	MONO	MONOPOTASSIUM PHOSPHATE			300	0.3
AGRIFOS 600	DIPOTASSIUM PHOSPHATE	DIPOTASSIUM PHOSPHATE			300	0.3
MAGFER	SILICONE	SILICONE			1000	1
DIAFENTHIORON	SPIROXAMINE	SPIROXAMINE	500			0.5
SWITCH	CYPRODINIL	CYPRODINIL			375	0.375
CRUISER	THIAMETHOXAM	THIAMETHOXAM			700	0.7
SCORE	DIFENOCONAZOLE	DIFENOCONAZOLE		250		0.25
PRESERVE	ASCORBIC ACID	ASCORBIC ACID			100	0.1
QUADRIS	AZPXYSTROBIN	AZOXYSTROBIN			250	0.25
RHIZOPHONE	INDOLEBUTYRIC ACID	INDOLE BUTYRIC ACID			4	0.004
AVIMEC 1.8 EC	ABAMECTIN	ABAMECTIN	180			0.18
FOSTAIL 80 WP	FOSTAIL-ALUMINUM 80 WP	FOSETHYL ALUMINIUM			800	0.8
BIMATE 25 EC	BUBPIRIMATE 25 EC	BUPIRIMATE			250	0.25
PLANTOC 722 SC	PROPAMOCARB HCL 722 SC	PROPAMOCARB			722	0.722
CARBOZIM 50 SC	CARBENDAZIM 50 SC	CARBENDAZIM			500	0.5
BENOCURE 50 WP	BENOMYL50 WP	BENOMYL			500	0.5
ACET 20 SP	ACETAMIPRID 20 SP	ACETAMIPRID			200	0.2
OVERALL 50 SC	IPRODIONE 50 SC	IPRODIONE	500		500	0.5
CLIMATE 50 SC	KRESOXIM METHYL 50 SC	KRESOXIM METHYL			500	0.5
CLICK 20 SL	IMIDACLOPRID 20 SL	IMIDACLOPRID			200	0.2
KNOCKOUT 50 SC	CLOFENTEZINE 50 SC	CLOFENTEZINE			500	0.5
MILDEW 30 EC	BITERTANOL 30 EC	BITERTANOL			300	0.3
TALSTAR	BIFENTHRIN	BIFENTHRIN	200		100	0.1
BAYLETON 25 WP	TRIADIMEFON	TRIADIMEFON	250			0.25
CALYPSO 480 SC	THIACLOPRID	THIACLOPRID			480	0.48
ALIETTE WG 80	FOSTAIL-ALUMINUM 80 WP	FOSETHYL ALUMINIUM			800	0.8
DECIS 2.5 EC	DELTAMETHRINE	DELTAMETHRIN		25		0.025
PREVICUR N	PROPAMOCARB	PROPAMOCARB			600	0.6
SAPROL	TRIFORINE	TRIFORINE			190	0.19
EFENTAZINE	CLOFENTAZINE	CLOFENTEZINE			500	0.5
GOLAN	ACETAMIPRID 20 SP	ACETAMIPRID			200	0.2
OVYMETRINE	OXYMATRINE	OXYMATRINE		980		0.98
TEPPEKI WP	FLONICAMID	FLONICAMID			500	0.5
FRUGICO	DIETHOFENCARB 250 g	DIETHOFENCARB			250	0.25
B NINE	DAMINOZIDE 85%	DAMINOZIDE			850	0.85
SYSTHANE	MYCLOBUTANIL	MYCLOBUTANIL	200			0.2
PREVICUR	PROPAMOCARB	PROPAMOCARB			600	0.6
PREVICUR	F0SETYL	FOSETHYL ALUMINIUM			240	0.24

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
BELLIS	BOSCAIID	BOSCALID	200		200	0.2
KARATEZEON	LAMBDA-CYHALOTHRIN 50	LAMBDA CYHALOTHRIN			50	0.05
RIDOMIL GOLD PEPITER	METALAXYL	METALAXYL	80		80	0.08
RIDOMIL GOLD PEPITER	MANCOZEB	MANCOZEB	800		640	0.64
POLYTRIN	PROFENOFOS	PROFENOFOS	720			0.72
THUNDER 145 OD	IMIDACLOPRID	IMIDACLOPRID	200			0.2
VERTIA	FENAMIDONE 44.4	FENAMIDONE			444	0.444
STROBY 50 WG	KRESOXIM-METHYL 50 WG	KRESOXIM METHYL			500	0.5
PREVICUR SL 840	PROPAMOCARB	PROPAMOCARB			840	0.84
BAVISTIN	CARBENDAZIM 50 SC	CARBENDAZIM			500	0.5
CHRYZOTEK 0.04%	3-INDOLYBUTRIC ACID	INDOLE BUTYRIC ACID			4	0.04
FOLIMAT	OMETHOATE	OMETHOATE			800	0.8
STRATHENE	ACEPHATE	ACEPHATE	750			0.75
SPORKILL	DIDECYL DIMETHYL	DIDECYL DIMETHYL			1000	1
PUROGENE	SODIUM CHLORITE	SODIUM CHLORITE			20	0.02
PIRIMOR	PIRICARB	PIRIMICARB			500	0.5
THIONEX	ENDOSULPAN 350 g	ENDOSULFAN			350	0.35
ACTELLIC 50 EC	PIRIMIPHOS -METHYL	PIRIMIPHOS METHYL			500	0.5
AMITIR	AZAXSTROBIN	AZOXYSTROBIN			250	0.25
ORTIVA	AZOXYSTROBIN	AZOXYSTROBIN	250			0.25
GRAMOXONE	PARAQUAT DECHLORIDE	PARAQUAT DICHLORIDE		200		0.2
RHIZOLEX	TOLCLOFOS METHYL	TOLCLOFOS METHYL			500	0.5
CAPTAN	CAPTAN	CAPTAN			800	0.8
THIRAM GRANOFLO	THIRAM	THIRAM			800	0.8
DEXONSP	FENAMINOSULF	FENAMINOSULF			700	0.7
DANISOROBA	CYFLUMETOFEN	CYFLUMETOFEN			980	0.98
IMPACT	FLUTRIAFOL	FLUTRIAFOL			250	0.25
EQUATION PRO	CYMOXANIL	CYMOXANIL	300			0.3
BRIGADE 25 EC	BIFENTHRIN	BIFENTHRIN	200		250	0.25
OBRON 240 SC	SPIROMESIFEN	SPIROMESIFEN			240	0.24
CRUISER 350 FS	THIAMETHOXAM 350g	THIAMETHOXAM			350	0.35
BAYCOR 300 EC	BITERTANOL 300 EC	BITERTANOL			300	0.3
AMISTAR	AZOXYSTROBIN 48% SC	AZOXYSTROBIN			480	0.48
ANTRACOL 70 WP	PROPINEB	PROPINEB	600		700	0.7
FOLPAN 500g/kg	FOLPET	FOLPET			500	0.5
ONDAR	CAPTAN	CAPTAN			800	0.8
DACONIL 75% WP	CHLOROTHALONIL	CHLOROTHALONIL	825	750		0.75
RIDOMIL GOLD PEPITER 8+64%	METALAXIL	METALAXYL			80	0.08
RIDOMIL GOLD PEPITER 8+64%	MANCOZEB	MANCOZEB	800		640	0.64
ACROBAT8+64% WP	DIMETH-O-RPH	DIMETHOMORPH			80	0.08
ACROBAT8+64% WP	MAC-ZEB	MANCOZEB			640	0.64
MANCOZEB 80% WP	MANCOZEB	MANCOZEB	800			0.8
TALSTAR 10% EC	BIFENTHRIN	BIFENTHRIN	200		100	0.1
DOMREX	CYANAMIDE	CYANAMIDE			500	0.5
CHAMPION	CHAMPION	COPPER HYDROXIDE			770	0.77
ETHREL	ETHEFOS 480 g	ETHEFOS			480	0.48
ALAR	DAMINOZIDE	DAMINOZIDE			850	0.85
ROVRAL 250 SC	IPRODIONE	IPRODIONE	500		250	0.25
KILITTAC	AMITRAZ	AMITRAZ	200			0.2

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
AGRIXYL	METALAXYYL 70g	METALAXYL			70	0.07
CHRYZOTEK 0.4%	INDOLEBUTYRIC ACID	INDOLE BUTYRIC ACID			4	0.004
KUMULUS	SULFUR	SULFUR	800			0.8
BAVESTIN DF	CARBENDAZIM 50 SC	CARBENDAZIM			500	0.5
ROVERAL AQUA FLO	IPRODIONE	IPRODIONE	500			0.5
PREVACURE ENERGY	PROPAMOCARB	PROPAMOCARB			600	0.6
PREVACURE ENERGY	F0SETYL	FOSETHYL ALUMINIUM			240	0.24
ROVRAL AQUA	IPRODIONE	IPRODIONE	500			0.5
CASCADE	FLUFENOXURON	FLUFENOXURON	100			0.1
MERPAN	CAPTAN	CAPTAN			800	0.8
GERASOL	ORGANIC SALT	ORGANIC SALT			900	0.9
BIODENW	ALCOHOL ALKOXYLATE	ALCOHOL ALKOXYLATE			0.1	1
BENOMYL	1-BUTYLCARBAMOYL	1-BUTYLCARBAMOYL			500	0.5
EMTHANE	MANCOZEB	MANCOZEB	800			0.8
PLANTVAX	OXYCARBOXIN	OXYCARBOXIM			750	0.75
ALIETTE WG 80 FLASH	FOSEFYL-ALUMINIUM	FOSETHYL ALUMINIUM			800	0.8
VERITA WG	FENAMIDONE 44.4	FENAMIDONE			444	0.444
BOTANIGARD	BEAUVERIA BASSIANA	BEAUVERIA BASSIANA			11.8	0.0118
PREVACUR N 12	PROPAMOCARB	PROPAMOCARB			600	0.6
PREVACUR N 12	F0SETYL	FOSETHYL ALUMINIUM			240	0.24
SECURE	CHLORFENAPYR	CHLORFENAPYR	360			0.36
ANTISCALANT SGSC	CELLUSE ACETATE	CELLULOSE ACETATE			350	0.35
MIRAGE	PROCHLORAZ	PROCHLORAZ			450	0.45
A.A TERRA	GLASGRUENTRY	GLASGRUENTRY			1000	1
NISSORUN	HEXYTHIAZOX	HEXYTHIAZOX			100	0.1
X MITE	ACEQUINOCYL	ACEQUINOCYL			1000	1
IPPON	DINOTEFURAN 20%	DINOTEFURAN			200	0.2
PROCLAIM	EMARNECTIN BENZOATE	EMARMECTIN BENZOATE			44	0.044
SPARTA	SPINETORAM	SPINETORAM			120	0.12
DIZICTOL 15%	DIAZINON 15%	DIAZINON			150	0.15
TRACER ULTRA	SPINOSID	SPINOSAD			480	0.48
GIBERLLON	GIBBERELLIC ACID	GIBBERELLIC ACID			40	0.04
ZEEMGUARD	NEEM OIL	NEEM OIL			1000	1
BRAVO 720	CHLOROTHALONIL	CHLOROTHALONIL	825		720	0.72
TRIGARD	CYROMAZINE	CYROMAZINE			750	0.75
ZOHAR OC6	ANIONIC	ANIONIC			6	0.006
ZOHAR OC6	NONIONICS	NONIONICS			994	0.994
BRODITOP WAX BLOCK	BRODIFACOUM	BRODIFACOUM			200	0.2
METHAMORE	METHAM SODIUM	METHAM SODIUM			900	0.9
DOMARK COMBI	TETRACONAZOL	TETRACONAZOLE			200	0.2
DOMARK COMBI	SULPHUR	SULFUR			800	0.8
TOTACH	PYRETHRUM	PYRETHRUM			50	0.05
TOTACH	NEEM OIL	NEEM OIL			90	0.09
SKIPPER	DIFENOCONAZOLE	DIFENOCONAZOLE	250			0.25
OMER	PENCONAZOL	PENCONAZOLE			100	0.1
MILOR	MANCZB 56%	MANCOZEB			560	0.56
MILOR	METALAXYL 7.5%	METALAXYL			75	0.075
DAYNON	PROPAMOCARB	PROPAMOCARB			600	0.6
ROVRAL POWDER	IPRODIONE	IPRODIONE	500			0.5
BLAD BUFF	THAMANA	THAMANA			1000	1
FONGANIL GOLD	METALAXYL	METALAXYL	80			0.08
PHYTON 27	COPPER SULPHATE	COPPER SULPHATE			212.7	0.2127
ANRACOL	PROPINEB	PROPINEB	600			0.6
GOLTIX 70 WP	METAMITRO	METAMITRON			700	0.7
INFINITO	PROPAMOCARB	PROPAMOCARB			600	0.6

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
MATCH 050	LUFENURON	LUFENURON			500	0.5
CONSERVE	SPINOSAD	SPINOSAD			480	0.48
NEATNESS	BUPRIMITE	BUPIRIMATE			250	0.25
PROUD	KRESOXIM-METHYL 50 WG	KRESOXIM METHYL			500	0.5
TRIBUTE	SPRIOXAMINE	SPIROXAMINE			500	0.5
CONQUEST	ACEFAMPRID	CHLORPYRIFOS			500	0.5
METHRINE	OXYMATRINE	OXYMATRINE		980		0.98
ADONA	CHLOROTHALONIL	CHLOROTHALONIL	825			0.825
STRIKER	OXYMATRINE	OXYMATRINE		980		0.98
PYRIMEC	PYRIMETHANIL	PYRIMETHANIL	400			0.4
TILT	PROPICONAZOLE	PROPICONAZOLE	250			0.25
DYGALL 160G	AGROBACTARIUM	AGROBACTARIUM			160	0.16
TOG3	THIOBENDAZOLE 75	THIOBENDAZOLE			750	0.75
STS 75	SILVER THIOSULFATE	SILVER THIOSULFATE			75	0.075
NISSORUN 10 EC	HEXYTHIAZOX	HEXYTHIAZOX			100	0.1
CALyPSO	THIACLOPRID	THIACLOPRID			480	0.48
GRAMAXONE	PARAQUAT	PARAQUAT DICHLORIDE			200	0.2
TRACER	SPINOSAD	SPINOSAD			480	0.48
RIDOMIL GOLD	METALAXYL	METALAXYL	80			0.08
RIDOMIL GOLD	MANCOZEB	MANCOZEB	800		640	0.64
TEDOR	FENHEXAMID	FENHEXAMID	500			0.5
AVID	ABAMECTIN	ABAMECTIN	180			0.18
AMIGUS	DIAFETHIURON	DIAFETHIURON			500	0.5
DUKATALON	PARAQUAT DICHLORIDE	PARAQUAT DICHLORIDE			200	0.2
MESUROL	METHIOCARB	METHIOCARB			500	0.5
PYRUS 300	PYRIMETHANIL	PYRIMETHANIL	400			0.4
STS	SILVER THIOSULFATE	SILVER THIOSULFATE			75	0.075
TOG 30	THIOBENDAZOLE 75	THIOBENDAZOLE			750	0.75
KODKOD	IMIDACLOPRID	IMIDACLOPRID	200			0.2
TOG6	THIOBENDAZOLE 75	THIOBENDAZOLE			750	0.75
SULPHUR GOLD	SULPHUR	SULFUR			800	0.8
AGRITHANE 80 WP	MANCOZEB	MANCOZEB	800			0.8
AGRIBAT 69 WP	DIMETHOMORPH9%	DIMETHOMORPH			90	0.09
AGRIBAT 69 WP	MANCOZEB 60%	MANCOZEB			600	0.6
BLUE COP 61.4 WP	METALLIC COPPER	METALLIC COPPER			61.4	0.0614
DIZONE 60 EC	DIAZINON 60%	DIAZINON			600	0.6
MISSTRESS 72 WP	METALAXYL	METALAXYL	80		80	0.08
MISSTRESS 72 WP	MANCOZEB	MANCOZEB	800		640	0.64
PROFEN 72 WP	PROFENOFOS	PROFENOFOS	720			0.72
CATCH 50 EC	LUFENURON	LUFENURON			500	0.5
TOPNATE 50 SC	THIOPHANATE-METHYL 50%	THIOPHANATE METHYL			500	0.5
CYROZINE 75 WP	CYROMAZINE	CYROMAZINE			750	0.75
STRIOBIN 25 SC	AZOXYSTROBIN	AZOXYSTROBIN	250			0.25
PLANTOC	PRPAMOCARB	PROPAMOCARB			600	0.6
RVB FLOWER FEED	CITIRIC ACID	CITIRIC ACID			10	0.01
CHRYZOTEC BEIGE 0.4%	INDOLEBUTYRIC ACID	INDOLE BUTYRIC ACID			4	0.004
LQ 215	ANIONIC ABD CATIONIX	ANIONIC ABD CATIONIX			1000	1
SODIUM CHLORITE	SODIUM CHLORITE	SODIUM CHLORITE			1000	1
DPDI BUFFER	DPDI BUFFER	DPDI BUFFER			100	0.1
DPDI REAGENT	DPDI REAGENT	DPDI REAGENT			900	0.9
TOG 3	HORMON	THIABENDAZOLE			75	0.075
TOG-3	HORMON	THIABENDAZOLE			75	0.075
FULLUNGPHOS	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
HELOSATE 48 SL	ISOPROPYL AMINE	GLYPHOSATE			620	0.62
GRANSTAR 75 DF	TRIBENURON	TRIBENURON			750	0.75

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
PHOSTOXIN REGULAR	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
CELPHOS 56% TAB	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
SD-TOXIN	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
ZINC PHOSPHIDE	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
PRIMAGRAM GOLD 660 SL	S-METOLACHLOR	S-METOLACHLOR			290	0.29
PRIMAGRAM GOLD 660 SL	ATRAZINE	ATRAZINE	500		370	0.37
TOPIC 080 EC	CLADINAFOP PROPARGYL	CLODINAFOP PROPARGYL			80	0.08
WEED KILLER	2,4-D AMINE	2,4-D AMINE	720		463	0.72
MALT 50% EC	MALATHION	MALATHION	500	500		0.5
AGRO 2,4-D AMINE	2,4-D AMINE	2,4-D AMINE	720		463	0.72
GESAPRIM 500 FW	ATRAZINE	ATRAZINE	500		500	0.5
ZURA	2,4-D AMINE	2,4-D AMINE	720		463	0.72
THIRAM GRANUFLO 80 WG	THIRAM	THIRAM			800	0.8
CRUZATE R WP	CYMOXANIL	CYMOXANIL		850		0.85
CRUZATE R WP	COPPER OXICHLORIDE	COPPER OXYCHLORIDE		850		0.85
AGRO-THOATE 40 EC	DIMETHOAT	DIMETHOAT	400		400	0.4
NOBLE 25 WP	TRIADIMEFON	TRIADIMEFON	250			0.25
CHIVAD	2,4-D AMINE	2,4-D AMINE	720		463	0.72
SEVIN 85 WP	CARBARYL	CARBARYL	850			0.85
APPOLLO	CLOFENTEZINE	CLOFENTEZINE	500			0.5
TILT 250 EC	PROPICONAZOLE	PROPICONAZOLE	250			0.25
ROUNDUP	GLYPHOSATE	GLYPHOSATE	480		360	0.36
AGRO-THOATE	DIMETHOAT	DIMETHOAT	400		400	0.4
KARATE 5%EC	LAMBDA CYHALOTHRIN	LAMBDA CYHALOTHRIN			50	0.05
THIONEX 35 EC	ENDOSULFAN	ENDOSULFAN	350			0.35
NIMROD 25 EC	BUPIRMATE	BUPIRIMATE		250		0.25
LAMDEX 5 EC	LAMBDA CYHALOTHRIN	LAMBDA CYHALOTHRIN			50	0.05
DERBY 175 SC	FLURASULAM	FLURASULAM			75	0.075
DERBY 175 SC	FLUMETASULAM	FLUMETASULAM			100	0.1
HERBIKILL	2,4-D AMINE	2,4-D AMINE	720		463	0.72
PALLAS 45 OD	PYROXSULAM	PYROXSULAM	450			0.45
ALPHOS 56%	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
RIDOM 80%	MANCOZEB	MANCOZEB	800			0.8
GLYCEL 41%SL	GLYPHOSATE	GLYPHOSATE	480			0.48
MATCO	METALAXYL 8%	METALAXYL			80	0.08
MATCO	MANCOZEB 64%WP	MANCOZEB			640	0.64
INDOFIL M-45	MANCOZEB	MANCOZEB	800			0.8
KOCIDE 101	COPPER HYDROXIDE	COPPER HYDROXIDE			1000	1
PRIDE 200SL	PROPYZAMIDE	PROPYZAMIDE			200	0.2
SANAPHEN D 720 SL	2,4-D AMINE	2,4-D AMINE	720			0.72
HERBKNOCK	2,4-D AMINE	2,4-D AMINE	720		463	0.72
FASTAC 7.5 ULV	ALPHACYPERMETHRIM 7.5g	ALFA CYPERMETHRIN			7.5	0.075
RIDOMIL GOLD WZ 68 WG	METALAXYL 8%	METALAXYL			80	0.08
RIDOMIL GOLD WZ 68 WG	MANCOZEB 64%WP	MANCOZEB			640	0.64
LITAMINE 72 SL	2,4-D AMINE	2,4-D AMINE	720		463	0.72
DICAL	2,4-D AMINE	2,4-D AMINE	720		463	0.72
ACTELLIC 50% EC	PRIMIPHOS METHYL	PIRIMIPHOS METHYL			500	0.5
MAMBA 360 SL	GLYPHOSATE	GLYPHOSATE	480		360	0.36
GLYPHOSATE	GLYPHOSATE	GLYPHOSATE	480			0.48
PHOSTOXIN 56% /ROUND/ TAB	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
GLYPHOGAN 480 SL	GLYPHOSATE	GLYPHOSATE	480	480		0.48
MITIGAN 18.5 EC	DICOFOL	DICOFOL	185			0.185
FOLPAN 50 WP	FOLPET	FOLPET			500	0.5
PYRINEX 48 EC	CHLORPHRFOS	CHLORPYRIFOS			480	0.48

Trade name	Common name	Active Ingredient	Conc_ai Berhan	Conc_ai FAO	Conc_ai Deneer	Conc_ai_fraction used
MEGABAN PLUS	CHRORPYRIFOS ETHYL	CHLORPYRIFOS ETHYL			480	0.48
RIDIMOL GOLD M2 68 WG	MEFENOXAM	METALAXYL			480	0.48
MABA 360 SL	GLYPHOSATE	GLYPHOSATE	480			0.48
KARATE 5% EC	LAMBDA CYHALOTHRIN	LAMBDA CYHALOTHRIN			50	0.05
FLOWSANFS 42%	THIRAM 533g	THIRAM			533	0.533
DURSBAAN	CHLORPHRFOS	CHLORPYRIFOS			480	0.48
RIDIMOL 80% WP	MANCOZEB	MANCOZEB	800			0.8
RIDIMOL GOLD M2 68 WG	MANCOZEB	MANCOZEB	800		680	0.68
BAYFIDEN EC250	TRIADIMENOL	TRIADIMENOL			250	0.25
HELARAT 5% EC	LAMBDA CYHALOTHRIN	LAMBDA CYHALOTHRIN			50	0.05
SHENPHOS 57%	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			570	0.57
AMETRAZINE 500 SL	ATRAZINE 250g	ATRAZINE			250	0.25
AMETRAZINE 500 SL	AMETRYNe 250g	AMETRYNE			250	0.25
QUICK PHOSE	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
MANCOLAXYL 72 WP	METALAXYL 8%	METALAXYL			80	0.08
MANCOLAXYL 72 WP	MANCOZEB 64%WP	MANCOZEB			640	0.64
CURZATE R WP	LYMOXANIL	CYMOXANIL		850	600	0.85
CURZATE R WP	LYMOXANIL	COPPER OXYCHLORIDE		850	600	0.85
PHOSTOXIN	ALUMINIUM PHOSPHIDE	ALUMINIUM PHOSPHIDE			560	0.56
AGRO-THIATE 40 EC	DIAMETHOATE	DIAZINON			200	0.2
AGRO-THIATE 40 EC	DIAMETHOATE	DIMETHOATE			200	0.2
AGRO-LAXYL MZ 63.5	MANCOZEB 56%W	MANCOZEB			560	0.56
AGRO-LAXYL MZ 63.5	V METALEXY 75%	METALAXYL			75	0.075
TOPZOLE 250 EC	PROPICONAZOLE	PROPICONAZOLE	250			0.25
BEEUP OIL	EMULSIFIED	EMULSIFIED			1000	1
RIDOMIL GOLD MZ 68 WP	METALAXYL 8%	METALAXYL			80	0.08
RIDOMIL GOLD MZ 68 WP	MANCOZEB 64%WP	MANCOZEB			640	0.64
GLYPHOGAN T	GLYPHOSATE	GLYPHOSATE	480	480		0.48
ethiolathion 50% ec	Malathion	MALATHION			500	0.5
ethiosulfan 35% ec	Endosulfan	ENDOSULFAN			350	0.35
ethiozinon 60% ec	Diazinone (for crop use)	DIAZINON			600	0.6
ethiothoate 40% ec	Dimethoate	DIMETHOAT			400	0.4
ethiotrothion 50% ec	Fenitrothion	FENITROTHION			500	0.5
ethiodemethrin 2.5% ec	Deltamethrin	DELTAMETHRIN			25	0.025
vetazinon 60 % ec	Diazinone (for veterinary use)	DIAZINON			600	0.6
amitraz 12.5% ec	Amitraz	AMITRAZ			125	0.125
ethiosulfan 25 % ulv	Endosulfan	ENDOSULFAN			250	0.25
ethiothoate 40% ulv	Dimethoate	DIMETHOAT			400	0.4
ethiotrothion 95% ulv	Fenitrothion	FENITROTHION			950	0.95
ethiolathion 95% ulv	Malathion	MALATHION			950	0.95
ethio2,4-D 72% sl	2,4-D	2,4-D			720	0.72
ethiolathion 5% dust	Malathion	MALATHION			50	0.05
ethiosulfan 5% dust	Endosulfan	ENDOSULFAN			50	0.05
DDT 75% wdp	DDT	DDT			750	0.75
ethiozeb 80% wdp	Mancozeb	MANCOZEB			800	0.8
deltamthrin 2.5% wdp	Deltamethrin	DELTAMETHRIN			25	0.025

Appendix 4.4 Physico-chemical properties of active ingredients used in the calculations of Chapter 4.2 and 4.3

ADI and ARfD are both given as mg/kg body weight; under sources 'Berhan' denotes data provided by Berhan Teklu, 'PPDB' refers to data taken from the Pesticides Properties Database by John Deneer.

Active	ADI	Source ADI	ARfD	Estd Arfd	Source ARfD	DT50 soil	DT50 w/sed	Source DT50 w/sed	Koc	Source Koc
						(d)	(d)		(l/kg)	
1-BUTYLCARBAMOYL			Not alloc.	1.23	PPDB	67	0.8	PPDB	#N/A	Berhan
2,4-D	0.05	Berhan	Not alloc.	0.615	PPDB	10	29	PPDB	88.4	Berhan
2,4-D AMINE	0.05	Berhan	Not appl.	0.615	Berhan	10	29	PPDB	88.4	Berhan
ABAMECTIN	0.0025	Berhan	0.005	0.005	PPDB	30	89	PPDB	6631	Berhan
ACEPHATE	0.03	Berhan	0.1	0.1	PPDB	3	50	PPDB	302	Berhan
ACEQUINOCYL	0.023	PPDB	Not alloc.	0.28	PPDB	3	0.45	PPDB	58000	PPDB
ACETAMIPRID	0.07	Berhan	0.1	0.1	PPDB	3	34	PPDB	200	Berhan
ACRINATHRIN	0.01	Berhan	0.01	0.01	PPDB	39.2	18.6	PPDB	48231	Berhan
AGROBACTARIUM	-	-	-	-	-	-	-	-	-	-
ALCOHOL ALKOXYLATE	-	-	-	-	-	-	-	-	-	-
ALFA CYPERMETHRIN	0.015	Berhan	0.04	0.04	Berhan	35	21	PPDB	57889	Berhan
ALUMINIUM PHOSPHIDE	0.019	PPDB	0.032	0.032	PPDB	0.2	Very rapid	PPDB		
AMETRYNE	0.015	PPDB	Not alloc.	0.184	PPDB	37	Stable	PPDB	316	PPDB
AMITRAZ	0.01	PPDB	0.01	0.01	PPDB	0.2	1	PPDB	#N/A	Berhan
AMMONIUM CHLORIDE	-	-	-	-	-	-		-	-	-
ANIONIC	-	-	-	-	-	-		-	-	-
ANIONIC ABD CATIONIX	-	-	-	-	-	-		-	-	-
ASCORBIC ACID	-	-	-	-	-	-		-	-	-
ATRAZINE	0.02	Berhan	0.1	0.1	PPDB	75	80	PPDB	100	Berhan
AZOXYSTROBIN	0.2	PPDB	Not alloc.	2.46	PPDB	78	205	PPDB	#N/A	Berhan
BEAUVERIA BASSIANA	-	-	-	-	-	-		-	-	-
BENOMYL	0.1	Berhan	Not alloc.	1.23	PPDB	67	0.8	PPDB	1900	Berhan
BENSULFURON METHYL	0.2	PPDB	#N/A	2.46	PPDB	24	48	PPDB	409	NL-JD-PPBD
BETA CYFLUTHRIN	0.003	PPDB	0.02	0.02	PPDB	13	3	PPDB	64300	PPDB
BIFENAZATE	0.01	PPDB	Not alloc.	0.12	PPDB	1	0.25	PPDB	1778	PPDB
BIFENTHRIN	0.015	Berhan	0.03	0.03	PPDB	26	161	PPDB	236610	Berhan
BITERTANOL	0.01	PPDB	0.01	0.01	PPDB	23	39.2	PPDB	2461	NL-JDPPBD
BOSCALID	0.04	Berhan	Not alloc.	0.49	PPDB	200	Stable	PPDB	772	Berhan
BRODIFACOUM	Not alloc.	PPDB	Not alloc.	-	PPDB	84	30	PPDB	50000	Tomlin
BUPIRIMATE	0.05	PPDB	0.05	0.05	PPDB	79	42.5	PPDB	1882	NL-JDPPBD
BUPROFEZIN	0.01	PPDB	0.5	0.5	PPDB	50	49	PPDB	5363	PPDB
CADUSAFOS	0.0004	PPDB	0.003	0.003	PPDB	38	215	PPDB	225	Tomlin
CAPTAN	0.1	PPDB	0.3	0.3	PPDB	0.8	1	PPDB	200	PPDB
CARBARYL	0.0075	Berhan	0.01	0.01	PPDB	16	5.8	PPDB	300	Berhan
CARBENDAZIM	0.02	Berhan	0.02	0.02	PPDB	40	33.7	PPDB	225	Berhan

Active	ADI	Source ADI	ARfD	Estd Arfd	Source ARfD	DT50 soil	DT50 w/sed	Source DT50 w/sed	Koc	Source Koc
CELLULOSE ACETATE	-	-	-	-	-	-		-	-	-
CHLORFENAPYR	0.015	Berhan	Not alloc.	0.18	PPDB	1.4	Stable	PPDB	12000	Berhan
CHLOROTHALONIL	0.015	Berhan	0.6	0.6	PPDB	22	0.1	PPDB	850	Berhan
CHLORPYRIFOS	#N/A	Berhan	0.1	0.1	PPDB	50	36.5	PPDB	8151	PPDB
CHLORPYRIFOS ETHYL	#N/A	Berhan	0.1	0.1	PPDB	50	36.5	PPDB	8151	PPDB
CITIRIC ACID	-	-	-	-	-	-		-	-	-
CLODINAFOP PROPARGYL	0.003	Berhan	0.05	0.05	Berhan	0.8	0.2	PPDB	1466	NL-JD-PPBD
CLOFENTEZINE	0.02	Berhan	Not alloc.	0.25	PPDB	131.1	9.6	PPDB	No leaching in lab studies	Tomlin
COPPER HYDROXIDE	#N/A	Berhan	Not alloc.	1.85	PPDB	10000	Stable	PPDB	-	-
COPPER OXYCHLORIDE	0.15	Berhan	Not alloc.	1.85	PPDB	10000	Stable	PPDB	-	-
COPPER SULPHATE	0.15	PPDB	Not alloc.	1.85	PPDB	10000	Stable	PPDB	-	-
CYANAMIDE	0.002	PPDB	0.002	0.002	PPDB	1	3.7	PPDB	4.4	PPDB
CYFLUMETOFEN	0.17	PPDB	Not alloc.	2.091956	PPDB	9	1.32	PPDB	173900	PPDB
CYMOXANIL	0.013	Berhan	0.08	0.08	PPDB	0.7	0.3	PPDB	43.6	Berhan
CYPROCONAZOLE	0.02	PPDB	0.02	0.02	PPDB	142	1000	PPDB	364	NL-JD-PPBD
CYPRODINIL	0.03	PPDB	Not alloc.	0.37	PPDB	37	142	PPDB	2277	NL-JD-PPBD
CYROMAZINE	0.06	PPDB	0.1	0.1	PPDB	93	228	PPDB	409	NL-PPDB
DAMINOZIDE	0.45	PPDB	Not alloc.	5.54	PPDB	0.6	1	PPDB	18	NL-PPDB
DDT	0.01	PPDB	Not alloc.	0.123	PPDB	6200	Stable	PPDB	151000	PPDB
DELTAMETHRIN	0.01	Berhan	0.01	0.01	PPDB	13	65	PPDB	10240000	Berhan
DIAFETHIURON	#N/A	Berhan	Not alloc.	0.0369	PPDB	0.5	Stable	PPDB	43546	PPDB
DIAZINON	0.0002	Berhan	0.025	0.025	PPDB	9.1	10.4	PPDB	609	Berhan
DICHLORVOS	0.00008	PPDB	0.002	0.002	PPDB	2	0.22	PPDB	50	PPDB
DICOFOL	0.002	Berhan	Not alloc.	0.0246	PPDB	80	29	PPDB	6064	Berhan
DIDECYL DIMETHYL	-	-	-	-	-	-	-	-	-	-
DIETHOFENCARB	0.43	PPDB	Not alloc.	5.29	PPDB	5.4	24.9	PPDB	224	NL-PPDB
DIFENOCONAZOLE	0.01	Berhan	0.16	0.16	PPDB	130	1053	PPDB	3760	Berhan
DIFLUBENZURON	0.01	PPDB	Not alloc.	0.123	PPDB	3	4.5	PPDB	4620	NL-PPDB
DIMETHOAT	0.001	Berhan	0.01	0.01	Berhan	2.6	15.2	PPDB	28.3	Berhan
DIMETHOATE	0.001	Berhan	0.01	0.01	Berhan	2.6	15.2	PPDB	28.3	Berhan
DIMETHOMORPH	0.05	PPDB	0.6	0.6	PPDB	57	38	PPDB	348	NL-PPDB
DINOTEFURAN	0.22	PPDB	Not alloc.	2.71	PPDB	82	Stable	PPDB	26	PPDB
DIPOTASSIUM PHOSPHATE	-	-	-	-	-	-	-	-	-	-
DODEMORF ACETATE	0.1	PPDB	0.4	0.4	PPDB	41	45	PPDB	25200	NL-PPDB
DPDI BUFFER	-	-	-	-	-	-	-	-	-	-
DPDI REAGENT	-	-	-	-	-	-	-	-	-	-
EMARMECTIN BENZOATE	0.0025	PPDB	0.05	0.05	PPDB	300	Stable	PPDB	377000	PPDB
EMULSIFIED	-	-	-	-	-	-	-	-	-	-
ENDOSULFAN	0.006	Berhan	0.02	0.02	PPDB	50	20	PPDB	11500	Berhan
ETHEFOS	0.03	PPDB	0.05	0.05	PPDB	16	2.8	PPDB	2540	NL-PPDB
FATTY ACIDE	-	-	-	-	-	-	-	-	-	-
FENAMIDONE	0.03	PPDB	Not alloc.	0.369	PPDB	8.5	97	PPDB	388	NL-PPDB
FENAMINOSULF	Not alloc.	PPDB	Not alloc.	-	PPDB	2	Stable	PPDB	40	PPDB
FENARIMOL	0.01	PPDB	0.02	0.02	PPDB	250	Stable	PPDB	734	NL-PPDB
FENHEXAMID	0.5	PPDB	Not alloc.	6.15	PPDB	1	7	PPDB	#N/A	Berhan

Active	ADI	Source ADI	ARfD	Estd Arfd	Source ARfD	DT50 soil	DT50 w/sed	Source DT50 w/sed	Koc	Source Koc
FENITROTHION	0.005	Berhan	0.013	0.013	Berhan	2.7	1.57	PPDB	2000	PPDB
FERRIC PHOSPHATE	0.8	PPDB	Not alloc.	9.84	PPDB	Stable	Stable	PPDB		
FLONICAMID	0.025	PPDB	0.025	0.025	PPDB	3.1	40	PPDB	1.6	PPDB
FLUFENOXURON	0.01	Berhan	0.49	0.49	PPDB	42	53	PPDB	157643	Berhan
FLUMETASULAM	Not alloc.	PPDB	Not alloc.	-	PPDB	45	Stable	PPDB	28	PPDB
FLURASULAM	0.01	PPDB	0.07	0.07	PPDB	11	3.1	PPDB	16430	PPDB
FLUSILAZOLE	0.002	PPDB	0.005	0.005	PPDB	300	365	PPDB	1664	PPDB
FLUTRIAFOL	0.01	PPDB	0.05	0.05	PPDB	1358	Stable	PPDB	205	NL-PPDB
FOLPET	0.1	Berhan	0.1	0.1	PPDB	4.7	0.02	PPDB	304	NL-PPDB
FOSETHYL ALUMINIUM	#N/A	Berhan	Not alloc.	36.9	PPDB	0.1	4.2	PPDB	2217	PPDB
GIBBERELLIC ACID	-	-	-	-	-	-	-	-	-	-
GLASGRUENTRY	-	-	-	-	-	-	-	-	-	-
GLYCOLETHERS	-	-	-	-	-	-	-	-	-	-
GLYPHOSATE	0.3	Berhan	Not alloc.	3.69	PPDB	12	87	PPDB	1435	Berhan
HEXYTHIAZOX	0.03	PPDB	Not alloc.	0.369	PPDB	30	37	PPDB	9455	NL-PPDB
IMIDACLOPRID	0.06	Berhan	0.08	0.08	PPDB	191	129	PPDB	225	Berhan
INDOLE BUTYRIC ACID	-	-	-	-	-	-	-	-	-	-
IPRODIONE	0.06	Berhan	Not alloc.	0.738	PPDB	84	30	PPDB	700	Berhan
KRESOXIM METHYL	#N/A	Berhan	Not alloc.	4.92	PPDB	16	1.3	PPDB	308	NL-PPDB
LAMBDA CYHALOTHRIN	0.005	Berhan	0.0075	0.0075	Berhan	25	12	PPDB	157450	NL-PPDB
LUFENURON	0.0155	PPDB	Not alloc.	0.191	PPDB	16.3	112	PPDB	41182	NL-PPDB
MALATHION	0.03	Berhan	0.3	0.3	PPDB	0.17	0.4	PPDB	1800	Berhan
MANCOZEB	0.05	Berhan	0.6	0.6	PPDB	0.1	76	PPDB	998	Berhan
MANDIPROPAMID	0.03	Berhan	Not alloc.	0.369	PPDB	17	12.2	PPDB	847	Berhan
MCPA	0.05	PPDB	0.15	0.15	PPDB	24	17	PPDB	74	NL-PPDB
METALAXYL	0.08	Berhan	Not alloc.	0.984	PPDB	42	56	PPDB	162.3	Berhan
METALLIC COPPER	#N/A	Berhan	Not alloc.	1.85	PPDB	10000	Stable	PPDB		
METAMITRON	0.03	PPDB	0.1	0.1	PPDB	30	11.1	PPDB	77.7	PPDB
METHAM SODIUM	0.001	PPDB	0.1	0.1	PPDB	7	0.07	PPDB	17.8	PPDB
METHIOCARB	0.013	PPDB	0.013	0.013	PPDB	1.4	15	PPDB	660	NL-PPDB
METHOMYL	0.0025	PPDB	0.0025	0.0025	PPDB	7	3.7	PPDB	72	PPDB
METHOXYFENOCIDE	0.1	PPDB	0.2	0.2	PPDB	146	Stable	PPDB	402	PPDB
METRAFENONE	0.25	PPDB	Not alloc.	3.07	PPDB	250.6	9.3	PPDB	7061	PPDB
MILBEMECTIN	0.03	PPDB	0.03	0.03	PPDB	43	86	PPDB	2975	PPDB
MONOPOTASSIUM PHOSPHATE	-	-	-	-	-	-	-	-	-	-
MYCLOBUTANIL	0.025	PPDB	0.31	0.31	PPDB	560	626	PPDB	#N/A	Berhan
NEEM OIL	-	-	-	-	-	-	-	-	-	-
NONIONICS	-	-	-	-	-	-	-	-	-	-
OMETHOATE	0.0003	PPDB	0.002	0.002	PPDB	14	4.5	PPDB	41.3	PPDB
ORGANIC SALT	-	-	-	-	-	-	-	-	-	-
ORGANOSILICONE	-	-	-	-	-	-	-	-	-	-
OXAMYL	0.001	PPDB	0.001	0.001	PPDB	7	0.7	PPDB	16.6	PPDB
OXYCARBOXIM	0.15	PPDB	Not alloc.	1.85	PPDB	18	1000	PPDB	65	NL-PPDB
OXYMATRINE	-	-	-	-	-	-	-	-	-	-
PARAQUAT DICHLORIDE	0.004	PPDB	0.005	0.005	PPDB	365	Stable	PPDB	100000	PPDB
PENCONAZOLE	0.03	PPDB	0.5	0.5	PPDB	117	853	PPDB	2205	NL-PPDB
PENDIMETHALIN	0.125	PPDB	Not alloc.	1.54	PPDB	90	16	PPDB	17581	PPDB
PHENOL ETHYLENE	-	-	-	-	-	-	-	-	-	-
PIRIMICARB	0.035	PPDB	0.1	0.1	PPDB	86	195	PPDB	388	NL-PPDB
PIRIMIPHOS METHYL	0.004	PPDB	0.15	0.15	PPDB	39	Stable	PPDB	#N/A	Berhan
POLYOXIN	-	-	-	-	-	-	-	-	-	-

Active	ADI	Source ADI	ARfD	Estd Arfd	Source ARfD	DT50 soil	DT50 w/sed	Source DT50 w/sed	Koc	Source Koc
PROCHLORAZ	0.01	PPDB	0.2	0.2	PPDB	120	359	PPDB	500	PPDB
PROFENOFOS	0.03	Berhan	1	1	PPDB	7	Stable	PPDB	2016	Berhan
PROPAMOCARB	0.29	Berhan	1	1	Berhan	39.3	Stable	PPDB	706	NL-PPDB
PROPICONAZOLE	0.04	Berhan	0.3	0.3	PPDB	214	636	PPDB	1221	Berhan
PROPINEB	0.007	Berhan	0.1	0.1	PPDB	3	30	PPDB	Not mobile	Tomlin
PROPYZAMIDE	0.02	PPDB	Not alloc.	0.246	PPDB	47	94	PPDB	850	PPDB
PYRETHRUM	0.04	PPDB	0.2	0.2	PPDB	8	60	PPDB	100000	PPDB
PYRIMETHANIL	0.17	Berhan	Not alloc.	2.09	PPDB	55	80	PPDB	301	Berhan
PYRIPROXYFEN	0.1	PPDB	Not alloc.	1.23	PPDB	10	6.5	PPDB	21175	NL-PPDB
PYROXSULAM	0.9	Berhan	Not alloc.	11.1	PPDB	3.3	Stable	PPDB	30	Berhan
SILICONE	-	-	-	-	-	-	-	-	-	-
SILVER THIOSULFATE	Not alloc.	PPDB	Not alloc.	-	PPDB					
S-METOLACHLOR	0.1	Berhan	Not alloc.	1.23	PPDB	15	47.5	PPDB	226.1	Berhan
SODIUM CHLORITE	Not alloc.	PPDB	Not alloc.	-	PPDB					
SPINETORAM	0.021	PPDB	Not alloc.	0.258	PPDB	16.1	273	PPDB	22836	PPDB
SPINOSAD	0.024	Berhan	#N/A	0.295	Berhan	176		PPDB	20328	PPDB
SPIROMESIFEN	0.03	PPDB	2	2	PPDB	23	5.95	PPDB	30900	PPDB
SPIROXAMINE	0.025	Berhan	0.1	0.1	PPDB	25	66.2	PPDB	14567	Berhan
SULFUR	-	-	-	-	-	-	-	-	No leaching	Tomlin
TEBUCONAZOLE	0.03	Berhan	0.03	0.03	PPDB	62	365	PPDB	1152	Berhan
TEFLUBENZURON	0.01	PPDB	Not alloc.	0.123	PPDB	92	16.4	PPDB	26062	PPDB
TETRACONAZOLE	0.004	PPDB	0.05	0.05	PPDB	61	340	PPDB	1152	NL-PPDB
THAMANA	-	-	-	-	-	-	-	-	-	-
THIABENDAZOLE	0.1	PPDB	Not alloc.	1.23	PPDB	500	4	PPDB	7344	PPDB
THIACLOPRID	0.01	PPDB	0.03	0.03	PPDB	15.5	28	PPDB	615	NL-PPDB
THIAMETHOXAM	0.026	PPDB	0.5	0.5	PPDB	50	40	PPDB	56.2	PPDB
THIOBENDAZOLE	0.1	PPDB	Not alloc.	1.23	PPDB	500	4	PPDB	7344	PPDB
THIOCYCLAM	0.008	PPDB	Not alloc.	0.098	PPDB	1		PPDB	20	PPDB
THIOPHANATE METHYL	0.08	PPDB	0.2	0.2	PPDB	0.6	2	PPDB	1.2	Kd, Tomlin
THIRAM	0.01	PPDB	0.6	0.6	PPDB	15.2	1.6	PPDB	9629	NL-PPDB
TOLCLOFOS METHYL	0.064	PPDB	Not alloc.	0.79	PPDB	3.7	15	PPDB	3620	NL-PPDB
TRIADIMEFON	0.03	Berhan	0.08	0.08	Berhan	26	43	PPDB	300	PPDB
TRIADIMENOL	0.05	PPDB	0.05	0.05	PPDB	250	91	PPDB	750	PPDB
TRIBENURON	0.01	Berhan	0.2	0.2	Berhan	14	26	PPDB	31	NL-PPDB
TRICHODERMA VIRIDE	-	-	-	-	-	-	-	-	-	-
TRIFLOXYSTROBIN	0.1	Berhan	Not alloc.	1.23	PPDB	7	2.4	PPDB	2377	Berhan
TRIFORINE	0.02	PPDB	Not alloc.	0.25	PPDB	19	22	PPDB	527	PPDB

Appendix 4.5 Summary of ranking pesticide risks for surface water

(Powerpoint presentation presented at the Workshop held in Wageningen 5-9 November 2012, sightly improved, 3 June 2013)

Ranking: surface water

Protection goal: humans and cattle using surface water as drinking water

Goal: - identify current actives with highest hazard
- identify most relevant crops and cropping systems
- on the basis of cropping system devise a scenario

Condition: do not consider pesticides used for migratory pests

Note: ranking on basis of toxicity only is less relevant for scenario choice, occupational/consumer risk should be dealt with separately.

John Deneer, Paulien Adriaanse
Alterra, Wageningen UR, October 2012.

