HAIR2010 Documentation

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harmonised environmental indicators for pesticide risk

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Calculating risk indicators related to agricultural use of pesticides within the European Union

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Abstract

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The HAIR instrument calculates risk indicators related to the agricultural use of pesticides in EU Member States. HAIR combines databases and models for calculating potential environmental effects expressed by the exposure toxicity ratio. The set of risk indicators currently built in HAIR includes aquatic indicators for algae, daphnia and fish, a groundwater indicator, terrestrial indicators for birds, mammals, earthworms and honey bees, and occupational risk indicators for operators, re-entry workers, bystanders and residents. The intended use of HAIR is to calculate trends in aggregated risk at national scale in support of the evaluation of EU policies, based on compound properties from EFSA and pesticide sales and usage from EUROSTAT databases. HAIR can also be used with more refined usage input data.

Keywords: risk indicator, environmental, occupational, pesticide, policy evaluation, EU, HAIR.

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Contents

Preface

The HAIR (HArmonised environmental Indicators for pesticide Risk) instrument can calculate risk indicators related to the agricultural use of pesticides in the member states of the European Union. The first version of HAIR was developed in January 2004 – March 2007 within the HAIR project funded by the European Commission DG RTD within the framework of the 6th Environmental Action Programme (Contract No. SSP-CT-2003-501997). The aim of this original HAIR project was to develop and integrate European scientific expertise on the agricultural use, emissions, environmental fate, and the impact of pesticides on the environment and human health. The Hair consortium developed a set of indicators, to be used by the EU in order to evaluate the effectiveness of EU-policies aimed at sustainable agriculture.

The Hair software package and user manual released in March 2007 were not fully operational and self-explanatory. In 2009, the European Commission DG RTD and Alterra Wageningen UR agreed that Alterra would develop a new version of the software package and user manual in 2010.

The new version HAIR2010, described in this report and in a separate User Manual, was developed in 2010 by Alterra, Wageningen UR with financial support from the Dutch Ministry of Economic Affairs, Agriculture & Innovation, the Dutch Ministry of Infrastructure and the Environment, and the National Institute for Public Health and the Environment/RIVM.

The intended use of HAIR is to support the evaluation of EU-policies (Sustainable Use Directive, EU 2009-128), based on the compound data from EFSA databases and the pesticide usage and sales data from DG-EUROSTAT databases (Regulation on Pesticide Statistics, EU 2008-1185).

We wish to thank the following colleagues in particular;

- Robert Luttik (RIVM) for his contributions to the terrestrial risk indicators and for testing the programme
- Ton van der Linden (RIVM) for preparing a new example compound database with data from the Dutch registration
- Aaldrik Tiktak (PBL) for providing soil data from the PERsistance in Soil Analytical Model/PERSAM
- Adrian Leip (DG-JRC) for providing crop maps for the European Union
- Nanny Heidema (Alterra) for processing the geographical data
- Wim de Winter and Rob Lokers (Alterra) for testing and debugging the software components.

Summary

The HAIR instrument (HArmonised environmental Indicators for pesticide Risk) calculates risk indicators related to the agricultural use of pesticides in member states of the European Union. The first version of the instrument was developed within the HAIR project funded by the European Commission DG RTD within the framework of the 6th Environmental Action Programme (Contract No. SSP-CT-2003-501997). The aim of this original HAIR project was to develop and integrate European scientific expertise on the agricultural use, emissions, environmental fate, and the impact of pesticides on the environment and human health.

The Hair consortium developed a set of indicators, to be used by the EU in order to evaluate the effectiveness of EU-policies aimed at sustainable agriculture (Sustainable Use Directive, EU 2009/128). The Hair software and user manual released in March 2007 were not fully operational and self-explanatory. In 2009, the European Commission DG RTD and Alterra Wageningen UR agreed that Alterra would develop a new, user-friendly and more robust version of the software package and user manual by the end of the year 2010. In order to reach this goal, the HAIR Repair project was conducted by Alterra Wageningen UR in the year 2010, with financial support from the Dutch Ministry of Economic Affairs, Agriculture & Innovation, the Dutch Ministry of Infrastructure and the Environment, and the National Institute for Public Health and the Environment/RIVM.

This report describes the input data and the methodology behind the risk indicators built in HAIR2010. The software components are described in a separate User Manual. These reports and the software installation file were delivered to the European Commission DG RTD at January 3, 2011.

The primary aim of HAIR is to calculate trends in aggregated risk resulting from pesticide use in agricultural crops within the European Union. The calculated trend can be compared for example with risk reduction targets set in a national policy plan. The new HAIR instrument is intended to be used by DG-EUROSTAT during the 1st implementation round of the Thematic Strategy, for calculating selected risk indicators and for reporting trends on the basis of sales - and use data from EU Member States. According to the Implementation Regulations (Pesticide Statistics Regulation 2009/1185), these data will be retrieved from databases maintained by DG-EUROSTAT.

HAIR2010 input data is stored in different types of databases. The Usage database contains the regional pesticide use data, including the regional area treated and (optional) risk mitigation parameters. The Compound database contains the physico-chemical properties and toxicological properties of the compounds, i.e. the active ingredients of pesticides excluding metabolites. The HAIR database contains the crop maps, soil and climate maps, crop definitions and all other input data required for calculating the risk indicators. The user is responsible for the Usage database and the Compound database. The HAIR database forms part of the software package; these data need not to be edited by the user. The software has a modular structure so that existing risk indicators may be updated or new risk indicators may be added, when necessary.

The crop interception model has a central place in the HAIR concept and is used in combination with the risk indicator models built in HAIR2010. For each application the crop interception is determined based on climate and crop characteristics. This amount deposited at the application event may be reduced due to volatilisation from the soil surface. HAIR2010 contains a set of 29 risk indicators expressed by the exposure toxicity ratio. The aquatic indicators express the potential risk to the aquatic ecosystem in a standard volume of surface water in a field ditch with standard cross-sectional dimensions. Considering loadings by spray drift, run-off and erosion, separate risk indicators with different exposure concentration are calculated for standing water

conditions and flowing water conditions, and for acute and chronic exposure regimes. These exposure concentrations are related to the toxicity data for algae, daphnia and fish. The indicator for the risk of leaching towards deep groundwater layers is based on the long-term average leaching concentration in the soil solution at 1 m depth. For this particular indicator, exposure is related to the drinking water criterion instead of toxicity. The terrestrial risk indicator group includes acute- and chronic risk indicators for birds and for mammals, acute- and chronic risk indicators for earthworms, and the aqute hazard quotient for bees. The set of occupational indicators comprises acute and chronic indicators which estimate the risk to operators, re-entry workers, bystanders, child bystanders, and residents.

The HAIR instrument can also be used with more refined usage input data, originating from farm based or field based survey data. To point out the flexibility of the risk indicators in HAIR2010, some alternative ways are described to aggregate field based pesticide usage data or to disaggregate country based usage and sales data for preparing the Usage database.

1 Introduction

1.1 General introduction

The HAIR instrument (HArmonised environmental Indicators for pesticide Risk) calculates risk indicators related to the agricultural use of pesticides in the member states of the European Union. The first version of the HAIR instrument was developed within the HAIR project funded by the European Commission DG RTD within the framework of the 6th Environmental Action Programme, during the period January 2004 – March 2007 (Contract No. SSP-CT-2003-501997). The aim of this original HAIR project was to develop and integrate European scientific expertise on the agricultural use, emissions, environmental fate, and the impact of pesticides on the environment and human health.

The Hair consortium developed a set of indicators, to be used by the EU in order to evaluate the effectiveness of EU-policies aimed at sustainable agriculture. The Hair software and user manual released in March 2007 were not fully operational and self-explanatory. These shortcomings of the Hair software package hampered the realisation of the European Commission objectives that were set out in the Thematic Strategy on the sustainable use of pesticides. In the year 2008, on behalf of EC-EUROSTAT, ARCADIS Belgium performed a test and evaluation of the Hair software package and its indicators. At the request of EC-EUROSTAT, Alterra provided ARCADIS Belgium with support to finish their assessments.

In 2009, the European Commission DG RTD and Alterra Wageningen UR agreed that Alterra would develop a new, user-friendly and more robust version of the software package and user manual by the end of the year 2010. In order to reach this goal, the HAIR Repair project was conducted by Alterra Wageningen UR in the period from March 2010 untill December 2010, with financial support from the Dutch Ministry of Economic Affairs, Agriculture & Innovation, the Dutch Ministry of Infrastructure and the Environment, and the National Institute for Public Health and the Environment/RIVM.

This report describes the input data and the methodology behind the risk indicators built in HAIR2010. The software package is described in a separate User Manual (Vlaming et al., 2011). These reports and the software installation file were delivered to the European Commission DG RTD at January 3, 2011.

A set of 29 risk indicators expressed by the exposure toxicity ratio is currently built in HAIR. The input data is stored in different types of databases. The user is responsible for the Usage database and for the Compound database. The HAIR database contains all other input data and forms part of the software package; these data need not to be edited by the user. Different modules cover the aquatic risk indicator group considering loadings by spray drift, run-off and erosion, the groundwater indicator, the risk indicators for birds and mammals, the risk indicators for earthworms, a hazard indicator for bees, and the occupational risk indicators for operators, workers, and bystanders. New developments can be incorporated by updating specific risk indicator modules, or by adding new modules to the existing software package.

1.2 Overview of report

This report describes the input data and the methodology behind the risk indicators, currently built in HAIR2010 based on the results of the original HAIR consortium. The software package is described in a separate User Manual (Vlaming et al., 2011).

The input data is stored in different types of databases, as described in Section 1.5. The crop interception module and the volatilisation module have a central place in the HAIR concept of harmonised risk indicators for different environmental compartments. These modules are described in Chapter 2.

Chapters 3 to 6 describe the aquatic risk indicator group, the groundwater indicator, the terrestrial risk indicator group, and the occupational risk indicator group, respectively. Indicators for consumers are not included in HAIR2010. For each of the 29 risk indicators currently built in HAIR, these chapters contain the definition and scope and a complete description of the algorithms and input requirements. Some alternative ways to generate input usage data from detailed surveys or from country based usage data and sales volumes are described in Chapter 7.

The annexes provide lookup tables for application crops in the Usage database, internal crop definitions, crop calendar data, soil and climate maps, crop maps, and the region codes that can be referred to in the Usage database. Annex 7 describes the way in which the recommendations made by ARCADIS Belgium B.V. were handled.

1.3 HAIR software package

The HAIR software package includes databases and programmes for calculating risk indicators and for visualisation and presentation of the output. These software components are described in the HAIR User Manual (Vlaming et al., 2011). The input data are stored in 3 types of databases (Figure 1).

1. The Usage database contains the regional pesticide use data, including the regional area treated and (optional) risk mitigation parameters.
2. The Compound database contains the physico-chemical properties and toxicological properties of the compounds, i.e. the active ingredients of pesticides excluding metabolites.
3. The HAIR database contains the crop maps, soil - and climate maps, crop definitions and all other input data required for calculating the risk indicators.

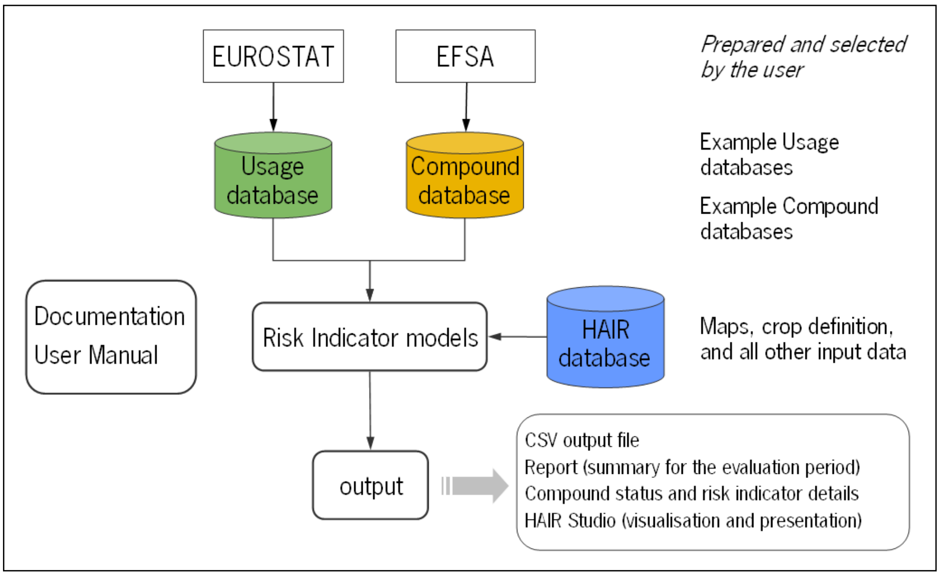

Figure 1
The HAIR software package with 3 types of databases. All components are described in the HAIR User Manual (Vlaming et al., 2011).