Ranking: surface water

Material to work with:

- Lists of imported products (commercial farms and flower farms in separate lists) and locally produced products; only data for 2010 was used
- Information which actives are contained in the products (spreadsheet by Berhan, some additional info added)
- Information on acute (ARfD) and chronic (ADI) risk to humans (spreadsheet by Berhan, lots of additional info added)
- Information on pests and crops (Consultancy report Elaboration of Registered List of Pesticides in Ethiopia According to PSMS Template)
- Paper D. Gorfu and E. Ahmed

Ranking: surface water

Condition: do not consider pesticides used for migratory pests

- Seems 'logical' if this is considered 'non-agricultural' use
- Actives against army worm, locust, quelea bird excluded only if use for this purpose is actually mentioned by Berhan
- Actives involved are quite toxic and high volume:
  - Carbaryl (ARfD: 0.01 mg/kg, volume 2010: 19 tons)
  - Diazinon (ARfD: 0.025 mg/kg, volume 2010: 47 tons)
  - Fenitrothion (ARfD: 0.013 mg/kg, volume 2010: 22 tons)

Ranking: surface water

Condition: do not consider pesticides used for migratory pests

Consequence:
- These actives are not included in any of the rankings
- This may underestimate actual hazards/risks
- Devised scenario will not include use for migratory pests

Although these actives are not considered in the process of scenario construction, the risk of possible **agricultural** uses can be evaluated using the relevant scenario

- Carbaryl (ARfD: 0.01 mg/kg, volume 2010: 19 tons)
- Diazinon (ARfD: 0.025 mg/kg, volume 2010: 47 tons)
- Fenitrothion (ARfD: 0.013 mg/kg, volume 2010: 22 tons)

Ranking: surface water

Outline of procedure:

- Convert volumes of products into volumes of active ingredients
- National scale: divide national volume of active by
  - ARfD → Index for acute risk
  - ADI → Index for chronic risk
- Local scale: divide application rate by
  - ADI → Index for chronic risk at local scale
- Select actives with highest acute/chronic risk
- Identify most relevant crops and cropping systems

Ranking: surface water

Some corrections necessary:

- Exclude irrelevant types of formulations (pellets, baits), indoor use (granules are not excluded, they are considered relevant)
- Exclude compounds with low mammalian toxicity, these will most likely not cause problems at a local scale, even if national volume is high
- Do not consider actives used against army worm, locust, quelea bird, domestic use etc.
- If ARfD is not available, use mean ratio ARfD/ADI to calculate ARfD from ADI
- For chronic risk, exclude compounds which rapidly degrade in water (DT50 ≤ 2 days) because of irrelevance

Ranking: surface water

Exclude irrelevant types of formulations (pellets, baits), indoor use

- DDT (indoor use against mosquito)
- Dichlorvos (indoor use, cockroach, mosquito, flies)
- Aluminiumphosphide (pellets, storage pests)
- Brodifacoum (baits)

The scenario(s) to be devised are not suitable for risk assessment for these types of uses

Ranking: surface water

Exclude low chronic toxicity actives, irrespective of volume

Appears infeasible on the basis of present data, the only compounds with ADI ≥ 0.3 mg/kg are:
- Glyphosate
- Kresoxim-methyl
- Pyroxsulam
- Fosethyl-aluminum

Possible to use WHO classification (but: considers acute hazard only)

More expert knowledge is needed to justify this step, which is therefore not included in the present analysis

Ranking: surface water

Overview of actives excluded from the analysis:

Indoor use: DDT, dichlorvos

Formulation type: brodifacum, aluminiumphosphide

Migratory pests: carbaryl, diazinon, fenitrothion

Ranking: surface water

Result – Volume of Active Ingredient

Active	Volume (2010, tons)	Type[a], crop	ADI (mg/kg)	ARfD (mg/kg)
2,4-D (AMINE)	1824	H, wheat	0.05	-
GLYPHOSATE	195	H, coffee	0.3	-
MALATHION	193	I, sweet potato	0.03	0.3
MANCOZEB	148	F, tomato	0.05	0.6
ENDOSULFAN	84	I, cotton	0.006	0.02
DIMETHOATE	63	I, barley	0.001	0.01
THIRAM	52	F, seed treatment	0.01	0.6
ATRAZINE	40	H, maize	0.02	0.1
DELTAMETHRIN	30	I, cotton	0.01	0.01
S-METOLACHLOR	20	H, haricot beans	0.1	-

[a] (H)erbicide, (I)nsecticide, (F)ungicide

Ranking: surface water

Result – Acute risk

Active	Volume (2010, tons)	ARfD (mg/kg)	Volume / ARfD (10^3 units)	Remarks
DIMETHOATE	63	0.01	6247	
ENDOSULFAN	84	0.02	4208	
DELTAMETHRIN	30	0.01	3024	
2,4-D (AMINE)	1824	0.62*	2964	High estd. ARfD
MALATHION	193	0.3	642	
λ-CYHALOTHRIN	3	0.0075	403	
ATRAZINE	40	0.1	397	
ABAMECTIN	1.4	0.005	285	
MANCOZEB	148	0.6	247	
OXAMYL	0.23	0.001	232	

* Estimated value

Ranking: surface water

Result – Acute risk

Most interesting actives:

Dimethoate, endosulfan, deltamethrin, due to high toxicity

(Possibly 2,4-D, due to its high volume)

Ranking: surface water

Result – Chronic risk

Active	Volume (2010, tons)	ADI (mg/kg)	Volume / ADI (10^3 units)	Remarks
DIMETHOATE	63	0.001	62471	
2,4-D (AMINE)	1824	0.05	36471	High ADI
ENDOSULFAN	84	0.006	14025	
MALATHION	193	0.03	6422	
DELTAMETHRIN	30	0.01	3023	
MANCOZEB	148	0.05	2959	High ADI
ATRAZINE	40	0.02	1983	
DICOFOL	2	0.002	947	
CLODINAFOP	3	0.003	938	
CHLORPYRIFOS	8	0.01	801	

Ranking: surface water

Result – Chronic risk

Most interesting actives:

Dimethoate, endosulfan, due to high toxicity

(Possibly 2,4-D, due to its high volume)

Ranking: surface water

Result – Chronic risk

Caution: outcome is influenced by a priori excluding some compounds.

The following compounds would rank in top-10 list for chronic risk

aluminiumphosphide
carbaryl
diazinon
dichlorvos
fenitrothion
malathion

Ranking: surface water

Result – Local chronic risk

Active	Applic. Rate (N * kg/ha)	ADI (mg/kg)	AR / ADI	Remarks
METAM-SODIUM	153	0.001	153000	Soil desinfestant, greenhouse?
OXAMYL	4	0.001	4000	Nematicide, greenhouse?
DIMETHOATE	0.4	0.001	400	
PROPINEB	1.425	0.007	204	
ENDOSULFAN	0.78	0.006	131	
B-CYFLUTHRIN	0.31	0.003	104	
THIOPHANATE-M.	0.75	0.08	94	
CHLOROTHALONIL	1.24	0.015	82	
PROPYZAMIDE	1.5	0.02	75	
ACEPHATE	1.88	0.03	63	

Application rate and frequency taken from Berhan's list of registered pesticides or from www.fytostat.nl (Dutch registrations)

Ranking: surface water

Result – Local chronic risk

Most interesting actives:

Metam-sodium, oxamyl, dimethoate, endosulfan, β-cyfluthrin, due to high toxicity

Possibly propineb, combination of high rate and high toxicity

Ranking: surface water

Result – Combined acute/chronic/local chronic risk

Active	Crops	Volume (2010, tons)	ADI (mg/kg)	Criterion
Dimethoate	Barley, french beans	63	0.001	Acute, chronic, local
Endosulfan	Cotton	84	0.006	Acute, chronic, local
Deltamethrin	Cotton, flowers, maize, sweet potato, cabbage	30	0.01	Acute (chronic)
2,4-D	Wheat cereals, maize, teff	1824	0.05	Acute, chronic
Metam-Na	? soil desinfestant	0.9	0.001	Local
Oxamyl	? Nematicide	0.23	0.001	Local
b-Cyfluthrin	? similar to deltamethrin	0.02	0.003	Local
Propineb	Flowers	0.51	0.007	Local

Ranking: surface water

Overall result – Combined acute/chronic/local chronic risk

Insecticides, due to their high toxicity:
Dimethoate, Endosulfan, Deltamethrin, β-Cyfluthrin

Herbicide, due to its high volume: 2,4-D (amine)

Fungicide, due to high application rate and high toxicity: Propineb

Crops: Barley, cotton, wheat, maize, teff, flowers, sweet potato, french beans

Note that some high toxicity actives are not considered, because of their use against migratory pests

Ranking: surface water

Preliminary results

- Suggestion for choice of **Crops**: barley, cotton
- **Possible additional crops** according to Content report WP B2.1/CR1: horticulture, floriculture (high acreage, high use rate)
- **Cropping systems** should be choosen on the basis of selected crops
- Devise **scenario**(s) on the basis of cropping systems and zones
- Scenario with selected cropping system suitable for estimation of risk for all actives in open air (including those a priori excluded from the analysis)
- Be aware that scenarios for regular crops are not suitable for greenhouses

Appendix 4.6 Detailed outcomes of leaching calculations for all active ingredients of Chapter 4.3

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
Active	pKa	according to JD	(is PPDB)	(l/kg)	(l/kg)	(days)	(days)	(ug/L)	Value	(mg/kg)	(ug/L)	value	too high?
1-BUTYLCARBAMOYL	4.48	B	0	1900	0	67	67.00	7.14E+01	3.57E+05	0.1	7.14E+01	0.071378	
2,4-D	2.87	A	0	88.4	51.3	10	10.00	1.65E-08	2.67E-05	0.05	1.65E-08	3.31E-11	
2,4-D AMINE	2.87	A	0	88.4	51.3	10	10.00	1.65E-08	6.03E-01	0.05	1.65E-08	3.31E-11	
ABAMECTIN	Not applicable	N	0	6631	3846	30	30.00	1.56E-206	8.93E-201	0.0025	1.56E-206	6.3E-208	
ACEPHATE	8.35	B	0	302	0	3	3.00	6.79E-04	3.40E+00	0.03	6.79E-04	2.26E-06	
ACEQUINOCYL	Not applicable	N	0	58000	33643	3	3.00	0.00E+00	0.00E+00	0.023	0.00E+00	0	
ACETAMIPRID	0.7	B	Very weak base	200	116	3	3.00	1.93E-66	4.46E-63	0.07	1.93E-66	2.76E-69	
ACRINATHRIN	Does not dissociate	N	0	48231	27976	39.2	39.20	0.00E+00	0.00E+00	0.01	0.00E+00	0	
AGROBACTARIUM										-	0.00E+00		
ALCOHOL ALKOXYLATE										-	0.00E+00		
ALFA CYPERMETHRIN	Not applicable	N	#N/A	57889	33578	35	35.00	0.00E+00	0.00E+00	0.015	0.00E+00	0	
ALUMINIUM PHOSPHIDE	Not applicable	N	#N/A			0.2	0.20	-9.00E+00	-5.22E+07	0.019	-9.00E+00	-0.04737	
AMETRYNE	4.1	B	#N/A	316	0	37	37.00	4.60E+01	1.69E+07	0.015	4.60E+01	0.306632	yes
AMITRAZ	4.2	B	Weak base	1000	0	0.2	0.20	1.71E-77	2.52E-72	0.01	1.71E-77	1.71E-79	
AMMONIUM CHLORIDE										-	0.00E+00		
ANIONIC										-	0.00E+00		
ANIONIC ABD CATIONIX										-	0.00E+00		
ASCORBIC ACID					0					-	0.00E+00		
ATRAZINE	1.7	B	Very weak base	100	58	75	75.00	4.24E+00	8.41E+06	0.02	4.24E+00	0.02122	
AZOXYSTROBIN	Not applicable	N	No dissociation	589	342	78	78.00	6.34E-06	1.32E-02	0.2	6.34E-06	3.17E-09	
BEAUVERIA BASSIANA										-	0.00E+00		

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
BENOMYL	4.48	B	0	1900	0	67	67.00	7.14E+01	3.93E+05	0.1	7.14E+01	0.071378	
BENSULFURON METHYL	5.2	A?	#N/A	409	237	24	24.00	2.78E-15	1.22E-11	0.2	2.78E-15	1.39E-18	
BETA CYFLUTHRIN	Not applicable	N	#N/A	64300	37297	13	13.00	0.00E+00	0.00E+00	0.003	0.00E+00	0	
BIFENAZATE	12.94	B	0	1778		1	1.00	-9.00E+00	-3.31E+05	0.01	-9.00E+00	-0.09	
BIFENTHRIN	Not applicable	N	No dissociation	236610	137245	26	26.00	0.00E+00	0.00E+00	0.015	0.00E+00	0	
BITERTANOL	Not applicable	N	No dissociation	2461	1428	23	23.00	1.04E-99	1.39E-94	0.01	1.04E-99	1E-101	
BOSCALID	Not applicable	N	No dissociation	772	448	200	200.00	2.45E-02	3.90E+02	0.04	2.45E-02	6.12E-05	
BRODIFACOUM	Not applicable	N	Very weak acid	50000	29002	84	84.00	0.00E+00		Not alloc.	0.00E+00		
BUPIRIMATE	0	N	0	1882	1092	79	79.00	3.46E-21	2.39E-16	0.05	3.46E-21	6.92E-24	
BUPROFEZIN	Not applicable	N	Not determinable	5363	3111	50	50.00	1.39E-99	3.58E-95	0.01	1.39E-99	1.4E-101	
CADUSAFOS	Not applicable	N	No dissociation	225	131	38	38.00	1.31E-04	4.14E+01	0.0004	1.31E-04	3.29E-05	
CAPTAN	Not applicable	N	No dissociation	200	116	0.8	0.80	6.77E-253	2.98E-249	0.1	6.77E-253	6.8E-256	
CARBARYL	10.4	A?	0	300	174	16	16.00	3.25E-17	8.64E-11	0.0075	3.25E-17	4.34E-19	
CARBENDAZIM	4.2	B	Weak base	225	0	40	40.00	4.95E+01	2.14E+06	0.02	4.95E+01	0.247541	yes
CELLULOSE ACETATE										-	0.00E+00		
CHLORFENAPYR	0	N	0	12000	6961	1.4	1.40	0.00E+00	0.00E+00	0.015	0.00E+00	0	
CHLOROTHALONIL	Not applicable	N	No dissociation	850	493	22	22.00	1.33E-35	2.03E-30	0.015	1.33E-35	8.88E-38	
CHLORPYRIFOS	Not applicable	N	Not determinable	8151	4728	50	50.00	6.79E-152	2.31E-146	0.01	6.79E-152	6.8E-154	
CHLORPYRIFOS ETHYL	Not applicable	N	#N/A	8151	4728	50	50.00	6.79E-152	3.13E-146	0.01	6.79E-152	6.8E-154	
CITIRIC ACID										-	0.00E+00		
CLODINAFOP PROPARGYL	Not applicable	N?	#N/A	1466	850	0.8	0.80	0.00E+00	0.00E+00	0.003	0.00E+00	0	
CLOFENTEZINE	0	N	0	No leaching in lab studies	1.00E+06	131.1	131.10	0.00E+00	0.00E+00	0.02	0.00E+00	0	
COPPER HYDROXIDE										0.15	0.00E+00	0	
COPPER OXYCHLORIDE										0.15	0.00E+00	0	
COPPER SULPHATE										0.15	0.00E+00	0	
CYANAMIDE	Not applicable	N	No dissociation	4.4	2.55	1	1.00	1.55E-18	7.74E-14	0.002	1.55E-18	7.74E-20	
CYFLUMETOFEN	0	N	#N/A	173900	100870	9	9.00	0.00E+00	0.00E+00	0.17	0.00E+00	0	
CYMOXANIL	9.7	A	0	43.6	25.3	0.7	0.70	1.33E-79	6.37E-74	0.013	1.33E-79	1.02E-81	
CYPROCONAZOLE	Not applicable	N	No dissociation	364	211	142	142.00	3.74E-01	9.54E+01	0.02	3.74E-01	0.00187	

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
CYPRODINIL	4.44	B	Weak base	2277	0	37	37.00	4.60E+01	1.72E+05	0.03	4.60E+01	0.153316	yes
CYROMAZINE	5.22	B	Weak base	409	0	93	93.00	8.31E+01	7.58E+05	0.06	8.31E+01	0.138428	yes
DAMINOZIDE	4.68	A?	0	18	10.4	0.6	0.60	4.55E-53	1.22E-50	0.45	4.55E-53	1.01E-56	
DDT	0	N	0	151000	87587	6200	6200.00	1.73E-21	0.00E+00	0.01	1.73E-21	1.73E-23	
DELTAMETHRIN	Not applicable	N	No dissociation	10240000	5939675	13	13.00	0.00E+00	0.00E+00	0.01	0.00E+00	0	
DIAFETHIURON	Not applicable	N	#N/A	43546	25259	0.5	0.50	0.00E+00	0.00E+00	0.003	0.00E+00	0	
DIAZINON	2.6	B?	0	609	353	9.1	9.10	3.72E-63	8.71E-55	0.0002	3.72E-63	1.86E-63	
DICHLORVOS	0	N	0	50	29	2	2.00	5.61E-30	6.58E-23	0.00008	5.61E-30	7.01E-30	
DICOFOL	0	N?	0	6064	3517	80	80.00	6.00E-70	5.68E-64	0.002	6.00E-70	3E-71	
DIDECYL DIMETHYL										-	0.00E+00		
DIETHOFENCARB	0	N	0	224	130	5.4	5.40	1.78E-40	2.07E-39	0.43	1.78E-40	4.15E-44	
DIFENOCONAZOLE	<0	?	0	3760	2181	130	130.00	6.80E-26	2.55E-22	0.01	6.80E-26	6.8E-28	
DIFLUBENZURON	0	N	0	4620	2680	3	3.00	0.00E+00	0.00E+00	0.01	0.00E+00	0	
DIMETHOAT	Not applicable	N	#N/A	28.3	16.4	2.6	2.60	6.48E-15	3.74E-07	0.001	6.48E-15	6.48E-16	
DIMETHOATE	Not applicable	N	No dissociation	28.3	16.4	2.6	2.60	6.48E-15	3.11E-08	0.001	6.48E-15	6.48E-16	
DIMETHOMORPH	-1.3	B?	Calculated	348	202	57	57.00	1.21E-04	2.57E-01	0.05	1.21E-04	2.43E-07	
DINOTEFURAN	12.6	N	#N/A	26	15.1	82	82.00	3.97E+01	3.61E+02	0.22	3.97E+01	0.018061	
DIPOTASSIUM PHOSPHATE										-	0.00E+00		
DODEMORF ACETATE	8.5	A?	#N/A	25200	14617	41	41.00	0.00E+00	0.00E+00	0.1	0.00E+00	0	
DPDI BUFFER										-	0.00E+00		
DPDI REAGENT										-	0.00E+00		
EMARMECTIN BENZOATE	7.7	A?	#N/A	377000	218677	300	300.00	0.00E+00	0.00E+00	0.0025	0.00E+00	0	
EMULSIFIED										-	0.00E+00		
ENDOSULFAN	0	N	0	11500	6671	50	50.00	9.83E-215	1.38E-207	0.006	9.83E-215	1.6E-216	
ETHEFOS	2.82	A	#N/A	2540	1473	16	16.00	0.00E+00	0.00E+00	0.03	0.00E+00	0	
FATTY ACIDE										-	0.00E+00		
FENAMIDONE	Not applicable	N	No dissociation	388	225	8.5	8.50	2.56E-43	5.69E-40	0.03	2.56E-43	8.54E-46	
FENAMINOSULF	0	N	#N/A	40	23.2	2	2.00	2.75E-25		Not alloc.	2.75E-25		
FENARIMOL	0	N	0	734	426	250	250.00	1.87E-01	1.55E+03	0.01	1.87E-01	0.001868	
FENHEXAMID	0	N	0	475	276	1	1.00	0.00E+00	0.00E+00	0.5	0.00E+00	0	
FENITROTHION	Not applicable	N	No dissociation	2000	1160	2.7	2.70	0.00E+00	0.00E+00	0.005	0.00E+00	0	
FERRIC PHOSPHATE										0.8	0.00E+00	0	

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
FLONICAMID	11.6	A?	0	1.6	0.93	3.1	3.10	3.29E-04	1.65E-01	0.025	3.29E-04	1.32E-06	
FLUFENOXURON	10.1	A?	0	157643	91440	42	42.00	0.00E+00	0.00E+00	0.01	0.00E+00	0	
FLUMETASULAM	4.6	A?	#N/A	28	16.2	45	45.00	1.43E+01		Not alloc.	1.43E+01		
FLURASULAM	4.54	A	weak acid	28.5	16.5	8.5	8.50	1.22E-03	1.65E+01	0.01	1.22E-03	1.22E-05	
FLUSILAZOLE	2.5	B	Very weak base	1664	965	300	300.00	6.80E-04	6.80E+01	0.002	6.80E-04	3.4E-05	
FLUTRIAFOL	2.3	A	0	205	119	1358	1358.00	8.62E+01	6.47E+05	0.01	8.62E+01	0.862418	yes
FOLPET	Not applicable	N	No dissociation	304	176	4.7	4.70	1.13E-62	1.36E-58	0.1	1.13E-62	1.13E-65	
FOSETHYL ALUMINIUM	4.7	B	#N/A	2217	1286	0.1	0.10	0.00E+00	0.00E+00	3	0.00E+00	0	
GIBBERELLIC ACID										-	0.00E+00		
GLASGRUENTRY										-	0.00E+00		
GLYCOLETHERS										-	0.00E+00		
GLYPHOSATE	2.34	A	0	1435	832	12	12.00	3.84E-112	2.50E-106	0.3	3.84E-112	1.3E-115	
HEXYTHIAZOX	Not applicable	N	No dissociation	9455	5484	30	30.00	7.60E-295	4.48E-291	0.03	7.60E-295	2.5E-297	
IMIDACLOPRID	Not applicable	N	No dissociation	225	131	191	191.00	7.97E+00	4.15E+04	0.06	7.97E+00	0.013275	
INDOLE BUTYRIC ACID										-	0.00E+00		
IPRODIONE	Not applicable	N	No dissociation	700	406	84	84.00	1.21E-06	1.82E-02	0.06	1.21E-06	2.02E-09	
KRESOXIM METHYL	Not applicable	N	#N/A	308	179	16	16.00	1.10E-17	5.57E-14	0.4	1.10E-17	2.76E-21	
LAMBDA CYHALOTHRIN	Not applicable	N	#N/A	157450	91328	25	25.00	0.00E+00	0.00E+00	0.005	0.00E+00	0	
LUFENURON	10.2	A?	0	41182	23887	16.3	16.30	0.00E+00	0.00E+00	0.0155	0.00E+00	0	
MALATHION	Not applicable	N	No dissociation	1800	1044	0.17	0.17	0.00E+00	0.00E+00	0.03	0.00E+00	0	
MANCOZEB	10.3	B?	0	998		0.1	0.10	-9.00E+00	-2.66E+07	0.05	-9.00E+00	-0.018	
MANDIPROPAMID	0	A?	0	847	491	17	17.00	2.62E-46	5.45E-44	0.03	2.62E-46	8.72E-49	
MCPA	3.73	A	0	74	43	24	24.00	3.46E-02	3.46E+01	0.05	3.46E-02	6.92E-05	
METALAXYL	0	N	0	162.3	94	42	42.00	1.22E-02	2.14E+03	0.08	1.22E-02	1.53E-05	
METALLIC COPPER										0.15	0.00E+00	0	
METAMITRON	Not applicable	N	No dissociation	77.7	45.1	30	30.00	4.70E+00	3.84E+03	0.03	4.70E+00	0.015661	
METHAM SODIUM	0	N	#N/A	17.8	10.3	7	7.00	9.14E-02	8.22E+04	0.001	9.14E-02	0.009138	
METHIOCARB	Not applicable	N	No dissociation	660	383	1.4	1.40	3.89E-172	4.40E-168	0.013	3.89E-172	3E-174	
METHOMYL	Not applicable	N	No dissociation	72	42	7	7.00	1.98E-04	1.51E+01	0.0025	1.98E-04	7.91E-06	
METHOXYFENOCIDE	Not applicable	N	#N/A	402	233	146	146.00	1.08E+01	5.44E+03	0.1	1.08E+01	0.010799	
METRAFENONE	Not applicable	Unknown	No dissociation	7061	4096	250.6	250.60	2.14E-08	2.16E-05	0.25	2.14E-08	8.54E-12	

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
MILBEMECTIN	Not applicable	N	No dissociation	2975	1726	43	43.00	8.19E-23	1.70E-20	0.03	8.19E-23	2.73E-25	
MONOPOTASSIUM PHOSPHATE										-	0.00E+00		
MYCLOBUTANIL	2.3	B?	0	517	300	560	560.00	5.53E+01	3.32E+04	0.025	5.53E+01	0.221384	yes
NEEM OIL										-	0.00E+00		
NONIONICS										-	0.00E+00		
OMETHOATE	0	N	0	41.3	24	14	14.00	8.86E-01	4.37E+05	0.0003	8.86E-01	0.295213	yes
ORGANIC SALT										-	0.00E+00		
ORGANOSILICONE										-	0.00E+00		
OXAMYL	-2.11	A?	Estimated	16.6	9.6	7	7.00	1.05E-01	2.43E+04	0.001	1.05E-01	0.010468	
OXYCARBOXIM	0	N	#N/A	65	37.7	18	18.00	9.33E-01	1.77E+03	0.15	9.33E-01	0.000622	
OXYMATRINE		Unknown	#N/A					-9.00E+00		-	-9.00E+00		
PARAQUAT DICHLORIDE	Not applicable	?	#N/A	100000	58005	365	365.00	0.00E+00	0.00E+00	0.004	0.00E+00	0	
PENCONAZOLE	1.51	B	Very weak base	2205	1279	117	117.00	2.94E-05	1.96E-02	0.03	2.94E-05	9.81E-08	
PENDIMETHALIN	2.8	A	0	17581	10198	90	90.00	4.89E-66	6.10E-61	0.125	4.89E-66	3.91E-69	
PHENOL ETHYLENE										-	0.00E+00		
PIRIMICARB	4.4	B	Weak base	388	0	86	86.00	8.05E+01	1.38E+04	0.035	8.05E+01	0.229881	yes
PIRIMIPHOS METHYL	4.3	B	#N/A	1100	0	39	39.00	4.84E+01	2.66E+07	0.004	4.84E+01	1.209228	yes
POLYOXIN	3	?								-	0.00E+00		
PROCHLORAZ	3.8	B	Weak base	500	0	120	120.00	9.07E+01	4.08E+04	0.01	9.07E+01	0.906839	yes
PROFENOFOS	Not applicable	N	No dissociation	2016	1169	7	7.00	5.32E-100	2.95E-95	0.03	5.32E-100	1.8E-102	
PROPAMOCARB	9.6	B	#N/A	706	0	39.3	39.30	4.87E+01	5.84E+05	0.29	4.87E+01	0.016798	
PROPICONAZOLE	1.09	B	Very weak base	1221	708	214	214.00	1.13E+00	1.80E+05	0.04	1.13E+00	0.002817	
PROPINEB	Not applicable	N	Not determinable	Not mobile	1.00E+06	3	3.00	0.00E+00	0.00E+00	0.007	0.00E+00	0	
PROPYZAMIDE	Not applicable		No dissociation	850	493	47	47.00	3.39E-05	1.63E-01	0.02	3.39E-05	1.69E-07	
PYRETHRUM	0	N	#N/A	100000	58005	8	8.00	0.00E+00	0.00E+00	0.04	0.00E+00	0	
PYRIMETHANIL	3.52	B	Weak base	301	0	55	55.00	6.34E+01	2.39E+05	0.17	6.34E+01	0.037304	
PYRIPROXYFEN	6.87	B	0	21175	0	10	10.00	3.25E+00	7.15E+02	0.1	3.25E+00	0.00325	
PYROXSULAM	4.67	A?	#N/A	30	17.4	3.3	3.30	1.52E-06	2.28E-03	0.9	1.52E-06	1.69E-10	
SILICONE										-	0.00E+00		
SILVER THIOSULFATE										Not alloc.	0.00E+00		
S-METOLACHLOR	Not applicable	N	No dissociation	226.1	131	15	15.00	7.08E-05	1.43E+01	0.1	7.08E-05	7.08E-08	
SODIUM CHLORITE										Not alloc.	0.00E+00		

Active	PPDB-JD	Base/Acid/ None	Base/Acid from fate.xlsx	Koc	Kom corr	DT50 soil	DT50 soil corrected	Cleach corrected	Cleach * Volume / ADI	ADI	Cleach	Cleach/ADI_50kg	
SPINETORAM	7.7	B?	#N/A	22836	0	16.1	16.10	1.29E+01	7.35E+02	0.021	1.29E+01	0.061258	
SPINOSAD	8.1	B?	7.87 Spinosyn D	20328	0	176	176.00	9.98E+01	9.00E+05	0.024	9.98E+01	0.416041	yes
SPIROMESIFEN	Not applicable	N	Does not dissociate	30900	17923	23	23.00	0.00E+00	0.00E+00	0.03	0.00E+00	0	
SPIROXAMINE	6.9	B	Base	14567	0	25	25.00	2.87E+01	8.83E+06	0.025	2.87E+01	0.11486	yes
SULFUR								0.00E+00		-	0.00E+00		
TEBUCONAZOLE	0	N	Very weak base	1152	668	62	62.00	2.76E-05	2.30E-02	0.03	2.76E-05	9.19E-08	
TEFLUBENZURON	0	N	0	26062	15117	92	92.00	2.70E-96	1.09E-92	0.01	2.70E-96	2.7E-98	
TETRACONAZOLE	0.65	B?	0.8-0.5 A5	1152	668	61	61.00	2.14E-05	3.06E+00	0.004	2.14E-05	5.36E-07	
THAMANA										-	0.00E+00		
THIABENDAZOLE	4.73	B?	pKa(2) 12.00	7344	0	500	500.00	1.14E+02	1.54E+04	0.1	1.14E+02	0.114134	yes
THIACLOPRID	Not applicable	N	No dissociation	615	357	15.5	15.50	2.61E-13	1.98E-09	0.01	2.61E-13	2.61E-15	
THIAMETHOXAM	Not applicable	N	No dissociation	56.2	32.6	50	50.00	2.44E+01	1.97E+04	0.026	2.44E+01	0.093704	
THIOBENDAZOLE	4.73	B?	#N/A	7344	0	500	500.00	1.14E+02	5.31E+05	0.1	1.14E+02	0.114134	yes
THIOCYCLAM	3.95	B?	Q3	20	0	1	1.00	2.08E-14	2.39E-10	0.008	2.08E-14	2.6E-16	
THIOPHANATE METHYL	7.28	B?	#N/A	1.2	0	0.6	0.60	6.36E-25	1.75E-21	0.08	6.36E-25	7.95E-28	
THIRAM	0	N	0	9629	5585	15.2	15.20	1.12E-217	5.83E-211	0.01	1.12E-217	1.1E-219	
TOLCLOFOS METHYL	Not applicable	N	#N/A	3620	2100	3.7	3.70	0.00E+00	0.00E+00	0.064	0.00E+00	0	
TRIADIMEFON	0	N	0	300	174	26	26.00	3.25E-03	4.74E+02	0.03	3.25E-03	1.08E-05	
TRIADIMENOL	0	N	0	750	435	250	250.00	9.85E+00	1.48E+06	0.05	9.85E+00	0.019702	
TRIBENURON	4.7	B?	#N/A	31	0	14	14.00	9.17E+00	6.87E+05	0.01	9.17E+00	0.091716	
TRICHODERMA VIRIDE										-	0.00E+00		
TRIFLOXYSTROBIN	Not applicable	N	No dissociation	2377	1379	7	7.00	9.52E-118	1.97E-114	0.1	9.52E-118	9.5E-121	
TRIFORINE	10.6	B	Strong base	527	0	19	19.00	1.82E+01	3.45E+04	0.02	1.82E+01	0.090754	

Appendix 4.7 Summary of ranking pesticide risks for groundwater

(Powerpoint presentation presented at the Workshop held in Wageningen 5-9 November 2012)

Ranking: leaching into ground water

Protection goal: ground water used as drinking water

Goal: - rank active ingredients
- assess suitability of method, identify pitfalls
- integrate leaching into risk assessment scenarios?

John Deneer, Paulien Adriaanse
Alterra, Wageningen UR, October 2012

Ranking: leaching into ground water

Material to work with:

- List of actives, previously derived for ranking risk in surface water
- Meta-model for leaching (Tiktak et al., 2006)
- Physico-chemical properties (K_{om}, pKa, DT_{50} soil) from Pesticides Properties Database (Footprint)

Ranking: leaching potential

Outline of procedure:

- Estimate leaching potential for actives on the basis of standard net soil deposition (1 kg/ha), using the EuroPEARL meta-model
- Rank by:
  - Leaching concentration for 1 kg/ha net soil deposition
  - Compare daily intake to ADI, are toxic effects likely?
- Investigate effect of choice of parameter values for annual rainfall, soil moisture and average soil temperature
- Identify shortcomings and pitfalls

Ranking: leaching potential

The EuroPEARL meta-model

$Ln\ (C_L) = \alpha_0 + \alpha_1 * X_1 + \alpha_2 * X_2$ *(Tiktak et al., 2006)*

C_L : the concentration (µg/L) in leaching water at 1 m depth, given a net soil deposition of 1 kg/ha

α_0 , α_1 , α_2 depend on
- temperature and annual rainfall
- not compound specific, but specific to a region

X1, X2 depend on
- soil properties (organic matter and water content)
- compound properties (K_{om}, DT50 degradation)

Ranking: leaching potential

The EuroPEARL meta-model

Extensive calibration of the model for European soils and a wide range of compounds *(Tiktak et al., 2006)*

A method has been devised to deal with compounds (acids) that undergo dissociation at lower soil pH ($2 \leq pH \leq 8$), necessary because some European soils tend to be charged *negative* at lower pH

Problem: this method is not going to work for tropic soils, which tend to be charged *positive* at lower pH

Ranking: leaching potential

Positive charge of tropic soils at lower pH will result in increased leaching of bases, *i.e. leaching of bases will be underestimated*

There is currently no suitable method to correct for this in an acceptable way

Way out:

- for bases always demand sorption studies with Ethiopian/tropical soils
- or conservative approach: calculate risk assuming no sorption at all, and demand sorption studies for cases where risk is not acceptable (on the basis of C_L / ADI ratio)
- This implies that there should be a reliable way to actually identify bases, i.e. 'which compounds are considered as bases'

Ranking: leaching potential

Is it worth the trouble to treat bases separately, and ask for sorption studies?

Compounds in list of actives:	165
Actual pesticides	144
Of which are bases:	34
Substantial part charged at 4 < pH <7:	24

Assumptions:
- Bases do not sorb at all
- A person of 50 kg drinks 5 liters of water per day
- C_L unacceptably high if Daily_Intake / ADI > 1

Ranking: leaching potential

Result: of the 24 partly charged bases, 10 are estimated to exceed 0.1 ADI when no sorption at all is assumed; pirimifos-methyl exceeds ADI

Pirimifos-m.	1.21	Prochloraz	0.91
Spinosad	0.42	Ametryn	0.30
Carbendazim	0.25	Pirimicarb	0.23
Cyprodinil	0.15	Cyromazine	0.14
Spiroxamine	0.11	Thiabendaz.	0.11

Conclusion: various basic compounds need a better estimate of K_{om} to avoid overestimation of leaching potential.

Ranking: leaching potential

Assumptions during calculation of leaching concentration for neutral compounds

Values within acceptable range for EuroPEARL meta-model:

- Annual rainfall: 1500 mm
- Average soil temperature: 20°C
- Organic matter content: 4.5%
- Soil moisture content: 25%

K_{om}, DT50's taken from Pesticides Properties Database

Calculations were done for non-bases only

Ranking: leaching potential

3 Compounds with Daily Intake > 0.1 ADI

Active	Daily Intake / ADI	K_{om} (L/kg)	DT50 (days)	C_{leach} (µg/L)
Flutriafol	0.86	119	1358	86
Omethoate	0.30	24	14	0.89
Myclobutanil	0.22	300	560	55
Thiamethoxam	0.09	33	50	24
Atrazine	0.02	58	75	4.2
Triadimenol	0.02	435	250	10

Ranking: leaching potential

16 Compounds with C_{Leach} > 0.1 µg/L

Active	C_{leach} (µg/L)	K_{om} (L/kg)	DT50 (days)	Daily Intake / ADI
Flutriafol	86	119	1358	0.86
Myclobutanil	55	300	560	0.22
Dinotefuran	40	15	82	0.02
Thiamethoxam	24	33	50	0.09
Flumetasulam	14	16	45	-
Methoxyfenocide	11	233	146	0.01
Triadimenol	9.8	435	250	0.02
Imidacloprid	8.0	130	191	0.01
Metamitron	4.7	45	30	0.02
Atrazine	4.2	58	75	0.02

Ranking: leaching potential

Results for neutral compounds

3 Compounds with Daily Intake > 0.1 ADI:
Flutriafol (0.86), Omethoate (0.30) and Myclobutanil (0.22)

→ Various compounds show severe leaching potential, some even have concentrations in ground water potentially rendering it hazardous as drinking water

16 Compounds with C_{leach} > 0.1 µg/L, 3 of which had a volume > 1 ton:
Atrazine (40 tons), Triadimenol (7.5 tons) and Propiconazole (6 tons)

→ Concentrations in ground water to be used for drinking water may be significant, and should be considered in regulatory scenarios

Ranking: leaching potential

Effect of the parameter values choosen for annual rainfall and temperature – results not shown in detail

Choosing **800 mm/year and 10°C** instead of 1500 mm/year and 20°C → the same list of compounds with highest leaching potential, although leaching concentrations are somewhat (3-fold) lower

Lowering **soil organic matter** content to 2.5% → same list of compounds, leaching concentrations somewhat (2.5-fold) higher

Changing **soil moisture content** to 0.40 instead of 0.25 L/kg results in the same top-10 for leaching, compounds 11-20 are the same but have slightly changed order

Conclusion: annual rainfall, temperature, soil moisture and soil organic matter have an effect, but are not critical for calculation of the leaching potential

Ranking: leaching potential - Conclusions

Sorption for basic compounds cannot be calculated using the standard procedure → sorption studies are needed, possibly after a first step in the risk assessment (compare C_{Leach} to ADI)

Various compounds on the market show severe leaching potential, potentially rendering ground water hazardous as drinking water → leaching should be considered in scenario calculations

Choice of annual rainfall, soil moisture content, organic matter content and temperature will influence outcome of estimations for neutral compounds, but is not critical

Linking to scenarios is not feasible until scenarios are developed in detail; the EuroPEARL meta-model is not intended for calculation in greenhouses

N.B. 1. If groundwater is used as drinking water for cattle, can ADI be used to perform a risk assessment for cattle ? (Marloes/Carolien)
2. Is ADI sufficiently protective for lighter people (Ethiopians, esp women)

Appendix 5.1 Pictures illustrating the drinking water produced from surface water protection goals: stream/small rivers and temporary, stagnant ponds

(Pictures taken by Ato Gizachew Assefa)

Figure 5.1 *Meki river with irrigation pipes diverting water to cropped fields.*

Figure 5.2 *Maize crop near Mojo River.*

Figure 5.3 *Tomato intercropped with maize adjacent to the Ketar River.*

Figure 5.4 *Maize crop at Demsisa River (Rophi site).*

Figure 5.6 *Children drinking from Ketar River.*

Figure 5.7 *Women collecting water and cattle drinking at Demsisa River (Gotu site).*

Appendix 6.1 Validity of extrapolating the EuroPEARL metamodel to Ethiopia

In this Appendix we explore the consequences of extrapolating the EuroPEARL metamodel to Ethiopia. We therefore investigated whether the values of the most important drivers for leaching to groundwater in EuroPEARL and Ethiopian datasets agreed. These drivers are the organic matter content and the size of downward water flow (determining pesticide concentrations in water percolating to the groundwater.

First the organic matter maps for EuroPEARL (see Figure 6.1.1 in Chapter 6) and Ethiopia (see Figure A4.1.3 in Appendix 4.1 Background information on soil data used) were compared. The organic matter map for EuroPEARL shows a large range of organic matter content from < 1% to > 3% with extremely low organic matter contents in the Mediterranean countries (Tiktak *et al.,* 2006). In the Ethiopian organic matter map the range is from 0 – 3%. The range of organic matter in Ethiopia is within the range of organic matter in the EuroPEARL dataset. So considering this aspect the metamodel is also valid for the Ethiopian situation.

Secondly, several areas in Ethiopia have higher annual average precipitation amounts and higher annual average temperatures than the areas in the EU in climate zone iv) warm and wet (> 800 mm/yr and > 12.5 °C). Considering the annual average precipitation amounts the following reasoning was made.

From the metamodel it can be derived that the concentration, C_L, increases with increasing q. We also know from experiences with the EU leaching scenarios that the concentration, C_L, increases with increasing precipitation and thus increasing percolation (i.e. the volume flux of water directed towards the groundwater) that C_L, reaches a plateau when this percolation continues to increase. This is illustrated in Figure A6.1.1. So, the leaching concentration is a continuously increasing function of the percolation.

Next, we compared the range of the annual average percolation fluxes in the database of the EuroPEARL model to the range of annual average percolation fluxes in our Ethiopian dataset. The database in the EuroPEARL model included annual average percolation fluxes of about 60 – 1000 m/yr (see Figure 6 in Tiktak *et al.,* 2006). Figure A6.1.2 shows that our Ethiopian database contains annual average percolations that are in the same range (only about 4% is above 1000 mm/yr with a maximum up to 1250 mm/yr).

The project group therefore concluded that using the EuroPEARL metamodel for the Ethiopian situation is a defensible approach, because the regression parameters in the metamodel are based upon a fit with leaching concentration obtained by simulations with the EuroPEARL model using annual average percolation fluxes and organic matter contents that are in the same range as those in the Ethiopian dataset.

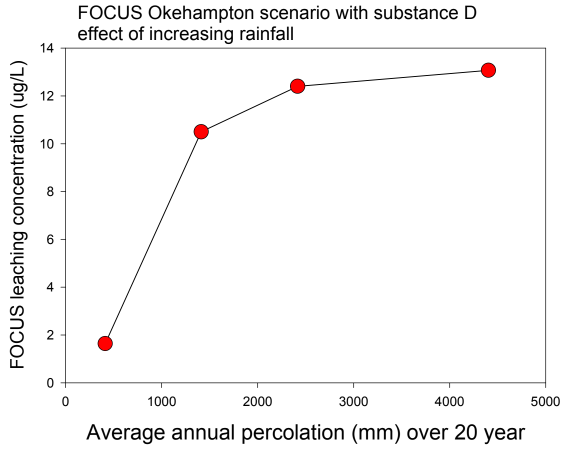


Figure A6.1.1 *The FOCUS leaching concentration of FOCUS GW substance D (DegT$_{50,soil}$ =20 d at 20°C and K$_{om}$ =35 L/kg at 20°C) as function of the average annual percolation over 20 year for the FOCUS groundwater scenario Okehampton.*

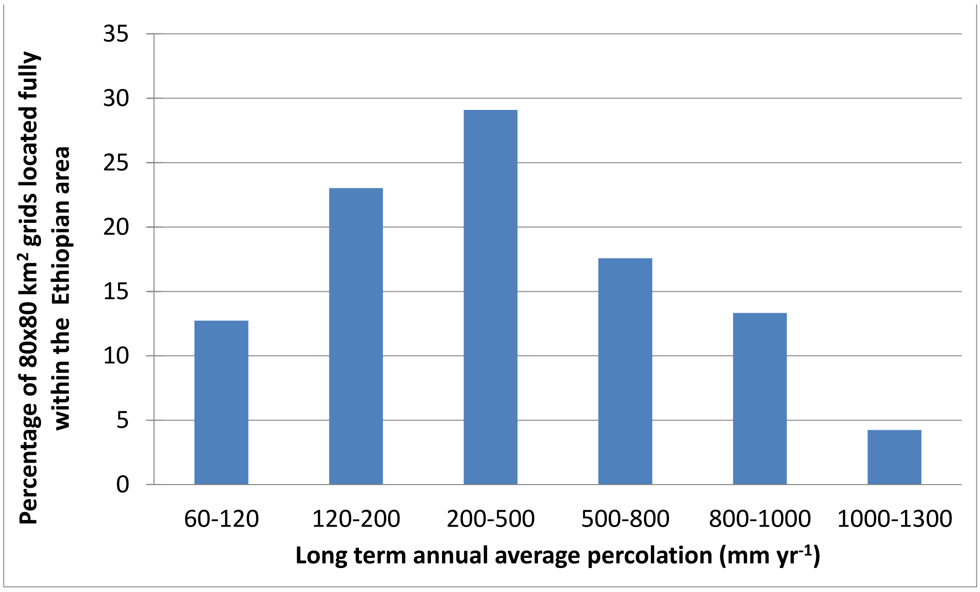


Figure A6.1.2 *Frequency distribution of long term annual average percolation of all 80x80 km^2 grid located fully within the Ethiopian area.*

References

Horst, M.M.S. ter, Adriaanse, P.I., Beltman, W.H.J., Berg, F. van den, Boesten, J.J.T.I., Deneer, J.W., Fait, G., Kroes, J.G., Li, W., Roller, J.A. te, Tao, C., Wipfler, E.L. 2011. Simulation of pesticide leaching to groundwater in paddy rice areas in Chin. In: Proceedings of the XIII Pesticide Chemistry Symposium, Piacenza, Italy, 30 August - 1 September 2011. - Piacenza, Italy: Universite Cattolica. Abstract and poster presentation can be found at http://convegni.unicatt.it/meetings_3667.html (last entered 1 October 2013).

Appendix 6.2 Spray drift deposition values (70^{th} percentile) for the Ethiopian pond scenarios (grid 217 and 373), calculated with the aid of the Step 3 FOCUS Drift Calculator

Paulien Adriaanse, vs 7, 1 Oct 2013

Global maximum exposure concentrations in the pond may be caused by spray drift deposition, runoff entries or a combination of both. As the hydraulic residence times in the pond are expected to be in the order of weeks to a few months, we expect that often concentrations caused by runoff are added on top of concentrations caused by spray drift entries. So, the probability of occurrence of the global maximum concentrations is not caused by two independent entry routes and thus we have to consider the probability of occurrence of the spray drift deposition in relation to the probability of occurrence for runoff. The scenario locations have been selected considering the 99^{th}%-ile overall probability of occurrence in time and place of the runoff entry route only (Chapter 3). In order to avoid stacking two extreme situations: 99^{th}%le runoff with the customary 90^{th}%ile FOCUS spray drift we here opt for Ethiopia not for the 90^{th}%ile but a lower 70^{th}%-ile probability of occurrence for the spray drift deposition entry route. Furthermore we simplify the spray drift deposition input into the TOXSWA model by using a single deposition value for each crop, i.e. not being a function of the number of applications as is done in the FOCUS surface water scenarios at EU level. This is defensible as for most crops the peak concentration caused by spray drift entries is a factor 10 lower than the peak concentration caused by runoff entries. The following example illustrates this.

Example calculations of peak concentrations in the R4 pond by spray drift entries and runoff entries.
The R4 pond measures 30 x 30 m and has a water depth of 1 m. A cropped and treated surface area of 4500 m^2 delivers it runoff water fluxes and pesticide fluxes into the pond. Spray drift deposition occurs over the entire length of 30 m by wind perpendicular to the pond length. Spray drift deposition (averaged over the 30 m width of the pond, seen as a completely mixed reservoir by the TOXSWA model) is for most crops approximately 0.2%. For a 1 kg/ha application this equals: 0.002* 100 mg/m2 in 1 m water depth corresponds to a peak concentration of 0.2 µg/L. Runoff water fluxes vary from nearly 0 to up to several (tens of) millimetres with lower runoff water fluxes having higher concentrations than higher runoff water fluxes, once a threshold of less than 1 mm has been trespassed (Adriaanse, pers. comm., 2014, Figure B). The lower the Koc of the compound, the higher the runoff concentration. Assuming a concentration of 250 µg/L for 5 mm runoff we calculate a load of 300 µg/L*5 mm* 4500m^2 = 6750 mg into the pond volume of 900 m3+22.5 m3 runoff water corresponding to a peak concentration of 7.3 µg/L.

Table 6.2.1 lists some results based on figures of Fig.6.2.1 (maize with RCN values of 91[2]).

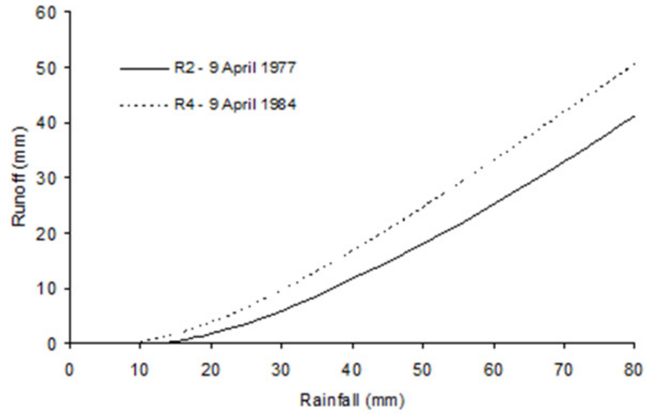
[2] N.B. Runoff concentrations heavily depend on RCN values. For the lower values used in FOCUS (e.g. 82, 87) during crop growth stages emergence, maturation and harvest runoff concentration may be more than 10 times lower. So, the conclusion on using the 70^{th} instead of 90^{th} percentile is then valid for all compounds.

Table 6.2.1

Estimation of concentration peaks in R4 pond for Koc values of 100 and 1000 L/kg and various runoff events.

K_{oc} L/kg	Size runoff mm	Concentration µg/L	Load into pond mg	Pond volume m3	Peak conc µg/L
100	1	450	2015	900+4.5	2.2
	5	300	6750	900+22.5	7.3
	20	240	21600	900+90	21.8
	50	200	45000	900+225	40
1000	1	100	450	900+4.5	0.50
	5	100	2250	900+22.5	2.4
	50	80	18000	900+225	16

Figure 6.2.1 combined with the results of Table 6.2.1 demonstrate that for compounds with Koc values of 100 L/kg or smaller the peak concentration caused by spray drift entries is a factor 10 lower than the peak concentration caused by runoff entries. The same holds for compounds with Koc values between 100 and 1000 L/kg with runoff events of 5 mm or higher. For smaller events, or compounds with Koc values above 1000 L/kg peaks concentration caused by runoff may be of the same order of magnitude of peaks caused by spray drift (although these will rapidly lower due to sorption to suspended solids and the sediment) and so, by using a 70th percentile probability spray drift entries may be underestimated in case the number of applns is smaller than 5. The underestimation of using the 70th percentile instead of the 90th percentile (1 appln) is for all crop groupings less than a factor 2. In view of the safety factors of 10 or 100 used in deriving human toxicological or ecotoxicological standards the procedure described above is defensible.



Runoff in FOCUS R4 scenario

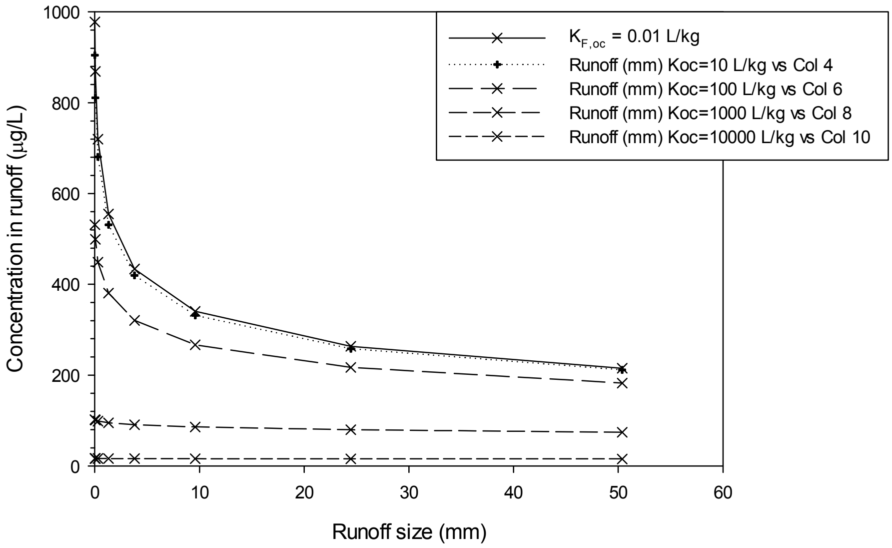


Figure 6.2.1 *Runoff water (mm per day) as a function of daily rainfall (mm, upper graph) and runoff concentrations (µg/L) as a function of runoff size (mm) and K_{oc} value (L/kg, lower graph) for maize with a RCN of 91 in the FOCUS runoff R2 and R4 scenarios*

Table 6.2.2 lists all crops that feature in the surface water scenarios. If the Ethiopian crops do not feature in the FOCUS Drift Table for the Step 3 surface water scenarios they are replaced by crops that are judged to behave as similar as possible with respect to spray drift deposition (i.e. considering crop height development, crop management like distance between rows, distance crop-water). For knapsack sprayers FOCUS values could be used. Appendix B as well as Table 2.4.1-1 of FOCUS (2001) show that Application, hand for crops < 50 cm have equal deposition numbers as the crop grouping Arable crops and vegetables <50 cm (e.g. vegetables, leafy) and that Application, hand for crops > 50 cm have equal deposition numbers as the crop grouping vines, late and vegetables > 50 cm. So, by using the FOCUS Drift calculator for these crop groupings (e.g. vegetables, leafy and vines, late) in the FOCUS Drift Calculator of SWASH for the FOCUS pond lay out and 6 applications we were able to find spray drift deposition figures that represent Application by knapsack sprayers in Ethiopia as well as possible with the Step 3 FOCUS drift deposition data.