The user is responsible for the Usage database and for the Compound database. These input data that need to be collected by the user are fully separated from the other input data stored in the HAIR database. The HAIR database has a more complex design than the Usage - and Compound databases and contains no data that need to be edited by the user. Therefore the HAIR database is regarded as a part of the software version.

Example Usage databases are included, anticipating the sales and usage databases available at EUROSTAT (EC 2009/1185). An example database filled with compound data from Dutch registration is included, anticipating the database that will be filled with endpoints stored in EFSA database.

1.4 Intended use of HAIR

The primary aim of HAIR is to calculate trends in aggregated risk resulting from pesticide use in agricultural crops within the European Union. The calculated trend in aggregated risk can be compared for example with risk reduction targets set in a national policy plan (Figure 2). Depending on the amount of detail in the input use data, trends can be identified for specific crop groups or chemical (product) groups. Applications causing relatively high risk levels may be identified by the spatial patterns of the outcomes and by their distribution among crops and several application parameter settings, including mitigation.

The risk indicators are not intended for assessments such as comparing the outcomes with criteria which are normally used in registration decisions.

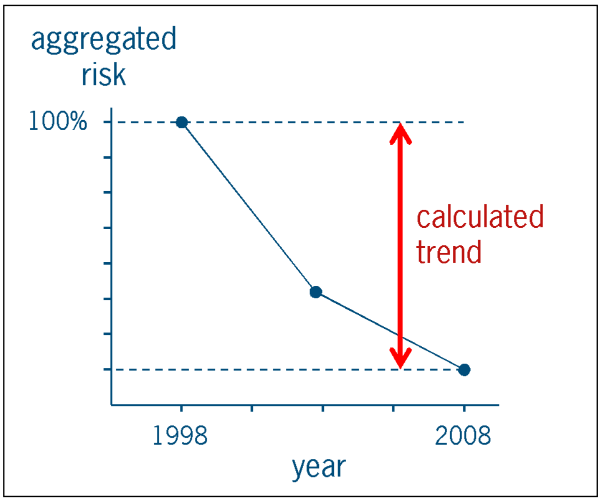

Figure 2
The primary aim of HAIR is calculating trends in aggregated risk.

The HAIR instrument may be used by DG-EUROSTAT during the 1st implementation round of the Thematic Strategy, for calculating selected risk indicators and for reporting trends. This intended use would be on the basis of sales – and use data from EU Member States. According to the Implementation Regulations (Pesticide Statistics Regulation 2009/1185), these data are stored in databases maintained by DG-EUROSTAT (period).

The HAIR instrument can also be used with more refined usage input data, originating from farm based or field based survey data (Chapter 7).

1.5 Data necessary for HAIR

This section describes the contents of the databases in HAIR2010 (Figure 1). The maps and crop definitions stored in the HAIR database are described in Section 1.5.3, and the remaining input parameters in the sections on specific risk indicators (Chapters 3, 4, 5 and 6). More technical detials are given in the HAIR User manual (Vlaming et al., 2011).

1.5.1 Usage database

This section includes the definition of all parameters stored in the Usage database. The Usage database contains rows of data being referred to as regional applications. The application includes fields for reference purposes, use parameters, the regional area treated, and mitigation parameters. The format of the Usage database is given in Table 3.

Application: A single row in the Usage database; with a treatment specified in terms of the year, region, area treated, compound, application crop, application rate, application date, method of application, formulation of the product, number of application events, and application interval. In adddition to these input requirements, an application may be specified by a drift mitigation factor, a buffer strip width, field margin width, and the presence of flowering weeds in the crop. Defaults for these additional mitigation parameters are provided by the software package, but the user may edit these values as explained in the HAIR User manual (Vlaming et al., 2011).

Application crop: Name of the application crop treated.

Application crop ID: Identifier for the application crop (all application crops are listed in Annex 1).

Application date: For single applications the date of the application event. For multiple applications the central date between the first and the last application event.

Application event: An application can consist of one or more application events. For single applications the number of application events equals one. For multiple applications the number of application events is more than one.

Application event date: The date of an application event. An example is given in Table 1.

Table 1
Examples of application event dates based on 4 applications with application date March 15, 7-days application interval, and different number of application events. The application date corresponds with Julian daynumber 74.

Number of application events	Application event day			
	1	2	3	4
1	74			
2	71	78		
3	67	74	81	
4	64	71	78	85

Application interval: The number of days between subsequent application events in a multiple application.

Application rate: The amount of a compound (active ingredient) per application event and per unit area of treated field (application rate is preferred instead of dose rate) (in kg a.i. ha^{-1})

Area treated: The crop area treated within the region, in one application (in ha).

Buffer strip: The area located between the crop and the edge of the adjacent surface water body.

Buffer strip width: Width of the area located between the crop edge and the closest edge of the adjacent surface waterbody (m). The default value is either 1 or 3 m, depending on the crop type. The user can define the buffer strip width in the Usage database. Increasing the buffer strip width reduces the calculated aquatic exposure resulting from spray drift and runoff.

Compound: Active ingredient specified in the Compound database (preferred instead of substance. Also active ingredient or a.i.).

Drift mitigation factor: Factor accounting for the use of improved spraying equipment. The drift mitigation factor reduces the calculated aquatic exposure resulting from spray drift. The default value = 1. The user can define the drift mitigation factor in the Usage database.

Field margin: Strip grown with vegetation that may receive spray drift from the adjacent crop treated. By definition, the field margin starts at 1 m distance from the crop edge. The field margin is part of the calculation scheme for the bees acute hazard indicator.

Field margin width: Width of the strip grown with vegetation that may receive spray drift from the adjacent crop treated. The default value = 6 m. The user can define the field margin width in the Usage database.

Flowering weeds in crop: Application attribute in the Usage database. When the crop treated is at a development stage attractive to bees, the bees acute hazard indicator is calculated based on the application rate. When the crop treated is not at a development stage attractive to bees, the presence of flowering weeds in the crop is evaluated:

- When flowering weeds are present in the crop, the bees acute hazard indicator is calculated based on the application rate.
- When flowering weeds are not present in the crop, the bees acute hazard indicator is calculated based on the spray drift deposition onto the field margin.

The default is False (i.e. “no flowering weeds in crop”). The user can switch to True (“flowering weeds in crop”) by editing the Usage database if relevant.

Formulation: The formulation of the product is required for calculating the occupational indicators. The formulation code in the Usage database can be either EC (Emulsifiable Concentrate), WP (Wettable Powder), or Granular (Granual formulations).

Method of application: Specifies whether the compound is applied manually or by machinery, and the type of equipment used. (Method of application is preferred instead of application technique). In Table 2 the methods of application codes currently used in HAIR are shown.

Table 2
Method of application codes currently used in HAIR.

Code in the Usage database	Method	Remarks
GS	Vehicle ground boom and other downward spraying	Downward
GSUP	Outdoor upward spraying	Upward
SS	Soil sterilant treatment	
ST	Seed treatment	
GB	Granular broadcast	Downward, mechanical
GI	Granular incorporated	Downward, mechanical
LVM	Low volume misting	Used in occupational indicator
MANUAL	Handheld spraying	Downward
MANUP	Handheld upward spraying	Upward
SPRGRH	Spraying techniques typical for greenhouses	Assumed: always downward

Number of application events: see **Application event**.

Region: The NUTS1 region in the application definition. The NUTS1 regionalisation is also used for distributing the Area treated among the gridcells within the region, and for selecting the area of interest as part of the case definition (Vlaming et al., 2011).

Region ID: Identifier for the NUTS1 region (all region codes are listed in Annex 5).

Table 3
Usage database format.

Usage database field	Type, format	Units	Range	Remarks
Application ID	Integer		≥ 1	Unique reference to application in Usage database
Year	yyyy			4-digit notation
Region ID	Character			NUTS1 code
Application crop ID	Integer		1 – 205	Integer, for identification
_Application crop name	Character			No input For reference only
Area grown	Decimal	(ha)	> 0.0	No input For reference only
Application date	dd-mm-yyyy			Note: In winter crops the application date may fall in the preceding year.
Compound ID	Integer		≥ 1	For identification
_Compound name	Character type			No input For reference only
Method of application	Character type			Domain: GS, GSUP, SS, ST, GB, GI, LVM, MANUAL, MANUP, SPRGRH
Formulation	Character type			Input for the occupational and worker indicators only. Domain: EC, WP, Granular
Application rate	Decimal	(kg a.i. ha^{-1})	> 0.0	Rate per event
Area treated	Decimal	(ha)	> 0.0	
Number of application events	Integer	(-)	≥ 1	
Application interval	Integer	(d)	> 1	Only if Number of applications > 1
Buffer strip width	Decimal	(m)	≥ 1.0	Default = 1 or 3 m, depending on crop
Drift mitigation factor	Decimal	(-)	0 – 1	Default = 1
Field margin width	Decimal	(m)	≥ 0.0	Default = 6 m
Flowering weeds in crop	Boolean	(-)	.True., .False.	Default .False. = “no flowering weeds in crop”. .True. = “flowering weeds in crop”

Some Method of application codes can only be combined with a limited number of Product formulation codes. Granular (GB, GI) and soil sterilant (SS) methods of application must be combined with the Product formulation code Granular (Table 4). In addition, some Method of application codes can only be used in combination with outdoor crops or with indoor crops. The program cannot calculate risk indicators resulting from applications with the parameter combinations indicated (N) in Table 4. These applications are discarded when reading the Usage database. The method of application and product formulation parameters are used to define the scope of the risk indicators (Chapters 3 to 6).

Crop system is not explicitly in the Usage database, but is internally defined as an attribute of the HAIR crop (Section 1.5.3). The application crops related to a HAIR crop with the attribute Crop system = Indoor are; Celery [27], Aubergines [7], Chinese cabbage [35], Cucumbers [42], Peppers [147], Raspberries [161], Strawberries [182], Tomatoes [191], Flowers and ornamentals [52].

Table 4
Combinations of Method of application codes with the Product formulation code and with the Crop system. The program cannot calculate risk indicators for combinations labeled (N). The crop system is internally defined as an attribute of the application crop (Section 1.5.3).

Method of Application	Product Formulation			Crop system	
	EC	Granular	WP	Outdoor	Indoor
GB	N	Y	N	Y	Y
GI	N	Y	N	Y	Y
GS	Y	Y	Y	Y	N
GSUP	Y	Y	Y	Y	Y
LVM	Y	Y	Y	N	Y
MANUAL	Y	Y	Y	Y	Y
MANUP	Y	Y	Y	Y	Y
SPRGRH	Y	Y	Y	N	Y
SS	N	Y	N	Y	Y
ST	Y	Y	Y	Y	Y

1.5.2 Compound database

This section includes the definition of all parameters stored in the Compound database. The format of the Compound database is given in Table 5.

The HAIR software package contains an example Compound database which is filled with part of the data collected by the original HAIR consortium (Van Vlaardingen et al., 2007). As far as possible physico-chemical properties as well as fate, tox and ecotox data have been checked against data available in the CTBase (Dorgelo 2006), which contains data evaluated in the authorisation procedure in the Netherlands. The resulting example database contains 267 compounds which are also present in the example Usage database from the United Kingdom (Thomas, 2007). The database format is described in this section.

In the example Compound database a part of the properties is not available for some compounds. The missing values for physico-chemical and toxic parameters of the compounds selected can be replaced by the missing values routine in HAIR, as will be explained in this section. In the future, when the EFSA Compound database will be used, this missing value routine may become obsolete.

Compound database format
The Compound database in HAIR contains fields for compound identification and for the physico-chemical properties and toxic data required for calculating the risk indicators. A compound is identified internally by an integer number (Compound ID). This key field corresponds the Compound ID field in the Usage database (Section 1.5.1). The Compound name and the CAS nr. fields are no input and can be used for reference only Table 5).

The chemical use and chemical class fields contain the compound classifications used by the missing values routine for compound properties. The user may also choose one of these two classifications for aggregating results with HAIR Studio. It is recommended to maintain a hierarchic, layered classification in these two fields (i.e. a chemical class group can be a part of only one chemical use group).

The physico-chemical compound properties comprise the saturated vapour pressure, the molar mass, the solubility in water, various sorption parameters, the octanol water partitioning coefficient, the degradation half-life in water sediment, and the degradation half-life in soil. The saturated vapour pressure, the solubility in water, and the degradation half-lives in the Compound database are defined at reference temperature (20 degr. C). These values at reference temperature are adjusted for local temperature, as described in the chapters on the risk indicator modules.

Two cases of sorption behaviour can be defined by the boolean parameter pH-dependent sorption. In case of normal sorption behaviour to soil organic matter, the boolean field pH_dependent_sorption is False. In case of pH-dependent sorption behaviour, the boolean field pH_dependent_sorption is True:

Case (a) pH-dependent sorption = False:
- the sorption coefficient in the Compound database is used
- the sorption constant of the acidic molecule, the sorption constant of the conjugated base, and the dissociation constant in the Compound database are not used.

Case (b) pH-dependent_sorption = True:
- the sorption constant of the acidic molecule, the sorption constant of the conjugated base, and the dissociation constant in the Compound database are used.
- the sorption coefficient in the Compound database is not used

The environmental toxicity data are;
- the lethal concentration (LC50) for algae, daphnia, fish, and for earthworms,
- the no-observed effect concentration (NOEC) for algae, daphnia and for fish,
- the lethal dose (LD50) for birds, mammals, bees, and for earthworms,
- the no-observed effect dose (NOED) for birds, mammals, and for bees.

Compounds having a specific mode of action are classified with the boolean parameters Insect Growth Regulator and Systemic Effect. These properties are required for the bees hazard indicator.
The systemic, short-term Acceptable Operator Exposure Level (AOEL) is required for the occupational indicators (Table 5).

Table 5
Compound database format.

Compound database field	Type	Units	Range	Missing value routine	Remarks
Compound ID	integer	-		no	Unique reference to compound in Compound database
Compound name	char	-		no	No input. For reference only.
CAS nr	char	-		no	No input. For reference only.
Chemical class	char	-		no	Chemical class
Chemical use	char	-		no	Product use in EU-compound list
DegT50 soil	decimal	d	> 0	yes	at reference temperature T = 20 degr C
DegT50 water sediment	decimal	d	> 0	yes	at reference temperature T = 20 degr C
pH dependent sorption	boolean		true/false	no	pH dependent sorption, or normal sorption behaviour
Kom base	decimal	L kg^{-1}	> 0	no	in case of pH dependent sorption: Kom base ≤ Kom acid. No input in case of normal sorption behaviour.
Kom acid	decimal	L kg^{-1}	> 0	no	in case of pH dependent sorption: Kom base ≤ Kom acid. No input in case of normal sorption behaviour.
Kom	decimal	L kg^{-1}	> 0	yes (*)	(*) only in case of normal sorption behaviour. In case of pH dependent sorption: No input
LogKow	decimal	-	all values	yes	logarithm of the octanol water partitioning coefficient (-)
MolMass	decimal	g mol^{-1}	> 0	yes	
pKa	decimal	-	> 0	no	No input in case of normal sorption behaviour.
Pvap	decimal	mPa	> 0	yes	at reference temperature T = 20 degr C
Solubility	decimal	mg L^{-1}	> 0	yes	at reference temperature T = 20 degr C
AOEL	decimal	mg a.i. kg bw^{-1} d^{-1}	> 0	yes	Systemic, short-term Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})
LC50 algae	decimal	mg a.i. L^{-1}	> 0	yes	lethal concentration for algae (mg L^{-1})
LC50 daphnia	decimal	mg a.i. L^{-1}	> 0	yes	Lethal concentration for daphnia (mg L^{-1})
LC50 earthworm	decimal	mg a.i. kg dw^{-1}	> 0	yes	Concentration causing 50% mortality after 14 d (mg a.i. kg dry weight $soil^{-1}$)
LC50 fish	decimal	mg a.i. L^{-1}	> 0	yes	lethal concentration for fish (mg L^{-1})
LD50 bee	decimal	µg a.i./bee	> 0	yes	Dose per bee that causes 50% mortality after 48h (µg a.i. bee^{-1})
LD50 bird acute	decimal	mg a.i./kg bw	> 0	yes	Dose causing 50% mortality in birds (mg a.i. kg body $weight^{-1}$ d^{-1})
LD50 mammal acute	decimal	mg a.i./kg bw	> 0	yes	Dose causing 50% mortality in mammals (in mg a.i. kg body $weight^{-1}$ d^{-1})
NOEC algae	decimal	mg a.i./L	> 0	yes	no observed effect concentration for algae (mg L^{-1})
NOEC daphnia	decimal	mg a.i./L	> 0	yes	no observed effect concentration for daphnia (mg L^{-1})
NOEC earthworm	decimal	mg a.i./kg	> 0	yes	Highest test concentration causing no effect on growth or reproduction after 28 d (mg a.i. kg dry weight $soil^{-1}$)
NOEC fish	decimal	mg a.i./L	> 0	yes	no observed effect concentration for fish (mg L^{-1})
NOED bird chronic	decimal	mg a.i./kg bw	> 0	yes	Dose causing no observed chronic effects on birds (mg kg body $weight^{-1}$ d^{-1}).
NOED mammal chronic	decimal	mg a.i./kg bw	> 0	yes	Dose causing no observed chronic effects on mammals (mg kg-1 body weight d^{-1}).
Insect Growth Regulator	boolean	-	true/false	no	Insect Growth Regulator
Systemic Effect	boolean	-	true/false	no	Systemic Effect

Missing values routine for compound properties

Missing values for fysico-chemical and toxicologic properties in the Compound database can be replaced with the missing values routine in HAIR. The procedure will be explained in this section. The basic idea is to take the average over the chemical class group to which the substance belongs. In case no substance from the same chemical class group is available, the chemical use group is taken. See substance list for two examples (Table 6).

Example 1: The mean of substance 1 to 7: Substance 11 belongs to the Organophosphorus chemical class, so the average is calculated over this group

Example 2: mean of substance 1 to 10: Substance 12 is the only pyrethroid in the list, so no average can be calculated for this chemical class. The average can be calculated for the chemical use group, using the values read from the datasets.

Table 6
Examples demonstrating the missing values routine for compound properties.

Substance ID	Chemical class	Chemical use	$LC50_{fish}$	Example
1	Organophosphorus	Insecticide	12	
2	Organophosphorus	Insecticide	35	
3	Organophosphorus	Insecticide	112	
4	Organophosphorus	Insecticide	7	
5	Organophosphorus	Insecticide	48	
6	Organophosphorus	Insecticide	22	
7	Organophosphorus	Insecticide	100	
8	Carbamate	Insecticide	9	
9	Carbamate	Insecticide	73	
10	Carbamate	Insecticide	78	
11	Organophosphorus	Insecticide	**48**	1
12	Pyrethroid	Insecticide	**50**	2

The procedure for replacement of missing values is based on the Compound database selected.
So, compounds may be included with no applications in the Usage database selected.

The programme assigns a status label to each compound property. The default Status = 0 (compound property read from the Compound database). Replacement of a missing value based on the chemical class group is indicated by Status 1 (property based on the chemical class group). Replacement based on the chemical use group is indicated by Status 2 (property based on the chemical use group). If replacement is not possible with the databases selected by the user, the compound property status is set equal to 3 (missing value). Compound status information is part of the output generated by the programme.

In the future, when the HAIR programme is used with compound data from the EFSA database, this missing values routine in HAIR may become obsolete.

1.5.3 HAIR database

The HAIR database contains the geographic data, the crop classifications and all the other input data needed for calculating the risk indicators, except usage (Section 1.5.2) and compound properties (Section 1.5.2). The geographic data in the HAIR database and the calculation of the area treated per gridcell are described in this section. The use of crop calendar data in the crop interception model is described in Chapter 2.

Geographic data
Climate - , soil - and crop maps are stored in the HAIR database at a 10 km x 10 km grid. A set of suitable maps was derived based on the deliveries of the original HAIR consortium and on more recent results obtained from the development of exposure scenarios for soil organisms (EFSA, 2010). These maps cover the entire European Union excluding Malta and Cyprus.

Climate maps
Longterm average temperature and average precipitation data were delivered by the original HAIR consortium. These meteorological parameters have been spatially interpolated onto the MARS 50 km x 50 km grid (Mulligan and Bouraoui, 2007). These MARS grid elements are referred to as climate map units. The HAIR database contains the average monthly- and annual temperature and precipitation amounts. Maps showing the annual average temperature and the annual precipitation amount are included in Annex 3.

Soil and slope maps
The soil data stored in the HAIR database include organic carbon, soil pH, soil texture class, soil hydrological group, and the slope (Table 7). The soil texture class determines the soil moisture content at field capacity. The hydrological soil group determines the susceptibility to soil erosion.

The soil organic carbon map for the topsoil (0.3 m) was delivered by the original HAIR consortium. The soil organic carbon content in the top 1 m of the soil profile was obtained from the average ratio between the organic carbon contents in both layers (derived from the EuroPEARL database, personal communication Aaldrik Tiktak);

$$OC100_{10K} = 0.538274\, OC30_{10K} \qquad \text{Equation 1}$$

OC100 Organic carbon content in the top 1 m soil layer (-)
OC30 Organic carbon content in the topsoil (0-0.3 m) (-)

A soil pH map was not available from the original HAIR consortium, but could be obtained from the soil database for the PERSAM model (EFSA, 2010).

Table 7
The use of soil- and slope maps in HAIR2010.

Property	Description, source	Indicator group
Topsoil organic carbon	Organic carbon fraction in the topsoil (0-30 cm) (in %) (HAIR 2007)	Aquatic, Groundwater, Terrestrial
Soil organic carbon	Organic carbon fraction in the top 1 m of the soil profile (in %) (Equation 1)	Groundwater
Soil pH	Average soil pH in the topsoil (PERSAM database, 2009)	Aquatic, Groundwater
Hydrologic soil group	Hydrologic soil group is used for calculating runoff (HAIR 2007)	Aquatic
Soil texture class	Soil texture class defines the moisture content at field capacity (HAIR 2007)	Aquatic, Groundwater
Average slope	The average slope is used for calculating runoff (in %) (HAIR 2007)	Aquatic

The original soil pH map covers the area grown with annual crops in the European Union excluding Malta and Cyprus. The original spatial resolution of 1 km x 1 km was increased to the 10 km x 10 km resolution used in HAIR and the spatial average soil pH was calculated. This aggregation reduced the number of 10K-gridcells with no data available to 12%. Most of these gridcells with no soil pH available are located in regions with minor agricultural area, as can be seen on the maps included in Annex 3 and 4. The only exception is Slovenia, where missing values for soil properties were replaced with average values (36 gridcells with soil pH, 202 gridcells with soil texture class and with soil hydrological group).

Crop maps
A set of 30 crop maps for HAIR was obtained from the CAPRI land-use maps (Leip et al., 2008). The CAPRI methodology combines remote sensing data, administrative crop data, land suitability data and statistical modelling. The maps for Tomatoes and Other fresh vegetables were joined into one combined crop. These maps cover the EU without Cyprus and Malta (EFSA, 2010). The original spatial resolution of 1 km x 1 km was decreased to the 10 km x 10 km resolution used in HAIR.

The scope of some risk indicators includes greenhouse crops and other covered crops. A map with these indoor crops was not available from the results of the original HAIR consortium, nor from (EFSA, 2010). In order to be able to test the risk indicators for indoor crops, it was decided to include a map with the greenhouse crops in the Netherlands. The HAIR database is prepared for a map with the greenhouse crops and other covered crops with the spatial extent of the other crop maps. The crop maps are included in Annex 4.

Crop definitions
This section describes the crop definitions in HAIR. A list of 205 application crops was created starting with crops in the UK for which maximum residue levels are available, and expanded with crops likely to be encountered around the EU countries on which pesticides might be applied. Only these application crops can be referred to in the Usage database. The application crops are internally related to the HAIR crops. The HAIR crop definition was derived from Farm Structure Survey (FSS) Reporting Regions with different agricultural crop classes at multiple levels. Redundant items were removed and the distinction between cereals grown with a winter crop calendar and a spring crop calendar was added (Kruijne et al., 2007).

All additional crop classifications and their properties required for calculating the risk indicators are defined as attributes of the internal HAIR crops;
- crop map group (all indicator groups)
- outdoor crop system versus indoor crop system (all indicator groups)
- FOCUS interception crop (aquatic indicators, groundwater indicator, terrestrial indicators)
- FOCUS drift crop group (aquatic indicators, bees indicator, occupatonal indicators)

– Curve Number crop group (aquatic indicators)
– erosion crop group (aquatic indicators)

These crop classifications and their properties can't be edited by the user. Tables with the HAIR crop names and their attributes are included in Annex 1. More details can be found in the next chapters on the geographical crop differentation and the risk indicator groups.