Table 6.2.2

Spray drift deposition in % of application rate for the Ethiopian pond scenarios calculated with the aid of the EU-FOCUS Drift Calculator. In case the Ethiopian crop does not feature between the FOCUS crops the Ethiopian crop has been replaced by a FOCUS crop with characteristics as similar as possible to the Ethiopian crop. The 70th%ile deposition corresponds to 6 applications in the FOCUS Drift Calculator. FOCUS drift deposition values are assumed to correspond to Large Scale Farming practices in Ethiopia. Knapsack sprayers are listed separately as applications, hand. For reasons of comparison the 90th percentile values, used at EU level are listed.

Crop	FOCUS-crop	70th ile deposition	90th ile deposition
		% of appln rate	% of appln rate
Tomato#	Vegetables, fruiting	0.1270	0.2191
Onion#	Vegetables, bulb	0.1270	0.2191
Cabbage#	Vegetables, leafy	0.1270	0.2191
Potato#	Potato	0.1229	0.2122
Teff	Cereals, spring	0.1270	0.2191
Wheat	Cereals, spring	0.1270	0.2191
Maize	Maize	0.1229	0.2122
Barley	Cereals, spring	0.1270	0.2191
Faba bean	Field beans	0.1229	0.2122
Sweet potato	Potato	0.1229	0.2122
Cotton	Cotton	0.1229	0.2122
Mango (pome/stone representative)	Pome,stone fruits, late applications	1.0459	1.6485
Sugarcane	Maize	0.1229	0.2122
Banana	Tobacco	0.1204	0.2079
Citrus (lemon)	Citrus	1.0459	1.6485
Coffee	Citrus	1.0459	1.6485
Appln, hand, crop<50 cm	Arable, veg<50 cm	0.1270	0.2191
Appln, hand, crop>50 cm	Vines, late	0.4722	0.6121

these 4 crops are cultivated twice: once in the rainy season Kremt and once with irrigation in Bega.

To be able to calculate the spray drift deposition when knapsack spraying is used Table XX is composed associating the crops with the deposition based upon the EU_FOCUS data (based upon crop stage averaged deposition).

Table 6.2.3

Association between Ethiopian crops and spray drift deposition for knapsack spraying.

Crop	FOCUS-crop	Deposition by knapsack spraying	No knapsack spraying possible
		% of appln rate	
Tomato#	Vegetables, fruiting	0.1270	
Onion#	Vegetables, bulb	0.1270	
Cabbage#	Vegetables, leafy	0.1270	
Potato#	Potato	0.1270	
Teff	Cereals, spring	0.1270	
Wheat	Cereals, spring	0.1270	
Maize	Maize	0.1270	
Barley	Cereals, spring	0.1270	
Faba bean	Field beans	0.1270	
Sweet potato	Potato	0.1270	
Cotton	Cotton	0.1270	
Mango (pome/stone representative)	Pome,stone fruits, late applications	-	No knapsack
Sugarcane	Maize	0.1270	
Banana	Tobacco	0.1270	
Citrus (lemon)	Citrus	-	No knapsack
Coffee	Citrus	-	No knapsack

these 4 crops are cultivated twice: once in the rainy season Kremt and once with irrigation in Bega

Appendix 6.3 Software program post-processing PRZM output (zts output file) (i) creating a 33-year p2t file plus (ii) running the FOCUS_stream metamodel of Appendix 6.4 and selecting the aimed overall 99th and 90th percentile

Goal of the software program:

i) Convert PRZM output in the *.zts file to output in the *.p2t file for a variable number of years
ii) Simulations with the metamodel (Appendix 6.4) for calculating incoming FOCUS stream concentrations
iii) Ranking of concentrations in the stream and selecting the aimed overall 90th and 99th percentiles

i) Convert PRZM output in the *.zts file to output in the *.p2t file for a variable number of years

The present FOCUS_PRZM version results in a *.p2t file with output data for 12 months. For Ethiopia output data of 33 years is needed.

The *.zts file starts at 1 Jan and ends at 31 Dec. The *.zts provides daily fluxes which need to be converted to hourly fluxes for the *. p2t file by distributing the daily values linearly over a number of hours. This number equals the rainfall event size divided by a constant rainfall intensity of 2 $mm.h^{-1}$, which was judged to be a representative European rainfall intensity (pers.comm. P.I. Adriaanse, WG FOCUS surface water scenarios). For Ethiopia we also consider 2 $mm.h^{-1}$ representative. So, if e.g. there was 18 mm rainfall causing 4.1 mm runoff the runoff event lasts 18 mm/2 $mm.h^{-1}$ = 9 h and so, from midnight to 9 am there is 4.1 mm/9 h = 0.46 $mm.h^{-1}$ runoff. Daily rainfalls of 48 mm or more will result in runoff events lasting 24 h. These hourly values are fed into the TOXSWA model.
N.B. This procedure implies that the hourly fluxes (both water as substance fluxes) have the same value during one day.

$$n_{Rh} = NInt(P/P_{rep.int}) \qquad \text{(eqn. A6.3.1)}$$

where n_{Rh} is the number hours of runoff within one day, P is the precipitation ($mm.d^{-1}$), $P_{rep.int}$ ($mm.h^{-1}$) is the representative rainfall intensity and NInt represents 'the nearest integer'. $P_{rep.int}$ is input in the post processing model and set to 2 $mm.h^{-1}$ for Ethiopia.

Taking the nearest integer is explained by the example below:

If $7.5 \leq P/P_{rep.int} < 8.5$ than: n_{Rh} =8. If $6.5 \leq P/P_{rep.int} < 7.5$ than n_{Rh} = 7.

Taking the nearest integer of $P/P_{rep.int}$ is not worst case. If for instance $P/P_{rep.int}$ = 7.5 and the total runoff water flux is 12 mm/d, taking the nearest integer means that the runoff is evenly spread over 8 hours (so 1. 5 mm/h; n_{Rh} = 8). It would be more precise to distribute 1.6 mm (12/7.5) over the first 7 hours and assigning a rest term of 0.8 mm to the 8th hour. However the present FOCUS PRZM version uses the method described in Eqn. A6.3.1 and we decided to follow this to avoid deviations from this model.

Furthermore the PRZM *.p2t file gives the monthly average of the infiltration flux ($q_{down,p2t}$ in $mm.h^{-1}$), while the *. zts file gives the actual infiltration flux on a daily basis (I_d; INFL in *.zts). The monthly average of the infiltration fluxes for the *.p2t file is calculated as follows:

$$q_{down,p2t} = \sum_{i=1}^{n_{dim}} I_d \Big/ 24 \qquad \text{(eqn. A6.3.2)}$$

Where n_{dim} is the number of days within one month

Table A6.3.1

*Relevant parameters in *.zts file.*

Parameter		Unit	Name in equations
RUNF	Runoff flux (water)	mm/d	-
ESLS	Erosion flux (sediment)	kg/d*	-
PRCP	Precipitation	mm/d	P
INFL	*Infiltration*	mm/d	I_d
RFLX1	Runoff flux (pesticide)	mg as/m2d	-
EFLX1	Erosion flux (pesticide)	mg as/m2d	-

Table A6.3.2

*Parameters in *.p2t file.*

Parameter	Unit	Description	Name in equations
Time	(YYYY-MM-DD-HH:mm)	Copy from *.zts + allocate hours	-
Runoff Volume	(mm/h)	RUNF / n_{Rh}	$q_{ro,p2t}$
Runoff flux	(mg as/m2/h)	RFLX1 / n_{Rh}	-
Erosion Mass	(kg/h)	ESLS / n_{Rh}	-
Erosion Flux	(mg as/m2/h)	EFLX1 / n_{Rh}	-
Infiltration	(mm/h)	Monthly average of INFL/24	$q_{down,p2t}$

Fluxes are imposed from mid night onwards. This means that if the number of hours that runoff occurs is 9, the fluxes are allocated to the first 9 hours of the day.

Exception 1: number of hours within a day is larger than 24

In case the number hours with runoff within one day (n_{Rh}, Eqn A6.3.1) is larger than 24, runoff and erosion fluxes (water, sediment, pesticide mass) are distributed over 24 hours.

Table A6.3.3

*Parameters in the *.p2t file in case the number of hours with runoff within one day is larger than 24.*

Parameter	Unit	
Time	(YYYYMMDDHHMM)	Copy from *.zts + allocate hours
Runoff Volume	(mm/h)	RUNF/24
Runoff flux	(mg as/m2 h)	RFLX1/24
Erosion Mass	(kg/h)	ESLS/24
Erosion Flux	(mg as/m2 h)	EFLX1/24
Infiltration	(mm/h)	Monthly average of INFL/24

Exception 2: Snowmelt

Snowmelt is assumed in case the runoff water flux exceeds the precipitation flux. Runoff and erosion fluxes (water, sediment, pesticide mass) are in such a case distributed over 12 hours. If RUNF>PRCP then snowmelt --> distribute all fluxes over 12 hours.

Table 6.3.4
*Parameters in the *.p2t file in case of snowmelt.*

Parameter	Unit	
Time	(YYYYMMDDHHMM)	Copy from *.zts + allocate hours
Runoff Volume	(mm/h)	RUNF/12
Runoff flux	(mg as/m2 h)	RFLX1/12
Erosion Mass	(kg/h)	ESLS/12
Erosion Flux	(mg as/m2 h)	EFLX1/12
Infiltration	(mm/h)	Monthly average of INFL/24

Exception 3: 0 < Precipitation < $P_{rep.int}$
In case precipitation is smaller than $P_{rep.int}$ (2 mm for FOCUS), Eqn. A6.3 1 calculates n_{Rh} = 0. This is unwanted, because P < $P_{rep.int}$ is an event.
So in case 0 < P < $P_{rep.int}$, n_{Rh} = 1

Exception 4: P > 0 and RUNF > 0 and RFLX1 < 0
In this case there is a precipitation event (P > 0), there is as runoff event (RUNF > 0) but there is no pesticide mass in the runoff event. In such a case, n_{Rh} ≥ 1 (depending on P) and the Runoff flux in mg as/m2/h (VmrRnf in TOXSWA code) should be set to 0.

ii) Simulations with the metamodel (Appendix 6.4) for calculating incoming FOCUS stream concentrations

iii) Ranking of concentrations in the stream and selecting the aimed overall 90th and 99th percentiles

Both ii) and iii) are described in Appendix 6.4.

The software program in FORTRAN consists of four modules:
- Module_PRZMpost
- PRZMpost
- sishell_2
- vislfor

The FORTRAN code of modules Module_PRZMpost and PRZMpost are given below. The FORTRAN codes of modules shishell_2 and vislfor are not given, because these are organising modules and therefore not containing any relevant calculations or operations.

module PRZM_post

```
!==========================================================================================
!
!==========================================================================================

   use SiShell
   use CompilerSpecific ! Module containing compiler specific statements

   implicit none

   ! Variables with constant value
   !------------------------------

   type ZtsProperty
      double precision :: Val
      logical :: Allocated,Output,OutputRead
      double precision :: Tim
   end type ZtsProperty

   type (ZtsProperty):: FlvRunOffLoc
   type (ZtsProperty):: FlmRunOffLoc
   type (ZtsProperty):: MasErsLoc
   type (ZtsProperty):: FlmErsLoc
```

```
   type (ZtsProperty):: FlvPrcLoc
   type (ZtsProperty):: FlvInfLoc

   integer :: FilZtsDay,FilZtsMnth

   double precision :: ShellRdTimZts

!==========================================================================================
! Overload section \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
!//////////////////////////////////////////////////////////////////////////////////////////

   interface Get
      module procedure GetZtsProperty
   end interface

   interface Set
      module procedure SetZtsProperty
   end interface

   interface Create
      module procedure CreateZtsProperty
   end interface
   private CreateZtsProperty

   interface Destroy
      module procedure DestroyZtsProperty
   end interface
   private DestroyZtsProperty

contains

!==========================================================================================
!==========================================================================================

   subroutine GetZtsStatus (Task)
   ! Read status of Zts-File
   !=======================================================================================

      ! Declaration of local variables
      !-------------------------------
      integer, intent(in) :: Task
      integer :: FilZtsTmp,IOS
      integer :: Rec
      character (len=WordLength) :: PRZMLoc
      character (len=WordLength) :: ZtsFileName,ZtsTmpFile
      character (len=WordLength) :: PRZMFileName
      character (len=LineLength) :: Buffer
      character (len=LineLength) :: TSR,PRZ
      integer :: YearLoc_1,YearLoc_2
      type (DateType) :: StartDate, EndDate,DateLoc
      integer :: DayLoc,MnthLoc,YearLoc,DayEndMnth
      double precision :: FlvRunOffTmp,MasErsTmp,FlvPrcTmp,FlvInfTmp,FlmRunOffTmp,FlmErsTmp
      double precision :: FlvInfSumTmp,FlvInfAvgTmp
      logical :: found = .false.
      logical :: first = .true.
      integer :: FilPRZM
      save

      ! Initial part of procedure
      !--------------------------
      select case (Task)

      case (StartUp)

         if (first) then

             first = .false.

             ! Open PRZM-file
             Call InitCh (PRZMLoc)
             Call GetInput('RunPRZM',PRZMLoc)
             PRZMFileName = trim(WorkingDirectory)//'\'//trim(PRZMLoc)//'.RUN'

             FilPRZM = FreeFil()
             Open (FilPRZM,file=trim(PRZMFileName),status='old',IOStat=IOS)
             if (IOS /= 0) then
                ! Error condition - abort program execution
                Error%Code = -1
                write ( Error%m1,'("Cannot find file ",a," with status old")')
trim(PRZMFileName)
                Call PrintError
             end if
```

```
            ! Find filename ZTS
            found = .false.
            do
               read (FilPRZM,'(a)',IOStat=IOS) Buffer
               if (IOS /= 0) exit

               if (index(Buffer,'TIME SERIES') .ne. 0) then

                  found = .true.

                  call SplitString (Buffer)

                  Call InitCh (ZtsFileName)
                  ZtsFileName = Words%Word(Words%NumWords)

                  exit

               end if

            end do

            close(FilPRZM)

            if (.not. found) then
               ! Error condition - abort program execution
               Error%Code = -1
               write ( Error%m1,'("Error can not find filename of ZTS-file")')
               write ( Error%m2,'("Error check TIME SERIES in file ",a)')
trim(PRZMFileName)
               Call PrintError
            end if

            ! Open Zts-file
            FilZtsTmp = FreeFil()
            Open (FilZtsTmp,file=trim(ZtsFileName),status='old',IOStat=IOS)
            if (IOS /= 0) then
               ! Error condition - abort program execution
               Error%Code = -1
               write ( Error%m1,'("Cannot find file ",a," with status old")')
trim(ZtsFileName)
               Call PrintError
            end if

            ! Go to start of file
            do Rec = 1,3
               read (FilZtsTmp,'(a)',IOStat=IOS) Buffer
               if (IOS /= 0) then
                  ! Error condition - abort program execution
                  Error%Code = -1
                  write ( Error%m1,'("Error while reading file ",a)') trim(ZtsFileName)
                  write ( Error%m2,'("Error reading line ",i1)')      Rec
                  Call PrintError
               end if
            end do

            ! Day and month of start time and end time
            StartDate      = GetDate (TimStart())
            EndDate        = GetDate (TimEnd())
            EndDate%Day    = EndDate%Day - 1.d0
            if (EndDate%Day .eq. 0.d0) then
               EndDate%Month = EndDate%Month - 1.d0
               if (EndDate%Month .eq. 0.d0) then
                  EndDate%Month = 12.d0
                  EndDate%Year  = EndDate%Year - 1.d0
               end if
               if (.not. LeapYear(EndDate%Year)) then
                  EndDate%Day = MonthLength365(int(EndDate%Month))
               else
                  EndDate%Day = MonthLength366(int(EndDate%Month))
               end if
            end if

            do
               read (FilZtsTmp,'(a)',IOStat=IOS) Buffer

               if (IOS /= 0) then
                  ! Error condition - abort program execution
                  Error%Code = -1
                  write ( Error%m1,'("Error while reading file ",a)') trim(ZtsFileName)
                  write ( Error%m2,'("Check format file")')
                  Call PrintError
```

```
            end if

            call SplitString (Buffer)

            ! Bug in PRZM
            ! Zero of Yearnumber not written to file. 19 3 --> 1903

            if (Words%NumWords .ne. 12 .and. Words%NumWords .ne. 13) then
               ! Error condition - abort program execution
               Error%Code = -1
               write ( Error%m1,'("Error while reading file ",a)') trim(ZtsFileName)
               write ( Error%m2,'("Check format file")')
               Call PrintError
            end if

            if (Words%NumWords .eq. 12) then

               TSR             = Words%Word( 1)
               PRZ             = Words%Word( 2)
               read(Words%Word( 3),*) YearLoc
               read(Words%Word( 4),*) MnthLoc
               read(Words%Word( 5),*) DayLoc
               read(Words%Word( 6),*) FlvRunOffTmp
               read(Words%Word( 7),*) MasErsTmp
               read(Words%Word( 8),*) FlvPrcTmp
               read(Words%Word( 9),*) FlvInfTmp
               read(Words%Word(10),*) FlmRunOffTmp
               read(Words%Word(11),*) FlmErsTmp

            elseif (Words%NumWords .eq. 13) then

               TSR             = Words%Word( 1)
               PRZ             = Words%Word( 2)
               read(Words%Word( 3),*) YearLoc_1
               read(Words%Word( 4),*) YearLoc_2
               read(Words%Word( 5),*) MnthLoc
               read(Words%Word( 6),*) DayLoc
               read(Words%Word( 7),*) FlvRunOffTmp
               read(Words%Word( 8),*) MasErsTmp
               read(Words%Word( 9),*) FlvPrcTmp
               read(Words%Word(10),*) FlvInfTmp
               read(Words%Word(11),*) FlmRunOffTmp
               read(Words%Word(12),*) FlmErsTmp

               if (YearLoc_1 .le. 9)  YearLoc_1 = YearLoc_1 * 1.d3
               if (YearLoc_1 .le. 99) YearLoc_1 = YearLoc_1 * 1.d2
               YearLoc = YearLoc_1 + YearLoc_2

            end if

            if (DayLoc == int(StartDate%day) .and. MnthLoc == int(StartDate%month) .and.
YearLoc == int(StartDate%year)) then
               backspace (FilZtsTmp)
               exit
            end if
         end do

         ! Copy Zts-file to Zts_day.tmp and Zts_Month.tmp
         FilZtsDay = FreeFil()
         call InitCh (ZtsTmpFile)
         write (ZtsTmpFile,'("zts_day.tmp")')
         call OpenAfterDelete (FilZtsDay,ZtsTmpFile)

         if (IOS /= 0) then
            ! Error condition - abort program execution
            Error%Code = -1
            write ( Error%m1,'("Cannot open file ",a," with status unknown")')
'zts_day.Tmp'
            Call PrintError
         end if

         FilZtsMnth = FreeFil()
         call InitCh (ZtsTmpFile)
         write (ZtsTmpFile,'("zts_month.tmp")')
         call OpenAfterDelete (FilZtsMnth,ZtsTmpFile)

         if (IOS /= 0) then
            ! Error condition - abort program execution
            Error%Code = -1
            write ( Error%m1,'("Cannot open file ",a," with status unknown")')
'zts_month.Tmp'
            Call PrintError
```

```
            end if

            FlvInfSumTmp     = 0.d0
            do
               read (FilZtsTmp,'(a)',IOStat=IOS) Buffer
               if (IOS /= 0) exit

               call SplitString (Buffer)

               if (Words%NumWords .ne. 12 .and. Words%NumWords .ne. 13) then
                  ! Error condition - abort program execution
                  Error%Code = -1
                  write ( Error%m1,'("Error while reading file ",a)') trim(ZtsFileName)
                  write ( Error%m2,'("Check format file")')
                  Call PrintError
               end if

               if (Words%NumWords .eq. 12) then

                  TSR             = Words%Word( 1)
                  PRZ             = Words%Word( 2)
                  read(Words%Word( 3),*) YearLoc
                  read(Words%Word( 4),*) MnthLoc
                  read(Words%Word( 5),*) DayLoc
                  read(Words%Word( 6),*) FlvRunOffTmp
                  read(Words%Word( 7),*) MasErsTmp
                  read(Words%Word( 8),*) FlvPrcTmp
                  read(Words%Word( 9),*) FlvInfTmp
                  read(Words%Word(10),*) FlmRunOffTmp
                  read(Words%Word(11),*) FlmErsTmp

               elseif (Words%NumWords .eq. 13) then

                  TSR             = Words%Word( 1)
                  PRZ             = Words%Word( 2)
                  read(Words%Word( 3),*) YearLoc_1
                  read(Words%Word( 4),*) YearLoc_2
                  read(Words%Word( 5),*) MnthLoc
                  read(Words%Word( 6),*) DayLoc
                  read(Words%Word( 7),*) FlvRunOffTmp
                  read(Words%Word( 8),*) MasErsTmp
                  read(Words%Word( 9),*) FlvPrcTmp
                  read(Words%Word(10),*) FlvInfTmp
                  read(Words%Word(11),*) FlmRunOffTmp
                  read(Words%Word(12),*) FlmErsTmp

                  if (YearLoc_1 .le. 9)  YearLoc_1 = YearLoc_1 * 1.d3
                  if (YearLoc_1 .le. 99) YearLoc_1 = YearLoc_1 * 1.d2
                  YearLoc = YearLoc_1 + YearLoc_2

               end if

               ! Write data to day-file
               write (FilZtsDay,'(i4.4," ",i2.2," ",i2.2," ",5e15.4)')
YearLoc,MnthLoc,DayLoc,    &
               &   FlvRunOffTmp,MasErsTmp,FlvPrcTmp,FlmRunOffTmp,FlmErsTmp

               ! Write data to month-file
               if (.not. LeapYear(dble(YearLoc))) then
                  DayEndMnth = MonthLength365(MnthLoc)
               else
                  DayEndMnth = MonthLength366(MnthLoc)
               end if

               if (DayLoc .ne. DayEndMnth) then

                  FlvInfSumTmp = FlvInfSumTmp + FlvInfTmp

               else

                  FlvInfSumTmp = FlvInfSumTmp + FlvInfTmp
                  FlvInfAvgTmp = FlvInfSumTmp / DayEndMnth
                  FlvInfSumTmp = 0.d0

                  write (FilZtsMnth,'(i4.4," ",i2.2," ",f14.4)')
YearLoc,MnthLoc,FlvInfAvgTmp

               end if

               ! Check end of simulation period
               if (DayLoc == int(EndDate%day) .and. MnthLoc == int(EndDate%month) .and.
YearLoc == int(EndDate%year)) then
```

```
                  Found = .true.
                  exit
               end if

            end do

            if (.not. Found) then
               ! Error condition - abort program execution
               Error%Code = -1
               write ( Error%m1,'("Error end of simulation period not in file ",a)')
trim(ZtsFileName)
               Call PrintError
            end if

         end if

         ! Reset timer Zts
         Call SetTimNxtRdZts(NxtTimZts=TimStart())

         ! Reset file Zts
         rewind (FilZtsDay)
         rewind (FilZtsMnth)

      case (Dynamic)

         ! Read Zts_daily Status
         read (FilZtsDay,*,IOStat=IOS) YearLoc,MnthLoc,DayLoc,   &
         &   FlvRunOffTmp,MasErsTmp,FlvPrcTmp,FlmRunOffTmp,FlmErsTmp

         ! Update Zts_daily variables
         Call UpdateFlvRunOff(FlvRunOffTmp)
         Call UpdateFlmRunOff(FlmRunOffTmp)
         Call UpdateMasErs(MasErsTmp)
         Call UpdateFlmErs(FlmErsTmp)
         Call UpdateFlvPrc(FlvPrcTmp)

         DateLoc = GetDate(TimShell())

         if (DateLoc%Day .eq. 1.d0) then

            ! Read Zts_monthly Status
            read (FilZtsMnth,*,IOStat=IOS) YearLoc,MnthLoc,FlvInfTmp

            ! Update Zts_monthly variables
            Call UpdateFlvInf(FlvInfTmp)

         end if

         ! SetTimNxtRdZts
         Call SetTimNxtRdZts(NxtTimZts=TimShell() + OneDay)

      end select

   end subroutine GetZtsStatus

!==========================================================================================
!==========================================================================================

   double precision function GetZtsProperty(Variable)
   ! Gets the contents of a variable of type ZtsProperty. This procedures is
   ! overloaded by the generic Get procedure.
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !------------------------------
      type (ZtsProperty) :: Variable

      ! Main part of procedure
      !----------------------
      GetZtsProperty = Variable%Val

   end function GetZtsProperty

!==========================================================================================
!==========================================================================================

   subroutine SetZtsProperty(Variable,Value)
   ! Sets Value equal to Variable. Variable is of type ZtsProperty.
   ! This procedures is overloaded by the generic Set procedure.
   !=======================================================================================
```

```
      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Value
      type (ZtsProperty) :: Variable

      ! Main part of procedure
      !-----------------------
      Variable%Val = Value

   end subroutine SetZtsProperty

!=========================================================================================
!=========================================================================================

   subroutine CreateZtsProperty (Property)
   ! Allocates memory for a variable of type ZtsProperty. Overloaded by generic
   ! Create.
   !======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      type (ZtsProperty) :: Property

      ! Main part of procedure
      !-----------------------
      Property%Val = 0.d0
      Property%Output = .false.
      Property%OutputRead = .false.
      Property%Allocated = .true.

   end subroutine CreateZtsProperty

!=========================================================================================
!=========================================================================================

   subroutine DestroyZtsProperty (Property)
   ! Deallocates memory for a variable of type ZtsProperty. Overloaded by generic
   ! Create.
   !======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      type (ZtsProperty) :: Property

      ! Main part of procedure
      !-----------------------

      Property%Val = 0.d0
      Property%Output = .false.
      Property%OutputRead = .false.
      Property%Allocated = .false.

   end subroutine DestroyZtsProperty

!=========================================================================================
!=========================================================================================

   subroutine UpdateFlvRunOff (Value)
   ! Updates the runoff volume-flux (given in mm.d-1)
   !======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
      save

      ! Initial part of procedure
      !--------------------------
      if (first) then

         first = .false.
         Call Create (FlvRunOffLoc)
```

```
      end if

      ! Main part of procedure
      !-----------------------
      call Set(FlvRunOffLoc,Value)

   end subroutine UpdateFlvRunOff

!==========================================================================================
!==========================================================================================

   subroutine UpdateFlmRunOff (Value)
   ! Updates the runoff mass-flux (given in mg as.m-1.h-1)
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
      save

      ! Initial part of procedure
      !--------------------------
      if (first) then

         first = .false.
         Call Create (FlmRunOffLoc)

      end if

      ! Main part of procedure
      !-----------------------
      call Set(FlmRunOffLoc,Value)

   end subroutine UpdateFlmRunOff

!==========================================================================================
!==========================================================================================

   subroutine UpdateMasErs (Value)
   ! Updates the erosion mass-flux (given in kg.d-1)
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
      save

      ! Initial part of procedure
      !--------------------------
      if (first) then

         first = .false.
         Call Create (MasErsLoc)

      end if

      ! Main part of procedure
      !-----------------------
      call Set(MasErsLoc,Value)

   end subroutine UpdateMasErs

!==========================================================================================
!==========================================================================================

   subroutine UpdateFlmErs (Value)
   ! Updates the erosion mass-flux (given in mg as.m-1.h-1)
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
```

```
      save

      ! Initial part of procedure
      !-------------------------
      if (first) then

         first = .false.
         Call Create (FlmErsLoc)

      end if

      ! Main part of procedure
      !----------------------
      call Set(FlmErsLoc,Value)

   end subroutine UpdateFlmErs

!==========================================================================================
!==========================================================================================

   subroutine UpdateFlvPrc (Value)
   ! Updates the precipitation volume-flux (given in mm.d-1)
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (first) then

         first = .false.
         Call Create (FlvPrcLoc)

      end if

      ! Main part of procedure
      !----------------------
      call Set(FlvPrcLoc,Value)

   end subroutine UpdateFlvPrc

!==========================================================================================
!==========================================================================================

   subroutine UpdateFlvInf (Value)
   ! Updates the infiltration volume-flux (given in mm.d-1)
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !------------------------------
      double precision, intent(in) :: Value
      logical :: first = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (first) then

         first = .false.
         Call Create (FlvInfLoc)

      end if

      ! Main part of procedure
      !----------------------
      call Set(FlvInfLoc,Value)

   end subroutine UpdateFlvInf

!==========================================================================================
!==========================================================================================

   double precision function PrecRepInt ()
   ! Returns representative rainfall intensity (mm.h-1)
```

```
   !===============================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: PrecRepIntLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (PrecRepIntLoc,'PrecRepInt','(mm.h-1)')

      end if

      ! Return part of procedure
      !----------------------
      PrecRepInt = PrecRepIntLoc
      return
   end function PrecRepInt

!==========================================================================================
!==========================================================================================

   double precision function AreaUpsWatCrsInp ()
   ! Returns size of area upstream catchment (ha)
   !===============================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: AreaUpsWatCrsInpLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (AreaUpsWatCrsInpLoc,'AreaUpsWatCrsInp','(ha)')

      end if

      ! Return part of procedure
      !----------------------
      AreaUpsWatCrsInp = AreaUpsWatCrsInpLoc
      return
   end function AreaUpsWatCrsInp

!==========================================================================================
!==========================================================================================

   double precision function FacInfConRnf ()
   ! Returns factor for infiltration contributing to runoff (-)
   !===============================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: FacInfConRnfLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (FacInfConRnfLoc,'FacInfConRnf','(-)',ValMin=0.d0,ValMax=1.d0)

      end if

      ! Return part of procedure
      !----------------------
      FacInfConRnf = FacInfConRnfLoc
      return
   end function FacInfConRnf
```

```
!==========================================================================================
!==========================================================================================

   double precision function QBasWatCrsInp ()
   ! Returns minimal flow into watercourse (m3.h-1)
   !=======================================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: QBasWatCrsInpLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (QBasWatCrsInpLoc,'QBasWatCrsInp','(m3.h-1)')

      end if

      ! Return part of procedure
      !----------------------
      QBasWatCrsInp = QBasWatCrsInpLoc
      return
   end function QBasWatCrsInp

!==========================================================================================
!==========================================================================================

   double precision function RatAreaUpsApp ()
   ! Returns ratio of upstream catchment treated
   !=======================================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: RatAreaUpsAppLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (RatAreaUpsAppLoc,'RatAreaUpsApp','(-)',ValMin=0.d0,ValMax=1.d0)

      end if

      ! Return part of procedure
      !----------------------
      RatAreaUpsApp = RatAreaUpsAppLoc
      return
   end function RatAreaUpsApp

!==========================================================================================
!==========================================================================================

   double precision function PrcDriWat ()
   ! Returns xth percentile of the incoming concentration in a stream of all runoff events
   ! Protection of drinking water produced from surface water (%)
   !=======================================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: PrcDriWatLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (PrcDriWatLoc,'PrcDriWat','(-)',ValMin=0.d0,ValMax=100.d0)

      end if
```

```
      ! Return part of procedure
      !-----------------------
      PrcDriWat = PrcDriWatLoc
      return
   end function PrcDriWat

!==========================================================================================
!==========================================================================================

   double precision function PrcAquEco ()
   ! Returns xth percentile of the incoming concentration in a stream of all runoff events
   ! Protection of aquatic ecosystems in surface water (%)
   !=======================================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      double precision :: PrcAquEcoLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.
         Call GetInput (PrcAquEcoLoc,'PrcAquEco','(-)',ValMin=0.d0,ValMax=100.d0)

      end if

      ! Return part of procedure
      !-----------------------
      PrcAquEco = PrcAquEcoLoc
      return
   end function PrcAquEco

!==========================================================================================
!==========================================================================================

   logical function RankConc ()
   ! Returns option if concentrations should be ranked
   !=======================================================================================

      ! Declaration of local variables
      !------------------------------
      implicit none
      character (len=LineLength) :: Identifier
      integer          :: OutputFlag
      logical :: RankConcLoc
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.

         Identifier = 'RankConc'
         Call RdOption (trim(Identifier),'No Yes',OutputFlag,RecordExist=.false.)

         RankConcLoc = .false.
         if (Outputflag .eq. 2) RankConcLoc = .true.

      end if

      ! Return part of procedure
      !-----------------------
      RankConc = RankConcLoc
      return
   end function RankConc

!==========================================================================================
!==========================================================================================

   double precision function FlvRunOff()
   ! Gets the runoff volume-flux from the zts-file (mm.d-1)
   !=======================================================================================

      implicit none

      ! Return part of the procedure
```

```
      !-----------------------------
      FlvRunOff=Get(FlvRunOffLoc)

   end function FlvRunOff

!=========================================================================================
!=========================================================================================

   double precision function FlmRunOff()
   ! Gets the runoff mass-flux from the zts-file (mg as.m-2.h-1)
   !======================================================================================

      implicit none

      ! Return part of the procedure
      !-----------------------------
      FlmRunOff=Get(FlmRunOffLoc)

   end function FlmRunOff

!=========================================================================================
!=========================================================================================

   double precision function MasErs()
   ! Gets the erosion mass-flux from the zts-file (mm.d-1)
   !======================================================================================

      implicit none

      ! Return part of the procedure
      !-----------------------------
      MasErs=Get(MasErsLoc)

   end function MasErs

!=========================================================================================
!=========================================================================================

   double precision function FlmErs()
   ! Gets the erosion mass-flux from the zts-file (mg as.m-2.h-1)
   !======================================================================================

      implicit none

      ! Return part of the procedure
      !-----------------------------
      FlmErs=Get(FlmErsLoc)

   end function FlmErs

!=========================================================================================
!=========================================================================================

   double precision function FlvPrc()
   ! Gets the precipitation volume-flux from the zts-file (mm.d-1)
   !======================================================================================

      implicit none

      ! Return part of the procedure
      !-----------------------------
      FlvPrc=Get(FlvPrcLoc)

   end function FlvPrc

!=========================================================================================
!=========================================================================================

   double precision function FlvInf()
   ! Gets the monthly infiltration volume-flux from zts-file (mm.d-1)
   !======================================================================================

      implicit none

      ! Return part of the procedure
      !-----------------------------
      FlvInf=Get(FlvInfLoc)

   end function FlvInf

!=========================================================================================
!=========================================================================================
```

```
   double precision function TimNxtRdZts ()
   ! Returns the time of the following regular print event
   !=====================================================================================

      implicit none

      ! Main part of procedure
      !-----------------------
      TimNxtRdZts = ShellRdTimZts

   end function TimNxtRdZts

!=========================================================================================
!=========================================================================================

   subroutine SetTimNxtRdZts (NxtTimZts)
   ! Sets the time of the following meteo state
   !=====================================================================================

      implicit none

      ! Declaration of locals
      !----------------------
      double precision, intent(in) :: NxtTimZts
      save

      ! Main part of procedure
      !-----------------------
      ShellRdTimZts = NxtTimZts

   end subroutine SetTimNxtRdZts

!=========================================================================================
!=========================================================================================

   subroutine PrintProperties ()
   ! Prints the Zts variables at time = Tim.
   !=====================================================================================

      implicit none

      ! Main part of the procedure
      !---------------------------

      ! runoff volume-flux
      if (.not. FlvRunOffLoc%OutputRead) then
         Call PrintFlvRunOff()
      elseif (FlvRunOffLoc%Output) then
         Call PrintFlvRunOff()
      end if

      ! runoff mass-flux
      if (.not. FlmRunOffLoc%OutputRead) then
         Call PrintFlmRunOff()
      elseif (FlmRunOffLoc%Output) then
         Call PrintFlmRunOff()
      end if

      ! erosion mass-flux
      if (.not. MasErsLoc%OutputRead) then
         Call PrintMasErs()
      elseif (MasErsLoc%Output) then
         Call PrintMasErs()
      end if

      ! erosion mass-flux
      if (.not. FlmErsLoc%OutputRead) then
         Call PrintFlmErs()
      elseif (FlmErsLoc%Output) then
         Call PrintFlmErs()
      end if

      ! precipitation volume-flux
      if (.not. FlvPrcLoc%OutputRead) then
         Call PrintFlvPrc()
      elseif (FlvPrcLoc%Output) then
         Call PrintFlvPrc()
      end if

      ! infiltration volume-flux
      if (.not. FlvInfLoc%OutputRead) then
```

```
         Call PrintFlvInf()
      elseif (FlvInfLoc%Output) then
         Call PrintFlvInf()
      end if


   end subroutine PrintProperties

!=========================================================================================
!=========================================================================================

   subroutine PrintFlvRunOff
   ! Prints the runoff volume-flux
   !======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !--------------------------
      Val = FlvRunOff()
      Call PrintOutput (TimShell(),Val,'FlvRunOff',OutputStatus,'(mm.d-1)')

      ! Set OutputStatus
      if (.not. FlvRunOffLoc%OutputRead) then

         FlvRunOffLoc%OutputRead = .true.

         FlvRunOffLoc%Output     = .false.
         if (OutputStatus .eq. 2) FlvRunOffLoc%Output = .true.

      end if

   end subroutine PrintFlvRunOff

!=========================================================================================
!=========================================================================================

   subroutine PrintFlmRunOff
   ! Prints the runoff mass-flux
   !======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !--------------------------
      Val = FlmRunOff()
      Call PrintOutput (TimShell(),Val,'FlmRunOff',OutputStatus,'(mg as.m-1.h-1)')

      ! Set OutputStatus
      if (.not. FlmRunOffLoc%OutputRead) then

         FlmRunOffLoc%OutputRead = .true.

         FlmRunOffLoc%Output     = .false.
         if (OutputStatus .eq. 2) FlmRunOffLoc%Output = .true.

      end if

   end subroutine PrintFlmRunOff

!=========================================================================================
!=========================================================================================

   subroutine PrintMasErs
   ! Prints the erosion mass-flux
   !======================================================================================

      implicit none

      ! Declaration of local variables
```

```
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !--------------------------
      Val = MasErs()
      Call PrintOutput (TimShell(),Val,'MasErs',OutputStatus,'(mm.d-1)')

      ! Set OutputStatus
      if (.not. MasErsLoc%OutputRead) then

         MasErsLoc%OutputRead = .true.

         MasErsLoc%Output     = .false.
         if (OutputStatus .eq. 2) MasErsLoc%Output = .true.

      end if

   end subroutine PrintMasErs

!==========================================================================================
!==========================================================================================

   subroutine PrintFlmErs
   ! Prints the erosion mass-flux
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !--------------------------
      Val = FlmErs()
      Call PrintOutput (TimShell(),Val,'FlmErs',OutputStatus,'(mg as.m-1.h-1)')

      ! Set OutputStatus
      if (.not. FlmErsLoc%OutputRead) then

         FlmErsLoc%OutputRead = .true.

         FlmErsLoc%Output     = .false.
         if (OutputStatus .eq. 2) FlmErsLoc%Output = .true.

      end if

   end subroutine PrintFlmErs

!==========================================================================================
!==========================================================================================

   subroutine PrintFlvPrc
   ! Prints the precipitation volume-flux
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !--------------------------
      Val = FlvPrc()
      Call PrintOutput (TimShell(),Val,'FlvPrc',OutputStatus,'(mm.d-1)')

      ! Set OutputStatus
      if (.not. FlvPrcLoc%OutputRead) then

         FlvPrcLoc%OutputRead = .true.

         FlvPrcLoc%Output     = .false.
         if (OutputStatus .eq. 2) FlvPrcLoc%Output = .true.
```

```
      end if

   end subroutine PrintFlvPrc

!==========================================================================================
!==========================================================================================

   subroutine PrintFlvInf
   ! Prints the infiltration volume-flux
   !=======================================================================================

      implicit none

      ! Declaration of local variables
      !-------------------------------
      double precision :: Val
      integer          :: OutputStatus
      save

      ! Main part of procedure
      !-------------------------
      Val = FlvInf()
      Call PrintOutput (TimShell(),Val,'FlvInf',OutputStatus,'(mm.d-1)')

      ! Set OutputStatus
      if (.not. FlvInfLoc%OutputRead) then

         FlvInfLoc%OutputRead = .true.

         FlvInfLoc%Output     = .false.
         if (OutputStatus .eq. 2) FlvInfLoc%Output = .true.

      end if

   end subroutine PrintFlvInf

!==========================================================================================
!==========================================================================================

   subroutine WriteP2tOutput (Task)
   ! Writes p2t-file
   !=======================================================================================

      ! Declaration of local variables
      !-------------------------------
      implicit none
      integer, intent(in) :: Task
      integer :: FilP2tTmp,IOS,FilPri,FilPRZM
      integer :: Evt,NumEvt
      character (len=LineLength) :: P2tTmpFile,TmpFile,PriFile,InFile
      character (len=LineLength) :: Buffer
      character (len=LineLength) :: string
      character (len=LineLength) :: PRZMLoc,PRZMFileName
      character (len=LineLength) :: MetFileName,ChemFileName
      character (len=LineLength) :: CropName,ScenName,ChemName
      character (len=LineLength) :: TimeNam,YearNam,MonthNam,DayNam,HourNam,MinNam
      integer          :: Nrh
      integer          :: Hour
      double precision :: FlvRunOffTmp,FlmRunOffTmp,MasErsTmp,FlmErsTmp,FlvInfTmp
      double precision :: QstreamIn,JstreamIn,CstreamIn,Qrodr
      double precision :: Cro
      double precision :: DayNumStart
      type (DateType)  :: DateLoc,DateLocStart,DateLocEnd
      type (TableType) :: Table_Daily,Table_Yearly
      logical          :: found
      integer          :: Year,Month,Day
      integer          :: YearNum,NumYear,YearNew,YearOld
      double precision :: Dosage
      double precision :: Time
      type (TableType) :: ApplScheme
      save

      ! Select case, depending on stage in calling programme
      !------------------------------------------------------

      select case (Task)

      case (StartUp)

         ! Open PRZM file
         Call InitCh (PRZMLoc)
         Call GetInput('RunPRZM',PRZMLoc)
```

```
        PRZMFileName = trim(WorkingDirectory)//'\'//trim(PRZMLoc)//'.RUN'

        FilPRZM = FreeFil()
        Open (FilPRZM,file=trim(PRZMFileName),status='old',IOStat=IOS)
        if (IOS /= 0) then
           ! Error condition - abort program execution
           Error%Code = -1
           write ( Error%m1,'("Cannot find file ",a," with status old")')
trim(PRZMFileName)
           Call PrintError
        end if

        ! Find filename METEOROLOGY
        found = .false.
        do
           read (FilPRZM,'(a)',IOStat=IOS) Buffer
           if (IOS /= 0) exit

           if (index(Buffer,'METEOROLOGY') .ne. 0) then

              found = .true.

              call SplitString (Buffer)

              Call InitCh (MetFileName)
              MetFileName = Words%Word(Words%NumWords)

              exit

           end if

        end do

        if (.not. found) then
           ! Error condition - abort program execution
           Error%Code = -1
           write ( Error%m1,'("Error can not find filename of Meteo-file")')
           write ( Error%m2,'("Error check METEOROLOGY in file ",a)') trim(PRZMFileName)
           Call PrintError
        end if

        ! Find filename CHEMICAL
        rewind(FilPRZM)

        found = .false.
        do
           read (FilPRZM,'(a)',IOStat=IOS) Buffer
           if (IOS /= 0) exit

           if (index(Buffer,'PRZM INPUT') .ne. 0) then

              found = .true.

              call SplitString (Buffer)

              Call InitCh (ChemFileName)
              ChemFileName = Words%Word(Words%NumWords)

              exit

           end if

        end do

        if (.not. found) then
           ! Error condition - abort program execution
           Error%Code = -1
           write ( Error%m1,'("Error can not find filename of Chemical-file")')
           write ( Error%m2,'("Error check PRZM INPUT in file ",a)') trim(PRZMFileName)
           Call PrintError
        end if

        close(FilPRZM)


        ! Get information from inp-file PRZM

        ! Open PRZM inp-file
        FilPRZM = FreeFil()
        Open (FilPRZM,file=trim(ChemFileName),status='old',IOStat=IOS)
        if (IOS /= 0) then
           ! Error condition - abort program execution
```

```
            Error%Code = -1
            write ( Error%m1,'("Cannot find file ",a," with status old")')
trim(ChemFileName)
            Call PrintError
         end if

         !Find name of crop
         found = .false.
         do
            read (FilPRZM,'(a)',IOStat=IOS) Buffer
            if (IOS /= 0) exit

            if (index(Buffer,'Crop:') .ne. 0) then

               found = .true.

               Call InitCh (CropName)
               CropName = adjustl(Buffer((index(Buffer,'Crop:',back=.true.) +
5):len_trim(Buffer)))

               exit

            end if

         end do

         if (.not. found) then
            ! Error condition - abort program execution
            Error%Code = -1
            write ( Error%m1,'("Error can not find name of crop")')
            write ( Error%m2,'("Error check Crop in file ",a)') trim(ChemFileName)
            Call PrintError
         end if

         !Find name of scenario
         rewind(FilPRZM)

         found = .false.
         do
            read (FilPRZM,'(a)',IOStat=IOS) Buffer
            if (IOS /= 0) exit

            if (index(Buffer,'Soil Series:') .ne. 0) then

               found = .true.

               Call InitCh (ScenName)
               ScenName = adjustl(Buffer((index(Buffer,'Soil Series:',back=.true.) +
12):len_trim(Buffer)))

               exit

            end if

         end do

         if (.not. found) then
            ! Error condition - abort program execution
            Error%Code = -1
            write ( Error%m1,'("Error can not find name of scenario")')
            write ( Error%m2,'("Error check Soil Series in file ",a)') trim(ChemFileName)
            Call PrintError
         end if

         !Find application scheme
         rewind(FilPRZM)

         found = .false.
         do
            read (FilPRZM,'(a)',IOStat=IOS) Buffer
            if (IOS /= 0) exit

            if (index(Buffer,'Chemical Input Data:') .ne. 0) then

               found = .true.

               read (FilPRZM,*)

               read (FilPRZM,'(a)',IOStat=IOS) Buffer

               Call InitCh (ChemName)
               ChemName = trim(Buffer)
```

```
            NumEvt = 0
            do

               read (FilPRZM,'(i4,i2,i2,10x,f6.4)',IOStat=IOS) Day,Month,Year,Dosage

               if (IOS /= 0) exit

               Year = Year + 1900
               Time = dble(Year * 1.d4 + Month * 1.d2 + Day)

               if (Time .ge. TimStart() .and. Time .le. TimEnd()) then
                  NumEvt = NumEvt + 1
               end if

            end do

            exit

         end if

      end do

      if (.not. found) then
         ! Error condition - abort program execution
         Error%Code = -1
         write ( Error%m1,'("Error can not find name of chemical")')
         write ( Error%m2,'("Error check Chemical Input Data in file ",a)')
trim(ChemFileName)
         Call PrintError
      end if

      ! Fill application scheme
      rewind(FilPRZM)

      call create (Table=ApplScheme,NumCol=1,NumRow=NumEvt)

      found = .false.
      do
         read (FilPRZM,'(a)',IOStat=IOS) Buffer
         if (IOS /= 0) exit

         if (index(Buffer,'Chemical Input Data:') .ne. 0) then

            found = .true.

            read (FilPRZM,*)
            read (FilPRZM,*)

            NumEvt = 0
            do

               read (FilPRZM,'(i4,i2,i2,10x,f6.4)',IOStat=IOS) Day,Month,Year,Dosage

               if (IOS /= 0) exit

               Year = Year + 1900
               Time = dble(Year * 1.d4 + Month * 1.d2 + Day + 9 * 1.d-2)

               if (Time .ge. TimStart() .and. Time .le. TimEnd()) then
                  NumEvt = NumEvt + 1

                  DateLoc = GetDate(Time)
                  ApplScheme%Z(NumEvt) = DateLoc%Date(1:17)
                  ApplScheme%X(NumEvt) = Dosage
               end if

            end do

            exit

         end if

      end do

      ! Open tmp-file
      FilP2tTmp = FreeFil()
      call InitCh (P2tTmpFile)
      write (P2tTmpFile,'(a,a,"p2t.tmp")') trim(WorkingDirectory),BackSlash
      Open (FilP2tTmp,file=trim(P2tTmpFile))

      FilTmp = FreeFil()
```

```
      call InitCh (TmpFile)
      write (TmpFile,'(a,a,"EvtIn.tmp")') trim(WorkingDirectory),BackSlash
      Open (FilTmp,file=trim(TmpFile))

      NumEvt = 0

      DateLoc = GetDate(TimShell())
      DayNumStart = DateLoc%DayNum

      DateLocStart = GetDate(TimStart())
      DateLocEnd   = GetDate(TimEnd())
      NumYear      = int(DateLocEnd%Year) - int(DateLocStart%Year)

   case (Dynamic)

      DateLoc = GetDate(TimShell())

      ! Set Nrh
      if (FlvRunOff() .eq. 0.d0) then
         Nrh = 0
      else

         ! Number of hours with rainfall
         Nrh = min(24,nint(FlvPrc() / PrecRepInt()))

         ! Snowmelt
         if (FlvRunOff() .gt. FlvPrc()) then
            Nrh = 12
         end if

         ! Runoff with litle rainfall
         Nrh = max(1,Nrh)

      end if

      ! Set values
      if (Nrh .gt. 0) then

         FlvRunOffTmp = FlvRunOff() / Nrh
         FlmRunOffTmp = FlmRunOff() / Nrh
         MasErsTmp    = MasErs()    / Nrh
         FlmErsTmp    = FlmErs()    / Nrh

      end if

      FlvInfTmp    = FlvInf()    / 24.d0

      ! Write p2t-file tmp
      do Hour = 1,24

         if (Hour .le. Nrh) then

            write(string,'(i2.2,"-",a3,"-",i4.4,"-",i2.2,":00",3x,5E15.4)')    &
            &   int(DateLoc%Day),MonthName(DateLoc%Month),int(DateLoc%Year),Hour, &
            &   FlvRunOffTmp,FlmRunOffTmp,MasErsTmp,FlmErsTmp,FlvInfTmp

         else

            write(string,'(i2.2,"-",a3,"-",i4.4,"-",i2.2,":00",3x,5E15.4)')    &
            &   int(DateLoc%Day),MonthName(DateLoc%Month),int(DateLoc%Year),Hour, &
            &   0.d0, 0.d0, 0.d0, 0.d0, FlvInfTmp

         endif

         write(FilP2tTmp,'(a)') trim(string)

      end do

      if (RankConc() ) then

         ! Save events

         if (Nrh .gt. 0.d0) then

            Qrodr     = FlvRunOffTmp + FacInfConRnf() * FlvInfTmp
            QstreamIn = QBasWatCrsInp() + 10.d0 * AreaUpsWatCrsInp() * Qrodr

            JstreamIn = 1.d4 * RatAreaUpsApp() * AreaUpsWatCrsInp() * FlmRunOffTmp

            CstreamIn = JstreamIn / QstreamIn

            Cro     = FlmRunOffTmp / (0.001 * FlvRunOffTmp)
```

```
               NumEvt = NumEvt + 1

               write(string,'(i2.2,"-",i2.2,"-",i4.4,6x,i6,2E15.4,i4,E15.4,6x,3E15.4)')    &
               &   int(DateLoc%Day),int(DateLoc%Month),int(DateLoc%Year), &
               &   int(DateLoc%DayNum -
DayNumStart),FlvRunOff(),CstreamIn,Nrh,FlvPrc(),FlvRunOffTmp,Cro,FacInfConRnf() * FlvInfTmp

               write(FilTmp,'(a)') trim(string)

            end if
         end if

      case (Final)

         close (FilZtsDay,status="delete")
         close (FilZtsMnth,status="delete")

         call SYS_Time(DateLoc)

         write(FilP2t,'("*  PRZM3 output file / TOXSWA input file")')
         write(FilP2t,'("*")')
         write(FilP2t,'("*  Filename:    ",a,"\",a,".p2t")')
trim(WorkingDirectory),trim(GetRun())
         write(FilP2t,'("*")')
         write(FilP2t,'("*  Generated by: PRZM-postprocessor ",a," ",a)')
trim(Model%ModelVersion),trim(Model%Date)
         write(FilP2t,'("*  Created:     ",a)') trim(DateLoc%Date)
         write(FilP2t,'("*")')
         write(FilP2t,'("*  PRZM3 input files")')
         write(FilP2t,'("*  Chem file: ",a)') trim(ChemFileName)
         write(FilP2t,'("*  Met file:  ",a)') trim(MetFileName)
         write(FilP2t,'("*")')
         write(FilP2t,'("*")')
         write(FilP2t,'("*  Chemical:  ",a)') trim(ChemName)
         write(FilP2t,'("*  Crop:      ",a)') trim(CropName)
         write(FilP2t,'("*  Scenario:  ",a)') trim(ScenName)
         write(FilP2t,'("*  Description: ")')
         write(FilP2t,'("*")')
         write(FilP2t,'("*  Number of applications:")')
         write(FilP2t,'("# ",i4)') ApplScheme%NumRow
         write(FilP2t,'("*")')
         write(FilP2t,'("*  Application    Time (DD-MMM-YYYY-HH:MM   Mass (g ai.ha-1)")')
         do Evt = 1,ApplScheme%NumRow
            TimeNam  = ApplScheme%Z(Evt)
            YearNam  = TimeNam(1:4)
            MonthNam = TimeNam(6:8)
            DayNam   = TimeNam(10:11)
            HourNam  = TimeNam(13:14)
            MinNam   = TimeNam(16:17)
            write(FilP2t,'("# "i4,"            ",a2,"-",a3,"-",a4,"-",a2,":",a2,"
",f12.4)') &
         &
Evt,trim(DayNam),trim(MonthNam),trim(YearNam),trim(HourNam),trim(MinNam),(ApplScheme%X(Evt)
* 1.d3)
         end do
         write(FilP2t,'("*")')
         write(FilP2t,'("*")')
         write(FilP2t,'("* Legend to columns:")')
         write(FilP2t,'("*                         Runoff Volume  Runoff Flux    Erosion Mass
Erosion Flux   Infiltration")')
         write(FilP2t,'("* Time                    (mm/h)         (mg as/m2/h)   (kg/h)
(mg as/m2/h)   (mm/h)      ")')

         ! Copy information into final file
         rewind (FilP2tTmp)
         do
            Call InitCh(Buffer)
            read (FilP2tTmp,'(a)',IOStat=IOS) buffer
            if (IOS /= 0) exit
            write (FilP2t,'(a)') trim(buffer)
         end do
         close (FilP2tTmp,status="delete")


         if (RankConc() ) then

            call Create(Table_Daily,10,NumEvt)

            rewind (FilTmp)

            do Evt = 1,NumEvt
```

```
      read (FilTmp,'(a)',IOStat=IOS) Buffer
      if (IOS /= 0) then
         ! Error condition - abort program execution
         Error%Code = -1
         write ( Error%m1,'("Error while reading file ",a)') trim(TmpFile)
         write ( Error%m2,'("Error reading line ",i1)')      Evt
         Call PrintError
      end if

      call SplitString (Buffer)

      read(Words%Word(1),*) Table_Daily%Z(Evt)   ! Date
      read(Words%Word(4),*) Table_Daily%X(Evt)   ! Cstream ()

      read(Words%Word(2),*) Table_Daily%Y(1,Evt) ! DayNum
      read(Words%Word(3),*) Table_Daily%Y(2,Evt) ! RunOff ()
      read(Words%Word(5),*) Table_Daily%Y(3,Evt) ! Nrh
      read(Words%Word(6),*) Table_Daily%Y(4,Evt) ! FlvPrc ()
      read(Words%Word(7),*) Table_Daily%Y(5,Evt) ! RunOff
      read(Words%Word(8),*) Table_Daily%Y(6,Evt) ! Cro
      read(Words%Word(9),*) Table_Daily%Y(7,Evt) ! Qdown
      Table_Daily%Y(8,Evt) = dble(Evt)           ! Evt
      Table_Daily%Y(9,Evt) = dble(Evt)           ! Evt
      Table_Daily%Y(10,Evt) = 0.d0               ! Percnt

   end do

   ! Create yearly table
   call Create(Table_Yearly,10,NumYear)
   do YearNum = 1,NumYear
      Table_Yearly%X(YearNum) = -1.d0
   end do

   YearNum = 0
   YearOld = -99
   do Evt = 1,NumEvt

      String = trim(Table_Daily%Z(Evt))
      read(String(7:10),*) YearNew

      if (YearNew .ne. YearOld) then
         YearNum = YearNum + 1
         YearOld = YearNew
      end if

      if (Table_Daily%X(Evt) .gt. Table_Yearly%X(YearNum)) then

         Table_Yearly%Z(YearNum)    = Table_Daily%Z(Evt)    ! Date
         Table_Yearly%X(YearNum)    = Table_Daily%X(Evt)    ! Cstream ()

         Table_Yearly%Y( 1,YearNum) = Table_Daily%Y( 1,Evt) ! DayNum
         Table_Yearly%Y( 2,YearNum) = Table_Daily%Y( 2,Evt) ! RunOff ()
         Table_Yearly%Y( 3,YearNum) = Table_Daily%Y( 3,Evt) ! Nrh
         Table_Yearly%Y( 4,YearNum) = Table_Daily%Y( 4,Evt) ! FlvPrc ()
         Table_Yearly%Y( 5,YearNum) = Table_Daily%Y( 5,Evt) ! RunOff
         Table_Yearly%Y( 6,YearNum) = Table_Daily%Y( 6,Evt) ! Cro
         Table_Yearly%Y( 7,YearNum) = Table_Daily%Y( 7,Evt) ! Qdown
         Table_Yearly%Y( 8,YearNum) = Table_Daily%Y( 8,Evt) ! Evt
         Table_Yearly%Y( 9,YearNum) = Table_Daily%Y( 9,Evt) ! Evt
         Table_Yearly%Y(10,YearNum) = Table_Daily%Y(10,Evt) ! Percnt

      end if

   end do

   ! Order tables
   call OrderTable(Table_Daily,'increase')
   call OrderTable(Table_Yearly,'increase')

   ! Calculate percentile
   do Evt = 1,NumEvt
      Table_Daily%Y(10,Evt) = GetPrcnt(Evt,NumEvt)
   end do

   do YearNum = 1,NumYear
      Table_Daily%Y(10,YearNum) = GetPrcnt(YearNum,NumYear)
   end do

   FilPri = FreeFil()
   call InitCh (PriFile)
   write (PriFile,'(3a,".primet")') trim(WorkingDirectory),BackSlash,trim(GetRun())
```

```
            Open (FilPri,file=trim(PriFile))

            Call InitCh (InFile)
            InFile  = trim(WorkingDirectory)//'/'//trim(GetRun())//'.inp'

            write(FilPri,'("* PRIMET-file: ",a)') trim(InFile)
            write(FilPri,'("*")')

            write(FilPri,'("* Aimed overall 99th percentile (temporal ",f6.2,"th percentile)
of the annual maximum incoming")') PrcDriWat()
            write(FilPri,'("* concentration in a stream due to runoff for 33 years for the
protection of drinking water produced")')
            write(FilPri,'("* from surface water.")')
            write(FilPri,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=PrcDriWat(),Values=Table_Yearly%X)
            if (GetPrcnt(NumYear,NumYear) .lt. PrcDriWat()) then
               write(FilPri,'("WARNING: There are insufficient runoff events in this
simulation to determine a 99th-ile probability of occurrence (in time)")')
               write(FilPri,'("WARNING: therefore the highest probability that can be
calculated is displayed (",E15.4,"th-ile)")') GetPrcnt(NumYear,NumYear)
            end if
            write(FilPri,'("*")')

            write(FilPri,'("* Aimed overall 90th percentile (temporal ",f6.2,"th percentile)
of the annual maximum incoming")') PrcAquEco()
            write(FilPri,'("* concentration in a stream due to runoff for 33 years for the
protection of aquatic ecosystems in")')
            write(FilPri,'("* surface water.")')
            write(FilPri,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=PrcAquEco(),Values=Table_Yearly%X)
            if (GetPrcnt(NumYear,NumYear) .lt. PrcAquEco()) then
               write(FilPri,'("WARNING: There are insufficient runoff events in this
simulation to determine a 99th-ile probability of occurrence (in time)")')
               write(FilPri,'("WARNING: therefore the highest probability that can be
calculated is displayed (",E15.4,"th-ile)")') GetPrcnt(NumYear,NumYear)
            end if
            write(FilPri,'("*")')

            write(FilPri,'("* Annual maximum incoming concentration in a stream from large
to small")')
            write(FilPri,'("*     Date        DayFromStart  EventNum     Percentile
Cstream    Runoff Flux       Nrh  Precipitation             Runoff Flux            Cro
Subsurface Drainage Flux")')
            write(FilPri,'("*                                (d)       (-)            (%)
(mg.m-3)       (mm.d-1)       (-)       (mm.d-1)                (mm.h-1)       (mg.m-3)
(mm.h-1)")')

            ! Write data
            do YearNum = NumYear,1,-1

               write(string,'(a10,10x,2i10,3E15.4,i10,E15.4,10x,3E15.4)')
&
               &   Table_Yearly%Z(YearNum),
int(Table_Yearly%Y(1,YearNum)),int(Table_Yearly%Y(8,YearNum)),Table_Yearly%Y(10,YearNum),Tab
le_Yearly%X(YearNum), &
               &
Table_Yearly%Y(2,YearNum),int(Table_Yearly%Y(3,YearNum)),Table_Yearly%Y(4,YearNum),
&
               &
Table_Yearly%Y(5,YearNum),Table_Yearly%Y(6,YearNum),Table_Yearly%Y(7,YearNum)

               write(FilPri,'(a)') trim(string)

            end do
            write(FilPri,'("*")')

            write(FilPri,'("* All runoff-events form large to small:")')
            write(FilPri,'("* Legend to columns:")')
            write(FilPri,'("*     Date        DayFromStart  EventNum        Cstream
Runoff Flux       Nrh  Precipitation             Runoff Flux            Cro Subsurface
Drainage Flux")')
            write(FilPri,'("*                                (d)       (-)        (mg.m-3)
(mm.d-1)       (-)       (mm.d-1)                (mm.h-1)       (mg.m-3)
(mm.h-1)")')

            ! Write data
            do Evt = NumEvt,1,-1

               write(string,'(a10,10x,2i10,2E15.4,i10,E15.4,10x,3E15.4)')
&
               &   Table_Daily%Z(Evt),
int(Table_Daily%Y(1,Evt)),int(Table_Daily%Y(8,Evt)),Table_Daily%X(Evt), &
```

```
               &   Table_Daily%Y(2,Evt),int(Table_Daily%Y(3,Evt)),Table_Daily%Y(4,Evt),
&
               &   Table_Daily%Y(5,Evt),Table_Daily%Y(6,Evt),Table_Daily%Y(7,Evt)

               write(FilPri,'(a)') trim(string)

            end do


            rewind (FilTmp)

            do Evt = 1,NumEvt

               Table_Daily%Y(9,Evt) = Table_Daily%X(Evt)
               Table_Daily%X(Evt)   = Table_Daily%Y(8,Evt)

            end do

            call OrderTable(Table_Daily,'increase')

            write(FilPri,'("*")')
            write(FilPri,'("* All runoff-events in chronological order:")')
            write(FilPri,'("* Legend to columns:")')
            write(FilPri,'("*     Date        DayFromStart  EventNum        Cstream
Runoff Flux       Nrh  Precipitation              Runoff Flux            Cro Subsurface
Drainage Flux")')
            write(FilPri,'("*                                    (d)       (-)       (mg.m-3)
(mm.d-1)       (-)       (mm.d-1)                 (mm.h-1)       (mg.m-3)
(mm.h-1)")')



            ! Write data
            do Evt = 1,NumEvt

               write(string,'(a10,10x,2i10,2E15.4,i10,E15.4,10x,3E15.4)')
&
               &   Table_Daily%Z(Evt),
int(Table_Daily%Y(1,Evt)),int(Table_Daily%Y(8,Evt)),Table_Daily%Y(9,Evt), &
               &   Table_Daily%Y(2,Evt),int(Table_Daily%Y(3,Evt)),Table_Daily%Y(4,Evt),
&
               &   Table_Daily%Y(5,Evt),Table_Daily%Y(6,Evt),Table_Daily%Y(7,Evt)

               write(FilPri,'(a)') trim(string)

            end do

            close (FilTmp,status="delete")
            close (FilPri)

         end if


      end select

   end subroutine WriteP2tOutput

!==========================================================================================
!==========================================================================================
```