Crop area per gridcell

The area treated in the region (NUTS1) is part of the application definition and is stored in the Usage database (Table 5). For each application in the Usage database, the area treated in the gridcell is calculated based on the crop map within the region;

$$A_i = A_{NUTS1} \frac{A_{map,i}}{A_{map,NUTS1}}$$ Equation 2

$$A_{map,NUTS1} = \sum_{i=1}^{k} A_{map,i}$$ Equation 3

A_i	area treated in the gridcell (ha)
A_{NUTS1}	area treated in the region (Usage database) (ha)
$A_{map,i}$	crop map area in the gridcell (HAIR database) (ha)
$A_{map,NUTS1}$	total crop map area within the region (ha)
i	index for the 10K gridcell
k	number of gridcells within the region

The relation between the 205 application crops and 50 HAIR crops is defined within the HAIR database. Also, the relation between the 50 HAIR crops and 30 crop maps is defined within the HAIR database. The crop area treated is read in the usage database. In case the crop map does not exist in the region ($A_{map,NUTS1}$ = 0), the area treated can't be distributed among the gridcells and no risk indicators are calculated. Note that the area grown is no input and is included in the Usage database format for reference only (Table 3).

Other input parameters

The use of crop calendars in the crop interception model is described in Chapter 2. Specific input data for each of the risk indicators in HAIR are described in Chapters 3 to 6.

2 Geographical crop differentiation

2.1 Introduction

The crop interception model has a central place in the HAIR concept and is used in combination with most of the risk indicator models currently built in HAIR. For each application the crop interception is determined based on climate data and crop characteristics (Section 2.2). The volatilisation module described in Section 2.3 estimates the cumulated volatilisation of the compound from the soil surface during the period starting at the application event.

2.2 Crop interception

In HAIR the crop interception factor is determined based on the crop characteristics, location and date of application event. The outlined procedure to estimate the crop interception factor is applicable to both outdoor and indoor crops.

The HAIR consortium (Strassemeier et al., 2007) provides only a general outline of how to calculate crop interception, suggesting that the procedure outlined by the FOCUS Surface Water Group (FOCUS, 2001) should be applied. The FOCUS Surface Water procedure, however, describes calculations for a limited number of crops on specific locations. For use in HAIR the procedure had to be expanded in order to enable calculations for all of the crops addressed by HAIR on a multitude of locations on which the crop is grown. This has resulted in the use of additional information and procedures which will be outlined in the following sections.

For each crop the range of the crop interception factor is given by a minimum and maximum interception factor. In the procedure crop growth is characterized by 4 typical dates, here referred to as a set of crop data:

- day of emergence,
- day of maturation,
- first day of senescence,
- day of fallow land.

These crop data define the start of 4 development stages (Figure 3);

1. emergence stage,
2. mature stage,
3. senescence stage, and
4. fallow stage.

Before the day of emergence the crop interception will be minimal; from emergence until maturation the interception factor will steadily increase from minimum to maximum interception. Crop interception is then assumed to remain maximal until the start of senescence, after which interception reduces to the minimal value until the crop has completely disappeared and the land is fallow.

As will be pointed out later, some of the data (e.g. the day of senescence and the day of fallow) are not usually available but an approximation to deal with these missing values will be outlined.

Some records in the usage database describe multiple application events. Such a record contains only a single date of application, but the application events will be distributed over time in a symmetric fashion around the application date given, taking into account the number of application events and the interval between application events (Section 1.5.1). For the dates derived for each of the application events, a separate value for crop interception will be calculated.

Moreover, some crops may (on some locations) have more than one growth cycle per year, and each growth cycle will then have its separate day of emergence etc. Thus a crop may have more than 1 set of crop data during a year. The application event under consideration determines which growth cycle applies to that specific application.

The steady increase (from emergence until maturation) of crop interception during maturation is given by Equation 4, whereas the decrease during senescence of the crop is given by Equation 5.

$$CIF(t) = CIF_{\min} + (CIF_{\max} - CIF_{\min}) f_{emergence}(t) \qquad \text{Equation 4}$$

$$CIF(t) = CIF_{\max} - (CIF_{\max} - CIF_{\min}) f_{senescence}(t) \qquad \text{Equation 5}$$

$CIF(t)$	current interception fraction at day t (-)
CIF_{max}	maximal interception fraction of crop (-)
CIF_{min}	minimal interception fraction of crop (-)
$f_{emergence}(t)$	increase of CIF(t) during emergence (-)
$f_{senescence}(t)$	decrease of CIF(t) during senescence (-)

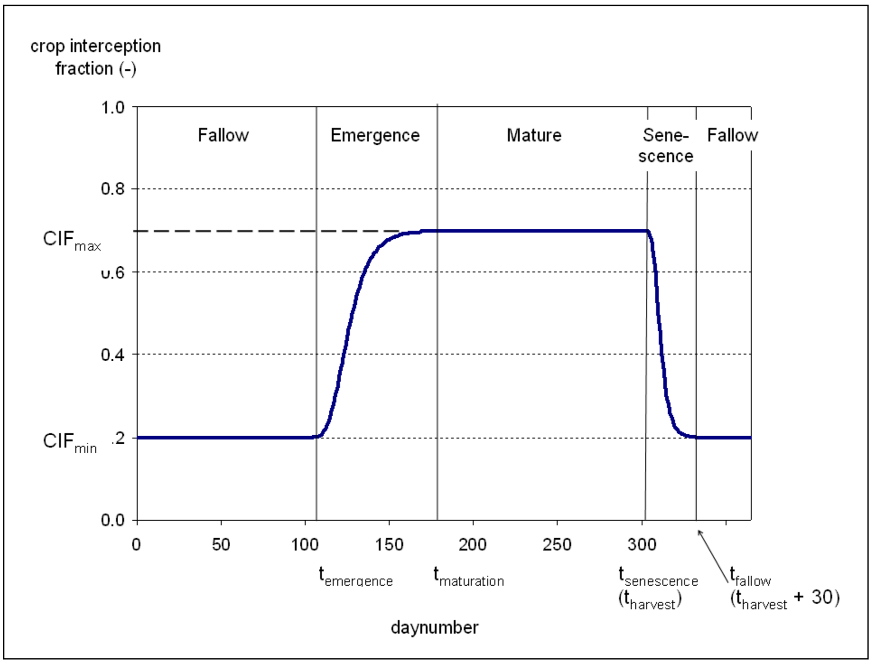

Figure 3
The crop interception fraction (CIF) during a single crop cycle.

The time-dependent factors $f_{emergence}$ and $f_{senescence}$ are given by:

$$f_{emergence}(t) = (1 + c_1 \; e^{-c_2 (t - t_{emergence})})^{c_3} \qquad \text{Equation 6}$$

$$f_{senesence}(t) = (1 + c_1 \; e^{-c_4 (t - t_{senescence})})^{c_3} \qquad \text{Equation 7}$$

$t_{emergence}$ emergence day (Julian day number) (-)
$t_{senescence}$ first day of senescence stage (Julian day number) (-)
$c_{1,}$ c_3 constants (c_1 = - 0.07; c_3 = 100)

The parameter c_2 is dependent on the length of the crop emergence stage:

$$c_2 = 8.2246\,(t_{maturation} - t_{emergence})^{-0.9855} \qquad \text{Equation 8}$$

$t_{maturation}$ first day of maturation stage (Julian day number) (-)

The parameter c_4 is dependent on the length of the crop senescence stage:

$$c_4 = 8.2246(t_{fallow} - t_{senescence})^{-0.9855} \qquad \text{Equation 9}$$

t_{fallow} first day of fallow stage (Julian day number) (-)

FOCUS Surface Water Group provides several sets of minimum and maximum interception factors for various crops, each belonging to a next higher tier in the risk evaluation scheme, denoted as Step 1, 2 and 3 resp. In HAIR the interception factors used for the Step 2 evaluation were used, as provided by FOCUS Surface Water Group (FOCUS, 2002; Table 2.4.2-1 on page 27, columns 'minimal cover' and 'full canopy'). To enlarge the number of crops, some data on crops used by the FOCUS Groundwater Group (FOCUS, 2000; Table 2.13 on page 41, Table 2.14 on page 42) were added (apples, beans (vegetables), bush berries, cabbage, carrots, linseed, onions, peas, strawberries and tomatoes).

FOCUS groundwater scenarios and FOCUS surface water scenarios provide data for crop stages for locations which are considered representative of the scenario calculation in which they are used. Utilization of these data in HAIR is only possible after solving 2 problems: 1) the data only apply to that specific FOCUS location, and 2) usually crop stage data is only given for a small number of crops.

These crops with interception data originating from FOCUS are referred to in HAIR as FOCUS interception crops. An overview of the maximum and minimum interception factors for all FOCUS interception crops available is given in Table 9. Table 10 gives an overview of all FOCUS interception crops for which data on emergence etc. are available in one or more of the FOCUS groundwater scenarios and surface water scenarios.

Retrieval of crop growth data for any gridcell in HAIR makes use of a classification on the basis of annual average rainfall and annual average temperature. This classification is based on FOCUS Groundwater (FOCUS, 2000) as given in Tables 2.2, 2.4 and 2.6 of that document.

In (FOCUS, 2000) a groundwater scenario location was assigned to European climate zones on the basis of the annual average rainfall and annual average temperature. These FOCUS groundwater scenario locations define the regions of similar growth stages referred to in HAIR as Crop calendar regions. As can be seen in Table 8, there are 9 crop calendar regions defined within 15 climate zones. These data are stored in the HAIR database.

Table 8
Crop calendar regions of similar growth stages used in HAIR, according to the FOCUS groundwater scenario locations (FOCUS, 2000). See also Figure 5.

Annual average precipitation (mm)	Annual average temperature (degr. C)		
	< 5	5 – 12.5	> 12.5
< 600	Jokioinen	Chateaudun	Sevilla
601 – 800	Jokioinen	Hamburg	Thiva
801 – 1000	Jokioinen	Kremsmunster	Piacenza
1001 – 1400	Jokioinen	Okehampton	Porto
> 1400	Jokioinen	Okehampton	Porto

It is assumed that if a gridcell has rainfall and temperature similar to the rainfall and temperature of one of these crop calendar regions, growth patterns of crops will also be similar. The distribution of these climate zones over Europe is shown in Figure 4. A map of the crop calendar regions is shown in Figure 5.

Combination of the appropriate rainfall and temperature data results in retrieval of the correct crop calendar region. Once a gridcell is assigned to the crop calendar region, crop data (date of emergence etc.) are retrieved. However, if the crop is not defined for this scenario (see Table 10) then crop data has to be taken from an alternative scenario. This alternative is chosen by expert judgment, taking into consideration:

1. the alternative scenario should preferably be in the same class of annual average precipitation and temperature,
2. if this is not possible, the alternative scenario should be as close as possible to the originally chosen scenario in terms of annual average precipitation and temperature, and
3. obviously the alternative scenario should provide data for the crop under consideration.
4. The procedure to search for an alternative scenario was limited to the crop calendar regions where the crop area exceeds 2% of the entire crop area in Europe (25 Member States). For this purpose, an overlay of the crop maps in HAIR with the crop calendar regions was made (Annex 2).

These considerations are already taken into account in the construction of the crop calendars. The procedure outlined above results in the following data for a crop at the location for which crop interception is calculated;

- day of emergence,
- day of maturation (at which maximum interception is reached), and
- day of harvest.

The standard equations for crop interception also use a day number for the start of senescence and a day number when the land is first barren after harvest (fallow), but these day numbers are not provided in the FOCUS tables. Therefore it is assumed that the start of senescence coincides with the date of harvest and the start of fallow is taken as 30 days after the date of harvest;

$$t_{senescence} = t_{harvest}$$ Equation 10

$$t_{fallow} = t_{harvest} + 30$$ Equation 11

Detailed steps of the procedure to calculate crop interception (CIF) for the crop treated, application event date and a given gridcell:

1. Retrieve the annual average temperature and the annual average rainfall for the gridcell
2. Translate the application crop in the usage record to the HAIR crop and its' FOCUS interception crop
3. Determine the applicable crop calendar region
4. Based on the crop calendar region and FOCUS interception crop, retrieve the day numbers for emergence, maturation and harvest for this crop
5. Determine the right crop cycle (some crops have multiple crop cycles per year);
   a. For crops emerging in spring, the application event day number is compared with t_{fallow} ;
   b. For crops emerging in winter, the application event day number is compared with $t_{maturation}$.;
6. If the application date is before emergence date or after fallow date, then $CIF = CIF_{min}$;
7. If the application date is between maturation date and senescence date, then $CIF = CIF_{max}$;
8. If the application date is between emergence and maturation date, calculate CIF;
9. If the application date is between senescence and fallow date, calculate CIF;
10. If $CIF < CIF_{min}$ for that crop, set $CIF = CIF_{min}$; if $CIF > CIF_{max}$ for that crop, set $CIF = CIF_{max}$.