end module PRZM_post

---

program PRZMpost

```
!==========================================================================================
!
! Postprocessing PRZM
! - translation of zts-file to p2t-file
!
!==========================================================================================

   use CompilerSpecific        ! Compiler specific statements
   use SiShell                 ! General routines ('Sishell')
   use PRZM_post               ! Module PRZM postprocessor
```

```
   ! Declaration of local variables
   !------------------------------
   implicit none
   character (len=LineLength) :: ScreenLine
   character (len=LineLength) :: LogFile,ErrFile,P2tFile,RunName

   save

   ! Initial part of program
   !------------------------

   Call Openfiles ()
   Call SetModelTimStp ()
   Call SetModelStamp ()

   Call ProgramHeader(StartUp)
   Call GetZtsStatus(StartUp)
   Call WriteP2tOutput(StartUp)

   ! Main part of porgramme
   !----------------------
   do

      Call ProgramHeader(Dynamic)

      if (TimShell() .ge. TimNxtRdZts()) Call GetZtsStatus (Dynamic)


      ! Print Properties
      if (TimShell() .ge. TimNxtPrn()) then

         Call PrintProperties()

         Call SetTimNxt (NamOfTimShell='Prn',TimStp='OneDay')

      end if

      ! Print final
      if (TimShell() .ge. TimEnd()) then

         Call WriteP2tOutput(Final)

         exit

      end if

      ! Print p2t-file
      if (TimShell() .ge. TimNxtPrnP2t()) then

         Call WriteP2tOutput(Dynamic)

         ! Update of print time
         Call SetTimNxt (NamOfTimShell='PrnP2t',TimStp='OneDay')

      end if


      Call SetTimNxt
(NamOfTimShell='PRZM',TimStp=ShellTimStp%TimStpBase,multiplier=ShellTimStp%TimStpMultiplier)

   end do

   ! Closing programme with error code zero
   !--------------------------------------
   Call ProgramHeader (Final)

   Call CloseAllFiles (0)

contains


!==========================================================================================
!==========================================================================================



!==========================================================================================
!==========================================================================================



   subroutine Openfiles
```

```
   ! creates and opens the files used by the Substance emission model
   !==========================================================================================

      ! Declaration of local variables
      !-------------------------------
      implicit none
      character (len=LineLength) :: InFile,OutFile
      integer :: IOS

      ! Main part of procedure
      !-----------------------

      ! Create Memory Space for the Words variable
      Words%Allocated = .false.
      Call Create (Words,NumWords)

      Call InitCh (RunName)
      RunName = GetRun()


      ! Construct the file names (add the extensions)
      InFile  = trim(WorkingDirectory)//'/'//trim(RunName)//'.inp'
      OutFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.out'
      P2tFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.p2t'
      LogFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.log'
      ErrFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.err'


      ! Open the input file
      Open (FilInp,file=trim(InFile),status='old',IOStat=IOS)
      if (IOS /= 0) then
         ! Error condition - abort program execution
         Error%Code = -1
         write ( Error%m1,'("Cannot find file ",a," with status old")') trim(InFile)
         stop 'Illegal run id - no error file generated'
      end if
      rewind (FilInp)


      IOMode = IOMode_Full
      do
         Call InitCh (ScreenLine)
         read (FilInp,'(a)',end=670) ScreenLine
         if (Index(ScreenLine,"IOMode_StdOut") /= 0) then
            IOMode = IOMode_StdOut
         end if
      end do


      ! Open all files
670   rewind (FilInp)
      Call OpenAfterDelete (FilErr,trim(ErrFile))
      Call OpenAfterDelete (FilOut,trim(OutFile))
      Call OpenAfterDelete (FilP2t,trim(P2tFile))
      Call OpenAfterDelete (FilLog,trim(LogFile))

      ! Get the start time, end-time and interval of the output
      Call RdTimers ()


   end subroutine Openfiles

!=============================================================================================
!=============================================================================================

   subroutine SetModelTimStp ()
   ! Set ModelStamp.
   ! Get ModelType A, B or C. ModelType 'A' combined with OptPots is not possible.
   !==========================================================================================

      ! Declaration of local variables
      !-----------------------
      implicit none

      ! Main part of procedure
      !-----------------------
      ShellTimStp%TimStpBase       = 'OneDay'
      ShellTimStp%TimStpMultiplier = 1

   end subroutine SetModelTimStp

!=============================================================================================
```

```
!==========================================================================================

   subroutine SetModelStamp ()
   ! Set ModelStamp.
   ! Get ModelType A, B or C. ModelType 'A' combined with OptPots is not possible.
   !=======================================================================================

      implicit none

      ! Main part of procedure
      !-----------------------
      Model%Date = '21-May-2013'
      Model%ModelVersion = 'v1.02'

   end subroutine SetModelStamp

!==========================================================================================
!==========================================================================================

   subroutine ProgramHeader (Task)
   ! Clears the screen, prints the Substrate header and sets the cursor position
   !=======================================================================================

      integer, intent(in) :: Task
      integer :: Minutes,Seconds,CPU_Used
      character (len=130) :: ScreenLine
      type (DateType) :: DateLoc
      save

      ! Main part of procedure
      !-----------------------
      Select Case (Task)

      Case (StartUp)

         Call CPU_Time (CPU_StartTime)

         if (IOMode == IOMode_Full) call PrintMessage(" ## ####  ## ####  ###### ##    ##
#           ", 1)
         if (IOMode == IOMode_Full) call PrintMessage("  ##   ##  ##   ##     ## ###  ###
#           ", 2)
         if (IOMode == IOMode_Full) call PrintMessage("  ##   ##  ##   ##    ##  ## ## ##
#####   ###   #### ###           ", 3)
         if (IOMode == IOMode_Full) call PrintMessage("  ######   ## ###    ##   ##    ##
#   # #   # #      #            ", 4)
         if (IOMode == IOMode_Full) call PrintMessage("  ##       ####     ##    ##    ##
#   # #   #  ###   #            ", 5)
         if (IOMode == IOMode_Full) call PrintMessage("  ##       ##  ##  ##     ##    ##
#   # #   #     #  #  #         ", 6)
         if (IOMode == IOMode_Full) call PrintMessage(" ###      ###   ## ###### ##    ##
####   ###  ####    ##          ", 7)
         if (IOMode == IOMode_Full) call PrintMessage(" ----------------------------------
#  --------------------------  ", 8)
         if (IOMode == IOMode_Full) call PrintMessage(" PRZM postprocessing
##                              ", 9)
         if (IOMode == IOMode_Full) call PrintMessage(" (c) Alterra
",10)
         if (IOMode == IOMode_Full) call PrintMessage("
",11)
         if (IOMode == IOMode_Full) call PrintMessage(" ------------------------------------
-----------------------------  ",12)

         Call InitCh (ScreenLine)
         write (ScreenLine,'(" Working directory        : ",a)') trim(WorkingDirectory)
         if (IOMode == IOMode_Full) call PrintMessage(trim(ScreenLine),19)

         DateLoc = GetDate(TimShell())
         Call InitCh (ScreenLine)
         write (ScreenLine,'(" Calculation (yyyy-mmm-dd): ",a11)') DateLoc%Date
         if (IOMode == IOMode_Full) call PrintMessage(trim(ScreenLine),20)
         if (IOMode == IOMode_Full) call SetCursorPos (0,22)

         ! Set the cursor at the top of the screen
         if (IOMode == IOMode_Full) call SetCursorPos (0,0)

      Case (Dynamic)

         DateLoc = GetDate(TimShell())
         Call InitCh (ScreenLine)
         write (ScreenLine,'(" Calculation (yyyy-mmm-dd): ",a11)') DateLoc%Date
         if (IOMode == IOMode_Full) call PrintMessage(trim(ScreenLine),20)
         if (IOMode == IOMode_Full) call SetCursorPos (0,22)
```

```
      Case (Final)

         Call CPU_Time (CPU_EndTime)
         if (CPU_EndTime < CPU_StartTime) then
            ! New day started
            CPU_Used = (86400.d0-CPU_StartTime) + CPU_EndTime
         else
            ! Within a single day
            CPU_Used = CPU_EndTime-CPU_StartTime
         end if
         Minutes = int(CPU_Used)/60
         Seconds = int(CPU_Used)-60*Minutes
         if (IOMode == IOMode_Full) Call PrintMessage (" End of PRZM postprocessing",30)
         Call InitCh (ScreenLine)
         write (ScreenLine,'(" The run time was ",i3," minutes and ",i2," seconds")') &
         Minutes,Seconds
         if (IOMode == IOMode_Full) Call PrintMessage (ScreenLine,19)
         Write (FilLog,'("* ",a)') trim(ScreenLine)

      end Select

   end subroutine ProgramHeader


!==========================================================================================
!==========================================================================================


!==========================================================================================
!==========================================================================================
```

end program PRZMpost

Appendix 6.4 FOCUS_stream metamodel, representing the Ethiopian stream scenario

Paulien Adriaanse, 17 mei 2013, versie 6

The FOCUS stream is fed by an upstream catchment of 100 ha, which is partly treated with pesticides. Runoff from this catchment flows via channels in the catchment into the 100 m FOCUS stream, which is 1 m wide and has a minimum water depth of 30 cm.

The FOCUS_PRZM model generates output on a daily basis. For the FOCUS runoff scenarios the daily fluxes were converted to hourly fluxes by distributing the daily values linearly over a number of hours. This number equals the rainfall event size divided by a constant rainfall intensity of 2 $mm.h^{-1}$, which was judged to be a representative European rainfall intensity (pers. comm. P.I. Adriaanse, WG FOCUS surface water scenarios). So, if e.g. there was 18 mm rainfall causing 4.1 mm runoff the runoff event lasts 18 mm/2 $mm.h^{-1}$ = 9 h and so, from midnight to 9 am there is 4.1 mm/9 h = 0.46 $mm.h^{-1}$ runoff. Daily rainfalls of 48 mm or more will result in runoff events lasting 24 h. These hourly values are fed into the TOXSWA model. For this purpose p2t files are created, listing these hourly fluxes: runoff fluxes ($mm.h^{-1}$) and its associated pesticide fluxes ($mg.m^{-2}.h^{-1}$), eroded soil mass fluxes ($kg.h^{-1}$) and its associated pesticide fluxes ($mg.m^{-2}.h^{-1}$) and a downward infiltration water flux at 1 m soil depth ($mm.h^{-1}$). So, the p2t file is input for the FOCUS_TOXSWA model and during the runoff event the hourly fluxes have a constant value. (An exception is the downward infiltration water flux in the p2t file, the hourly values are constant during the entire month.) These hourly fluxes are used in the calculations below.

The concentration of pesticide in the water flowing from the catchment into the FOCUS stream can be calculated by considering the water and pesticide mass fluxes that flow across the upper boundary of the 100 m FOCUS stream.

The discharge $Q_{stream,in}$ into the stream consists of a small constant base flow from the upstream catchment, the runoff water fluxes and the subsurface drainage water from the 100-ha upstream fields:

$$Q_{stream,in} = Q_{base} + 10\, A_{up}\, q_{rodr} \qquad \text{(eqn. A6.4.1)}$$

in which

$Q_{stream,in}$ = discharge across the upper boundary of the FOCUS stream ($m^3.h^{-1}$)
Q_{base} = base flow into the FOCUS stream ($m^3.h^{-1}$)
q_{rodr} = aeric volume flux of runoff water and subsurface drainage water into the channel calculated by PRZM and defined as volume flow of water per surface area of agricultural field and expressed on an hourly basis ($mm.h^{-1}$)
A_{up} = size of upstream catchment (ha)
10 = factor to convert mm*x*ha into m^3 (-)

The base flow, Q_{base}, is a constant and equals a fraction of the long-term annual total flow in a catchment. The variable q_{rodr} originates from the upstream catchment and it is an important component of the stream discharge, $Q_{stream,in}$. It consists of a highly variable surface runoff flux and a smaller, less dynamic subsurface drainage flux:

$$q_{rodr} = q_{ro,p2t} + F_{inf}\, q_{down,p2t} \qquad \text{(eqn. A6.4.2)}$$

in which

$q_{ro,p2t}$ = aeric volume flux of runoff water as calculated by PRZM originating from the agricultural fields and expressed on an hourly basis ($mm.h^{-1}$)

F_{inf} = fraction of downward aeric volume flux of water at 1 m soil depth that flows into the channel (-)

$q_{down,p2t}$ = downward infiltration aeric flux of water at 1 m soil depth as calculated by PRZM originating from the agricultural fields and expressed on an hourly basis ($mm.h^{-1}$)

For the R4 scenario F_{inf} equals 0.1 (FOCUS, 2001).

The base flow and subsurface drainage water flow are assumed to be free of pesticides, so the pesticide flux into the FOCUS stream is formed by the pesticide mass in the water running off the treated agricultural fields:

$$J_{stream,in} = 10^4 F_{tr} A_{up} J_{ro,p2t} \qquad \text{(eqn. A6.4.3)}$$

in which

$J_{stream,\,in}$ = pesticide mass flux across upper boundary of the FOCUS stream ($mg.h^{-1}$)

F_{tr} = fraction of upstream catchment treated with pesticide (-)

$J_{ro,p2t}$ = areic pesticide mass flux calculated by PRZM originating from the agricultural fields and expressed on an hourly basis ($mg.m^{-2}.h^{-1}$)

10^4 = factor to convert ha into m^2 (-)

So, the concentration in the water flowing across the upper boundary of the FOCUS stream equals

$$c_{stream,in} = \frac{J_{stream,in}}{Q_{stream,in}} = \frac{10^4 F_{tr} A_{up} J_{ro,p2t}}{Q_{base} + 10A_{up}\, q_{ro,p2t} + 10A_{up} F_{inf} q_{down,p2t}} \qquad \text{(eqn. A6.4.4)}$$

in which

$c_{stream,in}$ = concentration in water flowing across the upper boundary of the FOCUS stream ($mg.m^{-3}$)

The concentration in the runoff water, c_{ro}, is calculated as follows:

$$c_{ro} = \frac{J_{ro,p2t}}{0.001\, A_{1m2}\, q_{ro,p2t}} \qquad \text{(eqn. A6.4.5)}$$

in which

c_{ro} = concentration in water running off the treated agricultural field ($mg.m^{-3}$)

A_{1m2} = surface area of 1 m^2 (m^2)

0.001 = factor to convert m^2xmm into m^3 (-)

In the FOCUS streams of the runoff scenarios the base flow is approximately 10 $m^3.h^{-1}$; this is a constant value. This implies that q_{rodr} fluxes of 0.01 $mm.h^{-1}$ from the 100 ha upstream catchment result in a flow equal to the base flow size. For q_{rodr} fluxes of 0.1 $mm.h^{-1}$ and higher the incoming water flow is dominated by the q_{rodr} flux water, in which the runoff component dominates, as the subsurface drainage component (=fraction of downward infiltration water entering the channels in the catchment) is expected to be small[3]. So the concentration in the incoming water approximates the treatment ratio, F_{tr}, times the concentration in the runoff water originating from treated fields, e.g. if F_{tr} = 0.2, the concentration entering the FOCUS stream is five times lower than the concentration in the water running off treated fields.

In this meta model the concentration in the water flowing <u>into</u> the FOCUS stream is estimated. In the FOCUS surface water scenarios applied in the EU registration procedure peak concentration in FOCUS streams are calculated at the downstream end of the stream, and so, not at their inflow. At the downstream end of the FOCUS stream the contribution from the adjacent 1ha, treated field is taken into account. So, the spray drift deposition from this field as well as the runoff from this field is considered in the peak concentration calculated in the EU procedure. For runoff fluxes of 0.1 $mm.h^{-1}$ and higher the two procedures, i.e. the one described by Eqn. A6.4.4 and the one used in the EU registration, are expected to result in approximately the same peak concentrations in the FOCUS

[3] Later research demonstrated that the subsurface drainage flow may be substantial in some cases, so the simplification using the F_{tr} is not always correct.

streams for peaks resulting from runoff entries only. For smaller runoff fluxes we cannot predict if and how much the peak concentrations from both procedures differ from each other.

Possible improvements for the estimation of the concentration in the water flowing across the upper boundary of the stream are:

Calculation of the base flow for Ethiopian catchments (for use in the PRRP-Ethiopia project). The base flow can be calculated according to

$$Q_{base} = F_{MAM7} P_{excess} A_{up} \frac{10}{365} \qquad \text{(eqn. A6.4.6)}$$

in which

F_{MAM7} = *MAM7* fraction of the average, long-term discharge of the upstream catchment (this discharge equals $P_{excess}\ A_{up}$) (-),

P_{excess} = the long-term recharge equalling the average yearly precipitation excess on the catchment, i.e. precipitation - evaporation, during suitable months in Ethiopia ($mm.year^{-1}$) and

10/365 = factor to convert mm*x*ha*x*year^{-1} into $m^3.d^{-1}$.

The *MAM7* fraction can be specified for soil hydrological classes as defined in the Hydrology Of Soil Types (HOST) study (Boorman *et al.,* 1995) into which the catchments need to be classified. This implies that the base flow is a *MAM7* flow that corresponds to the annual average minimum daily flow within any 7-day period in the catchment (for more details see FOCUS, 2001 and Adriaanse and Boesten, in prep.).

More realistic distribution in time of runoff water and pesticide mass fluxes. The current FOCUS procedure distributes the daily runoff water and pesticide mass fluxes linearly over a number of hours. In reality water fluxes will first increase, possibly be approximately constant for some time and next decrease again. Pesticide mass fluxes are expected to be such that the pesticide concentration in the runoff water will steadily decrease from the moment runoff starts.

Ranking of concentrations in the stream

The output of step ii) are hourly values of $c_{stream,in}$ (concentration in water flowing into the FOCUS stream in $mg.m^{-3}$) over the number of years in the *.zst file (n_{yzst}).

Percentiles are calculated for the following protection goals:

The protection goal is defined as: for x % of all years we want the stream water to fulfil the required standard. The percentile is selected from the maximum $c_{stream,in}$ concentration of the 33 yearly, maximum values.

For protection of drinking water produced from surface water we ain the overall 99th –ile probability of occurrence in time and space of the $c_{stream,in}$ concentrations of the water flowing into the FOCUS stream of the annual maximum concentration. For protection of the aquatic ecosystem we aim the overall 90th-ile probability of occurrence in time and space of the annual maximum concentrations.

P1: the aimed 99th percentile probability of occurrence in time and space of the yearly maximum incoming concentration in a stream for 33 years for the protection of drinking water produced from surface water.
P2: the aimed 90th percentile probability of occurrence in time and space of the yearly maximum incoming concentration in a stream for 33 years for the protection of aquatic ecosystems in surface water.

The aimed overall 99th percentile in time and space corresponds to a 95.5th temporal percentile and the aimed overall 90th percentile in time and space corresponds to a 83.3rd temporal percentile (see Figure F1 in section 3.3). The post processing program calculates the temporal percentiles of the yearly maximum incoming concentration in a stream.

The post-processing program to calculate the aimed overall 99th and 90th percentile of the annual maximum incoming concentration in a stream for 33 years of output PRZM metamodel (described above) ranks only the incoming concentration in the stream. The aimed overall 99th and 90th percentile of the annual maximum incoming concentration in the stream is calculated and written together with its associated other output of the PRZM metamodel to the output file of the post-processing program (postproc.primet).

The method for ranking and calculation of the percentiles is described below.

The cumulative percentile (P_{cum}) is calculated as follows:

$$P_{cum} = 100\% \ \frac{(i-0.5)}{N} \qquad \text{(eqn. A6.4.7)}$$

where *i* is the rank number of the individual observation and *N* is the number of ranked observations. Table A.6.4.1 below shows an example of the calculation of P_{cum} for 33 values of observations.

Table A.6.4.1
Example of calculating the cumulative percentile (P_{cum}) for 33 observations.

i	P_{cum} (%)
1	1.5
2	4.5
3	7.6
4	10.6
5	13.6
6	16.7
7	19.7
8	22.7
9	25.8
10	28.8
11	31.8
12	34.8
13	37.9
14	40.9
15	43.9
16	47.0
17	50.0
18	53.0
19	56.1
20	59.1
21	62.1
22	65.2
23	68.2
24	71.2
25	74.2
26	77.3
27	80.3
28	83.3
29	86.4
30	89.4
31	92.4
32	95.5
33	98.5

For Ethiopia calculations are done for 33 years and the maximum concentrations per year are ranked.

The aimed 99th overall percentile corresponds to a temporal 95.5th percentile and this is the second highest value (*i* = 32 in Table A6.4.1.).

The aimed 90th overall percentile corresponds to a temporal 83.3rd percentile and this is the sixth highest value (*i* = 28 in Table A6.4.1.).

Appendix 6.5 Post-processing program to calculate the aimed overall 99th and 90th percentile concentrations for the Ethiopian ponds for 33 years of FOCUS_TOXSWA output

The protection goal is defined as follows:
In x percentile of the 33 yr simulation period we want the pond water to fulfil the required standard. So, the population to rank is the annual maximum pond concentration of 33 years.

Simulation for the Ethiopian pond are done with the TOXSWA model and daily output (OptDelTimPrn is 'Day' in the *.txw TOXSWA input file) of the total concentration in the water averaged over the day (g/m3; ConSysWatLay in the *.out file) and the concentration dissolved in water, at end of the day (g/m3; ConLiqWatLayCur in the *.out file) are written to an output file.

The post-processing program to calculate the aimed overall 99th and 90th percentile annual maximum concentrations for the Ethiopian ponds for 33 years of FOCUS_TOXSWA output ranks only the concentration dissolved in water, at end of the day (g/m3; ConLiqWatLayCur in the *.out file). The aimed overall 99th and 90th percentile of the concentration dissolved in water is calculated and written together with its associated total concentration in water averaged over the day to the output file of the post-processing program (primet.toxswa).

The aimed overall 99th percentile in time and space corresponds to a 95.5th temporal percentile and the aimed overall 90th percentile in time and space corresponds to a 83.3rd temporal percentile. The post processing program calculates the temporal percentiles of the yearly maximum incoming concentration dissolved in water, at end of the day.

The method for ranking and calculation of the temporal percentiles is described below.

The cumulative percentile (P_{cum}) is calculated as follows:

$$P_{cum} = 100\% \frac{(i-0.5)}{N} \qquad \text{(eqn. A6.5.1)}$$

where *i* is the rank number of the individual observation and *N* is the number of ranked observations.

Table A.6.5.1 below shows an example of the calculation of P_{cum} for 33 values of observations.

Table A6.5.1

Example of calculating the cumulative percentile (P_{cum}) for 33 observations

i	P_{cum} (%)
1	1.5
2	4.5
3	7.6
4	10.6
5	13.6
6	16.7
7	19.7
8	22.7
9	25.8
10	28.8
11	31.8
12	34.8
13	37.9
14	40.9
15	43.9
16	47.0
17	50.0
18	53.0
19	56.1
20	59.1
21	62.1
22	65.2
23	68.2
24	71.2
25	74.2
26	77.3
27	80.3
28	83.3
29	86.4
30	89.4
31	92.4
32	95.5
33	98.5

For Ethiopia calculations are done for 33 years and the maximum concentrations dissolved in water per year are ranked.

The aimed 99th overall percentiles for grids 373 and 217 correspond to a temporal 95.5th percentile and this is the second highest value (*i* = 32 in Table A.6.5.1.).

The aimed 90th overall percentiles for grids 373 and 217 correspond to a temporal 83.3rd percentile and this is the sixth highest value (*i* = 28 in Table A.6.5.1.).

The software program in FORTRAN consists of four modules:
- Module_TOXSWApost
- TOXSWApost
- sishell_2
- vislfor

The FORTRAN code of modules Module_TOXSWApost and TOXSWApost are given below. The FORTRAN codes of modules shishell_2 and vislfor are not given, because these are organising modules and therefore not containing any relevant calculations or operations.

module TOXSWA_post

```
!===========================================================================================
!
!===========================================================================================

   use SiShell
   use CompilerSpecific ! Module containing compiler specific statements

   implicit none

   ! Variables with constant value
   !-------------------------------

   double precision, parameter :: MinValue = 1.0d-10

contains

!===========================================================================================
!===========================================================================================

   subroutine ReadOutputTOXSWA ()
   ! Read status of Zts-File
   !========================================================================================

      ! Declaration of local variables
      !-------------------------------
      integer :: IOS
      character (len=LineLength) :: Buffer
      character (len=LineLength) :: RunName,InFile
      character (len=LineLength) :: String,MonthID
      double precision, dimension(:), pointer :: Values
      integer :: YearNew,YearOld,Day
      double precision :: Value
      type (TableType) :: Table_Daily,Table_Yearly
      integer :: Evt,NumEvt_Daily,NumEvt_Yearly

      double precision, parameter :: Percentile99 = 95.4545454545d0
      double precision, parameter :: Percentile90 = 83.3333333333d0

      save

      ! Main part of procedure
      !-------------------------
      Call InitCh (InFile)
      Call InitCh (RunName)
      RunName = GetRun()
      InFile  = trim(WorkingDirectory)//'/'//trim(RunName)//'.out'

      ! Get NumEvt (and number of years)
      call RewindAndSkipHeader()

      YearOld = -99
      NumEvt_Daily  = 0
      NumEvt_Yearly = 0
      do

         read (FilInp,'(a)',IOStat=IOS) Buffer

         if (IOS /= 0) then
            exit
         end if

         call SplitString (Buffer)

         if (index(Words%Word(3),'ConLiqWatLayCur')  .ne. 0) then

            NumEvt_Daily = NumEvt_Daily + 1

            String = Words%Word(2)

            read(String(8:11),*) YearNew
            read(String(1:2),*)  Day
            read(String(4:6),*)  MonthID

            if (Day .eq. 1 .and. trim(MonthID) .eq. 'Jan') then
               YearNew = YearNew - 1
            end if

            if (YearNew .ne. YearOld) then
               NumEvt_Yearly = NumEvt_Yearly + 1
               YearOld      = YearNew
            end if
```

```
   end if


end do

! Create tables
call Create(Table_Daily,4,NumEvt_Daily)
call Create(Table_Yearly,4,NumEvt_Yearly)
do Evt = 1,NumEvt_Yearly
   Table_Yearly%X(Evt) = -1.d0
end do

! Fill tables Daily
call RewindAndSkipHeader()
Evt = 0
do

   read (FilInp,'(a)',IOStat=IOS) Buffer

   if (IOS /= 0) exit

   call SplitString (Buffer)

   if (index(Words%Word(3),'ConLiqWatLayCur')  .ne. 0) then

      Evt = Evt + 1

      read(Words%Word(4),*) Value
      Value = Value * 1.d3

      Table_Daily%Z(Evt) = Words%Word(2)
      Table_Daily%X(Evt) = Value
      read(Words%Word(1),*) Table_Daily%Y(1,Evt)

      ! Add 'ConSysWatLay' to the same Evt
      backspace(FilInp)
      backspace(FilInp)

      read (FilInp,'(a)',IOStat=IOS) Buffer
      call SplitString (Buffer)

      if (index(Words%Word(3),'ConSysWatLay')  .eq. 0) then
         Error%Code = -1
         write ( Error%m1,'("Error while reading file ",a)') trim(InFile)
         write ( Error%m2,'("Error expected record with ConSysWatLay")')
         Call PrintError
      end if

      read(Words%Word(4),*) Value
      Value = Value * 1.d3

      Table_Daily%Y(2,Evt) = Value

      read (FilInp,*)

   end if

end do

! Fill tables Yearly
call RewindAndSkipHeader()

YearOld = -99
Evt = 0
do

   read (FilInp,'(a)',IOStat=IOS) Buffer

   if (IOS /= 0) exit

   call SplitString (Buffer)

   if (index(Words%Word(3),'ConLiqWatLayCur')  .ne. 0) then

      ! Get Evt of year
      String = Words%Word(2)
      read(String(8:11),*) YearNew
      read(String(1:2),*)  Day
      read(String(4:6),*)  MonthID

      if (Day .eq. 1 .and. trim(MonthID) .eq. 'Jan') then
```

```
            YearNew = YearNew - 1
         end if

         if (YearNew .ne. YearOld) then
            Evt = Evt + 1
            YearOld = YearNew
         end if

         read(Words%Word(4),*) Value
         Value = Value * 1.d3

         if (Value .gt. Table_Yearly%X(Evt)) then

            Table_Yearly%Z(Evt) = Words%Word(2)
            Table_Yearly%X(Evt) = Value
            read(Words%Word(1),*) Table_Yearly%Y(1,Evt)

            ! Add 'ConSysWatLay' to the same Evt
            backspace(FilInp)
            backspace(FilInp)

            read (FilInp,'(a)',IOStat=IOS) Buffer
            call SplitString (Buffer)

            if (index(Words%Word(3),'ConSysWatLay')  .eq. 0) then
               Error%Code = -1
               write ( Error%m1,'("Error while reading file ",a)') trim(InFile)
               write ( Error%m2,'("Error expected record with ConSysWatLay")')
               Call PrintError
            end if

            read(Words%Word(4),*) Value
            Value = Value * 1.d3

            Table_Yearly%Y(2,Evt) = Value

            read (FilInp,*)

         end if

      end if

   end do

   ! Order tables
   call OrderTable(Table_Daily,'increase')
   call OrderTable(Table_Yearly,'increase')

   do Evt = 1,NumEvt_Yearly
      Table_Yearly%Y(3,Evt) = GetPrcnt(Evt,NumEvt_Yearly)
   end do

   write(FilOut,'("* PRIMET-file: ",a)') trim(InFile)
   write(FilOut,'("*")')
   write(FilOut,'("* The aimed 99th overall percentile (corresponding to a temporal
95.5th percentile) of the annual maximum")')
   write(FilOut,'("* concentration dissolved in water at the end of the day of the
temporary pond of the scenarios 373 and")')
   write(FilOut,'("* 217 for the protection of drinking water produced from surface
water")')
   write(FilOut,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=Percentile99,Values=Table_Yearly%X)
   if (GetPrcnt(NumEvt_Yearly,NumEvt_Yearly) .lt. Percentile99) then
      write(FilOut,'("WARNING: There are insufficient runoff events in this simulation to
determine a 99th-ile probability of occurrence (in time)")')
      write(FilOut,'("WARNING: therefore the highest probability that can be calculated
is displayed (",E15.4,"th-ile)")') GetPrcnt(NumEvt_Yearly,NumEvt_Yearly)
   end if
   write(FilOut,'("*")')
   write(FilOut,'("* The aimed 90th overall percentile (corresponding to a temporal
83.3rd percentile) of the annual maximum")')
   write(FilOut,'("* concentration dissolved in water at the end of the day of the
temporary pond of the scenarios 373 and")')
   write(FilOut,'("* 217 for the protection of the aquatic ecosystem in surface water")')
   write(FilOut,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=Percentile90,Values=Table_Yearly%X)
   if (GetPrcnt(NumEvt_Yearly,NumEvt_Yearly) .lt. Percentile90) then
      write(FilOut,'("WARNING: There are insufficient runoff events in this simulation to
determine a 90th-ile probability of occurrence (in time)")')
      write(FilOut,'("WARNING: therefore the highest probability that can be calculated
is displayed (",E15.4,"th-ile)")') GetPrcnt(NumEvt_Yearly,NumEvt_Yearly)
   end if
```

```
      write(FilOut,'("*")')

      allocate(Values(NumEvt_Yearly))
      do Evt = 1,NumEvt_Yearly
         Values(Evt) = Table_Yearly%Y(2,Evt)
      end do

      write(FilOut,'("* Total concentration in water of the temporary pond averaged over the
day on the same day as the aimed")')
      write(FilOut,'("* overall 99th percentile of the annual maximum concentration
dissolved in water of the temporary pond at")')
      write(FilOut,'("* the end of the day of the scenarios 373 and 217 for the protection
of drinking water produced from")')
      write(FilOut,'("* surface water")')
      write(FilOut,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=Percentile99,Values=Values)
      if (GetPrcnt(NumEvt_Yearly,NumEvt_Yearly) .lt. Percentile99) then
         write(FilOut,'("WARNING: There are insufficient runoff events in this simulation to
determine a 99th-ile probability of occurrence (in time)")')
         write(FilOut,'("WARNING: therefore the highest probability that can be calculated
is displayed (",E15.4,"th-ile)")') GetPrcnt(NumEvt_Yearly,NumEvt_Yearly)
      end if
      write(FilOut,'("*")')

      write(FilOut,'("* 90th percentile of the total concentration in water of the temporary
pond averaged over the day on the")')
      write(FilOut,'("* same day as the aimed overall 90th percentile of the annual maximum
concentration dissolved in water of")')
      write(FilOut,'("* the temporary pond at the end of the day of the scenarios 373 and
217 for the protection of the aquatic")')
      write(FilOut,'("* ecosystem in surface water")')
      write(FilOut,'(" ",E15.4," (mg.m-3)")')
GetValXPrcnt(xPercnt=Percentile90,Values=Values)
      if (GetPrcnt(NumEvt_Yearly,NumEvt_Yearly) .lt. Percentile90) then
         write(FilOut,'("WARNING: There are insufficient runoff events in this simulation to
determine a 90th-ile probability of occurrence (in time)")')
         write(FilOut,'("WARNING: therefore the highest probability that can be calculated
is displayed (",E15.4,"th-ile)")') GetPrcnt(NumEvt_Yearly,NumEvt_Yearly)
      end if
      write(FilOut,'("*")')

      write(FilOut,'("* The annual maximum concentration dissolved in water of the temporary
pond at the end of the day")')
      write(FilOut,'("* (Cwatdis_pond) from large to small:")')
      write(FilOut,'("* Note that the concentration dissolved (Cwatdis_pond) given in the
table below at 02-Jan-1903-00:00 is")')
      write(FilOut,'("* the concentration at the end of 01-Jan-1903 and the total
concentration (Cwattot_pond) given in the")')
      write(FilOut,'("* table below at 02-Jan-1903-00:00 is the concentration averaged over
01-Jan-1903")')
      write(FilOut,'("* Legend to columns:")')
      write(FilOut,'("*               Date DayFromStart     Percentile   Cwatdis_pond
Cwattot_pond")')
      write(FilOut,'("*  dd-mmm-yyyy-hh:mm          (d)            (%)       (mg.m-3)
(mg.m-3)")')

      do Evt = NumEvt_Yearly,1,-1

         write(String,'(a14,"-00:00",f13.3,f15.1,2E15.6)') trim(Table_Yearly%Z(Evt)),
Table_Yearly%Y(1,Evt),Table_Yearly%Y(3,Evt),Table_Yearly%X(Evt),Table_Yearly%Y(2,Evt)

         write(FilOut,'(a)') trim(String)

      end do
      write(FilOut,'("*")')

      write(FilOut,'("* All concentrations dissolved in water of the temporary pond at the
end of the day (Cwatdis_pond) from")')
      write(FilOut,'("* large to small:")')
      write(FilOut,'("* Legend to columns:")')
      write(FilOut,'("*               Date DayFromStart   Cwatdis_pond   Cwattot_pond")')
      write(FilOut,'("*  dd-mmm-yyyy-hh:mm          (d)       (mg.m-3)       (mg.m-3)")')
      do Evt = NumEvt_Daily,1,-1

         write(String,'(a14,"-00:00",f13.3,2E15.6)') trim(Table_Daily%Z(Evt)),
Table_Daily%Y(1,Evt),Table_Daily%X(Evt),Table_Daily%Y(2,Evt)

         write(FilOut,'(a)') trim(String)

      end do
      write(FilOut,'("*")')
```

```
      ! Put table in chronological order
      do Evt = 1,NumEvt_Daily

         Table_Daily%Y(4,Evt) = Table_Daily%X(Evt)
         Table_Daily%X(Evt)   = Table_Daily%Y(1,Evt)

      end do

      call OrderTable(Table_Daily,'increase')

      write(FilOut,'("* All concentrations dissolved in water of the temporary pond at the
end of the day pond (Cwatdis_pond)")')
      write(FilOut,'("* in chronological order:")')
      write(FilOut,'("* Note that the concentration dissolved (Cwatdis_pond) given in the
table below  at 02-Jan-1903-00:00 is")')
      write(FilOut,'("* the concentration at the end of 01-Jan-1903 and the total
concentration (Cwattot_pond) given in the")')
      write(FilOut,'("* table below at 02-Jan-1903-00:00 is the concentration averaged over
01-Jan-1903")')
      write(FilOut,'("* Legend to columns:")')
      write(FilOut,'("*              Date DayFromStart   Cwatdis_pond   Cwattot_pond")')
      write(FilOut,'("*  dd-mmm-yyyy-hh:mm          (d)       (mg.m-3)       (mg.m-3)")')
      do Evt = 1,NumEvt_Daily

         write(String,'(a14,"-00:00",f13.3,2E15.6)') trim(Table_Daily%Z(Evt)),
Table_Daily%X(Evt),Table_Daily%Y(4,Evt),Table_Daily%Y(2,Evt)

         write(FilOut,'(a)') trim(String)

      end do

   end subroutine ReadOutputTOXSWA

!==========================================================================================
!==========================================================================================

   subroutine RewindAndSkipHeader()

      implicit none

      integer :: IOS
      integer :: Rec
      character (len=LineLength) :: Buffer
      character (len=LineLength) :: RunName,InFile
      logical :: First = .true.
      save

      ! Initial part of procedure
      !-------------------------
      if (First) then

         First = .false.

         Call InitCh (InFile)
         Call InitCh (RunName)
         RunName = GetRun()
         InFile  = trim(WorkingDirectory)//'/'//trim(RunName)//'.out'

      end if

      ! Main part of procedure
      !-------------------------
      rewind(FilInp)
      do Rec = 1,17
         read (FilInp,'(a)',IOStat=IOS) Buffer
         if (IOS /= 0) then
            ! Error condition - abort program execution
            Error%Code = -1
            write ( Error%m1,'("Error while reading file ",a)') trim(InFile)
            write ( Error%m2,'("Error reading line ",i1)')      Rec
            Call PrintError
         end if
      end do

   end subroutine

!==========================================================================================
!==========================================================================================
```