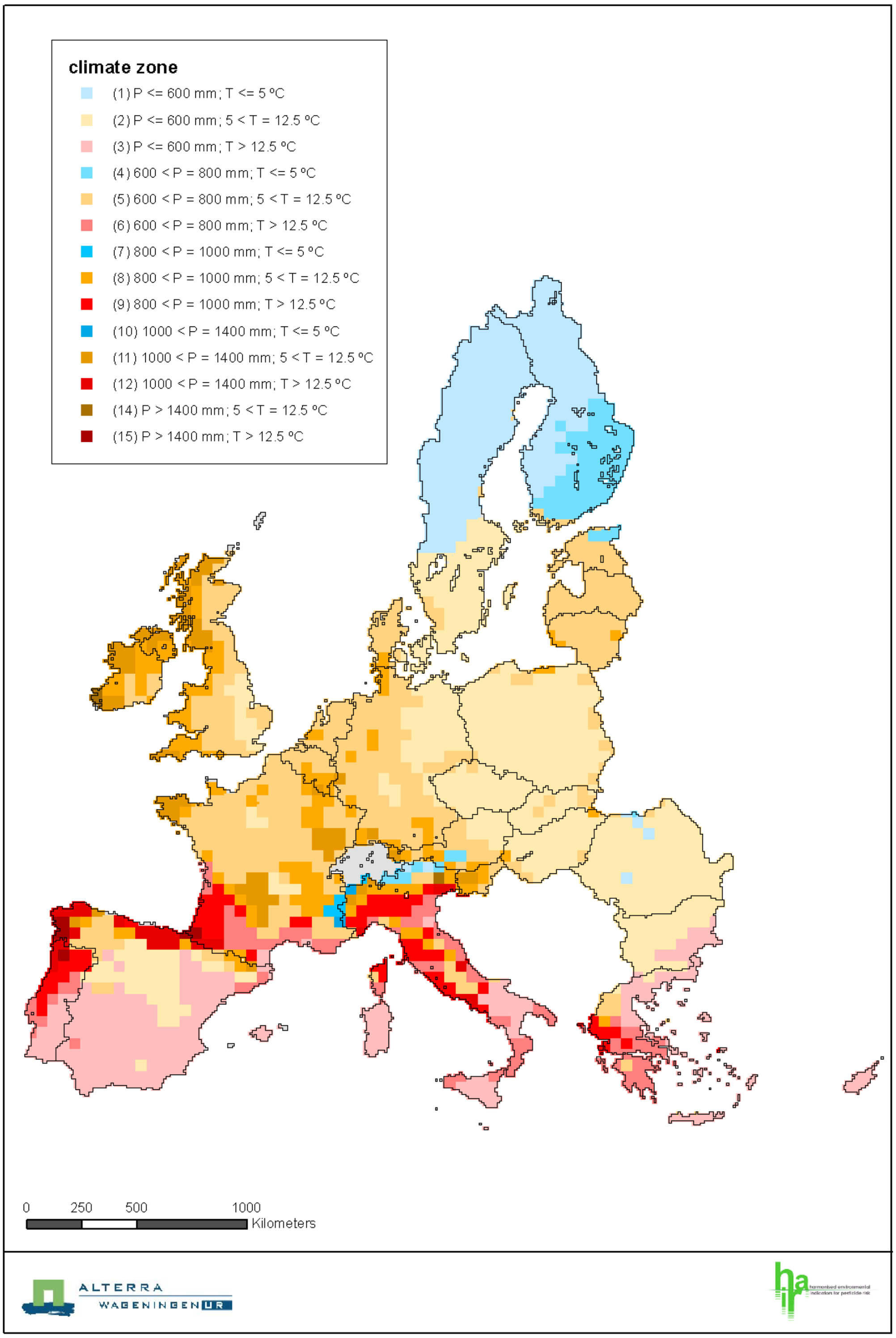

Figure 4
The climate zones in HAIR are defined by annual average rainfall and annual average temperature classes.

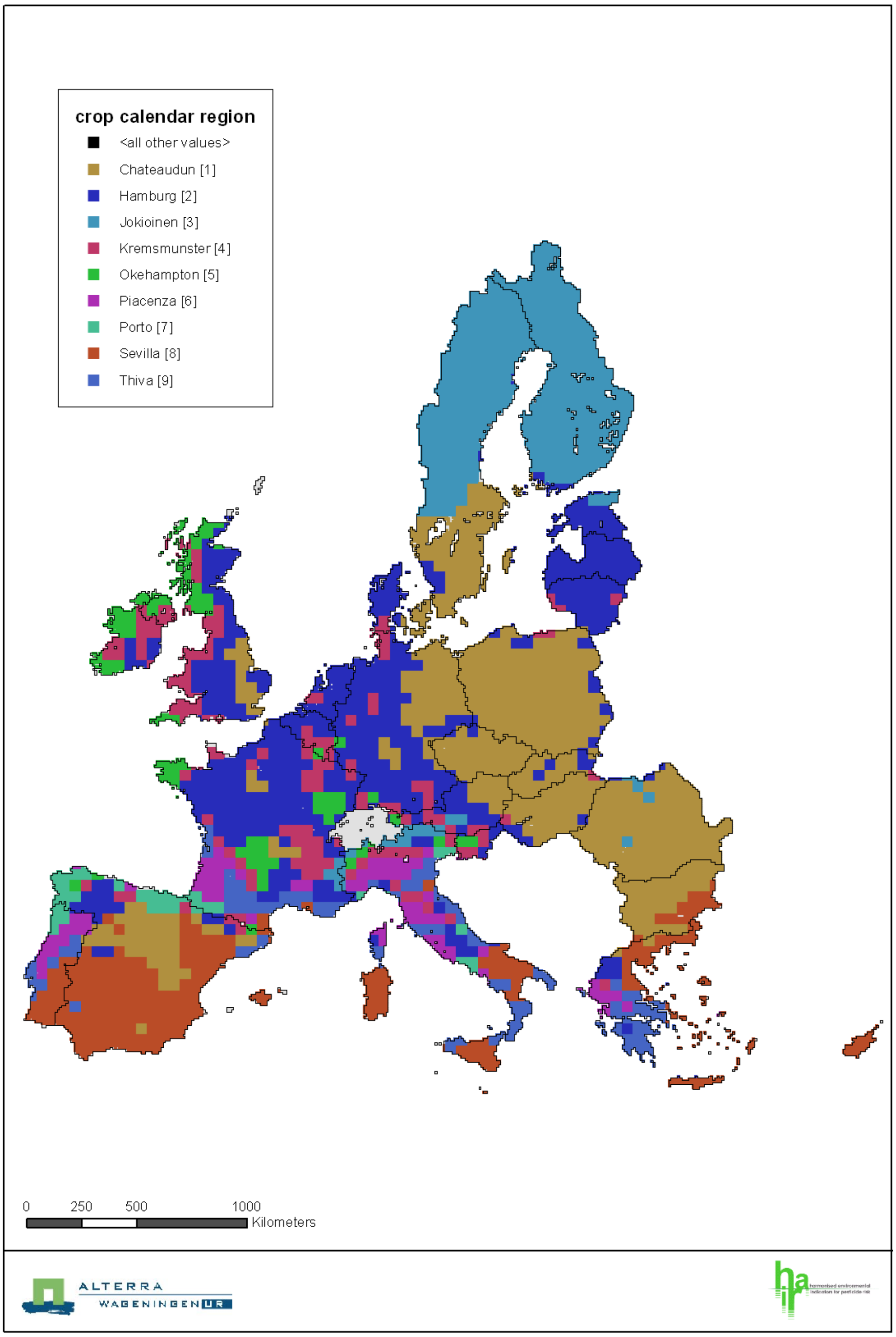

Figure 5
Crop calendar regions in HAIR are defined as climate zones with similar growth patterns of crops.

Table 9
FOCUS interception crops, with the minimum interception factor CIF_{min} and maximum interception factor CIF_{max} (FOCUS 2000, FOCUS 2002).

FOCUS interception crop		CIF_{min}	CIF_{max}
1	Apples	0.5	0.8
2	Beans (field)	0	0.7
3	Beans (vegetables)	0	0.8
4	Bush berries	0.5	0.8
5	Cabbage	0	0.9
6	Carrots	0	0.8
7	Citrus	0.7	0.7
8	Cotton	0	0.75
9	Grass (+alfalfa)	0.4	0.75
10	Hops	0	0.7
11	Legumes	0	0.7
12	Linseed	0	0.9
13	Maize	0	0.75
14	Oil seed rape (summer)	0	0.75
15	Oil seed rape (winter)	0	0.75
16	Olives	0.7	0.7
17	Onions	0	0.6
18	Peas (animals)	0	0.85
19	Pome/stone fruit	0.2	0.7
20	Potatoes	0	0.7
21	Soybean	0	0.75
22	Spring cereals	0	0.7
23	Strawberries	0	0.6
24	Sugar beets	0	0.75
25	Sunflower	0	0.75
26	Tobacco	0	0.75
27	Tomatoes	0	0.8
28	Vegetables, bulb	0	0.4
29	Vegetables, fruiting	0	0.7
30	Vegetables, leafy	0	0.7
31	Vegetables, root	0	0.7
32	Vines	0	0.7
33	Winter cereals	0	0.7

Table 10
FOCUS interception crops included in FOCUS groundwater scenarios and FOCUS surface water scenarios; adapted from FOCUS groundwater (FOCUS, 2000; Tables 2.13 and 2.14) and supplemented with FOCUS Surface Water (FOCUS, 2002; Table 2.4.2-1) denoted as D (Drainage scenarios) and R (Runoff scenarios).

FOCUS Interception Crop	C	H	J	K	N	P	O	S	T	D1	D2	D3	D4	D5	D6	R1	R2	R3	R4
Apples	+	+	+	+	+	+	+	+	+										
Beans (field)		+		+	+						+	+	+		+	+	+	+	+
Beans (vegetables)							+		+										
Bush berries			+																
Cabbage	+	+	+	+			+	+	+										
Carrots	+	+	+	+			+		+										
Citrus						+	+	+	+						+				+
Cotton								+	+						+				
Grass (+alfalfa)	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+	
Hops																+			
Legumes												+	+	+	+	+	+	+	+
Linseed					+														
Maize	+	+		+	+	+	+	+	+			+	+	+	+	+	+	+	+
Oil seed rape (summer)			+		+		+			+		+	+	+		+			
Oil seed rape (winter)	+	+		+	+	+	+				+	+	+	+		+		+	
Olives															+				+
Onions	+	+	+	+			+		+										
Peas (animals)	+	+	+		+														
Pome/stone fruit												+	+	+		+	+	+	+
Potatoes	+	+	+	+	+	+	+	+	+			+	+		+	+	+	+	
Soybean						+												+	+
Spring cereals	+	+	+	+	+		+			+		+	+	+					+
Strawberries		+	+	+				+											
Sugar beets	+	+	+	+	+	+	+	+	+			+	+			+		+	
Sunflower						+		+						+		+		+	+
Tobacco						+			+									+	
Tomatoes	+					+	+	+	+										
Vegetables, bulb												+	+		+	+	+	+	+
Vegetables, fruiting															+		+	+	+
Vegetables, leafy												+	+		+	+	+	+	+
Vegetables, root												+			+	+	+	+	+
Vines	+	+		+		+	+	+	+						+	+	+	+	+
Winter cereals	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+

C = Châteaudun, H = Hamburg, J = Jokioinen, K = Kremsmünster, N = Okehampton, P = Piacenza, O = Porto, S = Sevilla, T = Thiva D1 = Lanna, D2 = Brimstone, D3 = Vredepeel, D4 = Skousbo, D5 = La Jailliere, D6 = Váyia, Thiva, R1 = Weiherbach, R2 = Valadares, Porto, R3 = Ozzano, Bologna, R4 = Roujan.

2.3 Soil deposition

In the concept of several risk indicators in HAIR it is assumed that the proportion of the application rate that remains after correction for crop interception is entirely deposited at the soil. This initial amount deposited at the application event may be reduced due to volatilisation from the soil surface. In the Dutch Environmental Indicator for pesticides (Van der Linden et al., 2008), the initial soil deposition fraction is adjusted for the cumulative volatilization from the soil surface during the 14 day period starting at the application event. The procedure is also used in HAIR for estimating the cumulated volatilisation of the compound from the soil, as will be described in this section.

$$NSDF_i = (1 - CIF_i)\left(1 - \frac{CV_{soil,i}}{100}\right)$$ Equation 12

$NSDF_i$	net soil deposition fraction (-)
CIF_i	crop interception fraction (-)
$CV_{soil,i}$	cumulated volatilisation from the soil surface (%)
i	index denoting the application event number

Volatilization depends on the partitioning of the compound among the solid, liquid and gas phases in the top layer of the soil profile (usually taken as the top 0.05 m).

The cumulative volatilization fraction is calculated;

$$CV_{soil} = 71.9 + 11.6 \log(100\ FP_{gas})$$ Equation 13

FP_{gas} the fraction of the compound in the gas phase (%)

The fraction FP_{gas} depends on compound properties and soil properties;

$$FP_{gas} = \frac{\varepsilon_{gas}}{\left(\varepsilon_{gas} + \frac{\varepsilon_{liquid}\ K_{lg} + \rho\ K_{lg}\ K_{sl}}{f_{ND,soil}}\right)}$$ Equation 14

with

ε_{gas}	volumetric gas fraction (volume gas per volume soil)
ε_{liquid}	volumetric liquid fraction (volume soil solution per volume soil)
ρ	soil dry bulk density (upper 0.05 m; in kg dm^{-3})
K_{lg}	liquid to gas partitioning coefficient (-)
K_{sl}	soil to liquid partitioning coefficient ($dm^3\ kg^{-1}$)
$f_{ND,crop}$	fraction of compound at the soil surface in non-dissociated form (-)

For Case (a): compounds with normal sorption behaviour;

$$f_{ND,soil} = 1$$ Equation 15

For Case (b): compounds with pH-dependent sorption behaviour, only the compound present in non-dissociated form is available for volatilization;

$$f_{ND,soil} = \frac{1}{1+10^{(pH-pK_a)}}$$ Equation 16

pH	the soil pH at the 10K-gridcell (upper 0.05 m; -)
pK_a	dissociation constant of the compound (-)

The soil pH is stored in the HAIR database. The dissociation constant is stored in the compound database.

The liquid to gas partitioning coefficient is the inverse of the Henry-coefficient;

$$K_{lg} = \frac{1}{K_H}$$ Equation 17

K_{lg}	liquid to gas partitioning coefficient (-)
K_H	dimensionless Henry coefficient (-)

$$K_H = \frac{0.001\, P_{vap}\, M}{R\, T_{gridcell}\, S}$$ Equation 18

P_{vap}	saturated vapour pressure (mPa)
M	molar mass (g mol^{-1})
R	molar gas constant (8.314 J mol^{-1} K^{-1})
$T_{gridcell}$	temperature of the gridcell (K)
S	Solubility in water (mg L^{-1})
0.001	factor to convert mPa to Pa

The molar mass is stored in the Compound database. The saturated vapour pressure in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value at the climate map unit and average temperature at the month of the application event is obtained using the Arrhenius equation;

$$P_{vap} = \frac{P_{vap,ref}}{f_T}$$ Equation 19

$$f_T = \exp\left(\frac{-E_{vol}}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T_{month}}\right)\right)$$ Equation 20

with

f_T	temperature correction factor (-)
$P_{vap,ref}$	saturated vapour pressure of the compound at reference temperature (mPa)
P_{vap}	saturated vapour pressure (mPa)
E_{vol}	molar enthalpy of volatilisation (J mol^{-1}) (95000 J mol^{-1})
R	molar gas constant (J mol^{-1} K^{-1}) (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (K), (value 293.15 K ≡ 20 °C)
T_{month}	temperature at the month of the application event (K)

The solubility in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value at the climate map unit and average temperature at the month of the application event is obtained using the Arrhenius equation;

$$S = \frac{S_{ref}}{f_T}$$ Equation 21

$$f_T = \exp\left(\frac{-E_{dis}}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T_{month}}\right)\right)$$ Equation 22

with

f_T	temperature correction factor (-)
S_{ref}	solubility in water of the compound at reference temperature (mg L^{-1})
S	solubility in water (mg L^{-1})
E_{dis}	molar enthalpy of dissolution (J mol^{-1}), (27000 J mol^{-1})
R	molar gas constant (J mol^{-1} K^{-1}), (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (K), (value 293.15 K ≡ 20 °C)
T_{month}	temperature at the month of the application event (K)

For Case (a): compounds with normal sorption behaviour, the soil to liquid partitioning coefficient K_{sl};

$$K_{sl} = f_{om}\ K_{om}$$ Equation 23

For Case (b): compounds with pH-dependent sorption behaviour;

$$K_{sl} = f_{om}\ K_{om,com}$$ Equation 24

with

f_{om}	soil organic matter fraction in the topsoil (upper 0.05 m), (-)
K_{om}	sorption coefficient (dm^3 kg^{-1})
$K_{om,com}$	combined sorption constant (according to Equation 86; dm^3 kg^{-1})

Since the organic matter fraction in the topsoil (0.05 m) is not available, the soil organic matter fraction of the plough layer (0-0.3 m) is used instead. The organic carbon percentage is converted into soil organic matter content using Equation 83.

The volumetric liquid fraction;

$$\varepsilon_{liquid} = \frac{\theta_{topsoil}}{100} \qquad \text{Equation 25}$$

ε_{liquid} volumetric liquid fraction (volume soil solution per volume soil)
$\Theta_{topsoil}$ average soil moisture content in the topsoil (= 18,4 %)

The volumetric gas fraction is derived according to

$$\varepsilon_{gas} = 1 - \varepsilon_{liquid} - \varepsilon_{solid} \qquad \text{Equation 26}$$

$$\varepsilon_{solid} = \frac{\rho}{\rho_{solid}} \qquad \text{Equation 27}$$

$$\rho_{solid} = \frac{1}{\frac{f_{om}}{\rho_{om}} + \frac{(1 - f_{om})}{\rho_{\min}}} \qquad \text{Equation 28}$$

ε_{solid} volumetric solid fraction (volume solid parts per volume soil)
ρ soil dry bulk density (kg dm^{-3})
ρ_{solid} density of the solid phase (kg dm^{-3} of soil);
ρ_{om} density of organic matter (= 1.47 kg dm^{-3} of soil)
ρ_{min} density of mineral parts (= 2.66 kg dm^{-3} of soil)

The soil dry bulk density is calculated from soil organic matter content (Equation 83).

3 Aquatic risk indicators

3.1 Introduction and scope

The aquatic indicators in HAIR express the risk to the aquatic ecosystem in a standard volume of surface water in a field ditch with standard cross-sectional dimensions. Separate indicators with different exposure concentration are calculated for standing water conditions and flowing water conditions, and for acute and chronic exposure regimes. These exposure concentrations are related to the toxicity data for algae, daphnia and fish. For each application in the Usage database, 12 aquatic risk indicators are calculated.

The aquatic indicators are calculated for applications to outdoor crops, and not for applications to indoor crops. Depending on the method of application, loadings due to spray drift, run-off and erosion are converted into exposure concentrations in a standard field ditch. Loadings due to spray drift are calculated for spraying applications (i.e. the method of application code GS, GSUP, MANUAL, or MANUP; Table 2). Loadings due to run-off and erosion are calculated for all outdoor applications (i.e. with the method of application code GS, GSUP, MANUAL, MANUP, ST, SS, ST, GB, or GI).

Section 3.2 describes the loadings onto the surface water and its conversion into exposure concentrations. The risk indicators are given in Section 3.3. Deviations from the report produced by the original HAIR consortium (Strassemeier et al., 2007) are given in Section 3.4.

3.2 Exposure

The aquatic indicators express the risk to species in a volume of water in a ditch with standard water width and water depth, located at the edge of the field treated. The loadings due to spray drift, run-off and erosion are assumed to occur at different time. The spray drift event coincides with the application event, whereas the run-off and erosion events occur 3 days after the application event. Other possible entry routes, such as drainage from the field treated, point sources, atmospheric deposition, or surface water inflow from the upstream catchment are not considered.

The loadings onto the surface water in a ditch adjacent to the field treated are converted into exposure concentrations. Section 2.1 describes the calculation of exposure concentrations in a surface water body with standing water conditions and in a surface water body with flowing water conditions. The next sections describe in more detail the contributions from the drift, run-off and erosion processes to the calculated exposure level in the surface water body.

3.2.1 Concentration in a standard field ditch

The aquatic risk indicators consider loadings due to spray drift, run-off and erosion. For spray drift, the risk event occurs at application time. At the application event day, the spray drift load function is equal to the initial spray drift load (Section 3.2.2). For run-off, the risk event is assumed to occur 3 days after the application event (Section 3.2.3). Also for erosion, a 3 days time lag between the risk event and the application event is assumed (Section 3.2.4).

The concentration in the water body at any time starting at the application event day is calculated based on separate load functions, assuming first order degradation of the compound, and assuming a trapezoid shape of the water body with side angles of 45°. According to (Strassemeier et al., 2007);

Standing water

$$C_{sw,i}(t) = \left(L_{drift}(t_i) + L_{runoff}(t_{i+\Delta t}) + L_{erosion}(t_{i+\Delta t})\right) e^{-\frac{\ln(2)}{DegT50_{ws}}(t-t_i)} \frac{d}{Wd-d^2}\, 0.1 \quad \text{Equation 29}$$

$C_{sw,i}(t)$	concentration in the surface water at day t, caused by application event *i* at t_i (mg L^{-1})
$L_{drift}(t_i)$	spray drift load function (kg ha^{-1})
$L_{run\text{-}off}(t_{i+\Delta t})$	run-off load function (kg a.i. ha^{-1})
$L_{erosion}(t_{i+\Delta t})$	erosion load function (kg a.i. ha^{-1})
$DegT50_{ws}$	degradation half-life of the compound in water sediment (d
t	time (d)
Δt	time interval between the application event and the erosion event (= 3 d)
d	standard depth of the surface water body (m)
W	standard width of the surface water body (m)
0.1	conversion factor from (kg ha^{-1} m^{-1}) to (mg L^{-1})
i	index denoting the application event number (-)

In standing water, the initial concentration in the water body at the application event day results from the spray drift load function. At the next days, the concentration in the water body is reduced as a result of degradation. In line with the assumed time lag between the risk event and the application event, the run-off load function and the erosion load function are equal to zero at $t < t_i + 3$ days. At $t = t_i + 3$ days, the calculated run-off and erosion load functions contribute to the concentration in the water body. Again, at the next days the concentration in the water body is reduced as a result of degradation.

Flowing water

$$C_{sw,i}(t) = \left(L_{drift}(t) + L_{runoff}(t) + L_{erosion}(t)\right) \frac{d}{Wd-d^2}\, 0.1 \quad \text{Equation 30}$$

Similar to the water body with standing water, the initial concentration in the water body with flowing water at the application event day results from the spray drift load function. Contrary to the water body with standing water, the compound is diluted by surface water coming from upstream. It is assumed that the concentration in the water body is reduced to zero at the next day. At $t = t_i + 3$ days, the calculated run-off and erosion load functions determine the concentration in the water body. The next day, the concentration in the water body is reduced to zero.

Multiple applications

In case of multiple applications, a series of daily concentrations in the water body is obtained by adding the concentrations caused by each application event:

$$C_{sw}(t) = \sum_{i=1}^{n} C_{sw,i}(t) \qquad \text{Equation 31}$$

$C_{sw}(t)$	concentration in the surface water at day t (mg L^{-1})
$C_{sw,i}(t)$	concentration in the surface water at day t, caused by application event *i* (mg L^{-1})
n	the number of application events (-)

Equation 31 is used for standing water conditions and for flowing water conditions. The number of application events and the interval between the application events are stored in the Usage database.

Short-term exposure

For standing water conditions and for flowing water conditions alike, the short-term exposure concentration in surface water is the maximum concentration;

$$sPEC_{sw} = \max_{t_1}^{t_n + \Delta t} C_{sw}(t) \qquad \text{Equation 32}$$

$sPEC_{sw}$	short-term exposure concentration in surface water (mg L^{-1})
t_1	first application event day (d)
t_n	last application event day (d)
Δt	time interval between an application event and run-off event (= 3 d)
$C_{sw}(t)$	concentration in the surface water at day t (mg L^{-1})

Long term exposure

For standing water conditions and for flowing water conditions alike, the integral over a time interval, which is equal to the duration of the NOEC standard test, is calculated for every day of the period of interest. The long-term exposure concentration in surface water is the maximum of these integrals;

$$lPEC_{sw} = \max_{t_1}^{t_n + \Delta t + t_{NOEC}} \frac{\int_{t-t_{NOEC}}^{t} C_{sw}(t)}{t_{NOEC}} \qquad \text{Equation 33}$$

$lPEC_{sw}$	long-term exposure concentration in surface water (mg L^{-1})
t_1	first application event day (d)
t_n	last application event day (d)
Δt	time interval between an application event and run-off event (= 3 d)
t_{NOEC}	duration of the NOEC standard test (Section 3.3) (d)
$C_{sw}(t)$	concentration in the surface water at day t (mg L^{-1})

Examples with the calculated time weighted average concentrations are shown in Figure 6 (standing water) and Figure 7 (flowing water).