end module TOXSWA_post

program TOXSWApost

```
!=========================================================================================
!
! Postprocessing TOXSWA
!
!=========================================================================================

   use CompilerSpecific         ! Compiler specific statements
   use SiShell                  ! General routines ('Sishell')
   use TOXSWA_post              ! Module TOXSWA postprocessor



   ! Declaration of local variables
   !-------------------------------
   implicit none
   character (len=LineLength) :: ScreenLine
   character (len=LineLength) :: LogFile,ErrFile,RunName

   save

   ! Initial part of program
   !------------------------

   Call Openfiles ()
   Call SetModelStamp ()

   Call ProgramHeader(StartUp)

   ! Main part of porgramme
   !-----------------------
   Call ReadOutputTOXSWA()

   ! Closing programme with error code zero
   !---------------------------------------
   Call ProgramHeader (Final)

   Call CloseAllFiles (0)

contains

!=========================================================================================
!=========================================================================================

   subroutine Openfiles
   ! creates and opens the files used by the Substance emission model
   !======================================================================================

      ! Declaration of local variables
      !-------------------------------
      implicit none
      character (len=LineLength) :: InFile,OutFile
      integer :: IOS

      ! Main part of procedure
      !-----------------------

      ! Create Memory Space for the Words variable
      Words%Allocated = .false.
      Call Create (Words,NumWords)

      Call InitCh (RunName)
      RunName = GetRun()


      ! Construct the file names (add the extensions)
      InFile  = trim(WorkingDirectory)//'/'//trim(RunName)//'.out'
      OutFile = trim(WorkingDirectory)//'/'//trim(RunName)//'_primet.toxswa'
      LogFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.log'
      ErrFile = trim(WorkingDirectory)//'/'//trim(RunName)//'.err'


      ! Open the input file
      Open (FilInp,file=trim(InFile),status='old',IOStat=IOS)
      if (IOS /= 0) then
         ! Error condition - abort program execution
         Error%Code = -1
         write ( Error%m1,'("Cannot find file ",a," with status old")') trim(InFile)
         stop 'Illegal run id - no error file generated'
```

```
      end if
      rewind (FilInp)


      IOMode = IOMode_Full
      do
         Call InitCh (ScreenLine)
         read (FilInp,'(a)',end=670) ScreenLine
         if (Index(ScreenLine,"IOMode_StdOut") /= 0) then
            IOMode = IOMode_StdOut
         end if
      end do


      ! Open all files
670   rewind (FilInp)
      Call OpenAfterDelete (FilErr,trim(ErrFile))
      Call OpenAfterDelete (FilOut,trim(OutFile))
      Call OpenAfterDelete (FilLog,trim(LogFile))

      ! Get the start time, end-time and interval of the output
      !Call RdTimers ()


   end subroutine Openfiles

!=========================================================================================
!=========================================================================================

   subroutine SetModelStamp ()
   ! Set ModelStamp.
   ! Get ModelType A, B or C. ModelType 'A' combined with OptPots is not possible.
   !======================================================================================

      implicit none

      ! Main part of procedure
      !-----------------------
      Model%Date = '25-Jun-2013'
      Model%ModelVersion = 'v1.01'

   end subroutine SetModelStamp

!=========================================================================================
!=========================================================================================

   subroutine ProgramHeader (Task)
   ! Clears the screen, prints the Substrate header and sets the cursor position
   !======================================================================================

      integer, intent(in) :: Task
      integer :: Minutes,Seconds,CPU_Used
      character (len=130) :: ScreenLine
      save

      ! Main part of procedure
      !-----------------------
      Select Case (Task)

      Case (StartUp)

         Call CPU_Time (CPU_StartTime)

         if (IOMode == IOmode_Full) Call PrintMessage(" ###### #####  ##   ##  ##### ##   ##
#####                      #    ",1)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##  ##   ## ##   ## ##     ##   ##
##   ##                     #    ",2)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##  ##   ##  ## ##  ##     ##   ##
##   ## #####   ###   #### ###   ",3)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##  ##   ##   ###    ####  ##   ##
##   ##  #   # #   # #      #    ",4)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##  ##   ##  ## ##      ## ## # ##
#######  #   # #   #  ###   #    ",5)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##  ##   ## ##   ##     ## ## # ##
##   ##  #   # #   #     #  #  # ",6)
         if (IOMode == IOmode_Full) Call PrintMessage("   ##   #####  ##   ## #####   ## ##
##   ##  ####   ###  ####    ##  ",7)
         if (IOMode == IOMode_Full) call PrintMessage(" ------------------------------------
--------  #  -------------------- ",8)
         if (IOMode == IOMode_Full) call PrintMessage(" TOXSWA postprocessing
##                       ",9)
```

```
         if (IOMode == IOMode_Full) call PrintMessage(" (c) Alterra
",10)
         if (IOMode == IOMode_Full) call PrintMessage("
",11)
         if (IOMode == IOMode_Full) call PrintMessage(" -----------------------------------
-------------------------------- ",12)

         Call InitCh (ScreenLine)
         write (ScreenLine,'(" Working directory        : ",a)') trim(WorkingDirectory)
         if (IOMode == IOMode_Full) call PrintMessage(trim(ScreenLine),19)

         ! Set the cursor at the top of the screen
         if (IOMode == IOMode_Full) call SetCursorPos (0,0)

      Case (Final)

         Call CPU_Time (CPU_EndTime)
         if (CPU_EndTime < CPU_StartTime) then
            ! New day started
            CPU_Used = (86400.d0-CPU_StartTime) + CPU_EndTime
         else
            ! Within a single day
            CPU_Used = CPU_EndTime-CPU_StartTime
         end if
         Minutes = int(CPU_Used)/60
         Seconds = int(CPU_Used)-60*Minutes
         if (IOMode == IOMode_Full) Call PrintMessage (" End of TOXSWA postprocessing",30)
         Call InitCh (ScreenLine)
         write (ScreenLine,'(" The run time was ",i3," minutes and ",i2," seconds")') &
         Minutes,Seconds
         if (IOMode == IOMode_Full) Call PrintMessage (ScreenLine,19)
         Write (FilLog,'("* ",a)') trim(ScreenLine)

      end Select

   end subroutine ProgramHeader


!==========================================================================================
!==========================================================================================


!==========================================================================================
!==========================================================================================
```

end program TOXSWApost

Appendix 7.1 Procedure to convert the 80th temporal percentile leaching concentrations of the EuroPEARL metamodel into the 99th temporal percentile concentrations

In order to calculate the correction factor needed to convert leaching concentration given by the EuroPEARL metamodel, so, based upon the 80th temporal percentile, into a leaching concentration representing the 99th temporal percentile required, we compared 80th and 97.5th percentile leaching concentrations resulting from simulations with the FOCUS groundwater scenarios in the PEARL model. We therefore applied FOCUS GW substance D (FOCUS, 2001) in Maize and used the same application scheme as used by Tiktak *et al*. (2006; pp 1214 and 1216) for fitting the regression parameters of the metamodel. The application scheme used is an annual application of 1 kg/ha to the soil surface 1 day after emergence.

Results

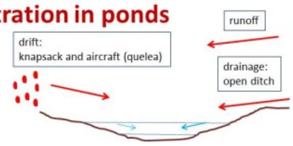
EU FOCUS scenario	Leaching concentration (μg L^{-1})		97.5th/80th
	80th percentile	97.5th percentile	
Chateaudun	0.138	0.443	3.2
Hamburg	0.435	1.692	3.9
Kremsmuenster	0.258	0.749	2.9
Okehampton	0.715	1.491	2.1
Piacenza	0.212	0.710	3.3
Porto	0.036	0.082	2.3
Sevilla	0.0005	0.001	2.0
Thiva	0.018	0.112	6.2

For this particular case the 97.5th percentile leaching concentration is on average about a factor 3 higher than the 80th percentile leaching concentration. The correction factor of 3 will therefore be applied on the results of the metamodel used for Ethiopia.

We realize that this is a very simplified procedure to convert 80th percentile leaching concentrations into 99th percentile leaching concentrations because i) different compound properties may result in different correction factors, ii) vulnerability of the EU FOCUS scenarios might differ and iii) the EU FOCUS scenarios differ from the Ethiopian scenarios.

Appendix 7.2 Back-of-the-envelope calculations demonstrating that runoff is the main vulnerability driver for the concentrations in the Ethiopian stream water and pond water

Drivers for concentration in ponds



Relevant entry routes:

- Spray drift deposition
- Runoff (include furrows draining runoff water)
- ~~Drainage channels~~ (draining excess groundwater)

Surface water: (spray drift)

Temporary pond, back-of-envelope calculation:

Assume application equals 1 kg/ha:
20*20 m wide, 1 m deep;
5% spray drift over strip of 10 m (10-0%), i.e.
0.05*100 mg/m^2 in 1 m depth corresponds to 5 ug/L
diluted by factor 2, so pond concentration is 2.5 ug/L

100*100 m, 1 m deep;
5% spray drift over strip of 100 m, i.e.
5 ug/L diluted by factor 5, so pond concentration is 1 ug/L

(# what if overspray ?
100 mg/m^2 in 1 m depth corresponds to 0.1 mg/L,
so 100 ug/L)

Surface water: (runoff)

Temporary pond, back-of-envelope calculation:

Assume application equals 1 kg/ha and 10 ha treated around:
20*20 m wide, 1 m deep;
4 mm runoff (20 mm rain) with 500 ug/L (**tracer,** R4 FOCUS scen)
pond becomes 20 * 40 m (1 m deep) and concentration in runoff is
diluted by factor 2, so pond concentration is 250 ug/L

100*100 m, 1 m deep;
4 mm runoff (20 mm rain) with 500 ug/L (tracer)
pond becomes 100 * 104 m) and
concentration in pond becomes ~20 ug/L

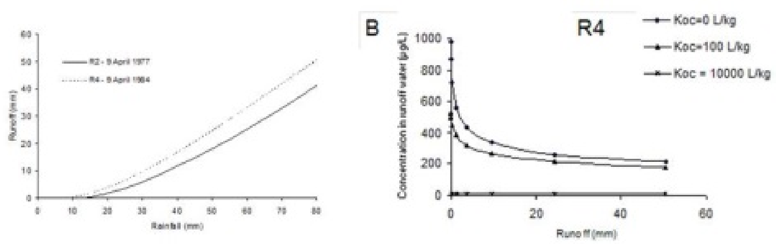
100*100 m, 1 m deep, 100 ha treated around;
4 mm runoff (20 mm rain) with 500 ug/L (tracer)
pond becomes 100 * 140 m and
concentration in pond becomes ~150 ug/L

so, runoff entries may be more important than spray drift entries (not overspray) !

Runoff estimation

Estimation of runoff entries (Adr. et al, in prep):

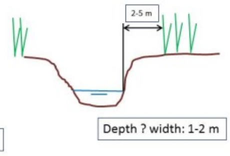
Use FOCUS R4 stream scenario:
highest potential for runoff of 4 EU runoff scenarios
(Roujan, France, soil group C, low oc (0.6%), high RCN (maize, fallow, 91))
simulations for runoff=f(daily rain), 3 compounds, 1 kg/ha
20 mm rain -> 5 mm runoff with 500 ug/L (tracer)
50 mm rain -> 30 mm runoff with 200 ug/L (tracer)

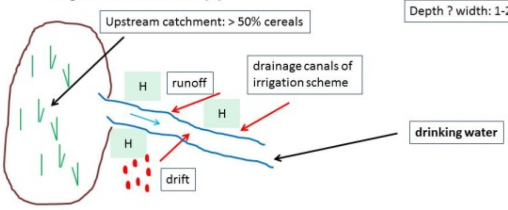


Protection goals: surface water

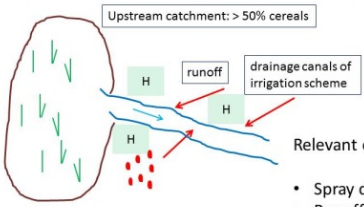
3. Stream/small rivers

- Drinking water (villages) until depleted (just before Kiremt, horticulture still done)
- Drinking water for cattle
- Irrigation of horticulture (H)





Drivers for concentration in streams



Relevant entry routes:

- Spray drift deposition
- Runoff (include furrows draining runoff water)
- ~~Drainage channels (draining excess groundwater)~~

Surface water: (spray drift)

Stream/small river, back-of-envelope calculation:

Assume application equals 1 kg/ha :

2 m wide, 0.50 m deep;

5% spray drift, i.e. 0.05*100 mg/m^2 in 0.5 m water depth corresponds to 10 ug/L

(# what if overspray ?

100 mg/m^2 in 0.5 m depth corresponds to 0.2 mg/L, so 200 ug/L)

Surface water: (runoff)

Stream/small river, back-of-envelope calculation:

Assume all stream water replaced by runoff :

4 mm runoff (20 mm rain) with 500 ug/L (**tracer,** R4 FOCUS scen)

30 mm runoff (50 mm rain) with 200 ug/L (**tracer**)

N.B. contributing area is 100% treated !

so, also in stream: runoff entries may be more important than spray drift entries (not overspray) !

Surface water: conclusion on drivers

- These calculations show that for both temporary pond and stream/small river **runoff** is a more important entry route than spray drift
- So, in designing the exposure scenario we should focus more on the runoff entry route

N.B. PRZM calculates sheet runoff flow, not via gullies !

Appendix 8.1 Relevant grids for Alluvial aquifers at Rift Valley margins and in lowlands

Protection goal 3 (Alluvial aquifers at Rift Valley margins and in lowlands) is only found in areas with specific geological deposits (Tertiary and younger sediments and Late Tertiary volcanics). They are located within the red circles of Figure A8.1.1.

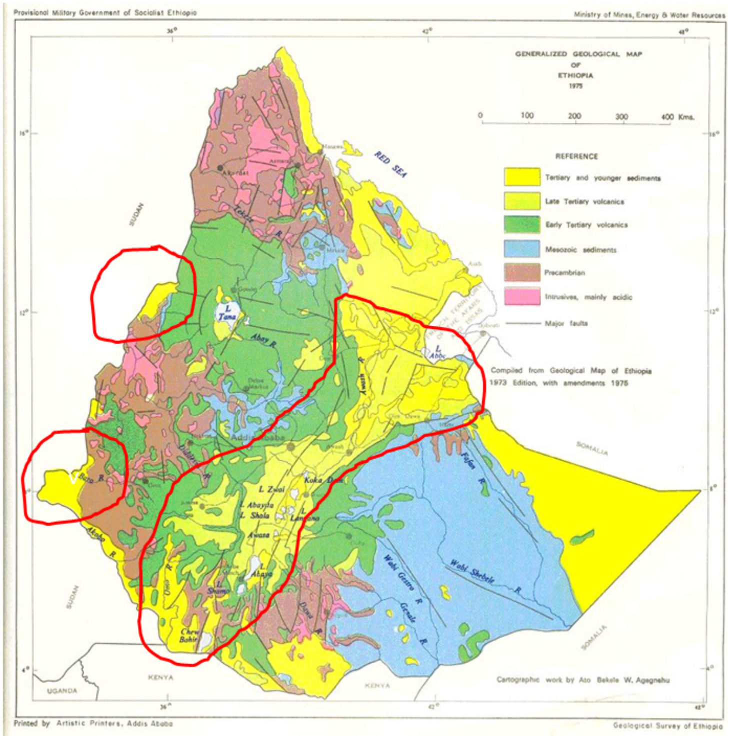


Figure A8.1.1 *Location of the area of occurrence of protection goal 3 indicated by the Ethiopian experts by red circles on the geological map of Ethiopia: Tertiary and younger sediments and Late Tertiary volcanics*

The grids relevant for protection goals 3a and 3b were selected manually using Figures A8.1.1 and A8.1.2. A rather wide selection was made. The grids selected are given in Table A8.1.1. Candidate grid cells that are less relevant for protection goals 3a and 3b were discarded during the last step in the scenario selection procedure where the Ethiopian partners used their expert judgement to indicate suitable grids for the final scenario locations.

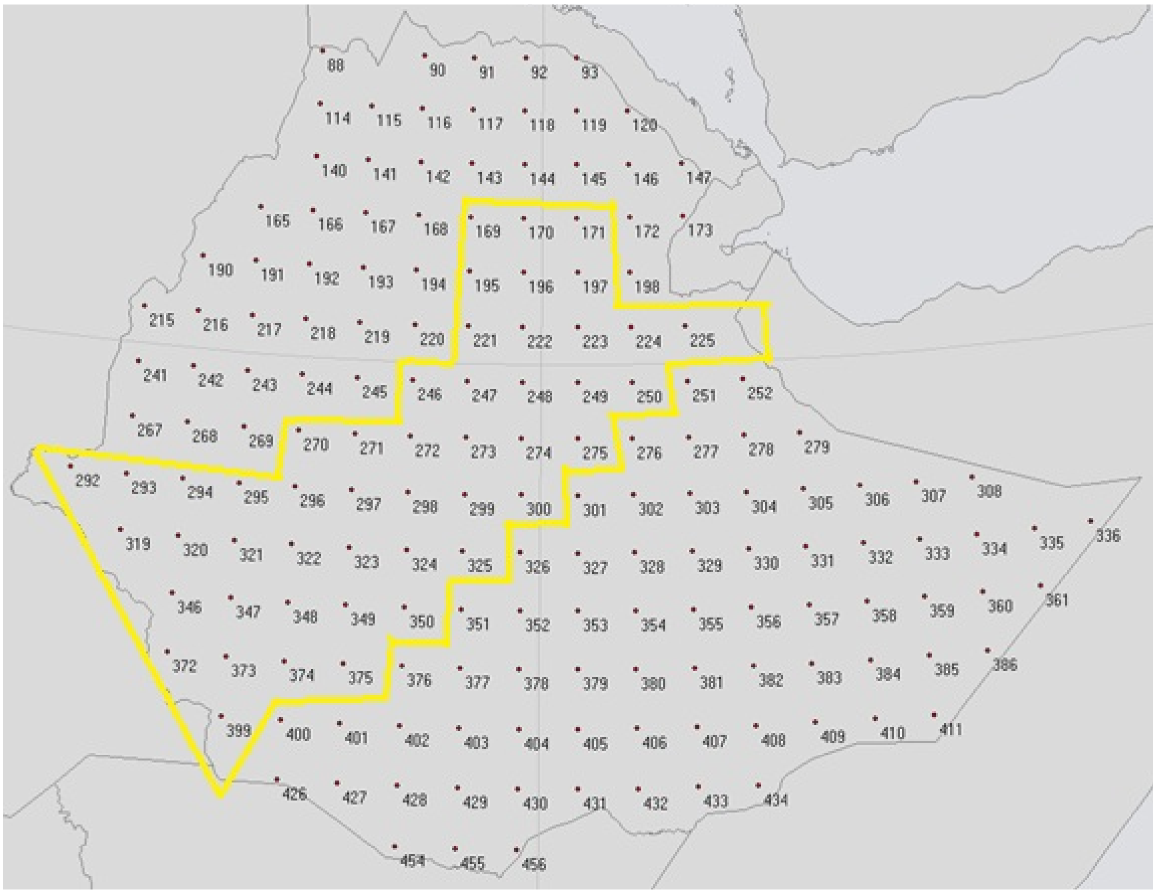


Figure A8.1.2 *Overview of the locations of the 80x80 km grid cells. Each dot represents the centre of the corresponding grid. The grids within the yellow area are the grids selected to be relevant for protection goals 3a and 3b.*

Table A8.1.1

The grids relevant for protection goals 3a and 3b.

138*	163*	164*	169	170	171	195	196	197	221
222	223	224	225	246	247	248	249	250	270
271	272	273	274	275	290*	291*	295	296	297
298	299	300	316*	317*	320	321	322	323	324
325	345	346	347	348	349	350	371	372	373
374	375	398*	399	425*					

*Grids are not shown in Figure A8.1.2.

Appendix 8.2 Candidate locations for the three groundwater protection goals

Groundwater protection goals 1 and 2

Location of the candidates on the Ethiopian map can be found in Figure A8.2.1. Specifications about the candidate locations are given in Tables A8.2.1.

Figure A8.2.1 *Candiate location for the groundwater protection goals 1 and 2: alluvial aquifers along small rivers and volcanic aquifers on shallow wells in areas above 1500 m altitude.*

The maximum number of pixels in a grid is 225. However, due to the selection citeria of an organic matter content > 0 and realistic sets of organic matter content and dry bulk density for each pixel, the number of relevant pixels per grid varies. An important selection criterion for the selection of the candidate locations and the scenario location is that the locations should posses spatial units that are vulnerable (preferably vulnerable for all 49 tested substances). A grid is considered to be more vulnerable as the number tested substances resulting in 98-100 percentile concentrations increase for an increasing number of pixels in that grid. The candidate locations in Table A8.2.1 are ranked according vulnerability. The top row shows the locations with the highest vulnerability (so with all 49 substances resulting in 98-100 percentile concentrations).

Table A8.2.1
Candidate locations for the groundwater protection goals 1 and 2.

Grid	Altitude (m)	Longitude	Latitude	Number of relevant pixels in grid	Number of substances resulting in 98-100 percentile concentrations for y pixels*
217	1705	36.75	10.5	223	49 substances for 68 pixels + 35 substances for 10 pixels
244	1978	37.5	9.75	214	49 substances for 25 pixels
219	2190	38.25	10.5	225	49 substances for 22 pixels
245	2163	38.25	9.75	225	42 substances for 18 pixels
220	2265	39.0	10.5	225	42 substances for 12 pixels + 35 substances for 39 pixels

* indicating that x substances out of 49 resulted in 98-100 percentile concentrations for y (unique) pixels out of maximal 225 in the corresponding grid.

The longitude and latitude of the grid represent the centre of the grid cell. Areas 40 km north, south, east and west of the candidate locations were checked for the presence of agriculture and small streams using Google Earth. For all candidate locations agriculture and small streams were visible.

Groundwater protection goals 3a
Location of the candidates on the Ethiopian map can be found in Figure A8.2.2. Specifications about the candidate locations are given in Tables A8.2.2.

Figure A8.2.2 *Candiate locations for the groundwater protection goal 3a: alluvial aquifers in the Rift Valley margins and lowlands in areas below 1500 m altitude.*

Table A8.2.2

Candidate locations for the groundwater protection goal 3a for altitude < 1500 m and 98-100 percentile leaching concentrations.

Grid	Altitude (m)	Longitude	Latitude	Number of relevant pixels in grid	Number of substances resulting in 98-100 percentile concentrations for y pixels*
347	1486	36.75	6.75	225	49 substances for 45 pixels + 35 substances for 11 pixels + 21 substances for 6 pixels
164	905	36	12	225	49 substances for 18 pixels + 28 substances for 15 pixels + 21 substances for 15 pixels + 14 substances for 11 pixels + 7 substances for 8 pixels
346	1363	36	6.75	225	49 substances for 13 pixels
398	714	36	5.25	225	28 substances for 15 pixels

* indicating that x substances out of 49 resulted in 98-100 percentile concentrations for y (unique) pixels out of maximal 225 in the corresponding grid.

The longitude and latitude of the grid represent the centre of the grid cell. Areas 40 km north, south, east and west of the candidate locations were checked for the presence of agriculture using Google Earth. For candidate locations 164 and 346 agriculture was visible on Google Earth.

Groundwater protection goals 3b

Location of the candidates on the Ethiopian map can be found in Figures A8.2.3a and A8.2.3b. Specifications about the candidate locations are given in Tables A8.2.3a and A8.2.3b.

Groundwater protection goal 3b (alluvial aquifers in the Rift Valley margins in areas between 1500 and 2000 m altitude) is only found in a limited area of Ethiopia (see Appendix 8.1.). Figure A8.2.3a and Table A8.2.3a show all grids with pixels resulting in 98-100 percentile leaching concentrations. The candidate locations, 321, 322 in the 98-100 percentile probability of occurrence were considered to be not suitable, because they were judged to be not well representing the Rift Valley margins. Of these 322 was best, but it is located slightly outside the Rift Valley.

Grid cell 299 was not suitable, because the alluvial deposits there are underlain by a thick tuff layer and the groundwater is very deep: more than 400 m. So, in reality water is supplied to this area from the highlands more than 70 km southwest of the grid cell.

We then expanded the probability analysis to 2500 m, i.e. we analysed the grids between 1500 and 2500 m and identified the grids in the 98-100 percentile probability of occurrence (specified in Figure A8.2.3b and Table A8.2.3b). Out of these candidate locations we selected 323 because this grid cell covers the areas west of Lake Ziway and Lake Koka where groundwater is known to be extracted from shallow wells, while the Rift Valley margins as well as the nearby plains are intensively cultivated with a high use of pesticides.

Figure A8.2.3a *Candiate locations for the groundwater protection goal 3b: alluvial aquifers in the Rift Valley margins in areas between 1500 – **2000** m altitude.*

Figure A8.2.3b *Candiate locations for the groundwater protection goal 3b: alluvial aquifers in the Rift Valley margins in areas between 1500 – **2500** m altitude.*

Table A8.2.3a

*Candidate locations for the groundwater protection goal 3b: for altitude 1500-**2000** m and 98-100 percentile leaching concentrations.*

Grid	Altitude (m)	Longitude	Latitude	Number of relevant pixels in grid	Number of substances resulting in 98-100 percentile concentrations for y pixels*
322	1863	37.5	7.5	225	49 substances for 31 pixels + 35 substances for 1 pixel
321	2049	37.5	9	221	49 substances for 28 pixels
299	1966	39.75	8.25	225	14 substances for 1 pixel

* indicating that x substances out of 49 resulted in 98-100 percentile concentrations for y (unique) pixels out of maximal 225 in the corresponding grid.

Table A8.2.3b

*Candidate locations for the groundwater protection goal 3b: for altitude 1500-**2500** m and 98-100 percentile leaching concentrations.*

Grid	Altitude (m)	Longitude	Latitude	Number of relevant pixels in grid	Number of substances resulting in 98-100 percentile concentrations for y pixels*
321	1832	36.75	7.5	225	49 substances for 28 pixels
246	2238	39	9.75	225	49 substances for 24 pixels + 42 substances for 14 pixels + 21 substances for 2 pixels
296	2029	37.5	8.25	225	49 substances for 2 pixels + 21 substances for 11 pixels + 14 substances for 1 pixel + 7 substances for 15 pixels
270	2049	37.5	9	221	49 substances for 1 pixel + 28 substances for 36 pixels + 21 substances for 7 pixels + 7 substances for 14 pixels
323	2056	38.25	7.5	209	28 substances for 5 pixels + 21 substances for 6 pixels
271	2226	38.25	9	225	28 substances for 2 pixels

* indicating that x substances out of 49 resulted in 98-100 percentile concentrations for y (unique) pixels out of maximal 225 in the corresponding grid.

The longitude and latitude of the grid represent the centre of the grid cell. Areas 40 km north, south, east and west of the candidate locations were checked for the presence of agriculture using Google Earth. For all candidate locations agriculture was visible.

Appendix 8.3 Candidate locations for the three surface water protection goals

Protection goal 1: small streams in areas above 1500 m
Three candidate locations for the scenario for protection goal 1 are shown in Figure A8.3.1. Specifications about the locations are given in Tables A8.3.1 and A8.3.2.

Figure A8.3.1 *Three candiate location for the surface protection goal 1: small streams in areas above 1500 m.*

Table A8.3.1
Candidate locations for the surface protection goal 1: small streams in areas above 1500 m. Cumulative percentiles calculated over 57 grids.

80x80 grid_id	Altitude (m)	Longitude	Latitude	Number of days with P>20mm	Percentile (in space)
217	1705	36.75	10.5	46	99.1
191	1682	36.75	11.25	46	97.4
269	1793	36.75	9	42	95.6

The longitude and latitude of the 80x80 km^2 grid cells represent the centre of the grid cells. Areas 40 km north, south, east and west of the candidate locations shown in Figure A8.3.1 were checked for the presence of agriculture and small streams using Google Earth.

Table A8.3.2
Presence of agriculture and small streams in the 80x80 km^2 grid cells of the candidate locations for the surface protection goal 1: small streams in areas above 1500 m.

80x80 grid_id	Presence of agriculture	Presence of small streams
217	Yes	Difficult to judge
191	Yes	Yes
269	Yes	Yes

Based upon the expert judgement of the Ethiopian partners present during the November 2012 workshop candidate location 191 was selected as the final scenario location, because it fitted best the selection criteria of presence of small streams and intensive agriculture.

Protection goal 2: temporary ponds

Protection goal 2a: temporary ponds below 1500 m altitude and with more than 500 mm rain (long term, annual average)
Eleven candidate locations for the scenario for protection goal 2a (temporary ponds below 1500 m and with more than 500 mm rain; long term, annual average) are shown in Figure A8.3.2. Specifications about the locations are given in Tables A8.3.3 and A8.3.4.

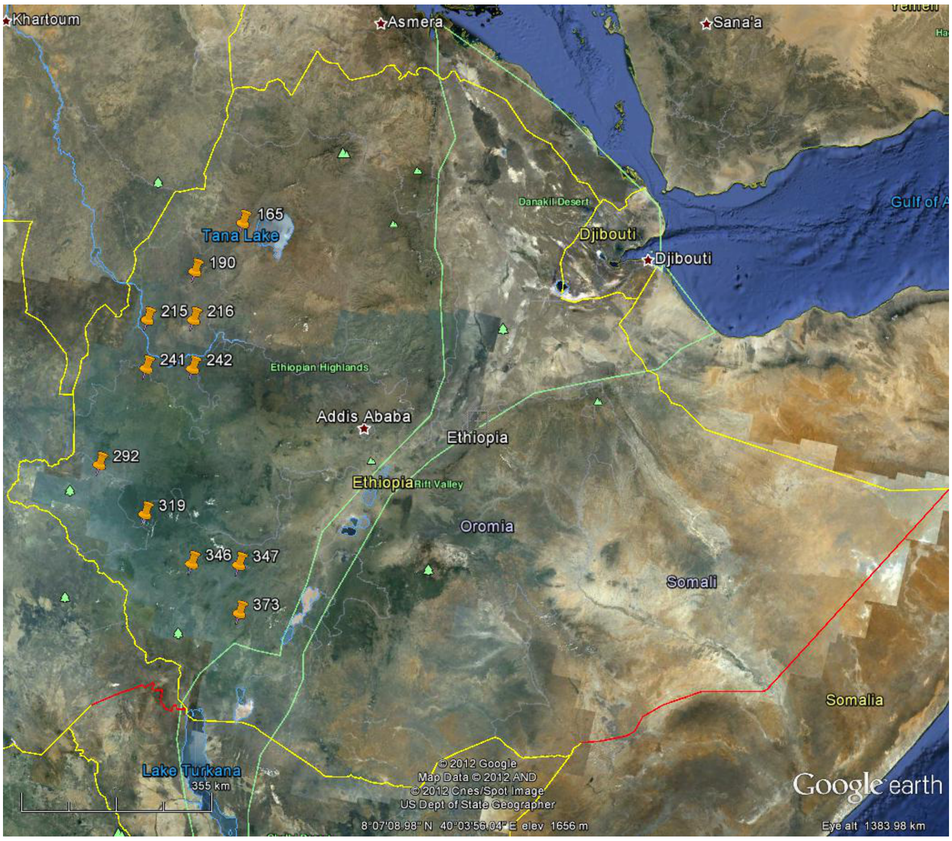


Figure A8.3.2 *Top eleven candidate locations for the surface protection goal 2a: temporary ponds in areas below 1500 m and with more than 500 mm rain (long term, annual average).*

Table A8.3.3

Candidate locations for the surface water protection goal 2a: temporary ponds in areas below 1500 m and with more than 500 mm rain (long term, annual average). Cumulative percentiles calculated over 38 grids.

80x80 grid_id	Altitude (m)	Longitude	Latitude	Number of days with P>20mm	Percentile (in space)	Long term, annual average precipitation (mm)
190	1134	36	11.25	47	98.7	2558
216	1268	36	10.5	46	96.1	2890
165	1437	36.75	12	41	93.4	2120
242	1398	36	9.75	36	90.8	2453
215	974	35.25	10.5	35	88.2	2091
319	1324	35.25	7.5	32	85.5	2773
241	1298	35.25	9.75	28	82.9	2150
292	855	34.5	8.25	27	80.3	2227
347	1486	36.75	6.75	24	77.6	2106
346	1363	36	6.75	23	75	2078
373	1288	36.75	6	21	72.4	1702

The longitude and latitude of the 80x80 km^2 grid cells represent the centre of the grid cell. Areas 40 km north, south, east and west of the candidate locations shown in Figure A8.3.2 were checked for the presence of agriculture and temporal ponds using Google Earth. Remarks of the PHRD staff were incorporated while reviewing the grids upon their suitability.

Table A8.3.4

Presence of agriculture and temporary ponds in the 80x80 km^2 grid cells of the candidate locations for the surface protection goal 2a: temporary ponds in areas below 1500 m and with more than 500 mm rain (long term, annual average).

80x80 grid_id	Presence of agriculture	Presence of temporary ponds (flat area, streams far apart)
190 Not suitable	Yes	No
216 Not suitable	Yes	No
165 Possibly suitable	Yes Vegetables with pesticide use is common here. Some flat areas with teff, maize, sorghum, some vegetables	No
242	Probably some in the southern part of the grid cell. Some mechanised agriculture (maize, sorghum) and smallholder vegetables	It seems largely a hilly area with streams from the hills to the more flat areas. Ponds are possible here.
215 Not suitable.	Seems mostly shrubs and pasture.	No
319 Not suitable, mostly forest	Mostly forest, but agricultural crops around Teppi, and other small areas	Area around Teppi seems flat.
241, near Mendi Not suitable	Yes, patches of forest, agricultural crops and pasture/shrubs. Possible crops are maize, teff, root crops, no barley, no sorghum	Good area for ponds, but these are not used for cattle drenching as they contain parasites. Moreover there is so much rain that rivers are regularly fed by the rain (every month).
292 Not suitable	Some areas, for instance around Dembi Dolo. There is maize, some small scale coffee.	Area around Dembi Dolo seems rather flat, but there seem to be some small streams.
347 Not suitable, always rain, see 241	No, or very little Possible crops are coffee, tea, sugarcane, some maize. There are few cereals.	No
346 Not suitable, always rain, see 241	Yes	Difficult to judge. Google Earth images are not clear
373 along RV, E of Arba Minch, suitable	Yes, Possible crops: mango, banana, sugarcane, lemon (for household use), cereals such as maize, teff, sorghum (no wheat, no barley), large scale cotton and vegetables.	There are flat areas with agriculture, but the pattern of trees/shrubs indicate streams from the mountains into the flat area. Ponds are there, rainfed, by moderate rain.

The Ethiopian partners of the PHRD decided based on their expert judgement which of the eleven candidate locations was most suitable as the final scenario location to be used in the PRIMET software tool. All candidate locations were reviewed and finally 373 was selected as being the most suitable one, fulfilling best all criteria of presence of temporary ponds, intensive agriculture with high pesticide use and a large variety of crops being cultivated in this area. Grid cell 165 would also be a possible location but fitted less well all criteria (less crops being cultivated, while already other scenario locations are also located in the region (grid cell 191 for small streams). The grid cell 373 is located near Arba Minch in the Rift Valley, between or next to Rift Valley lakes and it is densely populated, while there is also cattle. Crops grown are: vegetables, mango, banana, sugarcane, citrus (lemon, for household use only), cereals (maize, teff, sorghum, no wheat, no barley), while there is also large scale cotton cultivation. In the PRIMET software wheat has also been associated with the scenario in grid 373, as we wanted to to be able to perform the environmental risk assessment for as many crop-scenario combinations as possible

Protection goal 2b: temporary ponds between 1500 - 2000 m altitude

The top twelve candidate locations for the scenario for protection goal 2b (temporary ponds in areas between 1500 - 2000 m) are shown in Figure A8.3.3. Specifications about the locations are given in Tables A8.3.5 and A8.3.6.

Figure A8.3.3 *Top twelve candiate locations for the surface protection goal 2b: temporary ponds in areas between 1500 – 2000 m.*

Table A8.3.5

Candidate locations for the surface protection goal 2b: temporary ponds in areas between 1500 – 2000 m. Cumulative percentiles calculated over 34 grids.

80x80 grid_id	Altitude (m)	Longitude	Latitude	Number of days with P>20mm	Percentile (in space)	Long term, annual average precipitation (mm)
217	1705	36.75	10.5	46	98.5	2779
191	1682	36.75	11.25	46	95.6	2581
269	1793	36.75	9	42	92.6	2280
243	1978	36.75	9.75	41	89.7	2530
244	1677	37.5	9.75	38	86.8	1993
268	1648	36	9	37	83.8	2196
293	1511	35.25	8.25	31	80.9	2636
166	1968	37.5	12	29	77.9	1659
320	1818	36	7.5	28	75	2710
294	1885	36	8.25	28	72.1	2405
295	1908	36.75	8.25	26	69.1	2008
140	1703	37.5	12.75	26	66.2	1516

The longitude and latitude of the 80x80 km^2 grid cells represent the centre of the grid cell. Areas 40 km north, south, east and west of the candidate locations shown in Figure A8.3.3 were checked for the presence of agriculture and temporal ponds using Google Earth.

Table A8.3.6

Presence of agriculture and temporary ponds in the 80x80 km^2 grid cells of the candidate locations for the surface protection goal 2b: temporary ponds in areas between 1500 – 2000 m.

80x80 grid_id	Presence of agriculture	Presence of temporary ponds (flat area, streams far apart)
217 Suitable	Yes Possible crops are teff, mango, groundnut, maize, sorghum, vegetables (onions, tomatoes, cabbage), faba beans. No pome/stone fruit, no coffee, there is lemon (but without pesticides used) There is no forest here	There are flat areas with temporary ponds present
191 Not suitable	Yes	No
269 Not suitable	Yes	No
243	Yes Possible crops: see 217	Part of the area is flat, but there are streams coming from the more hilly areas There is a good rainy season, ponds are not used much as streams are always close
244	Yes Possible crops: see 217	Part of the area is flat, but there are streams coming from the more hilly areas.
268 Not suitable	Yes Possible crops are mango, wheat, papaya (no pesticides used), teff, maize, vegetables, faba bean and some forest coffee. There are no Irish potatoes.	No temporary ponds
293	Yes	There is too much rain here, this is tropical forest
166	Yes near the lake Tana	pretty flat area east of the lake; there are streams.
320	Yes, but also forest	Tropical rain forest
294	Yes	Too many streams
295	Yes	Too many streams
140	Yes	Area does not seem very flat

The Ethiopian partners of the PHRD decided based on their expert judgement which of the twelve candidate locations was most suitable as the final scenario location to be used in the PRIMET software tool. The first seven candidate locations, having the highest probabilities, were reviewed and the highest, i.e. grid 217 was selected as being the most suitable one, fulfilling best all criteria of presence of temporary ponds, intensive agriculture with high pesticide use and a large variety of crops being cultivated in this area. Crops grown in the area are teff, maize and sorghum, while given the altitude this scenario could also be associated with wheat and barley. Also vegetables are grown, such as onions, tomatoes and cabbage, as well as faba beans. No Irish potatoes are grown in the area, nor pome/stone fruits, neither coffee. Lemon is grown, but without pesticides being used. However, in the PRIMET software these crops have been associated with the scenario in grid 217, as (i) the crop-scenario combination is realistic from an agro-environmental point of view, and (ii) we wanted to to be able to perform the environmental risk assessment for as many crop-scenario combinations as possible.

Overall probability of occurrence of calculated concentrations in grids 191, 373 and 217

We now combine the spatial percentiles of the selected grids with the selected temporal percentiles for the concentrations calculated for the small stream and in the ponds to obtain the overall probability of occurrence. The approach to do this has been explained in Figure F1 of section 3.3 and is repeated here below. Figure A8.3.4 illustrates the calculations.

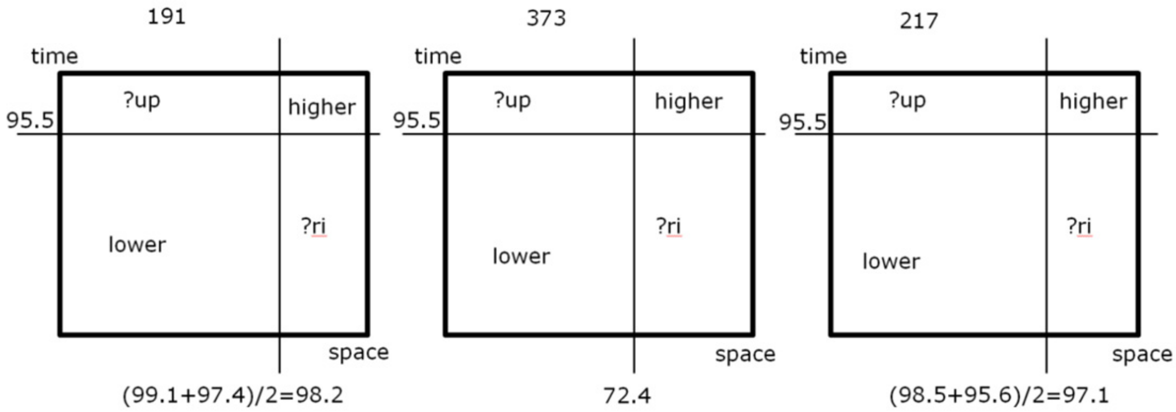


Figure A8.3.4 *Calculation of the overall percentile of occurrence in time and space for the concentrations in the grids 191 (small stream), 373 and 217 (both ponds) for the protection goal of drinking water produced from surface water.*

Grid 191 small stream above 1500 m
Lower = 0.955 * 0.982 * 100% = 93.78%
$?_{up}$ = 0.982 * 0.045 * 100% = 4.42%
$?_{right}$ = 0.955 * 0.018 * 100% = 1.72%
half of $?_{up}$ + $?_{right}$ = 3.07%

Overall = 93.78% + 3.07% = 96.85% ≈ 97%-ile

Grid 373 temporary pond below 1500 m and with more than 500 mm rain
Lower = 0.724 * 0.955 * 100% = 69.14%
$?_{up}$ = 0.724 * 0.045 * 100% = 3.26%
$?_{right}$ = 0.955 * 0.276 * 100% = 26.36%
half of $?_{up}$ + $?_{right}$ = 14.81%

Overall = 69.14% + 14.81% = 83.95% ≈ 84%-ile

Grid 217 temporary pond between 1500 and 2000 m
Lower = 0.971 * 0.955 * 100% = 92.73%
$?_{up}$ = 0.971 * 0.045 * 100% = 4.37%
$?_{right}$ =0.955 * 0.029 * 100% = 2.77%
half of $?_{up}$ + $?_{right}$ = 3.57%

Overall = 92.73% + 3.57% = 96.30% ≈ 96%-ile

So, for drinking water produced from surface water the realised overall probability of occurrence in time and in space of the surface water concentrations are the 97%-ile, the 84%-ile and the 96%-ile in the small stream of grids 191 and the temporary ponds of grids 373 and 217.
In the PRRP project also the risks for the aquatic ecosystem are assessed. For pragmatic reasons the same types of water bodies and grids were selected as those selected for the risks for drinking water produced from surface water. However, instead of an overall 99th percentile probability of occurrence an overall 90th percentile probability of occurrence was aimed for. This was done by selecting a lower temporal percentile, i.e. an 83.3 temporal percentile (instead of the 95.5 temporal percentile selected for drinking water produced from surface water). This resulted in the following overall percentiles probability of occurrence for the aquatic risk assessment (Figure A8.3.5):

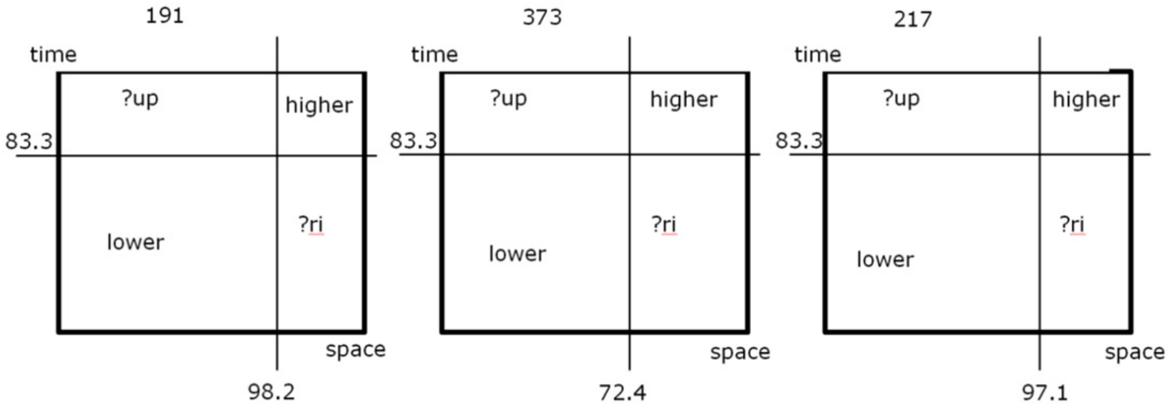


Figure A8.3.5 *Calculation of the overall percentile of occurrence in time and space for the concentrations in the grids 191 (small stream), 373 and 217 (both ponds) for the protection goal of the aquatic ecosystem.*

Grid 191 small stream above 1500 m
Lower = 0.833 * 0.982 * 100% = 81.80%
$?_{up}$ = 0.982 * 0.167 * 100% = 16.40%
$?_{right}$ = 0.833 * 0.018 * 100% = 1.50%
half of $?_{up}$ + $?_{right}$ =8.95%

Overall = 81.80% + 8.95% = 90.75% ≈ 91%-ile

Grid 373 temporary pond below 1500 m and with more than 500 mm rain
Lower = 0.833 * 0.724 * 100% = 60.31%
$?_{up}$ =0.724 * 0.167 * 100% = 12.09%
$?_{right}$ =0.833 * 0.276 * 100% = 22.99%
half of $?_{up}$ + $?_{right}$ =17.54%

Overall = 60.31% + 17.54% = 77.85% ≈ 78%-ile

Grid 217 temporary pond between 1500 and 2000 m
Lower = 0.833 * 0.971 * 100% = 80.88%
$?_{up}$ = 0.971 * 0.167 * 100% = 16.22%
$?_{right}$ = 0.833 * 0.029 * 100% = 2.42%
half of $?_{up}$ + $?_{right}$ = 9.32%

Overall = 80.88% + 9.32% = 90.20% ≈ 90%-ile

So, for the risk assessment for the aquatic ecosystem the realised overall probability of occurrence in time and in space of the surface water concentrations are the 91%-ile, the 78%-ile and the 90%-ile in the small stream of grids 191 and the temporary ponds of grids 373 and 217.

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Appendix 10.1 Soil data for the locations of the three groundwater locations

Table A10.1

Raw soil data of all relevant (i.e. organic matter content > 0 and realistic sets of organic matter content and dry bulk density) pixels of the scenario location of groundwater protection goals 1 and 2.

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
219	46963	0.1994	0.003438	1.5278	38.52154	10.83558	1
219	50085	0.1994	0.003438	1.5278	38.62154	10.43558	2
219	50084	0.1994	0.003438	1.5278	38.57154	10.43558	3
219	50863	0.1994	0.003438	1.5278	38.52154	10.33558	4
219	50864	0.1994	0.003438	1.5278	38.57154	10.33558	5
219	47744	0.1994	0.003438	1.5278	38.57154	10.73558	6
219	50083	0.1994	0.003438	1.5278	38.52154	10.43558	7
219	49304	0.1994	0.003438	1.5278	38.57154	10.53558	8
219	49305	0.1994	0.003438	1.5278	38.62154	10.53558	9
219	49693	0.1994	0.003438	1.5278	38.52154	10.48558	10
219	50865	0.1994	0.003438	1.5278	38.62154	10.33558	11
219	52424	0.1994	0.003438	1.5278	38.57154	10.13558	12
219	52425	0.1994	0.003438	1.5278	38.62154	10.13558	13
219	52032	0.1994	0.003438	1.5278	38.47154	10.18558	14
219	48133	0.1994	0.003438	1.5278	38.52154	10.68558	15
219	51643	0.1994	0.003438	1.5278	38.52154	10.23558	16
219	48523	0.1994	0.003438	1.5278	38.52154	10.63558	17
219	48913	0.1994	0.003438	1.5278	38.52154	10.58558	18
219	52035	0.1994	0.003438	1.5278	38.62154	10.18558	19
219	52421	0.1994	0.003438	1.5278	38.42154	10.13558	20
219	48134	0.1994	0.003438	1.5278	38.57154	10.68558	21
219	48135	0.1994	0.003438	1.5278	38.62154	10.68558	22
219	46964	0.4135	0.007129	1.3738	38.57154	10.83558	23
219	46965	0.4135	0.007129	1.3738	38.62154	10.83558	24
219	46961	0.4135	0.007129	1.3738	38.42154	10.83558	25
219	46962	0.4135	0.007129	1.3738	38.47154	10.83558	26
219	47741	0.4135	0.007129	1.3738	38.42154	10.73558	27
219	47742	0.4135	0.007129	1.3738	38.47154	10.73558	28
219	47345	0.4135	0.007129	1.3738	38.12154	10.78558	29
219	46959	0.4135	0.007129	1.3738	38.32154	10.83558	30
219	47350	0.4135	0.007129	1.3738	38.37154	10.78558	31
219	48128	0.4135	0.007129	1.3738	38.27154	10.68558	32
219	48129	0.4135	0.007129	1.3738	38.32154	10.68558	33
219	47738	0.4135	0.007129	1.3738	38.27154	10.73558	34
219	47739	0.4135	0.007129	1.3738	38.32154	10.73558	35
219	47740	0.4135	0.007129	1.3738	38.37154	10.73558	36
219	47745	0.4135	0.007129	1.3738	38.62154	10.73558	37
219	46958	0.4135	0.007129	1.3738	38.27154	10.83558	38
219	49688	0.4135	0.007129	1.3738	38.27154	10.48558	39
219	49689	0.4135	0.007129	1.3738	38.32154	10.48558	40
219	49691	0.4135	0.007129	1.3738	38.42154	10.48558	41
219	49694	0.4135	0.007129	1.3738	38.57154	10.48558	42
219	49695	0.4135	0.007129	1.3738	38.62154	10.48558	43
219	49297	0.4135	0.007129	1.3738	38.22154	10.53558	44
219	47346	0.4135	0.007129	1.3738	38.17154	10.78558	45
219	47347	0.4135	0.007129	1.3738	38.22154	10.78558	46

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
219	47348	0.4135	0.007129	1.3738	38.27154	10.78558	47
219	47349	0.4135	0.007129	1.3738	38.32154	10.78558	48
219	47352	0.4135	0.007129	1.3738	38.47154	10.78558	49
219	47354	0.4135	0.007129	1.3738	38.57154	10.78558	50
219	47355	0.4135	0.007129	1.3738	38.62154	10.78558	51
219	48914	0.4135	0.007129	1.3738	38.57154	10.58558	52
219	48915	0.4135	0.007129	1.3738	38.62154	10.58558	53
219	49298	0.4135	0.007129	1.3738	38.27154	10.53558	54
219	49301	0.4135	0.007129	1.3738	38.42154	10.53558	55
219	50471	0.4135	0.007129	1.3738	38.42154	10.38558	56
219	50081	0.4135	0.007129	1.3738	38.42154	10.43558	57
219	48525	0.4135	0.007129	1.3738	38.62154	10.63558	58
219	48524	0.4135	0.007129	1.3738	38.57154	10.63558	59
219	48908	0.4135	0.007129	1.3738	38.27154	10.58558	60
219	48909	0.4135	0.007129	1.3738	38.32154	10.58558	61
219	48519	0.4135	0.007129	1.3738	38.32154	10.63558	62
219	48520	0.4135	0.007129	1.3738	38.37154	10.63558	63
219	48518	0.4135	0.007129	1.3738	38.27154	10.63558	64
219	51253	0.4333	0.00747	1.3762	38.52154	10.28558	65
219	51254	0.4333	0.00747	1.3762	38.57154	10.28558	66
219	51255	0.4333	0.00747	1.3762	38.62154	10.28558	67
219	51645	0.4333	0.00747	1.3762	38.62154	10.23558	68
219	52033	0.4333	0.00747	1.3762	38.52154	10.18558	69
219	51644	0.4333	0.00747	1.3762	38.57154	10.23558	70
219	52422	0.4333	0.00747	1.3762	38.47154	10.13558	71
219	52423	0.4333	0.00747	1.3762	38.52154	10.13558	72
219	47341	0.528	0.009103	1.4393	37.92154	10.78558	73
219	48124	0.528	0.009103	1.4393	38.07154	10.68558	74
219	47342	0.528	0.009103	1.4393	37.97154	10.78558	75
219	47343	0.528	0.009103	1.4393	38.02154	10.78558	76
219	47732	0.528	0.009103	1.4393	37.97154	10.73558	77
219	47733	0.528	0.009103	1.4393	38.02154	10.73558	78
219	48121	0.528	0.009103	1.4393	37.92154	10.68558	79
219	48122	0.528	0.009103	1.4393	37.97154	10.68558	80
219	48123	0.528	0.009103	1.4393	38.02154	10.68558	81
219	46951	0.528	0.009103	1.4393	37.92154	10.83558	82
219	46952	0.528	0.009103	1.4393	37.97154	10.83558	83
219	46953	0.528	0.009103	1.4393	38.02154	10.83558	84
219	47731	0.528	0.009103	1.4393	37.92154	10.73558	85
219	49291	0.528	0.009103	1.4393	37.92154	10.53558	86
219	48513	0.528	0.009103	1.4393	38.02154	10.63558	87
219	48901	0.528	0.009103	1.4393	37.92154	10.58558	88
219	48902	0.528	0.009103	1.4393	37.97154	10.58558	89
219	48512	0.528	0.009103	1.4393	37.97154	10.63558	90
219	48511	0.528	0.009103	1.4393	37.92154	10.63558	91
219	48130	0.5764	0.009937	1.4216	38.37154	10.68558	92
219	47743	0.5764	0.009937	1.4216	38.52154	10.73558	93
219	50082	0.5764	0.009937	1.4216	38.47154	10.43558	94
219	51249	0.5764	0.009937	1.4216	38.32154	10.28558	95
219	51250	0.5764	0.009937	1.4216	38.37154	10.28558	96
219	51251	0.5764	0.009937	1.4216	38.42154	10.28558	97
219	51252	0.5764	0.009937	1.4216	38.47154	10.28558	98
219	49303	0.5764	0.009937	1.4216	38.52154	10.53558	99
219	49692	0.5764	0.009937	1.4216	38.47154	10.48558	100
219	51248	0.5764	0.009937	1.4216	38.27154	10.28558	101
219	50472	0.5764	0.009937	1.4216	38.47154	10.38558	102

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
219	47353	0.5764	0.009937	1.4216	38.52154	10.78558	103
219	50858	0.5764	0.009937	1.4216	38.27154	10.33558	104
219	50860	0.5764	0.009937	1.4216	38.37154	10.33558	105
219	50861	0.5764	0.009937	1.4216	38.42154	10.33558	106
219	50862	0.5764	0.009937	1.4216	38.47154	10.33558	107
219	52027	0.5764	0.009937	1.4216	38.22154	10.18558	108
219	52028	0.5764	0.009937	1.4216	38.27154	10.18558	109
219	52414	0.5764	0.009937	1.4216	38.07154	10.13558	110
219	52415	0.5764	0.009937	1.4216	38.12154	10.13558	111
219	52416	0.5764	0.009937	1.4216	38.17154	10.13558	112
219	52417	0.5764	0.009937	1.4216	38.22154	10.13558	113
219	49299	0.5764	0.009937	1.4216	38.32154	10.53558	114
219	49300	0.5764	0.009937	1.4216	38.37154	10.53558	115
219	49302	0.5764	0.009937	1.4216	38.47154	10.53558	116
219	50470	0.5764	0.009937	1.4216	38.37154	10.38558	117
219	51638	0.5764	0.009937	1.4216	38.27154	10.23558	118
219	50473	0.5764	0.009937	1.4216	38.52154	10.38558	119
219	50474	0.5764	0.009937	1.4216	38.57154	10.38558	120
219	50475	0.5764	0.009937	1.4216	38.62154	10.38558	121
219	52024	0.5764	0.009937	1.4216	38.07154	10.18558	122
219	52026	0.5764	0.009937	1.4216	38.17154	10.18558	123
219	52029	0.5764	0.009937	1.4216	38.32154	10.18558	124
219	52030	0.5764	0.009937	1.4216	38.37154	10.18558	125
219	52031	0.5764	0.009937	1.4216	38.42154	10.18558	126
219	50080	0.5764	0.009937	1.4216	38.37154	10.43558	127
219	52412	0.5764	0.009937	1.4216	37.97154	10.13558	128
219	51636	0.5764	0.009937	1.4216	38.17154	10.23558	129
219	51639	0.5764	0.009937	1.4216	38.32154	10.23558	130
219	51640	0.5764	0.009937	1.4216	38.37154	10.23558	131
219	52418	0.5764	0.009937	1.4216	38.27154	10.13558	132
219	48131	0.5764	0.009937	1.4216	38.42154	10.68558	133
219	48132	0.5764	0.009937	1.4216	38.47154	10.68558	134
219	51641	0.5764	0.009937	1.4216	38.42154	10.23558	135
219	51642	0.5764	0.009937	1.4216	38.47154	10.23558	136
219	48521	0.5764	0.009937	1.4216	38.42154	10.63558	137
219	48522	0.5764	0.009937	1.4216	38.47154	10.63558	138
219	48910	0.5764	0.009937	1.4216	38.37154	10.58558	139
219	52411	0.5764	0.009937	1.4216	37.92154	10.13558	140
219	52419	0.5764	0.009937	1.4216	38.32154	10.13558	141
219	48912	0.5764	0.009937	1.4216	38.47154	10.58558	142
219	52420	0.5764	0.009937	1.4216	38.37154	10.13558	143
219	48911	0.5764	0.009937	1.4216	38.42154	10.58558	144
219	50461	0.6722	0.011589	1.547	37.92154	10.38558	145
219	50462	0.6722	0.011589	1.547	37.97154	10.38558	146
219	50075	0.6722	0.011589	1.547	38.12154	10.43558	147
219	50076	0.6722	0.011589	1.547	38.17154	10.43558	148
219	47344	0.6722	0.011589	1.547	38.07154	10.78558	149
219	48125	0.6722	0.011589	1.547	38.12154	10.68558	150
219	48126	0.6722	0.011589	1.547	38.17154	10.68558	151
219	47734	0.6722	0.011589	1.547	38.07154	10.73558	152
219	47735	0.6722	0.011589	1.547	38.12154	10.73558	153
219	47736	0.6722	0.011589	1.547	38.17154	10.73558	154
219	46957	0.6722	0.011589	1.547	38.22154	10.83558	155
219	50464	0.6722	0.011589	1.547	38.07154	10.38558	156
219	50465	0.6722	0.011589	1.547	38.12154	10.38558	157
219	50466	0.6722	0.011589	1.547	38.17154	10.38558	158

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
219	49681	0.6722	0.011589	1.547	37.92154	10.48558	159
219	49682	0.6722	0.011589	1.547	37.97154	10.48558	160
219	49683	0.6722	0.011589	1.547	38.02154	10.48558	161
219	49684	0.6722	0.011589	1.547	38.07154	10.48558	162
219	49685	0.6722	0.011589	1.547	38.12154	10.48558	163
219	49686	0.6722	0.011589	1.547	38.17154	10.48558	164
219	49687	0.6722	0.011589	1.547	38.22154	10.48558	165
219	50071	0.6722	0.011589	1.547	37.92154	10.43558	166
219	50073	0.6722	0.011589	1.547	38.02154	10.43558	167
219	50074	0.6722	0.011589	1.547	38.07154	10.43558	168
219	46954	0.6722	0.011589	1.547	38.07154	10.83558	169
219	46955	0.6722	0.011589	1.547	38.12154	10.83558	170
219	46956	0.6722	0.011589	1.547	38.17154	10.83558	171
219	51245	0.6722	0.011589	1.547	38.12154	10.28558	172
219	49293	0.6722	0.011589	1.547	38.02154	10.53558	173
219	49294	0.6722	0.011589	1.547	38.07154	10.53558	174
219	49295	0.6722	0.011589	1.547	38.12154	10.53558	175
219	49296	0.6722	0.011589	1.547	38.17154	10.53558	176
219	51631	0.6722	0.011589	1.547	37.92154	10.23558	177
219	50854	0.6722	0.011589	1.547	38.07154	10.33558	178
219	50855	0.6722	0.011589	1.547	38.12154	10.33558	179
219	51241	0.6722	0.011589	1.547	37.92154	10.28558	180
219	51242	0.6722	0.011589	1.547	37.97154	10.28558	181
219	51243	0.6722	0.011589	1.547	38.02154	10.28558	182
219	51244	0.6722	0.011589	1.547	38.07154	10.28558	183
219	49292	0.6722	0.011589	1.547	37.97154	10.53558	184
219	50851	0.6722	0.011589	1.547	37.92154	10.33558	185
219	50852	0.6722	0.011589	1.547	37.97154	10.33558	186
219	50853	0.6722	0.011589	1.547	38.02154	10.33558	187
219	48903	0.6722	0.011589	1.547	38.02154	10.58558	188
219	48904	0.6722	0.011589	1.547	38.07154	10.58558	189
219	48514	0.6722	0.011589	1.547	38.07154	10.63558	190
219	51632	0.6722	0.011589	1.547	37.97154	10.23558	191
219	48515	0.6722	0.011589	1.547	38.12154	10.63558	192
219	48906	0.6722	0.011589	1.547	38.17154	10.58558	193
219	48905	0.6722	0.011589	1.547	38.12154	10.58558	194
219	48516	0.6722	0.011589	1.547	38.17154	10.63558	195
219	50079	0.694	0.011965	1.544	38.32154	10.43558	196
219	46960	0.694	0.011965	1.544	38.37154	10.83558	197
219	48127	0.694	0.011965	1.544	38.22154	10.68558	198
219	50077	0.694	0.011965	1.544	38.22154	10.43558	199
219	50078	0.694	0.011965	1.544	38.27154	10.43558	200
219	47737	0.694	0.011965	1.544	38.22154	10.73558	201
219	49690	0.694	0.011965	1.544	38.37154	10.48558	202
219	51246	0.694	0.011965	1.544	38.17154	10.28558	203
219	51247	0.694	0.011965	1.544	38.22154	10.28558	204
219	50467	0.694	0.011965	1.544	38.22154	10.38558	205
219	47351	0.694	0.011965	1.544	38.42154	10.78558	206
219	50856	0.694	0.011965	1.544	38.17154	10.33558	207
219	50857	0.694	0.011965	1.544	38.22154	10.33558	208
219	50859	0.694	0.011965	1.544	38.32154	10.33558	209
219	51637	0.694	0.011965	1.544	38.22154	10.23558	210
219	52034	0.694	0.011965	1.544	38.57154	10.18558	211
219	50468	0.694	0.011965	1.544	38.27154	10.38558	212
219	50469	0.694	0.011965	1.544	38.32154	10.38558	213
219	48907	0.694	0.011965	1.544	38.22154	10.58558	214

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
219	48517	0.694	0.011965	1.544	38.22154	10.63558	215
219	50463	0.7824	0.013489	1.526	38.02154	10.38558	216
219	50072	0.7824	0.013489	1.526	37.97154	10.43558	217
219	52413	1.1294	0.019471	1.361	38.02154	10.13558	218
219	52021	1.1294	0.019471	1.361	37.92154	10.18558	219
219	52022	1.1294	0.019471	1.361	37.97154	10.18558	220
219	52023	1.1294	0.019471	1.361	38.02154	10.18558	221
219	52025	1.1294	0.019471	1.361	38.12154	10.18558	222
219	51635	1.1294	0.019471	1.361	38.12154	10.23558	223
219	51633	1.1294	0.019471	1.361	38.02154	10.23558	224
219	51634	1.1294	0.019471	1.361	38.07154	10.23558	225

Table A10.2

Raw soil data of all relevant (i.e. organic matter content > 0 and realistic sets of organic matter content and dry bulk density) pixels of the scenario location of groundwater protection goal 3a.

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
346	77340	0.418	0.007206	1.3747	36.37154	6.935584	1
346	77337	0.418	0.007206	1.3747	36.22154	6.935584	2
346	77338	0.418	0.007206	1.3747	36.27154	6.935584	3
346	80459	0.4324	0.007455	1.3768	36.32154	6.535584	4
346	79679	0.4324	0.007455	1.3768	36.32154	6.635584	5
346	79680	0.4324	0.007455	1.3768	36.37154	6.635584	6
346	80069	0.4324	0.007455	1.3768	36.32154	6.585584	7
346	79290	0.4324	0.007455	1.3768	36.37154	6.685584	8
346	81237	0.443	0.007637	1.379	36.22154	6.435584	9
346	81628	0.443	0.007637	1.379	36.27154	6.385584	10
346	81625	0.443	0.007637	1.379	36.12154	6.385584	11
346	81627	0.443	0.007637	1.379	36.22154	6.385584	12
346	81239	0.443	0.007637	1.379	36.32154	6.435584	13
346	81233	0.713	0.012292	1.559	36.02154	6.435584	14
346	81232	0.713	0.012292	1.559	35.97154	6.435584	15
346	80844	0.713	0.012292	1.559	36.07154	6.485584	16
346	80845	0.713	0.012292	1.559	36.12154	6.485584	17
346	80454	0.713	0.012292	1.559	36.07154	6.535584	18
346	80455	0.713	0.012292	1.559	36.12154	6.535584	19
346	80456	0.713	0.012292	1.559	36.17154	6.535584	20
346	78896	0.713	0.012292	1.559	36.17154	6.735584	21
346	81234	0.713	0.012292	1.559	36.07154	6.435584	22
346	81235	0.713	0.012292	1.559	36.12154	6.435584	23
346	79675	0.713	0.012292	1.559	36.12154	6.635584	24
346	80063	0.713	0.012292	1.559	36.02154	6.585584	25
346	80064	0.713	0.012292	1.559	36.07154	6.585584	26
346	80065	0.713	0.012292	1.559	36.12154	6.585584	27
346	78893	0.713	0.012292	1.559	36.02154	6.735584	28
346	78894	0.713	0.012292	1.559	36.07154	6.735584	29
346	79284	0.713	0.012292	1.559	36.07154	6.685584	30
346	79285	0.713	0.012292	1.559	36.12154	6.685584	31
346	79286	0.713	0.012292	1.559	36.17154	6.685584	32
346	80066	0.713	0.012292	1.559	36.17154	6.585584	33
346	79283	0.713	0.012292	1.559	36.02154	6.685584	34
346	81623	0.713	0.012292	1.559	36.02154	6.385584	35
346	81624	0.713	0.012292	1.559	36.07154	6.385584	36

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
346	81622	0.713	0.012292	1.559	35.97154	6.385584	37
346	77726	0.7633	0.013159	1.3481	36.17154	6.885584	38
346	77327	0.7633	0.013159	1.3481	35.72154	6.935584	39
346	77326	0.7633	0.013159	1.3481	35.67154	6.935584	40
346	77328	0.7633	0.013159	1.3481	35.77154	6.935584	41
346	76548	0.7633	0.013159	1.3481	35.77154	7.035584	42
346	76936	0.7633	0.013159	1.3481	35.67154	6.985584	43
346	76937	0.7633	0.013159	1.3481	35.72154	6.985584	44
346	76938	0.7633	0.013159	1.3481	35.77154	6.985584	45
346	78115	0.7633	0.013159	1.3481	36.12154	6.835584	46
346	76547	0.7633	0.013159	1.3481	35.72154	7.035584	47
346	78505	0.7633	0.013159	1.3481	36.12154	6.785584	48
346	78506	0.7633	0.013159	1.3481	36.17154	6.785584	49
346	78116	0.7633	0.013159	1.3481	36.17154	6.835584	50
346	80850	0.9585	0.016525	1.2875	36.37154	6.485584	51
346	81626	0.9585	0.016525	1.2875	36.17154	6.385584	52
346	81240	0.9585	0.016525	1.2875	36.37154	6.435584	53
346	81236	0.9585	0.016525	1.2875	36.17154	6.435584	54
346	81238	0.9585	0.016525	1.2875	36.27154	6.435584	55
346	78110	1.1379	0.019617	1.2641	35.87154	6.835584	56
346	78111	1.1379	0.019617	1.2641	35.92154	6.835584	57
346	78112	1.1379	0.019617	1.2641	35.97154	6.835584	58
346	77721	1.1379	0.019617	1.2641	35.92154	6.885584	59
346	77724	1.1379	0.019617	1.2641	36.07154	6.885584	60
346	77725	1.1379	0.019617	1.2641	36.12154	6.885584	61
346	77727	1.1379	0.019617	1.2641	36.22154	6.885584	62
346	77730	1.1379	0.019617	1.2641	36.37154	6.885584	63
346	81231	1.1379	0.019617	1.2641	35.92154	6.435584	64
346	76156	1.1379	0.019617	1.2641	35.67154	7.085584	65
346	78113	1.1379	0.019617	1.2641	36.02154	6.835584	66
346	77728	1.1379	0.019617	1.2641	36.27154	6.885584	67
346	77729	1.1379	0.019617	1.2641	36.32154	6.885584	68
346	77336	1.1379	0.019617	1.2641	36.17154	6.935584	69
346	77339	1.1379	0.019617	1.2641	36.32154	6.935584	70
346	80841	1.1379	0.019617	1.2641	35.92154	6.485584	71
346	80842	1.1379	0.019617	1.2641	35.97154	6.485584	72
346	80843	1.1379	0.019617	1.2641	36.02154	6.485584	73
346	80846	1.1379	0.019617	1.2641	36.17154	6.485584	74
346	80847	1.1379	0.019617	1.2641	36.22154	6.485584	75
346	80848	1.1379	0.019617	1.2641	36.27154	6.485584	76
346	80849	1.1379	0.019617	1.2641	36.32154	6.485584	77
346	76946	1.1379	0.019617	1.2641	36.17154	6.985584	78
346	76947	1.1379	0.019617	1.2641	36.22154	6.985584	79
346	76948	1.1379	0.019617	1.2641	36.27154	6.985584	80
346	76949	1.1379	0.019617	1.2641	36.32154	6.985584	81
346	76950	1.1379	0.019617	1.2641	36.37154	6.985584	82
346	80452	1.1379	0.019617	1.2641	35.97154	6.535584	83
346	80453	1.1379	0.019617	1.2641	36.02154	6.535584	84
346	80457	1.1379	0.019617	1.2641	36.22154	6.535584	85
346	80458	1.1379	0.019617	1.2641	36.27154	6.535584	86
346	76555	1.1379	0.019617	1.2641	36.12154	7.035584	87
346	76556	1.1379	0.019617	1.2641	36.17154	7.035584	88
346	76557	1.1379	0.019617	1.2641	36.22154	7.035584	89
346	76558	1.1379	0.019617	1.2641	36.27154	7.035584	90
346	76559	1.1379	0.019617	1.2641	36.32154	7.035584	91
346	76560	1.1379	0.019617	1.2641	36.37154	7.035584	92

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
346	78897	1.1379	0.019617	1.2641	36.22154	6.735584	93
346	78898	1.1379	0.019617	1.2641	36.27154	6.735584	94
346	78899	1.1379	0.019617	1.2641	36.32154	6.735584	95
346	78114	1.1379	0.019617	1.2641	36.07154	6.835584	96
346	76166	1.1379	0.019617	1.2641	36.17154	7.085584	97
346	76167	1.1379	0.019617	1.2641	36.22154	7.085584	98
346	76168	1.1379	0.019617	1.2641	36.27154	7.085584	99
346	76169	1.1379	0.019617	1.2641	36.32154	7.085584	100
346	76170	1.1379	0.019617	1.2641	36.37154	7.085584	101
346	79672	1.1379	0.019617	1.2641	35.97154	6.635584	102
346	79673	1.1379	0.019617	1.2641	36.02154	6.635584	103
346	79674	1.1379	0.019617	1.2641	36.07154	6.635584	104
346	79676	1.1379	0.019617	1.2641	36.17154	6.635584	105
346	80061	1.1379	0.019617	1.2641	35.92154	6.585584	106
346	80062	1.1379	0.019617	1.2641	35.97154	6.585584	107
346	78118	1.1379	0.019617	1.2641	36.27154	6.835584	108
346	78119	1.1379	0.019617	1.2641	36.32154	6.835584	109
346	78120	1.1379	0.019617	1.2641	36.37154	6.835584	110
346	78501	1.1379	0.019617	1.2641	35.92154	6.785584	111
346	78502	1.1379	0.019617	1.2641	35.97154	6.785584	112
346	78503	1.1379	0.019617	1.2641	36.02154	6.785584	113
346	78504	1.1379	0.019617	1.2641	36.07154	6.785584	114
346	78507	1.1379	0.019617	1.2641	36.22154	6.785584	115
346	78508	1.1379	0.019617	1.2641	36.27154	6.785584	116
346	78892	1.1379	0.019617	1.2641	35.97154	6.735584	117
346	78895	1.1379	0.019617	1.2641	36.12154	6.735584	118
346	79287	1.1379	0.019617	1.2641	36.22154	6.685584	119
346	80067	1.1379	0.019617	1.2641	36.22154	6.585584	120
346	80068	1.1379	0.019617	1.2641	36.27154	6.585584	121
346	78117	1.1379	0.019617	1.2641	36.22154	6.835584	122
346	81629	1.1379	0.019617	1.2641	36.32154	6.385584	123
346	81630	1.1379	0.019617	1.2641	36.37154	6.385584	124
346	81617	1.1379	0.019617	1.2641	35.72154	6.385584	125
346	81616	1.1379	0.019617	1.2641	35.67154	6.385584	126
346	81618	1.1379	0.019617	1.2641	35.77154	6.385584	127
346	81619	1.1379	0.019617	1.2641	35.82154	6.385584	128
346	79282	1.1379	0.019617	1.2641	35.97154	6.685584	129
346	81621	1.1379	0.019617	1.2641	35.92154	6.385584	130
346	81230	1.142978	0.019705	1.3028	35.87154	6.435584	131
346	80460	1.142978	0.019705	1.3028	36.37154	6.535584	132
346	80838	1.142978	0.019705	1.3028	35.77154	6.485584	133
346	80839	1.142978	0.019705	1.3028	35.82154	6.485584	134
346	80840	1.142978	0.019705	1.3028	35.87154	6.485584	135
346	81229	1.142978	0.019705	1.3028	35.82154	6.435584	136
346	80450	1.142978	0.019705	1.3028	35.87154	6.535584	137
346	80451	1.142978	0.019705	1.3028	35.92154	6.535584	138
346	80448	1.142978	0.019705	1.3028	35.77154	6.535584	139
346	80449	1.142978	0.019705	1.3028	35.82154	6.535584	140
346	79668	1.142978	0.019705	1.3028	35.77154	6.635584	141
346	79669	1.142978	0.019705	1.3028	35.82154	6.635584	142
346	79670	1.142978	0.019705	1.3028	35.87154	6.635584	143
346	79671	1.142978	0.019705	1.3028	35.92154	6.635584	144
346	79677	1.142978	0.019705	1.3028	36.22154	6.635584	145
346	79678	1.142978	0.019705	1.3028	36.27154	6.635584	146
346	80059	1.142978	0.019705	1.3028	35.82154	6.585584	147
346	80060	1.142978	0.019705	1.3028	35.87154	6.585584	148

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
346	78500	1.142978	0.019705	1.3028	35.87154	6.785584	149
346	78889	1.142978	0.019705	1.3028	35.82154	6.735584	150
346	78890	1.142978	0.019705	1.3028	35.87154	6.735584	151
346	78891	1.142978	0.019705	1.3028	35.92154	6.735584	152
346	80070	1.142978	0.019705	1.3028	36.37154	6.585584	153
346	79288	1.142978	0.019705	1.3028	36.27154	6.685584	154
346	79289	1.142978	0.019705	1.3028	36.32154	6.685584	155
346	81620	1.142978	0.019705	1.3028	35.87154	6.385584	156
346	79281	1.142978	0.019705	1.3028	35.92154	6.685584	157
346	79280	1.142978	0.019705	1.3028	35.87154	6.685584	158
346	79279	1.142978	0.019705	1.3028	35.82154	6.685584	159
346	77717	1.2544	0.021626	1.2414	35.72154	6.885584	160
346	77718	1.2544	0.021626	1.2414	35.77154	6.885584	161
346	77716	1.2544	0.021626	1.2414	35.67154	6.885584	162
346	78106	1.2544	0.021626	1.2414	35.67154	6.835584	163
346	78107	1.2544	0.021626	1.2414	35.72154	6.835584	164
346	78108	1.2544	0.021626	1.2414	35.77154	6.835584	165
346	78109	1.2544	0.021626	1.2414	35.82154	6.835584	166
346	78496	1.2544	0.021626	1.2414	35.67154	6.785584	167
346	78497	1.2544	0.021626	1.2414	35.72154	6.785584	168
346	78498	1.2544	0.021626	1.2414	35.77154	6.785584	169
346	78499	1.2544	0.021626	1.2414	35.82154	6.785584	170
346	78886	1.2544	0.021626	1.2414	35.67154	6.735584	171
346	78887	1.2544	0.021626	1.2414	35.72154	6.735584	172
346	78888	1.2544	0.021626	1.2414	35.77154	6.735584	173
346	79277	1.2544	0.021626	1.2414	35.72154	6.685584	174
346	79278	1.2544	0.021626	1.2414	35.77154	6.685584	175
346	76157	1.329211	0.022916	1.240978	35.72154	7.085584	176
346	80836	1.329211	0.022916	1.240978	35.67154	6.485584	177
346	80837	1.329211	0.022916	1.240978	35.72154	6.485584	178
346	81226	1.329211	0.022916	1.240978	35.67154	6.435584	179
346	81227	1.329211	0.022916	1.240978	35.72154	6.435584	180
346	81228	1.329211	0.022916	1.240978	35.77154	6.435584	181
346	80446	1.329211	0.022916	1.240978	35.67154	6.535584	182
346	80447	1.329211	0.022916	1.240978	35.72154	6.535584	183
346	76546	1.329211	0.022916	1.240978	35.67154	7.035584	184
346	79667	1.329211	0.022916	1.240978	35.72154	6.635584	185
346	80056	1.329211	0.022916	1.240978	35.67154	6.585584	186
346	80057	1.329211	0.022916	1.240978	35.72154	6.585584	187
346	80058	1.329211	0.022916	1.240978	35.77154	6.585584	188
346	79276	1.329211	0.022916	1.240978	35.67154	6.685584	189
346	76158	1.329211	0.022916	1.240978	35.77154	7.085584	190
346	79666	1.329211	0.022916	1.240978	35.67154	6.635584	191
346	77719	1.3307	0.022941	1.2352	35.82154	6.885584	192
346	77720	1.3307	0.022941	1.2352	35.87154	6.885584	193
346	77329	1.3307	0.022941	1.2352	35.82154	6.935584	194
346	76939	1.3307	0.022941	1.2352	35.82154	6.985584	195
346	76940	1.3307	0.022941	1.2352	35.87154	6.985584	196
346	76165	1.3307	0.022941	1.2352	36.12154	7.085584	197
346	77722	1.407	0.024257	1.229	35.97154	6.885584	198
346	77723	1.407	0.024257	1.229	36.02154	6.885584	199
346	77330	1.407	0.024257	1.229	35.87154	6.935584	200
346	77331	1.407	0.024257	1.229	35.92154	6.935584	201
346	77332	1.407	0.024257	1.229	35.97154	6.935584	202
346	77333	1.407	0.024257	1.229	36.02154	6.935584	203
346	77334	1.407	0.024257	1.229	36.07154	6.935584	204

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
346	77335	1.407	0.024257	1.229	36.12154	6.935584	205
346	76943	1.407	0.024257	1.229	36.02154	6.985584	206
346	76944	1.407	0.024257	1.229	36.07154	6.985584	207
346	76945	1.407	0.024257	1.229	36.12154	6.985584	208
346	76549	1.407	0.024257	1.229	35.82154	7.035584	209
346	76550	1.407	0.024257	1.229	35.87154	7.035584	210
346	76551	1.407	0.024257	1.229	35.92154	7.035584	211
346	76552	1.407	0.024257	1.229	35.97154	7.035584	212
346	76553	1.407	0.024257	1.229	36.02154	7.035584	213
346	76554	1.407	0.024257	1.229	36.07154	7.035584	214
346	76941	1.407	0.024257	1.229	35.92154	6.985584	215
346	76942	1.407	0.024257	1.229	35.97154	6.985584	216
346	78900	1.407	0.024257	1.229	36.37154	6.735584	217
346	76159	1.407	0.024257	1.229	35.82154	7.085584	218
346	76160	1.407	0.024257	1.229	35.87154	7.085584	219
346	76161	1.407	0.024257	1.229	35.92154	7.085584	220
346	76162	1.407	0.024257	1.229	35.97154	7.085584	221
346	76163	1.407	0.024257	1.229	36.02154	7.085584	222
346	76164	1.407	0.024257	1.229	36.07154	7.085584	223
346	78509	1.407	0.024257	1.229	36.32154	6.785584	224
346	78510	1.407	0.024257	1.229	36.37154	6.785584	225

Table A10.3

Raw soil data of all relevant (i.e. organic matter content > 0 and realistic sets of organic matter content and dry bulk density) pixels of the scenario location of groundwater protection goal 3b.

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
323	71533	0.3317	0.005719	1.3897	38.52154	7.685584	1
323	71534	0.3317	0.005719	1.3897	38.57154	7.685584	2
323	71535	0.3317	0.005719	1.3897	38.62154	7.685584	3
323	71922	0.3317	0.005719	1.3897	38.47154	7.635584	4
323	72312	0.3317	0.005719	1.3897	38.47154	7.585584	5
323	70742	0.3512	0.006055	1.3736	37.97154	7.785584	6
323	71132	0.3512	0.006055	1.3736	37.97154	7.735584	7
323	71522	0.3512	0.006055	1.3736	37.97154	7.685584	8
323	71523	0.3512	0.006055	1.3736	38.02154	7.685584	9
323	70353	0.3512	0.006055	1.3736	38.02154	7.835584	10
323	75814	0.3512	0.006055	1.3736	38.07154	7.135584	11
323	75031	0.434	0.007482	1.485	37.92154	7.235584	12
323	75032	0.434	0.007482	1.485	37.97154	7.235584	13
323	73873	0.434	0.007482	1.485	38.52154	7.385584	14
323	73874	0.434	0.007482	1.485	38.57154	7.385584	15
323	74252	0.434	0.007482	1.485	37.97154	7.335584	16
323	73089	0.434	0.007482	1.485	38.32154	7.485584	17
323	73090	0.434	0.007482	1.485	38.37154	7.485584	18
323	73479	0.434	0.007482	1.485	38.32154	7.435584	19
323	73480	0.434	0.007482	1.485	38.37154	7.435584	20
323	73482	0.434	0.007482	1.485	38.47154	7.435584	21
323	73485	0.434	0.007482	1.485	38.62154	7.435584	22
323	73862	0.434	0.007482	1.485	37.97154	7.385584	23
323	72310	0.434	0.007482	1.485	38.37154	7.585584	24
323	70351	0.434	0.007482	1.485	37.92154	7.835584	25
323	70352	0.434	0.007482	1.485	37.97154	7.835584	26

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
323	70741	0.434	0.007482	1.485	37.92154	7.785584	27
323	72699	0.434	0.007482	1.485	38.32154	7.535584	28
323	72700	0.434	0.007482	1.485	38.37154	7.535584	29
323	72313	0.461	0.007948	1.3793	38.52154	7.585584	30
323	72702	0.461	0.007948	1.3793	38.47154	7.535584	31
323	72704	0.461	0.007948	1.3793	38.57154	7.535584	32
323	70747	0.4934	0.008506	1.3862	38.22154	7.785584	33
323	70748	0.4934	0.008506	1.3862	38.27154	7.785584	34
323	70749	0.4934	0.008506	1.3862	38.32154	7.785584	35
323	70750	0.4934	0.008506	1.3862	38.37154	7.785584	36
323	70751	0.4934	0.008506	1.3862	38.42154	7.785584	37
323	70752	0.4934	0.008506	1.3862	38.47154	7.785584	38
323	71137	0.4934	0.008506	1.3862	38.22154	7.735584	39
323	71138	0.4934	0.008506	1.3862	38.27154	7.735584	40
323	71139	0.4934	0.008506	1.3862	38.32154	7.735584	41
323	71140	0.4934	0.008506	1.3862	38.37154	7.735584	42
323	71141	0.4934	0.008506	1.3862	38.42154	7.735584	43
323	71526	0.4934	0.008506	1.3862	38.17154	7.685584	44
323	71527	0.4934	0.008506	1.3862	38.22154	7.685584	45
323	71528	0.4934	0.008506	1.3862	38.27154	7.685584	46
323	71529	0.4934	0.008506	1.3862	38.32154	7.685584	47
323	71918	0.4934	0.008506	1.3862	38.27154	7.635584	48
323	71919	0.4934	0.008506	1.3862	38.32154	7.635584	49
323	70360	0.4934	0.008506	1.3862	38.37154	7.835584	50
323	70361	0.4934	0.008506	1.3862	38.42154	7.835584	51
323	70362	0.4934	0.008506	1.3862	38.47154	7.835584	52
323	70363	0.4934	0.008506	1.3862	38.52154	7.835584	53
323	71131	0.5871	0.010122	1.4742	37.92154	7.735584	54
323	70743	0.5871	0.010122	1.4742	38.02154	7.785584	55
323	70746	0.5871	0.010122	1.4742	38.17154	7.785584	56
323	71133	0.5871	0.010122	1.4742	38.02154	7.735584	57
323	71134	0.5871	0.010122	1.4742	38.07154	7.735584	58
323	71135	0.5871	0.010122	1.4742	38.12154	7.735584	59
323	71136	0.5871	0.010122	1.4742	38.17154	7.735584	60
323	71911	0.5871	0.010122	1.4742	37.92154	7.635584	61
323	71912	0.5871	0.010122	1.4742	37.97154	7.635584	62
323	71913	0.5871	0.010122	1.4742	38.02154	7.635584	63
323	71521	0.5871	0.010122	1.4742	37.92154	7.685584	64
323	71524	0.5871	0.010122	1.4742	38.07154	7.685584	65
323	72301	0.5871	0.010122	1.4742	37.92154	7.585584	66
323	72302	0.5871	0.010122	1.4742	37.97154	7.585584	67
323	72303	0.5871	0.010122	1.4742	38.02154	7.585584	68
323	70359	0.5871	0.010122	1.4742	38.32154	7.835584	69
323	70354	0.5871	0.010122	1.4742	38.07154	7.835584	70
323	75811	0.6821	0.011759	1.5482	37.92154	7.135584	71
323	73082	0.713	0.012292	1.559	37.97154	7.485584	72
323	73083	0.713	0.012292	1.559	38.02154	7.485584	73
323	70753	0.7824	0.013489	1.526	38.52154	7.785584	74
323	70364	0.7824	0.013489	1.526	38.57154	7.835584	75
323	73865	0.916422	0.015799	1.348456	38.12154	7.385584	76
323	73866	0.916422	0.015799	1.348456	38.17154	7.385584	77
323	73867	0.916422	0.015799	1.348456	38.22154	7.385584	78
323	73087	0.916422	0.015799	1.348456	38.22154	7.485584	79
323	73476	0.916422	0.015799	1.348456	38.17154	7.435584	80
323	73477	0.916422	0.015799	1.348456	38.22154	7.435584	81
323	70744	0.953111	0.016432	1.402711	38.07154	7.785584	82

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
323	70745	0.953111	0.016432	1.402711	38.12154	7.785584	83
323	70357	0.953111	0.016432	1.402711	38.22154	7.835584	84
323	70358	0.953111	0.016432	1.402711	38.27154	7.835584	85
323	70355	0.953111	0.016432	1.402711	38.12154	7.835584	86
323	70356	0.953111	0.016432	1.402711	38.17154	7.835584	87
323	75435	0.953111	0.016432	1.402711	38.62154	7.185584	88
323	75824	0.953111	0.016432	1.402711	38.57154	7.135584	89
323	75825	0.953111	0.016432	1.402711	38.62154	7.135584	90
323	75821	0.9695	0.016714	1.205	38.42154	7.135584	91
323	75820	0.9695	0.016714	1.205	38.37154	7.135584	92
323	75822	0.9695	0.016714	1.205	38.47154	7.135584	93
323	75823	0.9695	0.016714	1.205	38.52154	7.135584	94
323	73861	1.1405	0.019662	1.31555	37.92154	7.385584	95
323	73081	1.1405	0.019662	1.31555	37.92154	7.485584	96
323	75812	1.1405	0.019662	1.31555	37.97154	7.135584	97
323	72691	1.1405	0.019662	1.31555	37.92154	7.535584	98
323	74641	1.2834	0.022126	1.2368	37.92154	7.285584	99
323	75421	1.2834	0.022126	1.2368	37.92154	7.185584	100
323	75422	1.2834	0.022126	1.2368	37.97154	7.185584	101
323	74251	1.2834	0.022126	1.2368	37.92154	7.335584	102
323	75429	1.4266	0.024595	1.0624	38.32154	7.185584	103
323	75430	1.4266	0.024595	1.0624	38.37154	7.185584	104
323	75431	1.4266	0.024595	1.0624	38.42154	7.185584	105
323	74650	1.4266	0.024595	1.0624	38.37154	7.285584	106
323	75040	1.4266	0.024595	1.0624	38.37154	7.235584	107
323	75432	1.4266	0.024595	1.0624	38.47154	7.185584	108
323	75819	1.4266	0.024595	1.0624	38.32154	7.135584	109
323	70754	1.7462	0.030104	1.0694	38.57154	7.785584	110
323	70755	1.7462	0.030104	1.0694	38.62154	7.785584	111
323	71142	1.7462	0.030104	1.0694	38.47154	7.735584	112
323	71143	1.7462	0.030104	1.0694	38.52154	7.735584	113
323	71144	1.7462	0.030104	1.0694	38.57154	7.735584	114
323	71145	1.7462	0.030104	1.0694	38.62154	7.735584	115
323	71530	1.7462	0.030104	1.0694	38.37154	7.685584	116
323	71531	1.7462	0.030104	1.0694	38.42154	7.685584	117
323	71532	1.7462	0.030104	1.0694	38.47154	7.685584	118
323	71920	1.7462	0.030104	1.0694	38.37154	7.635584	119
323	71921	1.7462	0.030104	1.0694	38.42154	7.635584	120
323	70365	1.7462	0.030104	1.0694	38.62154	7.835584	121
323	72311	1.7462	0.030104	1.0694	38.42154	7.585584	122
323	71917	1.754	0.030239	1.0734	38.22154	7.635584	123
323	73478	1.754	0.030239	1.0734	38.27154	7.435584	124
323	72308	1.754	0.030239	1.0734	38.27154	7.585584	125
323	72309	1.754	0.030239	1.0734	38.32154	7.585584	126
323	72698	1.754	0.030239	1.0734	38.27154	7.535584	127
323	74261	1.9028	0.032804	1.0298	38.42154	7.335584	128
323	74262	1.9028	0.032804	1.0298	38.47154	7.335584	129
323	74263	1.9028	0.032804	1.0298	38.52154	7.335584	130
323	74642	1.9028	0.032804	1.0298	37.97154	7.285584	131
323	74264	1.9028	0.032804	1.0298	38.57154	7.335584	132
323	74258	1.9028	0.032804	1.0298	38.27154	7.335584	133
323	74259	1.9028	0.032804	1.0298	38.32154	7.335584	134
323	74260	1.9028	0.032804	1.0298	38.37154	7.335584	135
323	74643	1.9028	0.032804	1.0298	38.02154	7.285584	136
323	74644	1.9028	0.032804	1.0298	38.07154	7.285584	137
323	74645	1.9028	0.032804	1.0298	38.12154	7.285584	138

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
323	74646	1.9028	0.032804	1.0298	38.17154	7.285584	139
323	74257	1.9028	0.032804	1.0298	38.22154	7.335584	140
323	75423	1.9028	0.032804	1.0298	38.02154	7.185584	141
323	75424	1.9028	0.032804	1.0298	38.07154	7.185584	142
323	75425	1.9028	0.032804	1.0298	38.12154	7.185584	143
323	75426	1.9028	0.032804	1.0298	38.17154	7.185584	144
323	75427	1.9028	0.032804	1.0298	38.22154	7.185584	145
323	74256	1.9028	0.032804	1.0298	38.17154	7.335584	146
323	74647	1.9028	0.032804	1.0298	38.22154	7.285584	147
323	74648	1.9028	0.032804	1.0298	38.27154	7.285584	148
323	74649	1.9028	0.032804	1.0298	38.32154	7.285584	149
323	74651	1.9028	0.032804	1.0298	38.42154	7.285584	150
323	74652	1.9028	0.032804	1.0298	38.47154	7.285584	151
323	74653	1.9028	0.032804	1.0298	38.52154	7.285584	152
323	74654	1.9028	0.032804	1.0298	38.57154	7.285584	153
323	75033	1.9028	0.032804	1.0298	38.02154	7.235584	154
323	75034	1.9028	0.032804	1.0298	38.07154	7.235584	155
323	75035	1.9028	0.032804	1.0298	38.12154	7.235584	156
323	75036	1.9028	0.032804	1.0298	38.17154	7.235584	157
323	75037	1.9028	0.032804	1.0298	38.22154	7.235584	158
323	75041	1.9028	0.032804	1.0298	38.42154	7.235584	159
323	75042	1.9028	0.032804	1.0298	38.47154	7.235584	160
323	75043	1.9028	0.032804	1.0298	38.52154	7.235584	161
323	74255	1.9028	0.032804	1.0298	38.12154	7.335584	162
323	71914	1.9028	0.032804	1.0298	38.07154	7.635584	163
323	71915	1.9028	0.032804	1.0298	38.12154	7.635584	164
323	71916	1.9028	0.032804	1.0298	38.17154	7.635584	165
323	75433	1.9028	0.032804	1.0298	38.52154	7.185584	166
323	73868	1.9028	0.032804	1.0298	38.27154	7.385584	167
323	73869	1.9028	0.032804	1.0298	38.32154	7.385584	168
323	73870	1.9028	0.032804	1.0298	38.37154	7.385584	169
323	73871	1.9028	0.032804	1.0298	38.42154	7.385584	170
323	73872	1.9028	0.032804	1.0298	38.47154	7.385584	171
323	74253	1.9028	0.032804	1.0298	38.02154	7.335584	172
323	74254	1.9028	0.032804	1.0298	38.07154	7.335584	173
323	73088	1.9028	0.032804	1.0298	38.27154	7.485584	174
323	73471	1.9028	0.032804	1.0298	37.92154	7.435584	175
323	73472	1.9028	0.032804	1.0298	37.97154	7.435584	176
323	73473	1.9028	0.032804	1.0298	38.02154	7.435584	177
323	73474	1.9028	0.032804	1.0298	38.07154	7.435584	178
323	73475	1.9028	0.032804	1.0298	38.12154	7.435584	179
323	73863	1.9028	0.032804	1.0298	38.02154	7.385584	180
323	73864	1.9028	0.032804	1.0298	38.07154	7.385584	181
323	71525	1.9028	0.032804	1.0298	38.12154	7.685584	182
323	73084	1.9028	0.032804	1.0298	38.07154	7.485584	183
323	73085	1.9028	0.032804	1.0298	38.12154	7.485584	184
323	73086	1.9028	0.032804	1.0298	38.17154	7.485584	185
323	72304	1.9028	0.032804	1.0298	38.07154	7.585584	186
323	72305	1.9028	0.032804	1.0298	38.12154	7.585584	187
323	72306	1.9028	0.032804	1.0298	38.17154	7.585584	188
323	72307	1.9028	0.032804	1.0298	38.22154	7.585584	189
323	75813	1.9028	0.032804	1.0298	38.02154	7.135584	190
323	75815	1.9028	0.032804	1.0298	38.12154	7.135584	191
323	75816	1.9028	0.032804	1.0298	38.17154	7.135584	192
323	72693	1.9028	0.032804	1.0298	38.02154	7.535584	193
323	72694	1.9028	0.032804	1.0298	38.07154	7.535584	194

grid_id	pixel_id	Org. carbon content	Fraction organic matter	Dry bulk density	Longitude	Latitude	No
		(%)	(-)	(kg dm^{-3})			
323	72695	1.9028	0.032804	1.0298	38.12154	7.535584	195
323	72696	1.9028	0.032804	1.0298	38.17154	7.535584	196
323	72697	1.9028	0.032804	1.0298	38.22154	7.535584	197
323	72692	1.9028	0.032804	1.0298	37.97154	7.535584	198
323	74265	2.0281	0.034964	0.8578	38.62154	7.335584	199
323	75428	2.0281	0.034964	0.8578	38.27154	7.185584	200
323	74655	2.0281	0.034964	0.8578	38.62154	7.285584	201
323	75038	2.0281	0.034964	0.8578	38.27154	7.235584	202
323	75039	2.0281	0.034964	0.8578	38.32154	7.235584	203
323	75044	2.0281	0.034964	0.8578	38.57154	7.235584	204
323	75045	2.0281	0.034964	0.8578	38.62154	7.235584	205
323	75434	2.0281	0.034964	0.8578	38.57154	7.185584	206
323	73875	2.0281	0.034964	0.8578	38.62154	7.385584	207
323	75817	2.0281	0.034964	0.8578	38.22154	7.135584	208
323	75818	2.0281	0.034964	0.8578	38.27154	7.135584	209

Appendix 11.1 R4 soil, site and scenario specific parameters and scenario specific runoff curve numbers for PRZM (taken from Appendix D of FOCUS, 2001)

Table A11.1.1
R4 soil and site parameters for PRZM (taken from Table D12 Appendix *D in FOCUS, 2001).*

Horizon (FAO, 1990)	Ap1	Ap2	2C1	2C2
Depth (cm)	0-30	30-60	60 - 170	170-300
BASIC PROPERTIES				
Sand (%)	53	53	69	65
Silt (%)	22	22	24	27
Clay (%)	25	25	7	8
Texture (FAO, 1990; USDA, 1999)	sandy clay loam	sandy clay loam	sandy loam	sandy loam
Organic carbon (%)	0.6	0.6 [a]	0.08	0.08
Bulk density (g/cm^3)	1.52	1.50 [a]	1.49	1.50
pH	8.4	8.4 [a]	8.8	8.8
Structure (FAO, 1990)				
Development	Moderate	Moderate	Apedal	Apedal
Size	Fine	Fine	N/A	N/A
Shape	Subangular blocky	Subangular blocky	Single grain	Single grain
HYDRAULIC PROPERTIES				
Field capacity (% volume)	26 [b]	27 [b]	14.5 [b]	16 [b]
Wilting point (%volume)	16 [b]	16 [b]	6 [b]	7 [b]
RUNOFF & SOIL LOSS PROPERTIES				
Parameter	**Value**	**Selection criteria**		**Reference**
Hydrologic group (HGRP)	C	appropriate for soil type		FOCUS definition
USLE K factor(USLEK)	0.26	sandy clay loam, 0.6% OM		PRZM manual
USLE LS factor (USLELS)	0.66	45 m length, 5% slope		PRZM manual
USLE P factor (USLEP)	0.50	contouring, 5% slope		PRZM manual
Area of field (AFIELD)	0.45 ha	assumption for scenario		FOCUS definition
IREG	2	heavier winter rain		FOCUS definition
Slope (SLP)	5%	appropriate for scenario		FOCUS definition
HL	20 m	assumption for scenario		FOCUS definition
Manning's coefficient	0.10	fallow, no-till or coulter		PRZM manual

[a] Estimated value based on horizon type and value for horizon above.
[b] Calculated using PRZM pedo-transfer functions with other data given in the table (FC = –33 kPa; WP = –1500 kPa).