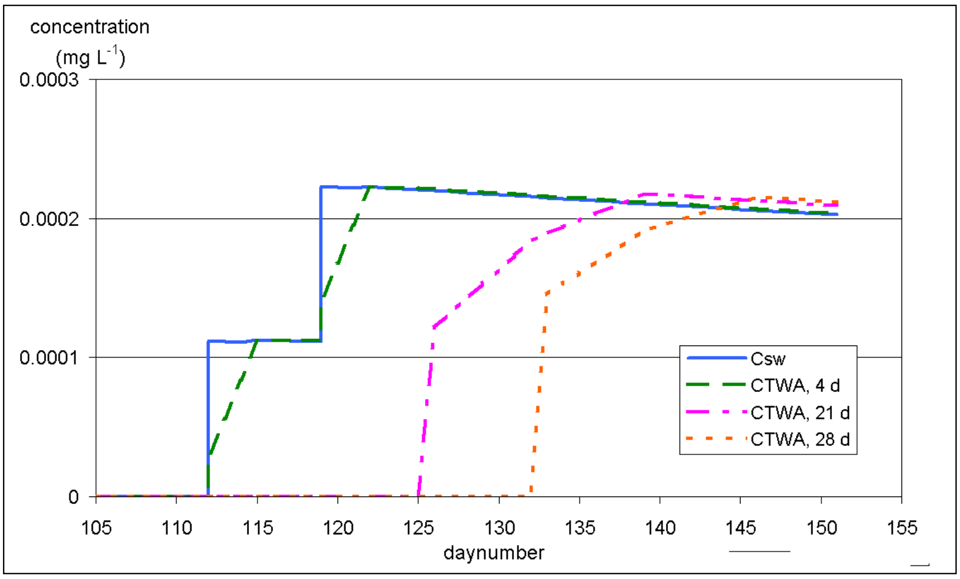

Figure 6

Example with exposure concentrations in a surface water body with standing water, resulting from spray drift (multiple application with 2 application events at daynumer 112 and 119). Solid line: daily average concentration (Equation 31). Dashed lines: daily, time weighted average concentration at different time frames according to the NOEC standard tests for algae, daphnia and fish (Section 3.3).

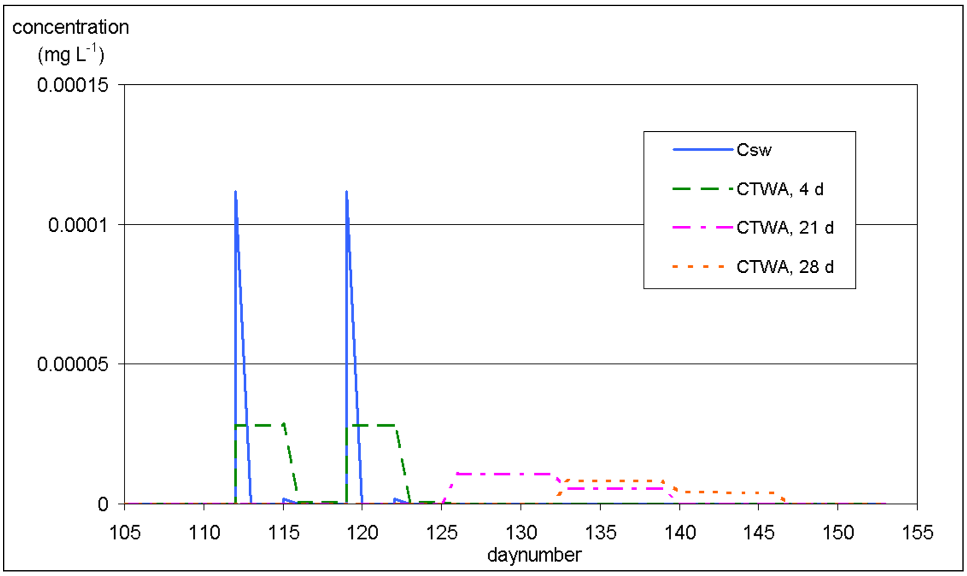

Figure 7

Example with exposure concentrations in a surface water body with flowing water (application according to Figure 6). Solid line: daily average concentration (Equation 31). Dashed lines: daily, time weighted average concentration at different time frames according to the NOEC standard tests for algae, daphnia and fish (Section 3.3).

Water temperature and degradation

The degradation half-life in water sediment in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value at the monthly average water temperature in the climate map unit (Section 1.5.3) is obtained using the Arrhenius equation;

$$DegT50_{water} = f_T \; DegT50_{ws,ref} \qquad \text{Equation 34}$$

$$f_T = \exp\left(\frac{-E_{trans}}{R} \left(\frac{1}{T_{ref}} - \frac{1}{T_{water}} \right) \right) \qquad \text{Equation 35}$$

with

f_T	temperature correction factor (-)
$DegT50_{ws,ref}$	degradation half-life of the compound in water sediment at reference temperature (d)
E_{trans}	molar enthalpy of transformation (54000 J mol^{-1})
R	molar gas constant (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (value 293.15 K ≡ 20 °C)
T_{water}	surface water temperature (K)

An equation developed by Stefan and Preud'homme (1993) is used to calculate surface water temperature from air temperature;

$$T_{water}(t) = 5.0 + 0.75 \; T_{air}(t) \qquad \text{Equation 36}$$

T_{water}	surface water temperature (C)
T_{air}	average monthly air temperature in the climate map unit (C)

3.2.2 Load by spray drift

The load by spray drift onto the water body at the application event day is directly proportional to the application rate:

$$L_{drift}(t) = AR \; \frac{drift}{100} \qquad \text{Equation 37}$$

$L_{drift}(t)$	initial load by spray drift at the application event day (kg ha^{-1})
AR	application rate (kg ha^{-1})
drift	percentage of application rate deposited onto the water body (-)

The application rate is stored in the Usage database. The spray drift is calculated on the basis of drift tables published by the BBA (Rautmann and Streloke 2001; BBA 2004). These tables describe the percentage of the application rate moving beyond the border of a treated field depending on the crop group (arable crops, fruits, vines, hops, vegetables), the crop stage (early, late) and the distance from the last nozzle of the spray equipment to the edge of the field.

Various regression functions have been derived from these drift tables (OECD, 2000; FOCUS 2001). The regression functions developed in the FOCUS Surface Water Group (FOCUS, 2001) are proposed by (Strassemeier et al., 2007) for use in HAIR. Spray drift is represented by the sum of two sequential power functions connected at the hinge distance (H). However, a simplification is possible when the entire water surface is located before the hinge point ($H \geq G + W$, in which case Equation 38 can be used) or when the entire water surface is located beyond the hinge point ($H \leq G$, in which case Equation 42 can be used). Only when the hinge point is located over the water surface Equation 39 has to be used. For arable crops and small vegetables, large vegetables and vines the hinge point is located at infinity, i.e. Equation 38 is used for these crops. For hops and fruits any of these equations can be used, depending on the location of the surface water relative to the hinge point.

$$drift = \left[A \int_{G}^{G+W} (x^B) dx \right] \frac{f_r}{W} \qquad H \geq G + W \qquad \text{Equation 38}$$

$$drift = \left[A \int_{G}^{H} (x^B) dx + C \int_{H}^{G+W} (x^D) dx \right] \frac{f_r}{W} \qquad G < H < G + W$$

Equation 39

$$drift = \left[C \int_{G}^{G+W} (x^D) dx \right] \frac{f_r}{W} \qquad H \leq G$$

drift	percentage of application rate deposited onto the water body (-)
A, B, C, D	regression parameters (-)
W	standard width of the water body (m)
G	buffer strip width; user defined (m)
H	distance limit for each regression (hinge point) (m)
f_r	drift mitigation factor for improved spraying equipment; user defined (-)

The buffer strip is located between the crop edge and the water body. The buffer strip width is defined as the distance between the edge of field and the closest edge of the water body (Figure 8). The drift functions are not applicable in close vicinity to the crop edge. According to (FOCUS, 2001), the minimum distance between the crop edge and the closest edge of the water body depends on the crop group: G_{min} = 1 m for arable crops and small vegetables, and G_{min} = 3 m for all other crops.

The buffer strip width G is read in the Usage database, and the range is defined as $G \geq G_{min}$. These minimum distances are the default values for the buffer strip width. The HAIR program will replace values out of range with the appropriate value of the minimum buffer strip width (Table 11).

The drift mitigation factor accounts for improved spraying equipment and is read in the Usage database. For example, with 90% drift reduction f_r = 0.1. The range is $0 \leq f_r \leq 1$. The default value f_r = 1, indicating no improved spaying equipment is used.

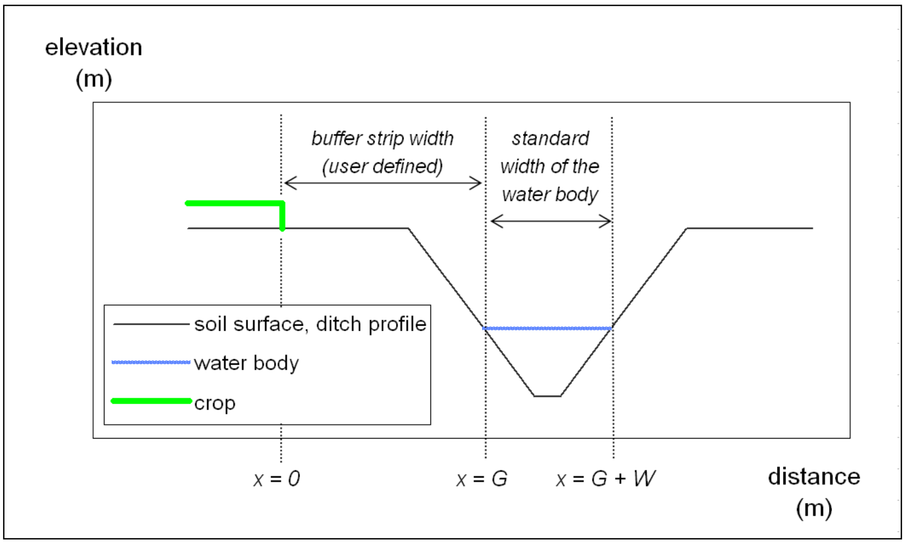

Figure 8
Cross-section with the crop edge, the surface water ditch and the buffer strip. The standard water width of the water body W = 1 m. The buffer strip width G is user defined. The default value for the buffer strip width is G_{min} (Table 11, according to FOCUS, 2001).

The function parameters A, B, C, D, the minimum buffer strip width and the hinge distance are shown in Table 11. The FOCUS drift crop groups connect the appropriate drift function parameters to the crops in the HAIR database.

Table 11
The minimum buffer strip width (G_{min}), function parameters (A, B, C and D) and hinge distance (H) for 90th-percentile drift functions applied in HAIR (FOCUS 2001).

FOCUS drift crop group	G_{min} (m)	Crop stage #	A	B	C	D	H (m)
Arable crops and small vegetables (< 0.5 m)	1	all stages	2.7593	-0.9778	-	-	∞
Large vegetables (> 0.5 m)	3	all stages	44.769	-1.5643	-	-	∞
Hops		all stages	58.247	-1.0042	8654.9	-2.8354	15.3
Vines		not in mature stage	15.793	-1.6080	-	-	∞
		mature stage	44.769	-1.5643	-	-	∞
Fruits		not in mature stage	66.702	-0.7520	3867.9	-2.4183	11.4
		mature stage	60.396	-1.2249	210.70	-1.7599	10.3

\# referred to as “early” (not in mature stage) and “late” (mature stage) in (Strassemeier et al., 2007).