Table A11.1.2
R4 scenario-specific parameters for PRZM (taken from Table D11 Appendix *D in FOCUS, 2001).*

Evaporation depth during fallow period (ANETD)	25 cm
Bottom boundary temperature (BBT)	14.0 ^{o}C

Table A11.1.3

R4 scenario-specific runoff curve numbers for PRZM (taken from Table D13 Appendix D in FOCUS, 2001).

Crop group	Runoff curve number (antecedent moisture condition II)			
	Emergence (cropping)	Maturation (cropping)	Harvest (residue)	Fallow
Cereals, spring	81	81	86	91
Cereals, winter	81	81	86	91
Citrus [b]	70	70	70	70
Field beans	82	82	87	91
Legumes	78	78	85	91
Maize	82	82	87	91
Olives [b]	70	70	70	70
Pome/stone fruit [b]	70	70	70	70
Soybean	82	82	87	91
Sunflowers	82	82	87	91
Vegetables, bulb	82	82	87	91
Vegetables, fruiting	82	82	87	91
Vegetables, leafy [a]	82	82	87	91
Vegetables, root	82	82	87	91
Vines [b]	70	70	70	70

[a] 2 crops per season with simulations performed separately for early crop and late crop

[b] Perennial crops

Table A11.1.4

General cropping parameters for all EU FOCUS SW runoff scenarios for PRZM (taken from Table D1 Appendix D in FOCUS, 2001).

	Pan evaporation factor, PFAC	Canopy interception, CINTCP	Maximum coverage, COVMAX	USLEC factor, fallow	USLEC factor, cropping	USLEC factor, residue
Cereals, Spring	0.92	0.15	90	0.9	0.2	0.4
Cereals, Winter	0.84	0.15	90	0.9	0.2	0.4
Citrus	0.69	0.30	70	0.2	0.2	0.2
Field beans	0.89	0.15	80	0.9	0.2	0.4
Grass/alfalfa	1.00	0.15	90	0.02	0.02	0.02
Hops	0.72	0.30	90	0.9	0.2	0.4
Legumes	0.96	0.15	85	0.9	0.2	0.4
Maize	0.94	0.30	90	0.9	0.2	0.4
Oilseed rape, spring	0.93	0.15	90	0.9	0.2	0.4
Oilseed rape, winter	0.78	0.15	90	0.9	0.2	0.4
Olive	0.83	0.30	80	0.2	0.2	0.2
Pome/stone fruit	0.83	0.30	80	0.9	0.2	0.4
Potatoes	0.94	0.15	80	0.9	0.2	0.4
Soybean	0.92	0.25	85	0.9	0.2	0.4
Sugar beets	0.93	0.15	90	0.9	0.2	0.4
Sunflower	0.86	0.30	90	0.9	0.2	0.4
Tobacco	0.98	0.25	90	0.9	0.2	0.4
Vegetables, bulb	0.91	0.15	60	0.9	0.2	0.4
Vegetables, fruiting	0.97	0.15	80	0.9	0.2	0.4
Vegetables, leafy	0.97	0.15	90	0.9	0.2	0.4
Vegetables, root	0.96	0.15	80	0.9	0.2	0.4
Vines	0.72	0.30	85	0.2	0.2	0.2

Appendix 11.2 Crop calendar for the crops featuring in the surface water scenarios

Information on the crop calendar has been obtained from Mr. Aweke Nigatu, irrigation agronomist at the Ministry of Agriculture (MoA), Ethiopa, working for the IFAD/irrigation project at 13 February 2013 (see Table I2) as well as from the Crop Variety Register of the Animal and Plant Health Regulatory Department (PHRD) of the Ministry of Agriculture (MoA) of Ethiopia, issue numbers 14 (2011), 13 (2010), 12 (2009), 11 (2008), 10 (2007) and 9 (2006). In collaboration with Mr Zebdewos Salato Amba of the PHRD, MoA it has been subdivided into the crop development stages by Paulien Adriaanse that are required for the PRZM model.

Table A11.2.1

Maximum crop height (cm), maximum rooting depth (cm) and lengths of crop development stages (d) for annual crops cultivated in the highlands (H, above 1500 m altitude) and low/midlands (M, below 1500 m altitude). For simplication we only use one crop development cycle per crop: the one where the crop is most commonly grown.

Crop	Altitude	Max crop height# (cm)	Max. rooting depth# (cm)	Length of crop development stage (d)					Total length crop cycle*
				Planting/ sowing till	Emergence till	Crop maturation till (halfway mid season)	Harvest till fallow	Fallow	
Tomato	~~H~~	~~110~~	~~80~~	~~20~~	~~13+30+30~~	~~25+20~~	~~10 (2nd harvest)~~		~~148~~
	M	110	80	15	13+30+25	20+20	10 (2nd harvest)		133
									135
Onion	H	60	40	12	4+30+30	30+30			136
	~~M~~	~~60~~	~~40~~	~~10~~	~~4+30+25~~	~~25+30~~			~~124~~
									135
Cabbage	H	30	60	15	13+35+25	25+20			133
	~~M~~	~~30~~	~~60~~	~~10~~	~~13+35+20~~	~~20+20~~			~~118~~
									130
Potato	H	100	60	25	3+30+30	25+20			133
	~~M~~	~~100~~	~~60~~	~~20~~	~~3+30+25~~	~~20+20~~			~~118~~
									125
						Flowering till			
Teff	H	70	40	7	48	45			100
	~~M~~	~~70~~	~~40~~	~~5~~	~~43~~	~~40~~			~~88~~
									90
Wheat	H	110	120	10	50	50			110
	~~M~~								
Barley	H	110	120	10	50	50			110
Maize	~~H~~	~~250~~	~~100~~	~~10~~	~~75~~	~~75~~			~~160~~
	M	250	100	7	70	70			147
									150
Faba bean	H	150	60	12	50	70			132

Crop	Altitude	Max crop height# (cm)	Max. rooting depth# (cm)	Length of crop development stage (d)					Total length crop cycle*
				Planting/ sowing till	Emergence till	Crop maturation till (halfway mid season)	Harvest till fallow	Fallow	
Sweet potato	H	-	-	15	65	60			140
	M	40	40	15	60	55			130
									<u>133</u>
Cotton	H	-	-	-	-	-			
	M	70	150	10	50	73			
									<u>133</u>

based on EU FOCUS R4 scenario, except for teff, sweet potato and cotton (Appendix D, Tables D1) and Appendix D, D12, except potato:D11)
* The underlined number stands for the average length of the total crop cycle, in the highlands the crop cycle generally is slightly longer and in the lowlands/midlands it is generally slightly shorter, mainly due to the difference in temperature.

The length of the crop development stages have been translated into calendar dates indicating when the crops are commonly grown in the selected zone (highland or midland) with the aid of Mr Berhan Teklu, PhD for Environmental Risk Assessment within the PRRP project. Only the zone where the crop is most commonly grown has been parameterized, in order to limit the number of input files to prepare for the PRZM model (see Tables 11.4.3 and 11.4.4 of Chapter 11.4).

Appendix 11.3 Irrigation data for the parameterisation of the PRZM model

Table A11.3.1 presents the estimated total irrigation gifts for the crops of tomato, onion, cabbage and potato as a function of their altitude and annual precipitation. As a general rule irrigation gifts are a function of the altitude (and corresponding annual rainfall): irrigation needs are higher in the low/midlands than those in the cooler highlands. The scenario locations at grid points 191 and 217 are considered to be highlands (H), while grid point 373 belongs to the midlands (M). The ranges indicated by Nigatu have been narrowed down into one value for each scenario location by Adriaanse.

Table A11.3.1
Total irrigation gift (mm) per crop cycle at the indicated surface water scenario locations (incl. altitude and annual precipitation) (Nigatu, pers.comm., 13Feb2013).

Sw scenario locations	191 (W of Lake Tana)	217 (SE of Bure)	373 (W of Arba Minch)
	1682 m	1705 m	1288 m
	2581 mm	2779 mm	1702 mm
Crops			
Tomato	600 (500-600)	550 (500-600)	750 (700-800)
Onion	450 (350-450)	400 (350-450)	450 (400-500)
Cabbage	400 (350-500)	350 (350-500)	500 (350-500)
Potato	600 (500-600)	550 (500-600)	700 (550-700)

The crop development stages and their corresponding water requirements have been summarised in Table A11.3.2.

Table A11.3.2
Length of crop development stages (d) and corresponding irrigation water requirements (% of total) for tomato, onion, cabbage and potato (Nigatu, pers.comm., 13Feb2013).

Crops	Initial	Crop development	Mid season	Late season	Total
Crop development stage (d)					
Tomato	30	30	55	20	135
Onion	15	30	60	30	135
Cabbage	25	35	50	20	130
Potato	25	30	45-55	20	120-130
Irrigation water requirement (%)					
Tomato, onion, potato	20	25	50	5	100
cabbage	20	20	45	15	100

The total irrigation gifts of Table A11.3.1 have been distributed between the various crop development stages according to the percentages water requirements of Table A11.3.2 for the selected scenario locations (Table A11.3.3).

Table A11.3.3

Total irrigation gifts (mm) subdivided per crop development stage for the specified grids.

Grid/crops	Crop development stage				Sum
	Initial	Crop development	Mid season	Late season	(check)
191					
Tomato	120	150	300	30	600
Onion	90	112.5	225	22.5	450
Cabbage	80	80	180	60	400
Potato	120	150	300	30	600
217					
Tomato	110	137.5	275	27.5	550
Onion	80	100	200	20	400
Cabbage	70	70	157.5	52.5	350
Potato	110	137.5	275	27.5	550
373					
Tomato	150	187.5	375	37.5	750
Onion	90	112.5	225	22.5	450
Cabbage	100	100	225	75	500
Potato	140	175	350	35	700

The data of Table A11.3.2 have been slightly adapted to account for altitude and harvesting practices, resulting in Table A11.3.4 that presents the estimated length of the crop development stages of tomato, onion, cabbage and potato for each of the three grids. As a general rule especially the initial crop development stage is a function of the altitude: the initial stage is somewhat shorter in the low/midlands than the initial stage is in the cooler highlands.

Table A11.3.4

Number of days per crop development stage for the specified grids.

Grid/crops	Crop development stage (d)				Sum (check)	
	Initial	Crop development	Mid season	Late season		
191 = 217						
Tomato	33	30	55	30	148	Late season tomato=20 d+10 d up to 2nd harvest
Onion	16	30	60	30	136	
Cabbage	28	35	50	20	133	
Potato	28	30	55	20	133	
373						
Tomato	28	30	45	30	133	Late season tomato=20 d+10 d up to 2nd harvest
Onion	14	30	50	30	124	
Cabbage	23	35	40	20	118	
Potato	23	30	45	20	118	

Table A11.3.5 presents information on crop development, cultivation practices and irrigation intervals. For the scenarios in the highlands (H, grids 191 and 217) and the midlands (M, grid 373) finally selected irrigation intervals have been specified, taking into consideration that the soil at the scenario locations will correspond to the worst case soil of the EU-FOCUS Runoff scenarios, i.e. the R4 soil of sandy clay loam with only 0.6% organic carbon in the upper 60 cm soil (for more details, see Table D17 in Appendix D of FOCUS (2001)).

Table A11.3.5
Information on crop development, cultivation practices and irrigation intervals in Ethiopia (Nigatu, pers.comm., 13Feb2013).

INFORMATION on initial crop development
Tomato, onion and cabbage: average 45 d in nursery before transplanting, so take H:50 d and M:45 d
Potato: From planting to sprouts above soil surface: 20-25 d. take for H 25 d and for M 20 d
TOMATO+ONION
Irrigation interval from planting/sowing up to transplanting is every 2, 3 d for tomatoe and onions equally. Take for FOCUS R4 soil (sandy clay loam) every 3 d.
From transplanting to late season: 3-5 d in M and 5-7 d in H. If clayey soils longer 10-12 d,and for vertisols up to15 d. Sandy soils shorter: 3-5 d. Take for H: 7 d and for M: 5 d
For late season irrigation is diminished by increasing the interval (7, 8 d) and by decreasing the size. Take for H 9 d and for M 7 d.
CABBAGE
Irrigation interval from planting/sowing up to transplanting is every 3-5 d for cabbage. Take for FOCUS R4 soil (sandy clay loam) every 5 d.
From transplanting up to end harvest interval is 5-7 d in M and 7-9,10 in H. Take for H 9 d and for M 7 d.
N.B. Head cabbage is harvested at once, but from local varieties leaves are harvested several times. Therefore irrigation continues untill the end of the harvest
POTATOES
Potatoes: not transplanted
From planting to sprouting above soil: 20-25 d and irrigation interval is 2,3 d. Take for FOCUS R4 soil (sandy clay loam) every 3 d
From sprouts emerged above soil surface irrigation interval is 3-5 d for M and 5-7 d for H. For clayey and vertisols longer (see tomatoes). Take for h: 7 d and for M: 5 d
In the late season the interval is longer and the gifts are smaller. Take for H: 9 d and for M: 7 d.

The information on period spent in the nursery (tomato, onion and cabbage) and period from planting to the emergence of sprouts above the soil surface (potato) of Table A11.3.5 has been combined with the length of the various crop development stages of Table A11.3.4 into Table A11.3.6. Next, the number of irrigation gifts per crop and per grid (Table A11.3.7) have been calculated by dividing the length of the crop stage (Table A11.3.6) by the selected irrigation interval (Table A11.3.5). Thereafter, the size of the irrigation gifts for the nursery and other crop development stages of Table A11.3.6 have been calculated by linear interpolation of the duration of the crop development stages specified in Table A11.3.4 and the irrigation gifts per development stage specified in Table A11.3.3, this resulted in Table A11.3.8.

Table A11.3.6

Number of days for the nursery and other crop stages mentioned in Table A11.3.5 for the selected crops and grids.

	Crop development stages					
Grid/crops						
191 = 217						
	nursery	nursery (cont.)				
	initial	crop dev (part)	crop dev (rem.)+midseason		late season	Sum (check)
Tomato	33	17	68		30	148
Onion	16	34	56		30	136
Cabbage	28	22	63		20	133
	sprouts above ss					
	initial	initial (remaining)	crop dev	mid season	late season	
Potato	25	3	30	55	20	133
373						
	nursery	nursery (cont.)				
	initial	crop dev (part)	crop dev (rem.)+midseason		late season	Sum (check)
Tomato	28	17	58		30	133
Onion	14	31	49		30	124
Cabbage	23	22	53		20	118
	sprouts above ss					
	initial	initial (remaining)	crop dev	mid season	late season	
Potato	20	3	30	45	20	118

Table A11.3.7

Number of irrigation gifts for each crop development stage for the specified crops and grids (191 and 217 are highlands (H) and 373 is midlands (M)).

	Crop development stages				
Grid/crops					
191 = 217					
	nursery	nursery (cont.)			
	initial	crop dev (part)	crop dev (rem.)+midseason		late season
Tomato	11.0	5.7	9.7		3.3
Onion	5.3	11.3	8.0		3.3
Cabbage	5.6	4.4	7.0		2.2
	sprouts above ss				
	initial	initial (remaining)	crop dev	mid season	late season
Potato	8.3	0.4	4.3	7.9	2.2
grid 373					
	nursery	nursery (cont.)			
	initial	crop dev (part)	crop dev (rem.)+midseason		late season
Tomato	9.3	5.7	11.6		4.3
Onion	4.7	10.3	9.8		4.3
Cabbage	4.6	4.4	7.6		2.9
	sprouts above ss				
	initial	initial (remaining)	crop dev	mid season	late season
Potato	6.7	0.6	6.0	9.0	2.9

Table A11.3.8

Size of the (total) irrigation gifts (mm) for the nursery and other stages for the specified crops and grids (191 and 217 are highlands (H) and 373 is midlands (M)).

	Crop development stages					
Grid/crops						
191						
	nursery	nursery (cont.)				
	initial	crop dev (part) (+midseason)	crop dev (rem.)+midseason		late season	Sum (check)
Tomato	120.0	85.0	365.0		30.0	600.0
Onion	90.0	127.5	210.0		22.5	450.0
Cabbage	80.0	50.3	209.7		60.0	400.0
	sprouts above ss					
	initial	initial (remaining)	crop dev	mid season	late season	
Potato	107.1	12.9	150.0	300.0	30.0	600.0
217						
	nursery	nursery (cont.)				
	initial	crop dev (part)	crop dev (rem.)+midseason		late season	Sum (check)
Tomato	110.0	77.9	334.6		27.5	550.0
Onion	80.0	113.3	186.7		20.0	400.0
Cabbage	70.0	44.0	183.5		52.5	350.0
	sprouts above ss					
	initial	initial (remaining)	crop dev	mid season	late season	
Potato	98.2	11.8	137.5	275.0	27.5	550.0
373						
	nursery	nursery (cont.)				
	initial	crop dev (part)	crop dev (rem.)+midseason		late season	Sum (check)
Tomato	150.0	106.3	456.3		37.5	750.0
Onion	90.0	116.3	221.3		22.5	450.0
Cabbage	100.0	62.9	262.1		75.0	500.0
	sprouts above ss					
	initial	initial (remaining)	crop dev	mid season	late season	
Potato	121.7	18.3	175.0	350.0	35.0	700.0

The data of Tables A11.3.7 and A11.3.8 have been transformed into irrigation schedules for the 12 crop/grid combinations (Appendix 11.4).

In Table A11.3.9 we determined the date in the year corresponding to day number 1 of the irrigation schedules for the 3 scenario locations given in Appendix 11.4.

Table A11.3.9

Starting date of the crop development for the four irrigated crops of tomato, onion, cabbage and potato at the 3 scenario locations. The starting date corresponds to the sowing in the nursery (tomato, onion and cabbage) or planting (potato).

	Emergence date*– days before emergence#	191 W of lake Tana	217 SE of Bure	373 W of Arba Minch
Tomato	15 Nov-15	31 Oct	31 Oct	31 Oct
Onion	15 Nov-12	3 Nov	3 Nov	3 Nov
Cabbage	15 Nov -15	31 Oct	31 Oct	31 Oct
Potato	1 Jan-25	7 Dec	7 Dec	7 Dec

* See Table C2, second crop

See Table I5

The crops of tomato, onion and cabbage are first grown in small nurseries (see Table A11.3.5) and only after 45 d (tomatoes, M) or 50 d (onions and cabbage, H) transplanted to their final fields. For the PRZM simulations, mimicking crops grown in a catchment we cannot take this phenomenon into account and we have to assume that the nurseries occupy the same area as the finally cropped fields. So, the dates of the crop development (emergence, etc.) that PRZM uses to determine the RCN numbers are used for the entire area of the finally cropped fields, even while we know this is not correct, and non-conservative with respect to runoff. For tomatoes this phenomenon occurs for 30 d, for onions 35 d and cabbage 38 d after emergence. Thereafter transplanting has taken place and *RCN* numbers are truly valid for the entire cropped area.

In order to reduce the number of simulations for the assessments we decided in a later stage to use the same crop development cycle for the 3 scenarios locations (grids 191, 217 and 373). This implies that we should use corresponding irrigation schedules (in order to prevent e.g. to irrigate when the crop is already harvested, or to stop irrigation before the crop is ready to be harvested).

Table A11.3.10 indicates which irrigation schedule is used in the simulations of the second irrigated crop cycle.

Table A11.3.10

Irrigation schedule for the simulated second irrigated crops of tomato, onion, cabbage and potato at the 3 scenario locations. See Appendix A11.4 for the selected schedule.

	Crop most commonly grown in (total irrigation gift in mm)	191 W of lake Tana	217 SE of Bure	373 W of Arba Minch
Tomato	M (750)	Grid 373	Grid 373	Grid 373
Onion	H (450)	Grid 191	Grid 191	Grid 191
Cabbage	H (400)	Grid 191	Grid 191	Grid 191
Potato	H (600)	Grid 191	Grid 191	Grid 191

Appendix 11.4 Irrigation schedule for the crops of tomato, onion, cabbage and potato at the three surface water scenario locations

Scenario	191	Crop	Tomato	Scenario	217	Crop	Tomato	Scenario	373	Crop	Tomato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
1		1	10.9	1		1	10	1		1	16.1
2				2				2			
3				3				3			
4		2	10.9	4		2	10	4		2	16.1
5				5				5			
6				6				6			
7		3	10.9	7		3	10	7		3	16.1
8				8				8			
9				9				9			
10		4	10.9	10		4	10	10		4	16.1
11				11				11			
12				12				12			
13		5	10.9	13		5	10	13		5	16.1
14				14				14			
15				15				15			
16		6	10.9	16		6	10	16		6	16.1
17				17				17			
18				18				18			
19		7	10.9	19		7	10	19		7	16.1
20				20				20			
21				21				21			
22		8	10.9	22		8	10	22		8	16.1
23				23				23			
24				24				24			
25		9	10.9	25		9	10	25		9	16.1
26				26				26			
27				27				27			
28		10	10.9	28		10	10	28		10	17.99

Scenario	191	Crop	Tomato	Scenario	217	Crop	Tomato	Scenario	373	Crop	Tomato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
29				29				29			
30				30				30			
31		11	10.9	31		11	10	31		11	18.8
32				32				32			
33				33				33			
34		12	15	34		12	13.8	34		12	18.8
35				35				35			
36				36				36			
37		13	15	37		13	13.8	37		13	18.8
38				38				38			
39				39				39			
40		14	15	40		14	13.8	40		14	18.8
41				41				41			
42				42				42			
43		15	15	43		15	13.8	43		15	18.8
44				44				44			
45				45				45			
46		16	15	46		16	13.8	46			
47				47				47			
48				48				48		16	39.3
49				49				49			
50				50				50			
51		17	21.78	51		17	19.98	51			
52				52				52			
53				53				53		17	39.3
54				54				54			
55				55				55			
56				56				56			
57				57				57			
58		18	37.6	58		18	34.4	58		18	39.3
59				59				59			
60				60				60			
61				61				61			
62				62				62			
63				63				63		19	39.3

Scenario	191	Crop	Tomato	Scenario	217	Crop	Tomato	Scenario	373	Crop	Tomato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
64				64				64			
65		19	37.6	65		19	34.4	65			
66				66				66			
67				67				67			
68				68				68		20	39.3
69				69				69			
70				70				70			
71				71				71			
72		20	37.6	72		20	34.4	72			
73				73				73		21	39.3
74				74				74			
75				75				75			
76				76				76			
77				77				77			
78				78				78		22	39.3
79		21	37.6	79		21	34.4	79			
80				80				80			
81				81				81			
82				82				82			
83				83				83		23	39.3
84				84				84			
85				85				85			
86		22	37.6	86		22	34.4	86			
87				87				87			
88				88				88		24	39.3
89				89				89			
90				90				90			
91				91				91			
92				92				92			
93		23	37.6	93		23	34.4	93		25	39.3
94				94				94			
95				95				95			
96				96				96			
97				97				97			
98				98				98		26	39.3

Scenario	191	Crop	Tomato	Scenario	217	Crop	Tomato	Scenario	373	Crop	Tomato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
99				99				99			
100		24	37.6	100		24	34.4	100			
101				101				101			
102				102				102			
103				103				103			
104				104				104		27	27.1
105				105				105			
106				106				106			
107		25	37.6	107		25	34.4	107			
108				108				108			
109				109				109			
110				110				110			
111				111				111		28	8.8
112				112				112			
113				113				113			
114		26	37.6	114		26	34.4	114			
115				115				115			
116				116				116			
117				117				117			
118				118				118		29	12.76
119				119				119		0.45	
120				120				120			
121				121				121			
122		27	20.44	122		27	18.74	122			
123				123				123			
124				124				124			
125				125				125		30	12.76
126				126				126		0.45	
127				127				127			
128				128				128			
129				129				129			
130				130				130			
131		28	12.6	131		28	11.62	131			
132		0.4		132		0.4		132			
133				133				133			

Scenario	191	Crop	Tomato	Scenario	217	Crop	Tomato	Scenario	373	Crop	Tomato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
134				134							
135				135							
136				136							
137				137							
138				138							
139				139							
140		29	11.7	140		29	10.79				
141		0.3		141		0.3					
142				142							
143				143							
144				144							
145				145							
146				146							
147				147							
148				148							
Sum			599.82				549.73				750.61
Check		29.7	600			29.7	550			30.9	750

Scenario 191	Crop	onion	Scenario 217	Crop	onion	Scenario 373	Crop	onion
	irrigation gift			irrigation gift			irrigation gift	
day nr	nr	size (mm)	day nr	nr	size (mm)	day nr	nr	size (mm)
1	1	16.9	1	1	15	1	1	19.3
2			2			2		
3			3			3		
4	2	16.9	4	2	15	4	2	19.3
5			5			5		
6			6			6		
7	3	16.9	7	3	15	7	3	19.3
8			8			8		
9			9			9		
10	4	16.9	10	4	15	10	4	19.3
11			11			11		
12			12			12		
13	5	16.9	13	5	15	13	5	16.9
14			14			14		
15			15			15		
16	6	12.98	16	6	11.5	16	6	11.3
17			17			17		
18			18			18		
19	7	11.3	19	7	10	19	7	11.3
20			20			20		
21			21			21		
22	8	11.3	22	8	10	22	8	11.3
23			23			23		
24			24			24		
25	9	11.3	25	9	10	25	9	11.3
26			26			26		
27			27			27		
28	10	11.3	28	10	10	28	10	11.3
29			29			29		
30			30			30		
31	11	11.3	31	11	10	31	11	11.3
32			32			32		
33			33			33		
34	12	11.3	34	12	10	34	12	11.3
35			35			35		

Scenario	191	Crop	onion	Scenario	217	Crop	onion	Scenario	373	Crop	onion
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
36				36				36			
37		13	11.3	37		13	10	37		13	11.3
38				38				38			
39				39				39			
40		14	11.3	40		14	10	40		14	11.3
41				41				41			
42				42				42			
43		15	11.3	43		15	10	43		15	11.3
44				44				44			
45				45				45			
46		16	11.3	46		16	10	46			
47				47				47			
48				48				48		16	22.6
49				49				49			
50				50				50			
51		17	17.3	51		17	15.32	51			
52				52				52			
53				53				53		17	22.6
54				54				54			
55				55				55			
56				56				56			
57				57				57			
58		18	26.3	58		18	23.3	58		18	22.6
59				59				59			
60				60				60			
61				61				61			
62				62				62			
63				63				63		19	22.6
64				64				64			
65		19	26.3	65		19	23.3	65			
66				66				66			
67				67				67			
68				68				68		20	22.6
69				69				69			
70				70				70			

Scenario	191	Crop	onion	Scenario	217	Crop	onion	Scenario	373	Crop	onion
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
71				71				71			
72		20	26.3	72		20	23.3	72			
73				73				73		21	22.6
74				74				74			
75				75				75			
76				76				76			
77				77				77			
78				78				78		22	22.6
79		21	26.3	79		21	23.3	79			
80				80				80			
81				81				81			
82				82				82			
83				83				83		23	22.6
84				84				84			
85				85				85			
86		22	26.3	86		22	23.3	86			
87				87				87			
88				88				88		24	22.6
89				89				89			
90				90				90			
91				91				91			
92				92				92			
93		23	26.3	93		23	23.3	93		25	19.14
94				94				94			
95				95				95			
96				96				96			
97				97				97			
98				98				98			
99				99				99			
100		24	26.3	100		24	23.3	100		26	7.95
101				101				101		0.5	
102				102				102			
103				103				103			
104				104				104			
105				105				105			

Scenario	191	Crop	onion	Scenario	217	Crop	onion	Scenario	373	Crop	onion
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
106				106				106			
107		25	18.5	107		25	12.92	107		27	7.95
108				108				108		0.5	
109				109				109			
110				110				110			
111				111				111			
112				112				112			
113				113				113			
114				114				114		28	5.83
115				115				115		0.1	
116		26	10.2	116		26	9	116			
117		0.5		117		0.5		117			
118				118				118			
119				119				119			
120				120				120			
121				121				121			
122				122				122			
123				123				123			
124				124				124			
125		27	9.52	125		27	8.4				
126		0.4		126		0.4					
127				127							
128				128							
129				129							
130				130							
131				131							
132				132							
133				133							
134				134							
135				135							
136				136							
Sum			450.1				395.24				451.37
check		28	450			28	400			29.1	450

Scenario	191	Crop	cabbage	Scenario	217	Crop	cabbage	Scenario	373	Crop	cabbage
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
1		1	14.3	1		1	12.5	1		1	21.7
2				2				2			
3				3				3			
4				4				4			
5				5				5			
6		2	14.3	6		2	12.5	6		2	21.7
7				7				7			
8				8				8			
9				9				9			
10				10				10			
11		3	14.3	11		3	12.5	11		3	21.7
12				12				12			
13				13				13			
14				14				14			
15				15				15			
16		4	14.3	16		4	12.5	16		4	21.7
17				17				17			
18				18				18			
19				19				19			
20				20				20			
21		5	14.3	21		5	12.5	21		5	18.74
22				22				22			
23				23				23			
24				24				24			
25				25				25			
26		6	13.14	26		6	11.5	26		6	14.3
27				27				27			
28				28				28			
29				29				29			
30				30				30			
31		7	11.4	31		7	10	31		7	14.3
32				32				32			
33				33				33			
34				34				34			
35				35				35			

Scenario	191	Crop	cabbage	Scenario	217	Crop	cabbage	Scenario	373	Crop	cabbage
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
36		8	11.4	36		8	10	36		8	14.3
37				37				37			
38				38				38			
39				39				39			
40				40				40			
41		9	11.4	41		9	10	41		9	14.3
42				42				42			
43				43				43			
44				44				44			
45				45				45			
46		10	11.4	46		10	10	46			
47				47				47		10	34.6
48				48				48			
49				49				49			
50				50				50			
51				51				51			
52				52				52			
53		11	30	53		11	26.2	53			
54				54				54		11	34.6
55				55				55			
56				56				56			
57				57				57			
58				58				58			
59				59				59			
60				60				60			
61				61				61		12	34.6
62		12	30	62		12	26.2	62			
63				63				63			
64				64				64			
65				65				65			
66				66				66			
67				67				67			
68				68				68		13	34.6
69				69				69			
70				70				70			

Scenario	191	Crop	cabbage	Scenario	217	Crop	cabbage	Scenario	373	Crop	cabbage
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
71		13	30	71		13	26.2	71			
72				72				72			
73				73				73			
74				74				74			
75				75				75		14	34.6
76				76				76			
77				77				77			
78				78				78			
79				79				79			
80		14	30	80		14	26.2	80			
81				81				81			
82				82				82		15	34.6
83				83				83			
84				84				84			
85				85				85			
86				86				86			
87				87				87			
88				88				88			
89		15	30	89		15	26.2	89		16	34.6
90				90				90			
91				91				91			
92				92				92			
93				93				93			
94				94				94			
95				95				95			
96				96				96		17	31.28
97				97				97			
98		16	30	98		16	26.2	98			
99				99				99			
100				100				100			
101				101				101			
102				102				102			
103				103				103		18	31.56
104				104				104		0.2	
105				105				105			

Scenario	191	Crop	cabbage	Scenario	217	Crop	cabbage	Scenario	373	Crop	cabbage
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
106				106				106			
107		17	30	107		17	26.2	107			
108				108				108			
109				109				109			
110				110				110		19	31.56
111				111				111		0.2	
112				112				112			
113				113				113			
114				114				114			
115				115				115			
116		18	32.4	116		18	28.32	116			
117		0.2		117		0.2		117			
118				118				118			
119				119							
120				120							
121				121							
122				122							
123				123							
124				124							
125		19	27	125		19	23.6				
126				126							
127				127							
128				128							
129				129							
130				130							
131				131							
132				132							
133				133							
Sum			399.64				349.32				499.34
check		19.2	400			19.2	350			19.4	500

Scenario	191	Crop	potato	Scenario	217	Crop	potato	Scenario	373	Crop	potato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
1		1	12.9	1		1	11.8	1		1	18.3
2				2				2			
3				3				3			
4		2	12.9	4		2	11.8	4		2	18.3
5				5				5			
6				6				6			
7		3	12.9	7		3	11.8	7		3	18.3
8				8				8			
9				9				9			
10		4	12.9	10		4	11.8	10		4	18.3
11				11				11			
12				12				12			
13		5	12.9	13		5	11.8	13		5	18.3
14				14				14			
15				15				15			
16		6	12.9	16		6	11.8	16		6	18.3
17				17				17			
18				18				18			
19		7	12.9	19		7	11.8	19		7	21.93
20				20				20			
21				21				21			
22		8	12.9	22		8	11.8	22			
23				23				23			
24				24				24		8	29.56
25				25				25			
26				26				26			
27		9	26.37	27		9	24.17	27			
28				28				28			
29				29				29		9	29.2
30				30				30			
31				31				31			
32				32				32			
33				33				33			
34		10	35	34		10	32.1	34		10	29.2
35				35				35			

Scenario	191	Crop	potato	Scenario	217	Crop	potato	Scenario	373	Crop	potato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
36				36				36			
37				37				37			
38				38				38			
39				39				39		11	29.2
40				40				40			
41		11	35	41		11	32.1	41			
42				42				42			
43				43				43			
44				44				44		12	29.2
45				45				45			
46				46				46			
47				47				47			
48		12	35	48		12	32.1	48			
49				49				49		13	29.2
50				50				50			
51				51				51			
52				52				52			
53				53				53			
54				54				54		14	35.99
55		13	35	55		13	32.1	55			
56				56				56			
57				57				57			
58				58				58			
59				59				59		15	38.9
60				60				60			
61				61				61			
62		14	38.2	62		14	35	62			
63				63				63			
64				64				64		16	38.9
65				65				65			
66				66				66			
67				67				67			
68				68				68			
69		15	38.2	69		15	35	69		17	38.9
70				70				70			

Scenario	191	Crop	potato	Scenario	217	Crop	potato	Scenario	373	Crop	potato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
71				71				71			
72				72				72			
73				73				73			
74				74				74		18	38.9
75				75				75			
76		16	38.2	76		16	35	76			
77				77				77			
78				78				78			
79				79				79		19	38.9
80				80				80			
81				81				81			
82				82				82			
83		17	38.2	83		17	35	83			
84				84				84		20	38.9
85				85				85			
86				86				86			
87				87				87			
88				88				88			
89				89				89		21	38.9
90		18	38.2	90		18	35	90			
91				91				91			
92				92				92			
93				93				93			
94				94				94		22	38.9
95				95				95			
96				96				96			
97		19	38.2	97		19	35	97			
98				98				98			
99				99				99			
100				100				100			
101				101				101		23	31.35
102				102				102		0.6	
103				103				103			
104		20	38.2	104		20	35	104			
105				105				105			

Scenario	191	Crop	potato	Scenario	217	Crop	potato	Scenario	373	Crop	potato
		irrigation gift				irrigation gift				irrigation gift	
day nr		nr	size (mm)	day nr		nr	size (mm)	day nr		nr	size (mm)
106				106				106			
107				107				107			
108				108				108		24	18.45
109				109				109		0.5	
110				110				110			
111		21	42.48	111		21	38.94	111			
112		0.6		112		0.6		112			
113				113				113			
114				114				114			
115				115				115			
116				116				116			
117				117				117			
118				118				118			
119				119							
120		22	20.25	120		22	18.6				
121		0.5		121		0.5					
122				122							
123				123							
124				124							
125				125							
126				126							
127				127							
128				128							
129				129							
130				130							
131				131							
132				132							
133				133							
Sum			599.7				549.51				704.28
check		23.1	600			23.1	550			25.1	700

Appendix 11.5 Example PRZM input files for an Ethiopian surface water scenario

PRZM has three input files:
1. *.run – specifies locations of input files
2. *.INP – contains all soil, crop, application, pesticide properties
3. *.met – meteorological data

1. *.run file

An example of the *. run file is given below. They contain path and names of the PRZM input files (*.MET and *.INP) and the PRZM output files (*.ZTS and *.OUT). For the Ethiopian surface water scenarios the start date is fixed to 1 Jan. 1903 and end date is fixed to 31 Dec. 1935. The *. MET file is crop dependent.

```
PRZM                    ON
VADOFT                  OFF
MONTE CARLO             OFF
TRANSPORT               ON
*** zone records
PRZM ZONES              1   3  92
ENDRUN
*** input file records
  PATH                  D:\RunPRZM\met\
  METEOROLOGY       1   191NOIRR.MET
  PATH                  D:\RunPRZM\24D\SW-PG_1 191\Maize\
  PRZM INPUT        1   191-MZ-.INP
*** output file records
  PATH                  D:\RunPRZM\24D\SW-PG_1 191\Maize\
  TIME SERIES       1   191-MZ-.ZTS
  PRZM OUTPUT       1   191-MZ-.OUT
*** scratch file records
  PATH                  D:\RunPRZM\24D\SW-PG_1 191\Maize\
  PRZM RESTART          RESTART.PRZ
ENDFILES
*** global records
  START DATE            010103
  END DATE              311235
NUMBER OF CHEMICALS     1
ENDDATA
*** display records
ECHO                    6
TRACE                   OFF
```

2. *.INP file

The *.INP file contains all data on soil, crop, application and pesticide properties. For Ethiopia (PRIMET) for each crop and location template *.INP files are made. This means that only data on application and pesticide properties need to be adjusted by the user in the template *.INP files. Some Ethiopian crops have two crop cycles a year. In this case template *.INP files are made per crop cycle and runs need to be performed for both crop cycles. We propose to select the run with the most worst case results of the two runs. The setup of *.INP file is described in Annex K of FOCUS (2001). Annex K describes for each record the parameters in that record. Table A11.5.1 shows for each line in the *.INP files for Ethiopia the corresponding record described in Annex K of FOCUS (2001). Those parameters in a record that need to be adapted by PRIMET or the expert user are highlighted in Table A11.5.1. A description of these parameters is given in Table A11.5.2. The position of the number in the *.INP file matters. So spacing between different numbers need to be exactly the same as in the template *.INP files.

Table A11.5.1

*Content of one of the template *.INP files for Ethiopia; showing per line the corresponding record in the 'PRZM in FOCUS user manual' in* Appendix *K of FOCUS (2001). Highlighted parameters need to be adapted by PRIMET or the expert user.*

Record	Line in template *.INP file
1	`FOCUS_PRZM_SW_3.1.1, 12 December 20                     PRZM3.20 beta`
2	`                    Simulation Location: 191Crop: Maize`
3	`    0.94    0.20       0   25.00       1       1`
6	`       4`
7	`    0.26    0.66    0.50    0.45               2    5.00   20.00`
8	`       1`
9	`       1    0.30  200.00   90.00       3   0   0   0    0.00  250.00`
9A	`       1       4`
9B	`1003 2405 0708 3001`
9C	`0.20 0.20 0.40 0.90`
9D	`0.10 0.10 0.10 0.10`
9E	`82   82   87   91`
10	`        33`

11	`  100303  240503  070803       1`
	`  100304  240504  070804       1`
	`  100305  240505  070805       1`
	`  100306  240506  070806       1`
	`  100307  240507  070807       1`
	`  100308  240508  070808       1`
	`  100309  240509  070809       1`
	`  100310  240510  070810       1`
	`  100311  240511  070811       1`
	`  100312  240512  070812       1`
	`  100313  240513  070813       1`
	`  100314  240514  070814       1`
	`  100315  240515  070815       1`
	`  100316  240516  070816       1`
	`  100317  240517  070817       1`
	`  100318  240518  070818       1`
	`  100319  240519  070819       1`
	`  100320  240520  070820       1`
	`  100321  240521  070821       1`
	`  100322  240522  070822       1`
	`  100323  240523  070823       1`
	`  100324  240524  070824       1`
	`  100325  240525  070825       1`
	`  100326  240526  070826       1`
	`  100327  240527  070827       1`
	`  100328  240528  070828       1`
	`  100329  240529  070829       1`
	`  100330  240530  070830       1`
	`  100331  240531  070831       1`
	`  100332  240532  070832       1`
	`  100333  240533  070833       1`
	`  100334  240534  070834       1`
	`  100335  240535  070835       1`

	Chemical Input Data:
13	33 1 0 0
15	24D
16	100303 0 2 4.00 1.4400 1.00 0.00
	100304 0 2 4.00 1.4400 1.00 0.00
	100305 0 2 4.00 1.4400 1.00 0.00
	100306 0 2 4.00 1.4400 1.00 0.00
	100307 0 2 4.00 1.4400 1.00 0.00
	100308 0 2 4.00 1.4400 1.00 0.00
	100309 0 2 4.00 1.4400 1.00 0.00
	100310 0 2 4.00 1.4400 1.00 0.00
	100311 0 2 4.00 1.4400 1.00 0.00
	100312 0 2 4.00 1.4400 1.00 0.00
	100313 0 2 4.00 1.4400 1.00 0.00
	100314 0 2 4.00 1.4400 1.00 0.00
	100315 0 2 4.00 1.4400 1.00 0.00
	100316 0 2 4.00 1.4400 1.00 0.00
	100317 0 2 4.00 1.4400 1.00 0.00
	100318 0 2 4.00 1.4400 1.00 0.00
	100319 0 2 4.00 1.4400 1.00 0.00
	100320 0 2 4.00 1.4400 1.00 0.00
	100321 0 2 4.00 1.4400 1.00 0.00
	100322 0 2 4.00 1.4400 1.00 0.00
	100323 0 2 4.00 1.4400 1.00 0.00
	100324 0 2 4.00 1.4400 1.00 0.00
	100325 0 2 4.00 1.4400 1.00 0.00
	100326 0 2 4.00 1.4400 1.00 0.00
	100327 0 2 4.00 1.4400 1.00 0.00
	100328 0 2 4.00 1.4400 1.00 0.00
	100329 0 2 4.00 1.4400 1.00 0.00
	100330 0 2 4.00 1.4400 1.00 0.00
	100331 0 2 4.00 1.4400 1.00 0.00
	100332 0 2 4.00 1.4400 1.00 0.00
	100333 0 2 4.00 1.4400 1.00 0.00
	100334 0 2 4.00 1.4400 1.00 0.00
	100335 0 2 4.00 1.4400 1.00 0.00
17	0. 1 0.50
18	0.0000 0.0693 0.5000
19	Soil Series: R4
20	300.00 0 0 2 0 0 0 2 1 0
26	4300.00 .12E-03 22.70
30	0.9000
31	0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.96 10.0
32	14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0
32a	2.20 20.00
32b	2 0.70 1.00
33	5
34-Lay1	1 10.000 1.520 0.260 0.000 0.000 0.000
36-Lay1	0.04951 0.04951 0.00000
37-Lay1	0.100 0.260 0.160 0.600 0.530
38-Lay1	14.00 53.00 25.00 0.00 0.00
34-Lay2	2 20.000 1.520 0.260 0.000 0.000 0.000
36-Lay2	0.04951 0.04951 0.00000
37-Lay2	5.000 0.260 0.160 0.600 0.530
38-Lay2	14.00 53.00 25.00 0.00 0.00
34-Lay3	3 30.000 1.500 0.270 0.000 0.000 0.000

36-Lay3	0.04951 0.04951 0.00000
37-Lay3	5.000 0.270 0.160 0.600 0.530
38-Lay3	14.00 53.00 25.00 0.00 0.00
34-Lay4	4 110.000 1.490 0.145 0.000 0.000 0.000
36-Lay4	0.04951 0.04951 0.00000
37-Lay4	5.000 0.145 0.060 0.080 0.071
38-Lay4	14.00 69.00 7.00 0.00 0.00
34-Lay5	5 130.000 1.500 0.160 0.000 0.000 0.000
36-Lay5	0.04951 0.04951 0.00000
37-Lay5	5.000 0.160 0.070 0.080 0.071
38-Lay5	14.00 65.00 8.00 0.00 0.00
40	0
42	WATR YEAR 10 PEST YEAR 10 CONC YEAR 10 0
45	7 DAY
46	RUNF TSER 0 0 10.0 ESLS TSER 0 0 1.E3 PRCP TSER 0 0 10.0 INFL TSER 118 118 10.0 RFLX1 TSER 0 0 1.E7 EFLX1 TSER 0 0 1.E7 TPAP TSER 0 0 1.0

Table A11.5.2

Description of the parameters highlighted in Table A11.5.1.

Location in *.ins file	Description
Record 13, 1st parameter	the number of applications times 33 years of simulation (so 1 * 33 = 33 in the example of Table A11.4.1). Note that PRZM can handle a maximum number of applications of 8.
Record 15, 1st parameter	Name of the chemical
Record 16, 1st column	date of the application in DDMMYY. Dates need to be entered in chronological order. The number of dates needs to correspond to the value of the 1st parameter of record 13. PRZM can read 050503 (5 May, 1903)
Record 16, 5th column	The application rate in kg/ha (note there is no space between 4.00 and the application rate). Format in the *.inp file is: x.xxxx (so one value before the decimal dot and 4 values behind the decimal dot; in fortran code: f6.4)
Record 26, 2nd parameter	Normalised Henry's law constant of the pesticide, H (-). H is calcualted as follows: ***H = P*M*1000/(C*R*T)*** Where *P* = Vapour pressure (mPa) Unit is millipascal, P is commonly given in Pascal *M* = molecular weight (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^6** L mPa/(mol K) *T* = absolute temperature (K) = **293** K Note that in Annex K, the value of R in L mPa/(mol K) is NOT correct. Format in the *.inp file is: **.xxEyxx** (x=number, y = + or – sign; no number before the decimal dot).
Record 30, 1st parameter	Freundlich exponent *1/n* (-). FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified. Format in the *.inp file is: **x.xxxx** (so one number before the decimal dot and 4 number behind the decimal dot; in fortran code: f6.4)

Location in *.ins file	Description
Record 36, 1st and 2nd parameter	Degradation rate, ***k* (1/d) = *ln(2)/DegT$_{50soil}$*** The k value needs to filled in in the *.inp file as follows; x.xxxxx (so one number before the decimal dot and 5 numbers behind the decimal dot; in fortran code: f7.5). For Ethiopia it was decided the use the FOCUS range for upper and lower limits: DegT$_{50soil}$: 0.1 -1000 d
Record 37, 5th parameter	Layer specific partition coefficient, **K_d (L/kg) = K_{oc} * *OC*** (so sorption coefficient to organic carbon in L/kg * fraction organic carbon content). OC = 4th parameter in record 37 in %. This means that the value of the 4th parameter in record 37 needs to be divided by 100 to convert to fraction OC So **K_d (L/kg) = K_{oc} * *OC*** (4th parameter in record 37 in %)**/100** ***Koc*** = *1.724* ***Kom*** The k_d value needs to be filled in in the *.inp file as follows; xxxxx.xxx (so a maximum of five numbers before the decimal dot and 3 numbers behind the decimal dot; in fortran code: f9.3).

3. *.met file

Below an example *.met file for Ethiopia is shown. The header clearly describe the parameters. **Note however, that to run properly PRZM the header of the *. met file (all lines starting with an '*') need to be deleted.**

```
* 191 Ethiopian scenario SW protection goal 1
* 33 year file
*
* Col    Variable  Description
* 1      Column 1  A space
* 2-3    MM        Month number
* 4-5    DD        Day number
* 6-7    YY        Year number; it is assumed by PRZM that the year is 19YY
* 8-17   PRECIPcm  Total daily precipitation in cm
* 18-27  PEVPcm    Pan evaporation in cm
* 28-37  TEMPav    Average daily temperature in degrees celsius
* 38-47  WIND10m   Average daily windspeed at 10m above ground-level in cm/s
* 48-57  SOLRADL   Total daily solar radiation in Langley
*
*MMDDYY  PRECIPcm    PEVPcm     TEMPav   WIND10m    SOLRADL
  1 103      0.00      0.43      19.5       155     384.8
  1 203      0.00      0.43      19.5       155     384.8
  1 303      0.00      0.44      19.2       147     420.0
  1 403      0.02      0.41      19.2       134     402.5
  1 503      0.18      0.33      18.5       128     381.7
  1 603      0.15      0.36      18.4       140     385.1
  1 703      0.51      0.31      18.0       137     339.2
  1 803      0.64      0.24      17.8       138     303.4
  1 903      0.98      0.19      16.1       120     285.5
  11003      0.14      0.26      16.6       123     340.8
  11103      0.30      0.27      16.6       125     360.6
  11203      0.45      0.24      17.3       116     296.1
  11303      0.89      0.20      17.1       120     240.6
  11403      0.81      0.24      16.6       137     340.7
  11503      0.00      0.36      17.5       134     428.5
  11603      0.00      0.37      18.3       123     427.7
```

11703	0.00	0.42	18.4	160	422.7
11803	0.04	0.40	18.8	144	430.1
11903	0.02	0.40	18.5	153	430.6
12003	0.15	0.28	17.7	116	361.5
12103	0.21	0.30	17.5	137	396.4
12203	0.22	0.27	17.1	129	351.3
12303	0.00	0.32	17.2	110	402.5
12403	0.00	0.33	17.5	106	418.4
12503	0.00	0.35	17.3	132	430.9
12603	0.00	0.36	18.4	114	401.8
12703	0.00	0.29	18.1	104	333.2
12803	0.00	0.39	17.7	129	445.2
12903	0.00	0.46	17.8	163	498.4
13003	0.00	0.44	16.8	151	499.3
13103	0.00	0.46	16.9	164	504.3

Appendix 12.1 Convergence test of TOXSWA calculations with the Ethiopian pond scenarios

Mechteld ter Horst and Cees Vink, 2014

A12.1.1 Introduction

TOXSWA is a numerical model (the mass balance equations are solved numerically, i.e. time and space are divided in discrete steps). Concentrations in water and sediment calculated with TOXSWA depend among others on the size of the numerical segments in the sediment (i.e. sediment segmentation). In order to get a stable and converging numerical solution of the mass conservation equations and accordingly correct exposure concentrations in the water layer and the sediment, smaller numerical segments in the sediment are needed as the $K_{om\_sediment}$ value increases. The smaller the numerical segments, the better the model approximates the 'true' concentrations. It is our hypothesis that a sediment segmentation that is too coarse will result in an overestimation of the concentration in the water layer. Smaller numerical segments in the sediment lead to longer simulation times. Moreover, relatively fine segmentations that are adequate for high $K_{om\_sediment}$ values may pose problems to the numerical solution scheme for relatively low $K_{om\_sediment}$ values. So, different ranges of $K_{om\_sediment}$ values might require different segmentations of the sediment. Hence it may not be appropriate to use one single discretisation of the sediment for the entire range of $K_{om\_sediment}$ values that covers typical compound properties.

The Ethiopian pond scenarios parameterised in TOXSWA use the standard FOCUS sediment segmentation (Table A12.1). For some compounds, however, $K_{om\_sediment}$ values are relatively high (e.g. pyrethroids) and a finer discretisation of the sediment might be necessary. The objective of the current study is (i) to get a rough indication of which numerical segmentation of the sediment is appropriate for which (sub) range of $K_{om\_sediment}$ values and (ii) to test our hypothesis that a sediment segmentation that is too coarse will result in an overestimation of the concentration in the water layer.

A.12.1.2 Method

The range of $K_{om\_sediment}$ values tested varies from 10 – 100 000 L/kg. A large number of model simulations was done for different $K_{om\_sediment}$ values, where every investigated $K_{om\_sediment}$ value was applied for two simulations, one with the normal (FOCUS) sediment segmentation (Table A12.1) and one with the fine segmentation (Table A12.1; FOCUS high KOC sediment segmentation). The total thickness of the sediment amounts to 0.1 m in both segmentations.

The runs were carried out for the two temporary pond scenarios in Ethiopia (grids 373 and 217), each with its own meteorological data. The simulated period comprised 33 years (1979-2011). Differences were assessed between the simulated exposure endpoints (i.e. the 90th and 99th percentile of the annual maximum water concentration in the pond) from model runs with the same $K_{om\_sediment}$ value but with different segmentations. Normal segmentation is considered appropriate where differences in exposure endpoints between simulations with the normal and with the fine sediment segmentation are negligible or when the $K_{om\_sediment}$ is so low that the simulation with the fine segmentation does not yield a solution. The fine segmentation is likely more appropriate where differences in simulated exposure endpoints with the normal segmentation are not negligible.

For the two pond scenarios TOXSWA was used to calculate the exposure endpoints. For each of the pond scenarios, the 33 annual maximum concentrations calculated with TOXSWA were determined, for the entire period (1979-2011) covered in the simulation. From the ranked list of annual maximum concentrations, the second highest concentration was used as the exposure concentration for the human risk assessment (i.e. surface water for drinking water), whereas the sixth highest annual maximum concentration was used as the exposure concentration in the aquatic risk assessment (i.e. aquatic ecosystem).

TOXSWA needs input of runoff (water and pesticide) fluxes calculated with PRZM and given in the PRZM output file: *.p2t (Figure A12.1). For this exercise for all $K_{om\_sediment}$ values tested, the same *.p2t file was used. Note however that for the two different pond scenarios, different application patterns were used, so the *p2t files for the different pond scenarios are not the same.

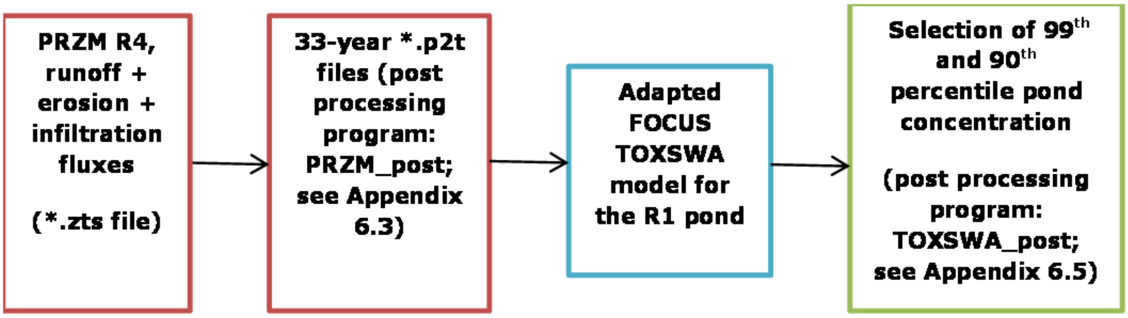

Figure A12.1 *Flowchart of the procedure for calculating the exposure endpoints in the temporary ponds.*

A12.1.3 Criterion

The relative error (δx) of the target concentrations was applied as criterion:

$$\delta x = \frac{x_0 - x}{x} \qquad \text{(eqn. A12.1)}$$

Where δx is the relative error, x is the true value of the target concentration (FOCUS fine sediment segmentation), $x0$ is the inferred value of the target concentration (FOCUS sediment segmentation). δx has a positive value in case the inferred value of the target concentration, $x0$, is larger than the true value of the target concentration, x. The implicit assumption here is that using the FOCUS fine sediment segmentation will result in a stable and converging numerical solution of the mass conservation equations and accordingly correct exposure concentrations in the water layer and the sediment for the tested pond scenarios, used application patterns and range of $K_{om\_sediment}$ values tested.

The test was conducted as follows:

A12.1.4 Substance

TOXSWA: DegT50 = 1000 d (water, sediment) and varying $K_{om\_sediment}$ = 10 – 100 000 L/kg, solubility = 1 mg/L, Psat = 1 E-10 Pa, freundlich exponent = 0.9 (default), molar mass = 300 g/mol.

PRZM: K_{om_soil} = 1000 kg/L, DT50soil = 100 d, Henry coefficient 1 E-10, freundlich exponent = 1 (linear sorption).

Note that the K_{om_soil} in the PRZM model is fixed. The only pesticide property varied is the $K_{om\_sediment}$ as input in the TOXSWA model.

A12.1.5 Application scheme

217: Potato, 1st crop cycle 3 applications of 1.0 kg/ha starting from 12 July with intervals of 7 days
373: Potato, 2nd crop cycle 3 applications of 1.0 kg/ha starting from 19 January with intervals of 7 days

It was our object to test a relatively worst case, but still realistic application pattern. We therefore opted for three applications with a 7 days interval. Reason for the different application schemes for the two scenarios, is that preliminary simulations showed that for 373 the exposure endpoints of simulation with the irrigated crop (2nd crop cycle) were higher than those of simulations with the non-irrigated crop (1st crop cycle).

A12.1.6 Sediment segmentation

Table A12.1
Proposed numerical sediment segmentation for the Ethiopian pond.

FOCUS sediment segmentation	FOCUS high KOC sediment segmentation
Number of sediment segments = 14	Number of sediment segments = 23
Thickness of the sediment segments from top to bottom of the sediment (m) =	Thickness of the sediment segments from top to bottom of the sediment (m) =
4 x 0.001	8 x 0.00003
3 x 0.002	2 x 0.00006
2 x 0.005	2 x 0.00012
2 x 0.01	3 x 0.0003
1 x 0.02	2 x 0.00075
1 x 0.03	2 x 0.002
	1 x 0.003
	2 x 0.005
	3 x 0.01
	1 x 0.02
	1 x 0.03

A12.1.7 Sediment properties

FOCUS sediment properties (Table A12.2) are assumed for the entire sediment.

Table A12.2
Sediment properties used for this test.

Sediment depth	Bulk density (kg.m-3)	Organic matter mass content (kg.kg-1)	Saturated water content (m3.m-3)	Relative diffusion coefficient (tortuosity) (-)
0-10 cm	800	0.09	0.6	0.6

A12.1.8 Time step

For the Ethiopian pond scenarios the maximum time step is set to 600s. The actual time step is calculated by TOXSWA (OptTimStp option).

A12.1.9 Results

The relative error between simulated concentrations of the normal and the fine segmentations was calculated for 33 $K_{om\_sediment}$ values, 2 locations and 2 segmentations. The results are displayed in Figures A12.2 to A12.5.

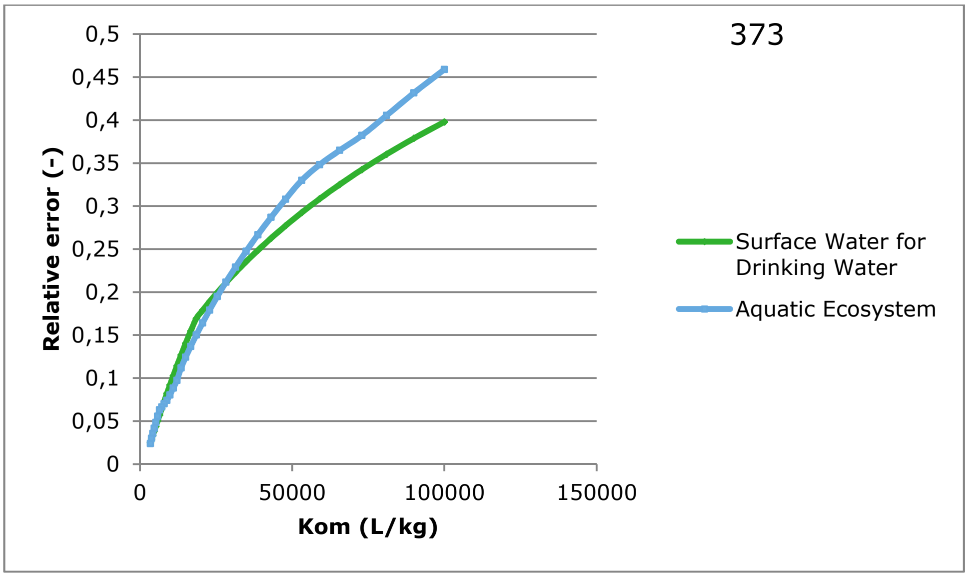

Figure A12.2 *Relative differences according to equation 1 as a function of $K_{om\_sediment}$ values for location 373 and the exposure endpoints for surface water for drinking water (green line) and aquatic ecosystem (blue line).*

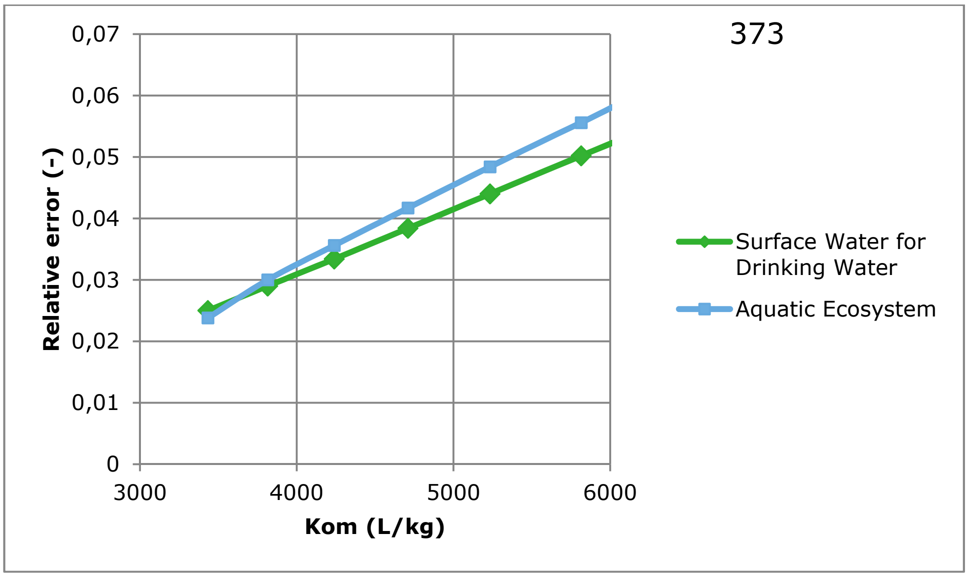

Figure A12.3 *Relative differences according to equation 1 as a function of $K_{om\_sediment}$ values (detail) for location 373 and the exposure endpoints for surface water for drinking water (green line) and aquatic ecosystem (blue line).*

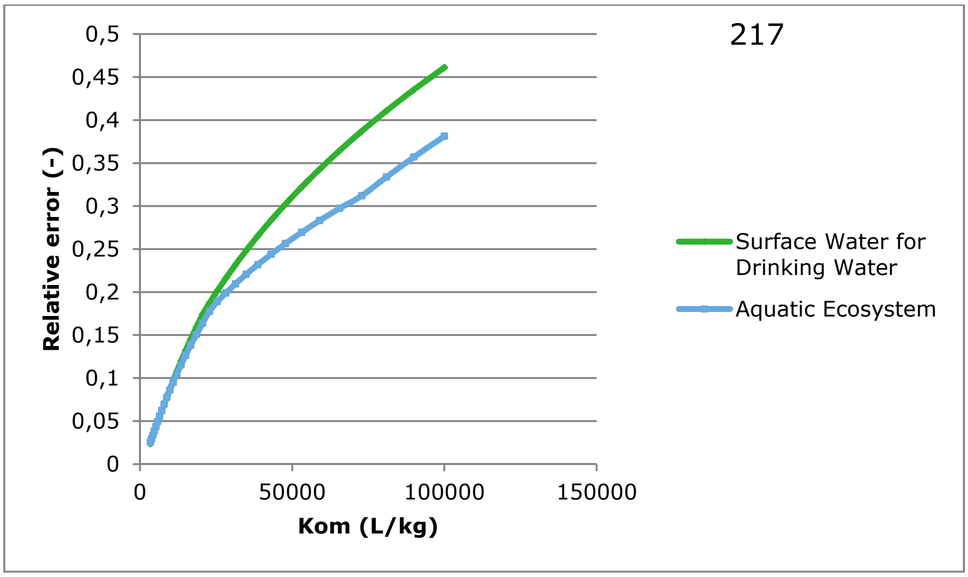

Figure A12.4 *Relative differences according to equation 1 as a function of $K_{om\_sediment}$ values for location 217 and the exposure endpoints for surface water for drinking water (green line) and aquatic ecosystem (blue line).*

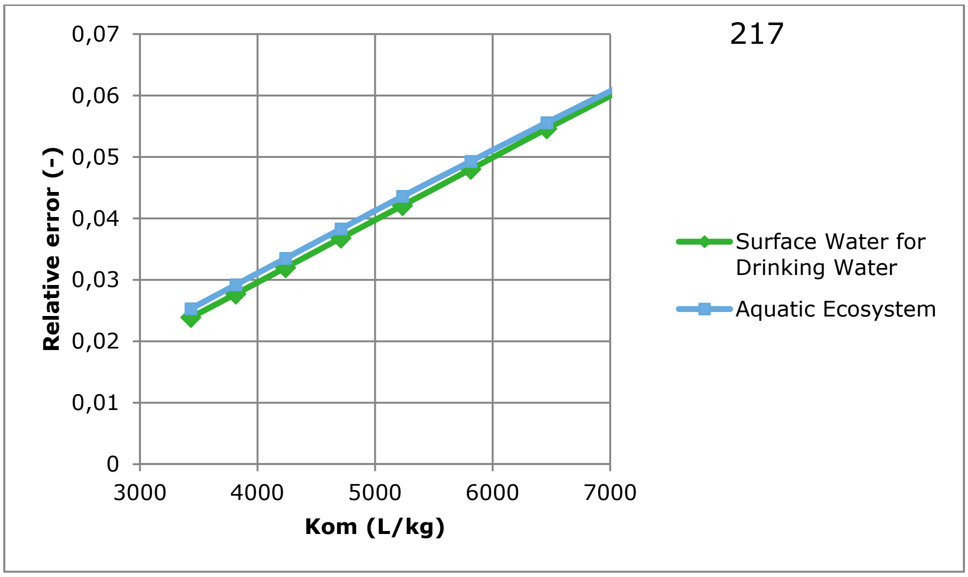

Figure A12.5 *Relative differences according to equation 1 as a function of $K_{om\_sediment}$ values (detail) for location 217 and the exposure endpoints for surface water for drinking water (green line) and aquatic ecosystem (blue line).*

Minimum $K_{om\_sediment}$ values that yielded a solution with the FOCUS fine sediment segmentation for both locations were in the range from 3400 to 3000 L/kg. The relative error for protection goals drinking water produced from surface water and aquatic ecosystem was there 2.4 – 2.5%. The relative error gradually increases to 38 – 46% for $K_{om\_sediment}$ values of 100 000 L/kg.

A12.1.10 Conclusion

Results of this preliminary study indicate that in case opted for the criterion of the smallest relative error possible (in this study about 2.4 – 2.5%), it is probably more appropriate for the Ethiopia scenarios to use the FOCUS fine sediment segmentation for simulations with $K_{om\_sediment}$ values that are higher than 3000 L/kg. However calculations with the normal FOCUS sediment segmentation result in higher concentrations than calculations with the FOCUS fine sediment segmentation. Using the normal FOCUS sediment segmentation therefore results in worst case, thus for pesticide registration conservative concentrations in the water layer.

Appendix 13.1 Protocol for selecting pesticide properties from the FOOTPRINT database

(vs: 3 June 2014)

For the following pesticide properties in the models choices need to be made between the different types of properties in the Footprint database: (URL: http://www.eu-footprint.org/ppdb.html)

Table 13.1

Property in model and properties in the Footprint database.

Property in models	Choices in Footprint	
DT50soil	DT50 typical	'Typical values' quoted are those given in the general literature and are often a mean of all studies field and laboratory. This is the value normally used in the regulatory modelling studies and is for aerobic conditions.
	DT50 lab at 20°C	DegT50 values of plant protection products in soil at 20°C obtained from laboratory studies
	DT50 field	DegT50 values of plant protection products in soil obtained from field dissipation studies
Koc	Koc	The linear adsorption coefficient normalised to the organic carbon content of the soil.
	Kfoc	The Freundlich adsorption coefficient normalised to the organic carbon content of the soil.
1/n or N	Freundlich exponent	Freundlich exponent describing the curvature of the Freundlich isotherm.
DT50water	Aqueous hydrolysis pH 5	DT50water for the process of hydrolysis obtained from an aqueous hydrolysis study at pH 5
	Aqueous hydrolysis pH 7	DT50water for the process of hydrolysis obtained from an aqueous hydrolysis study at pH 7
	Aqueous hydrolysis pH 9	DT50water for the process of hydrolysis obtained from an aqueous hydrolysis study at pH 9
	Aqueous photolysis	DT50water for the process of photolysis obtained from an aqueous photolysis study
	Water-sediment DT50	The DT50 of the total water-sediment system obtained from a water-sediment study in the dark (so including processes transformation in water and sediment due to hydrolysis and microbial degradation).

Table 13.2

Protocol for selecting pesticide properties from the Footprint database and justification of this choice.

Property in models	Chosen property from Footprint	Justification
DT50soil	DT50 lab at 20°C	DT50field values are very likely not determined according the latest EFSA guidance (EFSA, 2010) and therefore not adequate. This EFSA guidance proposes a procedure that ensures that the DegT50 derived from field dissipation studies reflects the degradation rate within in the soil matrix between 1 – 30 cm depth with sufficient accuracy. This procedure aims at diminishing the influence of other loss processes like volatilisation, photo-chemical degradation runoff etc. which are significant processes in the top millimetres of the soil matrix. Therefore the estimated DegT50 should not be influenced by these loss processes. This can be reached by a proper design of the field study: i.e. by applying irrigation shortly after pesticide application (EFSA advises 10 mm) or by using the proposed method for kinetic evaluation of the field dissipation study for determining the DegT50field. Most field dissipation studies in the dossiers used for the Footprint database are performed before the outcome of the EFSA opinion and it is not very likely that the kinetic evaluations are done according the method advised by EFSA (2010). For the same reason the DT50 typical is not suitable as this is often a mean of all studies both field and laboratory, so based upon inaccurate DegT50field values. *EFSA Panel on Plant Protection Products; Guidance for evaluating laboratory and field dissipation studies to obtain DegT50 values of plant protection products in soil. EFSA Journal 2010;8(12):1936 [67 pp.]. doi:10.2903/j.efsa.2010.1936*
Koc	KOC	KOC is very likely the most reliable parameter. Below an explanation is given why we consider KFoc data from the Footprint database to be less reliable. **Problems with the use of $K_{F,oc}$ data** The definition of the K_{oc} is based on a linear sorption isotherm: $X = m_{oc}\ K_{oc}\ C$ (A13.1) where X is mass of pesticide sorbed per mass of dry soil (mg kg^{-1}), m_{oc} is mass fraction of organic carbon of the soil (kg kg^{-1}), K_{oc} is the organic-carbon/water distribution coefficient (L kg^{-1}) and C is the mass concentration in the liquid phase (mg L^{-1}). The definition of the $K_{F,oc}$ is based on the Freundlich isotherm: $X = m_{oc}\ K_{F,oc}\ C^N$ (A13.2) where $K_{F,oc}$ is the Freundlich coefficient for distribution over organic carbon and water (L^N kg^{-1} mg^{1-N}) and N is the Freundlich exponent (-). So whereas the unit of K_{oc} depends only on the unit used for the mass of dry soil (kg) and the volume of liquid (L), the unit of $K_{F,oc}$ is also a function of the unit used for the mass of pesticide (mg) and also of N. This has the consequence that the value of $K_{F,oc}$ depends on the unit used for the mass of pesticide. E.g. the $K_{F,oc}$ value obtained by fitting of data with X expressed in mg kg^{-1} and C expressed in mg L^{-1} will differ from the $K_{F,oc}$ value obtained by fitting of the same data with X expressed in μg kg^{-1} and C expressed in μg L^{-1}. Let us consider the following example to illustrate this. **C (mg L^{-1}) — X (mg kg^{-1})** 0.001 — 0.0020 0.01 — 0.0158 0.1 — 0.1259 1 — 1 10 — 7.4943

Property in models	Chosen property from Footprint	Justification
		These numbers are calculated with Eqn 2 using m_{oc} = 0.01, $K_{F,oc}$ = 100 and N =0.9. So if these values would be fitted back to Eqn 2, a $K_{F,oc}$ value of 100 would have been obtained. Let us now consider a researcher that expresses the same data in µg instead of mg.

C (µg L^{-1})	X (µg kg^{-1})
1	2.0
10	15.8
100	125.9
1000	1000.0
10000	7494.3

		Fitting these data to Eqn 2 will give a $K_{F,oc}$ value of 200 instead of 100. This can be easily checked by putting the concentrations of the second table in a spreadsheet and calculating X with Eqn 2 (using $K_{F,oc}$ = 199.526 to get exactly the same result). Sometimes researchers use also mmol instead of mg (1 mmol is usually about 200 mg). So if a $K_{F,oc}$ value is provided, it is necessary to know in which unit the mass of pesticide is expressed. However, this is not done in the Footprint database. (pers.comm. J.J.T.I. Boesten, Alterra – Wageningen UR)
1/n or N	Freundlich exponent between 0.6 and 1.0	If 1/n > 1 use a value of 1.0 (see page 28/29 of Boesten *et al.,* 2011) *Boesten, J.J.T.I., Linden, A.M.A. van der, Beltman, W.H.J., Pol, J.W. 2011. Leaching of plant protection products and their transformation products : proposals for improving the assessment of leaching to groundwater in the Netherlands. Wageningen : Alterra, 2011 (Alterra-rapport 2264)* In case of absence of reliable data use a default value of 0.9. We consider data unreliable if 1/n < 0.6 (pers. Comm. J.J.T.I. Boesten, WUR) or if 1/n is determined using a Kfoc study which is judged less reliable by the Footprint database itself.
DT50water	Aqueous hydrolysis pH 7 Aqueous hydrolysis pH 9	Estimate the longest DegT50 in the pH range from 7 to 9.5 from the available measurements of hydrolysis experiments and calculate this back to a temperature of 20˚C using Eqn. 3 and using the temperature dependencies as measured in the hydrolysis studies to retrieve a value for the Arrhenius activation energy. If these temperature dependencies were not measured, it is recommended to assume an Arrhenius activation energy of 75 kJ/mol (Deneer *et al.,* 2010) $k(T) = k(T_{ref}) exp\left[\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right]$ (A13.3) where: T = Temperature (K) T_{ref} = Reference temperature (K) k = Transformation rate (d^{-1}) E = Molar Arrhenius activation energy (J mol^{-1}) R = Universal gas constant (≈ 8.3144 J mol^{-1} K^{-1}) *Deneer, J.W., W.H.J. Beltman, P.I. Adriaanse. 2010. Transformation reactions in TOXSWA; transformation reactions of plant protection products in surface water. Wageningen, Alterra. Alterra-report 2074. 94 pp.*

Appendix 13.2 Selected pesticides, pests and crops for which these are used and application pattern for example simulations for the three surface water scenarios

Pesticide application pattern request sheet (Berhan Teklu and John Deneer, 20 June 2013, updated 3 July 2013)

Pesticide	Use	Crop	Number of applications (how many times per crop season for each crop)	Rate of application of a.i kg/ha (different rates for different crops?)	Application interval (How many days between applications)	Possible crop stage during application Options: ¯E; before emergence E - ½M; emergence to halfway maturation ½M – M; halfway maturation to maturation M - ¯H; maturation to just before harvest (PHI)
dimethoate	Russian wheat aphides	Barley	1-2 (2)	0.6	A week	E-1/2 M (29 July, 5 Aug)
		Faba beans	1-2 (2)	0.48	A week	E-1/2 M (23July, 30 July)
endosulfan	African bollworm, Leafhoppers	Cotton	5-6 (6)	1.05	7-10 days	E-1/2M (12 July, 19 July, 26 July, 2 Aug, 9 Aug, 16 Aug)
		Maize	1-2 (2)	0.7	7-10 days	E-1/2M (10 April, 17 April)
deltametrin	African bollworm leafhoppers	Cotton	At least 5 (5)	0.18	A week	E-1/2 M (12 July, 19 July, 26 July, 2 Aug, 9 Aug)
		Maize	Mostly once (1)	0.021	-	E-1/2 M (17 April)
		Cabbage	4-5 (5)	0.025	10days	E-1/2 M 1st (4 June, 14 June, 24 June, 4 July, 14 July) 2nd (21 Nov, 1 Dec, 11 Dec, 21 Dec, 31 Dec)
		Sweet potato	3-4 (4)	0.09	7-10	E-1/2 M (19 July, 26 July, 2 Aug, 9 Aug)
2,4-D	broad leaf weeds	Wheat	1 (1)	1.44	-	E-1/2M (10 July)
		Teff	1 (1)	1.44	-	E-1/2M (5 July)
		Maize	1 (1)	1.44	-	E-1/2M (10 March)
		Sugar cane	1 (1)	2.88	-	E-1/2M (2 Jan)
malathion	Sweet potato butterfly	Sweet potato	5-7 (7)	1	10	E-1/2 M (10 July, 20 July, 30 July, 9 Aug, 19 Aug, 29 Aug, 8 Sept)
atrazine	Grass weeds, various weed ssp. Complex weeds, annual weeds, broad spectrum broad leaf	Maize	1 time (1)	1.75 liter/ha	-	(10 March)
	For the control of various weed spp in sugarcane	Sugar cane	1 time (1)	1.75 lit/ha	-	(2 Jan)
chlorothalonil *	Late blight	Potato	2-3 times (3)	*1.5 Kg/ha*	7-14 days	E-1/2E 1st (12 July, 19 July, 26 July) 2nd (19 Jan, 26 Jan, 1 Feb)

- *Chlorothalonil 75% WP was registered in the trade name Daconil 2787 W 75 in Ethiopia for the control cofeeberry disase on coffee. However, this pesticide has been cancelled from registration upon receipt of a notification, in writing, from the registrant of the same pesticide that it has been withdrawn from sale. Currently no stocks are available for sale. Moreover it seems all obsolete stocks have been shipped to Europe and disposed of using high temperature incineration. Moreover, although chlorothalonil was registered with the trade name Rova for the control coffeebery disease on coffee import to the country has not been done for many years. However, chlorothalonil has been registered for late blight control on potato with trade name Odeon 82.5
- A maximum number of applications (figure between brackets in the column 'Number of applications' indicates the number of applications used for the simulations) and minimum application interval has been selected for setting dates of possible crop stage during application.

Rules for selection of date of possible crop stage during application:

Herbicides: *start as soon as possible*
Insecticides/Fungicides: *start as late as possible*

Herbicides: *Set the first date of application on the first day possible and set later days of application according to the interval*
Insecticides/Fungicides: *Set the last date of application to the last day possible. Set earlier days according to the interval, not exceeding the first day given. If more dates are needed set them after the last day given according to the interval.*

Rate of application determination from FAO spread sheet.

Pesticide	FAO spread sheet ID	Crop	Conc active ingredient in formulated product	Rate of formulated product	Rate of active ingredient kg/ha	Remark
dimethoate	7	Faba Beans	400g/L	1.2L/ha	0.48kg/ha	
	48	Barley	400g/L	1.5L/ha	0.6kg/ha	
endosulfan	110	Cotton	350g/L	3L/ha	1.05kg/ha	
	110	Maize	350g/L	2L/ha	0.7kg/ha	
deltamethrin	26	Cotton	60g/L	3L/ha	0.18kg/ha	
	31	Sweet potato	60g/L	1.5L/ha	0.09kg/ha	
	43	Cabbage	25g/L	1L/ha	0.025kg/ha	
	44	Maize	25g/Kg	0.84kg/ha	0.021kg/ha	
24D	125	Sugar cane	720g/L	4L/ha	2.88kg/ha	
	129	wheat	720g/L	2L/ha	1.44kg/ha	
	129	Maize	720g/L	2L/ha	1.44kg/ha	
	129	Teff	720g/L	2L/ha	1.44kg/ha	
malathion	46	Sweet Potato	500g/L	2L/ha	1kg/ha	
atrazine	138	Sugarcane	250g/L	7L/ha	1.75kg/ha	
	160	Maize	250g/L	7L/ha	1.75kg/ha	
chlorothalonil	210	Potato	825Kg	1.5Kg/ha	1.5Kg/ha	Unit of conc AI in formulated product not clear Assumed therefore 100% AI formulated product

Appendix 13.3 Input data concerning pesticide properties for the groundwater and surface water scenarios calculations

Mechteld ter Horst, Berhan Teklu and John Deneer, 12 June 2013 adapted 3 July 2013.

The table below shows the parameters needed for running the PRZM and TOXSWA models; most values were taken from the Pesticides Properties Database (PPDB), which can be found at http://sitem.herts.ac.uk/aeru/footprint/index2.htm.

Parameter values highlighted in grey were used in the EuroPEARL metamodel or for the PRZM & TOXSWA simulations.

1/ Dimethoate

Parameter	Unit	Needed for model(s)	Value	Source, quality level
Molar mass	g/mol	PRZM, TOXSWA	229.26	PPDB
Saturated vapour pressure	Pa	PRZM, TOXSWA	0.25E-3(25),0.13E-3(20)	PPDB/ A5
Temperature at which the saturated vapour pressure is measured	C	TOXSWA	25°C	PPDB/ A5
Water solubility of substance	mg/L	PRZM, TOXSWA	39800	PPDB/A5
Temperature of reference at which the water solubility was measured	C	TOXSWA	20	PPDB/A5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)*	- Value in PPDB (if given)	PRZM	$=0.13*229.26*1000/(39800*8.314E^{6}*293)$ **=0.30E-9** PPDB:0.41E-05	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.					
Half-life transformation in soil	DT50(Typical)	d	PRZM	2.6	PPDB/A5
	DT50 (lab at 20ºC)	d		2.6	PPDB/A5
	DT50 field	d		7.2	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20ºC and pH 5	d	TOXSWA	156	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 7	d		68	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 9	d		4.4	PPDB/A5
	Aqueous photolysis DT50 at pH 7	d		175	PPDB/A5
	Water-Sediment DT50	d		15.2	PPDB/A5
Half-life transformation in sediment at 20ºC		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		Not applicable/no dissociation	A5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	NA	
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	28.3	PPDB/A5
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	1.014=1	PPDB A5
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.01	PPDB/A5
	Acceptable Daily Intake, ADI	mg/kg/day		0.001	PPDB/A5
Aquatic toxicity data	Algae, 72 h	mg/L	Risk assessment	90.4	PPDB/A5
	Daphnids, 48 h	mg/L		2	PPDB/A5
	Fish, 96 h	mg/L		30.2	PPDB/A5

2/ Endosulfan

Parameter	Unit	Needed for model(s)	Value	Source, quality level
Molar mass	g/mol	PRZM, TOXSWA	406.93	PPDB/
Saturated vapour pressure	Pa	PRZM, TOXSWA	0.83E-3(25),0.43E-3(20)	PPDB/L3
Temperature at which the saturated vapour pressure is measured	C	TOXSWA	25	PPDB/L3
Water solubility of substance	mg/L	PRZM, TOXSWA	0.32	PPDB/H4
Temperature of reference at which the water solubility was measured	C	TOXSWA	20	PPDB/H4
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.	-	PRZM	=0.43*406.93*1000/ (0.32*8.314 E^{6}*293) **=0.23E-3** PPDB:0.33E-03	
Half-life transformation in soil – DT50(Typical)	d	PRZM	50	PPDB/L3
DT50 (lab at 20°C)	d		39	PPDB/A5
DT50 field	d		86	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20°C and pH 5	d	TOXSWA	Na	
	Aqueous hydrolysis DT50 at 20°C and pH 7	d		20	PPDB/C4
	Aqueous hydrolysis DT50 at 20°C and pH 9	d		NA	
	Aqueous photolysis DT50 at pH 7	d		NA	
	Water-Sediment DT50	d		NA	
Half-life transformation in sediment at 20°C		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		NA	
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	11500	PPDB/L3
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	18.6	PPDB/R3
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	0.558=0.9	PPDB/R3
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.02	PPDB/JMPR 1998
	Acceptable Daily Intake, ADI	mg/kg/day		0.006	PPDB/JMPR 1998
Aquatic toxicity data	Algae, 96 h	mg/L	Risk assessment	2.15	PPDB/F4
	Daphnids, 48 h	mg/L		0.44	PPDB/F4
	Fish, 96 h	mg/L		0.002	PPDB/F4

3/ Deltametrin

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Molar mass		g/mol	PRZM, TOXSWA	505.2	
Saturated vapour pressure		Pa	PRZM, TOXSWA	0.12 E-07(25), 0.64E-10(20)	PPDB/A5
Temperature at which the saturated vapour pressure is measured		C	TOXSWA	25	PPDB/A5
Water solubility of substance		mg/L	PRZM, TOXSWA	0.0002	PPDB/A5
Temperature of reference at which the water solubility was measured		C	TOXSWA	20	PPDB/A5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.		-	PRZM	=0.64E-07*505.2*1000/ (0.0002*8.314E^{6}*293) **=0.67E-05** PPDB:0.42E-05	
Half-life transformation in soil	DT50(Typical)	d	PRZM	13	PPDB/A5
	DT50 (lab at 20°C)	d		26	PPDB/A5
	DT50 field	d		21	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20ºC and pH 5	d	TOXSWA	Stable (25 C)	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 7	d		Stable (25 C) =1000d@20	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 9	d		2.5 (25 C) 31 d at pH 8	PPDB/A5
	Aqueous photolysis DT50 at pH 7	d		48 (25 C)	PPDB/A5
	Water-Sediment DT50	d		65	PPDB/A5
Half-life transformation in sediment at 20ºC		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		Not applicable/No dissociation	PPDB/A5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	10240000	PPDB/A5
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	NA	
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	1.1=1	PPDB/R4
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.01	PPDB/A5
	Acceptable Daily Intake, ADI	mg/kg/day		0.01	PPDB/A5
Aquatic toxicity data	Algae, 96 h	mg/L	Risk assessment	9.1	PPDB/L2
	Daphnids, 48 h	mg/L		0.00056	PPDB/A5
	Fish, 96 h	mg/L		0.00026	PPDB/A5

4/ 2,4-D

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Molar mass		g/mol	PRZM, TOXSWA	221.04	
Saturated vapour pressure		Pa	PRZM, TOXSWA	0.19E-04(25), 0.97E-05(20)	PPDB/B5
Temperature at which the saturated vapour pressure is measured		C	TOXSWA	25	PPDB/B5
Water solubility of substance		mg/L	PRZM, TOXSWA	23180	PPDB/A5
Temperature of reference at which the water solubility was measured		C	TOXSWA	20	PPDB/A5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^6** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.		-	PRZM	=0.97E-02*221.04*1000/ (23180*8.314 E^6*293) **=0.38E-10** PPDB:0.14E-08	
Half-life transformation in soil	DT50(Typical)	d	PRZM	10	PPDB/B5
	DT50 (lab at 20°C)	d		14	PPDB/A5
	DT50 field	d		10	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20°C and pH 5	d	TOXSWA	Stable	PPDB/B5
	Aqueous hydrolysis DT50 at 20°C and pH 7	d		Stable=1000d	PPDB/B5
	Aqueous hydrolysis DT50 at 20°C and pH 9	d		Stable	PPDB/B5
	Aqueous photolysis DT50 at pH 7	d		13	PPDB/B4
	Water-Sediment DT50	d		29	PPDB/B5
Half-life transformation in sediment at 20°C		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		2.87(strong acid)	PPDB/B5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	88.4	PPDB/A5/R4
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	242	PPDB/A5
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	-??	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	1.13=1	PPDB/A5
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	None allocated	PPDB/A5
	Acceptable Daily Intake, ADI	mg/kg/day		0.05	PPDB/A5
Aquatic toxicity data	Algae, 96 h	mg/L	Risk assessment	100	PPDB/A5
	Daphnids, 48 h	mg/L		100	PPDB/A4
	Fish, 96 h	mg/L		63.4	PPDB/A4

Note: According to the value of the dissociation constant (pKa value) from the PDDB database 2,4-D is a strong acid. For European soils it is known that strongly acidic pesticides have a tendency to sorb less at increased soil pH values, due to the formation of anionic (negatively charged) species which are repelled instead of sorbed by the negatively charged soil particles. The PPDB K_{oc} value will for European soils result in an overestimation of sorption. Ethiopian soils do not carry negative charges, but are predominatly charged positive. Ethiopian soils have an estimated average pH value of 6.9 (average pH_{H20} of the top 30 cm of the soil in Ethiopia of approximately 5x5 km^2 grid cells of the Harmonized World Soil, see Figure A2.3), and 2,4-D will therefore be largely present in its dissociated, anionic, negatively charged form. Contrary to what is observed in European soils, the predominantly positive charges present in Ethiopian soils will not result in a decrease of sorption for anions, and the use of the value of K_{oc} in Footprint will most likely result in a conservative estimate of leaching in Ethiopian soil. For this reason the PPDB K_{oc} value is not corrected. For details on the correction of K_{oc} of acidic substances in European soils see: J.J.T.I. Boesten, A.M.A. van der Linden, W.H.J. Beltman, J.W. Pol (2011). Leaching of plant protection products and their transformation products. Alterra report 2264, Alterra, Wageningen.

5/ Malathion

Parameter	Unit	Needed for model(s)	Value	Source, quality level
Molar mass	g/mol	PRZM, TOXSWA	330.36	
Saturated vapour pressure	Pa	PRZM, TOXSWA	0.31E-02(25), 0.16E-02(20)	PPDB/A5
Temperature at which the saturated vapour pressure is measured	C	TOXSWA	25	PPDB/A5
Water solubility of substance	mg/L	PRZM, TOXSWA	148	PPDB/A5
Temperature of reference at which the water solubility was measured	C	TOXSWA	20	PPDB/A5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.	-	PRZM	=160*330.36*1000/ (148*8.314E6*293) **=0.15E-05** PPDB:0.48E-04	
Half-life transformation in soil: DT50(Typical)	d	PRZM	0.17	PPDB/A5
DT50 (lab at 20°C)	d		0.17	PPDB/A5
DT50 field	d		1	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20°C and pH 5	d	TOXSWA	107 at 25	PPDB/A5
	Aqueous hydrolysis DT50 at 20°C and pH 7	d		6.2 at25 =10.4d@20	PPDB/A5
	Aqueous hydrolysis DT50 at 20°C and pH 9	d		0.49 at 25	PPDB/A5
	Aqueous photolysis DT50 at pH 7	d		98	PPDB/B5
	Water-Sediment DT50	d		0.4	PPDB/A4
Half-life transformation in sediment at 20°C		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		Not applicable/no dissociation	PPDB/B5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	1800	
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	217	PPDB/A5
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	0.94	PPDB/A5
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.3	PPDB/A5
	Acceptable Daily Intake, ADI	mg/kg/day		0.03	PPDB/A5
Aquatic toxicity data	Algae, 72 h	mg/L	Risk assessment	13	PPDB/B5
	Daphnids, 48 h	mg/L		0.0007	PPDB/A5
	Fish, 96 h	mg/L		0.018	PPDB/A5

6/ Atrazine

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Molar mass		g/mol	PRZM, TOXSWA	215.68	
Saturated vapour pressure		Pa	PRZM, TOXSWA	0.39E-04(25), 0.20E-04(20)	PPDB/B5
Temperature at which the saturated vapour pressure is measured		C	TOXSWA	25	PPDB/B5
Water solubility of substance		mg/L	PRZM, TOXSWA	35	PPDB/B5
Temperature of reference at which the water solubility was measured		C	TOXSWA	20	PPDB/B5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.		-	PRZM	=0.20E-01*215.68*1000/ (35*8.314E6*293) **=0.51E-07** PPDB:0.12E-06	
Half-life transformation in soil	DT50(Typical)	d	PRZM	75	PPDB/B5 Laboratory
	DT50 (lab at 20°C)	d		75	PPDB/B4
	DT50 field	d		29	PPDB/B4

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20°C and pH 5	d	TOXSWA	NA Rapidly hydrolysed in strong acids and alkalis and at elevated temperatures	
	Aqueous hydrolysis DT50 at 20°C and pH 7	d		86	PPDB/K4
	Aqueous hydrolysis DT50 at 20°C and pH 9	d		NA Rapidly hydrolysed in strong acids and alkalis and at elevated temperatures	
	Aqueous photolysis DT50 at pH 7	d		2.6	PPDB/B5
	Water-Sediment DT50	d		80	
Half-life transformation in sediment at 20°C		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		1.7 (very weak base)	PPDB/B5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	100	PPDB/G3
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	174	PPDB/R4
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	1.07=1	PPDB/R4
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.1	PPDB/JMPR 2007
	Acceptable Daily Intake, ADI	mg/kg/day		0.02	PPDB/JMPR 2007
Aquatic toxicity data	Algae, 96 h	mg/L	Risk assessment	0.059	PPDB/B3
	Daphnids, 48 h	mg/L		85	PPDB/B3
	Fish, 96 h	mg/L		4.5	PPDB/B5

Note: For slightly basic compounds which are not likely to be protonated at pH=6.9 because they become protonated only under very acidic conditions, the value of Koc in Footprint is acceptable. E.g. atrazine is such a very weak base, with a pKa of 1.7. At pH=6.9 (average pHH20 of the top 30 cm of the soil in Ethiopia of approximately 5x5 km2 grid cells of the Harmonized World Soil, see Figure A2.3) this compound is for 100% present as a neutral molecule. We think it is justified to use the Koc value of 100 L/kg from the FOOTPRINT database; the fact that the Ethiopian soil is charged positively at the pH=6.9 should not have any grave consequences.

7/ Chlorothalonil

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Molar mass		g/mol	PRZM, TOXSWA	265.91	
Saturated vapour pressure		Pa	PRZM, TOXSWA	0.76E-04(25), 0.39E-04(20)	PPDB/A5
Temperature at which the saturated vapour pressure is measured		C	TOXSWA	25	PPDB/A5
Water solubility of substance		mg/L	PRZM, TOXSWA	0.81	PPDB/A5
Temperature of reference at which the water solubility was measured		C	TOXSWA	20	PPDB/A5
Normalised Henry's law constant of the pesticide, H (-). Please use the value of H that was calculated from solubility and vapour pressure. The value given in PPDB may be less reliable, will sometimes not be available; the use of H in models assumes ideal behaviour, which may not correspond to the experimental value of H. H should be calculated as follows: *H = P*M*1000/(C*R*T)* Where *P* = Vapour pressure (mPa) *M* = molecular mass (g/mol) *C* = water solubility (mg/L) *R* = gas constant = 8.314 J/(mol K) = **8.314E^{6}** L mPa/(mol K) fixed value *T* = absolute temperature (K) = **293** K fixed value This means for PRIMET that *P, M* and *C* are input in the model. Note that in Annex K, the value of R in L mPa/(mol K) (i.e. 8.314E^{-3}) is NOT correct. Note that in case saturated vapour pressure and water solubility are not given at 20 C (293 K), both parameters need a temperature correction.		-	PRZM	=0.39E-01*265.91*1000/ (0.81*8.314E6*293) **=0.53E-05** PPDB:0.14E-04	
Half-life transformation in soil	DT50(Typical)	d	PRZM	22	PPDB/A5
	DT50 (lab at 20°C)	d		15.7	PPDB/A5
	DT50 field	d		44	PPDB/A5

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Half-life transformation in water	Aqueous hydrolysis DT50 at 20ºC and pH 5	d	TOXSWA	Stable	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 7	d		Stable =1000d@20	PPDB/A5
	Aqueous hydrolysis DT50 at 20ºC and pH 9	d		16 – 38	PPDB/A5
	Aqueous photolysis DT50 at pH 7	d		65	PPDB/A4
	Water-Sediment DT50	d		0.1	PPDB/A5
Half-life transformation in sediment at 20ºC		d	TOXSWA	1000 (fixed value)	
Dissociation constant (pKa)		-		Not applicable/no dissociation	PPDB/A5
Sorption coefficient to organic carbon. **Koc** = 1.724 **Kom**	K_{oc} in footprint	L/kg	PRZM, TOXSWA	850	PPDB/A4
	K_{foc} in footprint (the sorption coefficient normalised to the organic carbon content of the soil)	L/kg	PRZM, TOXSWA	3032	PPDB/R4
Sorption coefficient to organic matter. **Kom** = **Koc** /1.724	K_{om} in footprint	L/kg	PRZM, TOXSWA	=Koc/1.724	
	K_{fom} in footprint (the sorption coefficient normalised to the organic matter content of the soil)	L/kg	PRZM, TOXSWA	NA	
Reference concentration in liquid phase: usually 1 mg/L unless specified other.		mg/L	TOXSWA	1	
Freundlich exponent *1/n*. FOCUS default value is 0.9. However, if the dossier has information on this parameter, the value can be modified.		-	PRZM, TOXSWA	0.9	PPDB/R4
Coefficient for linear sorption on macrophytes		L/kg	PRZM, TOXSWA	0	

Parameter		Unit	Needed for model(s)	Value	Source, quality level
Mammalian toxicity data	Acute Reference Dose, ARfD	mg/kg/day	Risk Assessment	0.6	PPDB/A5
	Acceptable Daily Intake, ADI	mg/kg/day		0.015	PPDB/A5
Aquatic toxicity data	Algae, 96 h	mg/L	Risk assessment	0.033	PPDB/A5
	Daphnids, 48 h	mg/L		0.084	PPDB/A5
	Fish, 96 h	mg/L		0.038	PPDB/A5

Explanations of quality indices of the PDDB

A	EU Regulatory & Evaluation Data as published by EC, EFSA (DAR & Conclusion dossiers), EMA / EU Annex III PIC DGD / EU MRL Database (See http://ec.europa.eu/sanco_pesticides/public/index.cfm)
AA	IOBC Database on classification of side effects to beneficial organisms, 2005
AB	SELECTV Database (See http://ipmnet.org/phosure/database/selctv/selctv.htm)
AC	EC Joint Research Centre ESIS European Chemical Substance Information Systems including EINECS (See http://ecb.jrc.ec.europa.eu/esis/)
AE	Joint Assessment of Commodity Chemicals ECETOC (See http://www.ecetoc.org)
AF	European Food Safety Agency (EFSA)
B	UK CRD and ACP Evaluation Documents / and other DEFRA (UK) documents (See http://www.pesticides.gov.uk/publications.asp?id=202)
C	AGRITIX (See http://www.dive.afssa.fr/agritox/index.php)
CA	Medical and toxicological databases and information systems e.g. TOXNET (See http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB)
D	Agricultural Research Information System (ARIS) Database
DW	Don Wauchope personal database for Pka data: Wauchope, R. D. and Edwards, J. Dissociation constants for pesticide active ingredients: a database and comparison with predicted values. MS in preparation
E	Manufacturers Safety Data Sheets
F	U.S. EPA ECOTOX Database (see http://cfpub.epa.gov/ecotox/) / U.S. EPA Pesticide Fate Database (See http://cfpub.epa.gov/pfate/home.cfm) / Miscellaneous WHO documents.
FAO	Miscellaneous FAO publications
G	Extension Toxicology network Database EXTOXNET (See http://extoxnet.orst.edu/ghindex.html)
H	The US ARS Pesticide Properties Database (See http://www.ars.usda.gov/Services/docs.htm?docid=14199)
J	Pesticide Action Network Database (See http://www.pesticideinfo.org/)
K	Research Datasets (e.g. Pandora, Demetra (see http://www.demetra-tox.net/))
L	Pesticide manuals and hard copy reference books / other sources
M	GLEAMS Model database (Groundwater Loading Effects of Agricultural Management Systems). (See http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm)
N	Various Trusts, NGOs & Charities Data
P	Other Governments and Regulators
O	Miscellaneous Data From On-line Sources
R	Peer Reviewed Scientific Publications
S	Expert Judgement
T	UN EPFA Database
US	US Dept of Agriculture National Resources Conservation Service - various datasheets, databases and online sources

Note: This list is non-exclusive and just provides an example of the sources utilised by the PPDB
Data is then weighted 1 (low) to 5 (high) according to the confidence level the PPDB has in that data. A low score does not necessarily indicate incorrect data but indicates that have not been able to obtain verification. Generally, as a guide the weighting scores are assigned according to the following:

1	Estimated data with little or no verification
2	Unverified data of unknown source
3	Unverified data of known source
4	Verified data
5	Verified data used for regulatory purposes.

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