The drift functions are built in HAIR in the integrated form. For arable crops and small vegetables, large vegetables, and vines only Equation 40 is used. For hops and fruits any of these equations can be used, depending on the location of the surface water relative to the hinge point.

$$drift = \frac{f_r\ A}{W\,(B+1)}\left[(W+G)^{B+1} - G^{B+1}\right] \qquad H \geq G + W$$ Equation 40

$$drift = \left[\frac{A}{B+1}\left(H^{B+1} - G^{B+1}\right) + \frac{C}{D+1}\left[\left(G+W\right)^{D+1} - H^{D+1}\right]\right]\frac{f_r}{W}$$ Equation 41

$$G < H < G + W$$

$$drift = \frac{f_r\ C}{W\,(D+1)}\left[(W+G)^{D+1} - G^{D+1}\right] \qquad H \leq G$$ Equation 42

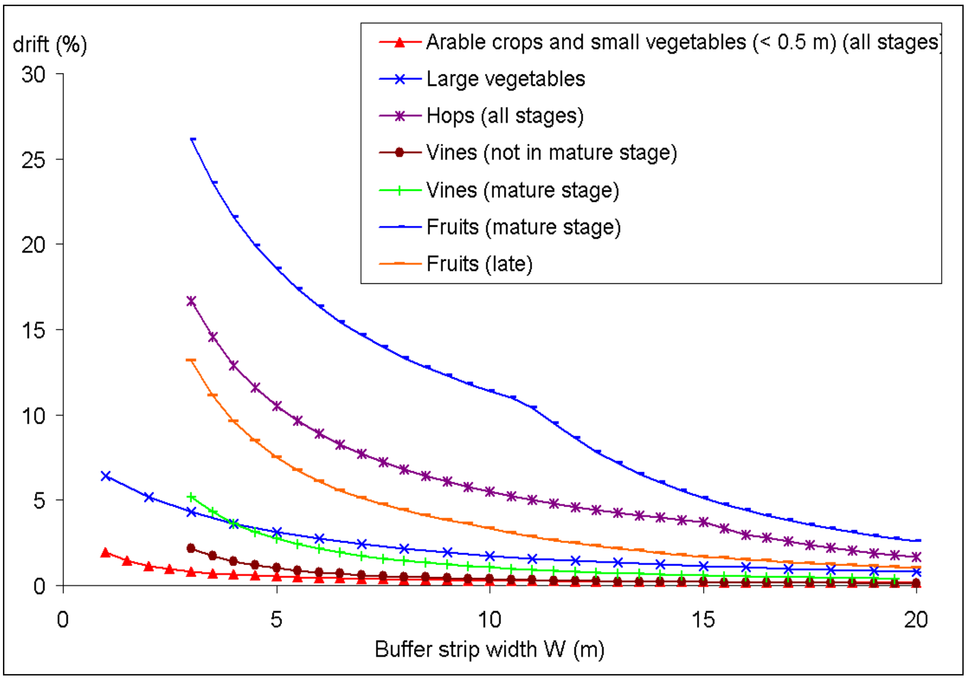

Figure 9
Drift functions for the combinations of FOCUS drift crop groups and crop development stages in Table 11.

3.2.3 Load by run-off

The method for calculating run-off is a modified Curve Number method developed by Lutz (1984), comparable to the run-off approaches in SYNOPS (Gutsche and Rossberg, 1999), REXTOX (OECD, 2000) and Drips (Röpke, 2003; Röpke et al., 2004) and described in detail in Bach et al. (2000).

The model estimates the load available in the run-off water according;

$$L_{run-off}(t) = AR\ \frac{Q}{P_{event}} F_{w,i}\ f_1\ f_2 \qquad \text{Equation 43}$$

$L_{run-off}(t)$	load by run-off at time t (kg a.i. ha^{-1})
AR	application rate (kg ha^{-1})
Q	volume of surface run-off (mm)
P_{event}	volume of precipitation (mm)
f_1	reflects the influence of the slope (-)
f_2	reflects the influence of a densely covered buffer zone (-)
$F_{w,i}$	fraction of application rate available for run-off, application event i (-)

The fraction of application rate dissolved in the water phase is assumed to be available for run-off, and will be influenced by factors such as precipitation, the time interval between the application event and the run-off event, plant interception, degradation of the compound, and soil organic matter content.

The method assumes that the run-off event occurs instantaneously after a default precipitation event. As a worst case, the default value for the precipitation event is set to 30 mm.

It is assumed a run-off event occurs 3 days after the application event. It is considered unlikely, that a run-off event will occur earlier than 3 days after application, since farmers bear in mind the weather forecast and therefore will not apply pesticides in times of high rainfall probability (EPPO 2003).

In order to estimate the amount of pesticide that is transported into the surface water by run-off, it is necessary to determine the proportion of application rate, which will reach the ground and will be dissolved in the soil water phase. Considering the crop interception fraction at the application event day (Chapter 2) and the degradation of the compound during the period between the application event and the run-off event, the fraction dissolved in the water phase is calculated as follows;

$$F_{w,i} = e^{-\frac{\ln(2)}{DegT50_{soil}}(\Delta t)} (1 - CIF_i)\ F_{w,0} \qquad \text{Equation 44}$$

$F_{w,i}$	fraction of application rate available for run-off, at Δt days after the application event i (-)
Δt	time interval between the application event and the run-off event (= 3 d)
$DegT50_{soil}$	degradation half-life of the compound in soil (d)
CIF_i	crop interception fraction at the application event day (-)
$F_{w,0}$	initial fraction of application rate dissolved in the water phase (-)

The degradation half-life in soil is used in Equation 44 to account for dissipation during the period between the application event and the run-off event. Degradation in soil is assumed to follow first order kinetics. The degradation half-life in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value in the climate map unit at the monthly average temperature is obtained using the Arrhenius equation;

$$DegT50_{soil} = f_T\ DegT50_{soil,ref} \qquad \text{Equation 45}$$

$$f_T = \exp\left(\frac{-E_{trans}}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T_{air}}\right)\right)$$ Equation 46

with

f_T	temperature correction factor (-)
$DegT50_{soil,ref}$	degradation half-life of the compound in soil at reference temperature (d)
E_{trans}	molar enthalpy of transformation (54000 J mol^{-1})
R	molar gas constant (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (value 293.15 K ≡ 20 °C)
T_{air}	average monthly air temperature in the climate map unit (K)

The initial fraction dissolved in the soil water phase is calculated according to;

$$F_{w,0} = \frac{1}{1 + K_d}$$ Equation 47

$F_{w,0}$	initial fraction of application rate dissolved in the soil water phase (-)
K_d	local sorption constant (-)

$$K_d = f_{om}\ K_{om,compound}$$ Equation 48

$K_{om,compound}$	the sorption coefficient of the compound (dm^3 kg^{-1})
f_{om}	fraction organic matter in the soil (kg kg^{-1})

The type of sorption behaviour is defined by the boolean parameter pH_dependent_sorption in the Compound database. For compounds with normal sorption behaviour in soil, the organic matter partitioning coefficient (K_{om}) is used inEquation 48. For compounds with pH-dependent sorption behaviour in soil, the combined sorption coefficient ($K_{om,com}$) is used. The combined sorption coefficient is calculated according to Equation 86.

The correction factor f_1 reflects the influence of the field slope (%);

$$f_1 = 0.02153\ slope + 0.001423\ slope^2 \qquad slope < 20\%$$

Equation 49

$$f_1 = 1 \qquad slope \geq 20\%$$

The average slope of the land surface is stored in the HAIR database.
The correction factor f_2 reflects the influence of a densely covered buffer zone;

$$f_2 = 0.83^G$$ Equation 50

G	width of the buffer zone (stored in the Usage database) (m)

The calculation of the run-off volume with the original US-SCS's Curve Number method (McCuen, 1981; US-SCS, 1990) is based on the principle that the ratio of run-off and precipitation is proportional to the ratio of actual infiltration and potential infiltration. The potential infiltration depends on local parameters describing land usage and soil properties, which are expressed by Curve Numbers.

The calculation of surface run-off is based on the 'percentage-capacitive approach' developed by Anderl (1975). This approach is based on the following physical assumptions;

$$Q = (P_{event} - I_a)\, CN + \frac{CN}{\alpha}\,(e^{-\alpha(P_{event} - I_a)} - 1) \qquad (P_{event} > I_a)$$
$$Q = 0 \qquad (P_{event} \le I_a)$$

Equation 51

Q	volume of surface run-off (mm)
P_{event}	volume of precipitation (default = 30 mm)
CN	Curve Number (-)
I_a	initial losses by interception, infiltration and surface storage (mm)
α	proportionality coefficient (-)

The parameter CN is the limit of a function converging at extreme precipitation volumes. Von Anderl et al. (1979) have reached excellent results with the percentage-capacity approach for regional aplications in Germany. The surface run-off in this model is calculated according to the modified method of Lutz (1984), who developed Curve Numbers using the methods of the US Soil Conservation Service (US-SCS, 1990) for four different hydrological soil groups and different land usages. These Curve Numbers were evaluated for average soil moisture conditions and extreme precipitation events (250 mm). The Curve Numbers and hydrological soil groups are summarized in Table 12.

The initial losses account for the processes of interception, initial infiltration and surface storage as part of the precipitation. Since detailed data for these processes are usually not available, the initial losses are calculated based on the Curve Number, according to Rode (1995);

$$I_a = 7.62\left(\frac{1}{CN} - 1\right)$$

Equation 52

The original Curve Number method takes into consideration the soil moisture condition at the run-off event. Therefore Curve Numbers are given for various soil moisture classes, which are derived from the cumulated precipitation during 5 days prior to the run-off event (McCuen 1981). Lutz (1984) considers the influence of soil moisture and the seasonal variation using the proportionality coefficient α. The proportionality coefficient sets the actual soil saturation, expressed by the base flow (Q_b) in relation to seasonal variation, which is described by the week number;

$$\alpha = k_1\, e^{\frac{-k_2}{wn}}\; e^{\frac{-k_3}{Q_b}}$$

Equation 53

α	proportionality coefficient (-)
Q_b	base flow (L s^{-1} km^{-2})

wn	week number (-)
k_1, k_2, k_3	empirical parameters (-)

The week number correlates to the day number (dn);

$$wn = INTEGER\left(\frac{dn}{7} + 1\right) \qquad \text{Equation 54}$$

The base flow describes the hydrological situation of the soil, according to Lutz (1984). At catchment scale, Bach et al (2000) found a very good correlation of the base flow and the annual average precipitation (1961-1990). Based on the long-term annual precipitation in the climate map unit;

$$\begin{aligned} Q_b &= -11.43 + 0.027\,P & P &\geq 460\ mm \\ Q_b &= 1 & P &< 460\ mm \end{aligned} \qquad \text{Equation 55}$$

Q_b	base flow (L s^{-1} km^{-2})
P	annual average precipitation (mm)

The base flow decreases with the annual precipitation amount. The annual precipitation amount in the HAIR database ranges between 212 and 1795 mm. A lower boundary for the annual precipitation amount P = 460 mm is introduced in order to avoid numerical problems (Equation 55). This value corresponds with a base flow Q_b = 0.018 L s^{-1} km^{-2}. According to Lutz (1984), Rode (1995) and Maniak (1992), the values for the empirical parameters k_1 = 0.05, k_2 = 4.6, and k_3 = 2.0.

The land use classes in (Table 4 in Strassemeier et al., 2007) are translated to the HAIR crops, as summarized in Table 12.

Table 12
Curve Numbers for crop groups and hydrological soil groups (Table 4 in Strassemeier et al., 2007). These land use classes are translated to HAIR crops in the HAIR database.

Land usage	Crops in HAIR	hydrological soil group			
		A	B	C	D
arable crops	arable crops	0.54	0.70	0.80	0.85
row fruits	rape and turnip, pulses, vegetables, hops, vines	0.62	0.83	0.89	0.93
fruits	fruit and berry, citrus, and olive plantations	0.17	0.48	0.62	0.70
grass	grassland and meadow, fallow land	0.20	0.46	0.63	0.72
-) other feeding crops	(not used in HAIR)	0.46	0.49	0.75	0.81

Typically, soil surveys list soil types by their name, which is based on certain physical characteristics of the soils. However, the information needed to determine a Curve Number is the hydrologic soil group, which indicates the infiltration capacity of the soil. Significant infiltration occurs in sandy soils while no infiltration occurs in heavy clay soils or rock formations. A map of the hydrological soil group according to Table 13 is stored in the HAIR database at 10K resolution.

Table 13
SCS Hydrological soil groups (summary Table 5 in Strassemeier et al., 2007).

Soil map unit	Runoff potential	Soil texture
A	Lowest	Sand, loamy sand, sandy loam
B	Moderately low	Silt loam, loam
C	Moderately high	Sandy clay, loam
D	Highest	Silty clay, loam, sandy clay, silty clay, clay

3.2.4 Load by erosion

Introduction
Haider (1996) calculated the partitioning of compound between the water phase and the solid phase and he concluded that for most compounds and erosion conditions run-off occurs to a great extent (> 90%) in the soil water phase. This is also observed in a number of field studies (Agassi et al., 1995; Burgoa and Wauchope, 1995), which show that for the majority of compounds the main part of the transport during run-off events occurs in the water phase. Only highly sorptive compounds ($K_{om,compound}$ >1000 L kg^{-1}) contribute with a substantial part bound to the solid phase. As stated in the EPPO standards (EPPO, 2003a) 'erosion is considered to be the result of bad soil management and, as such, this process is not included within this sub-scheme'. Soil erosion by water has been assessed by several authors (Auerswald and Kutilek, 1998; Gobin et al., 2004). The erosion model proposed by (Strassemeier et al., 2007) is based on the Modified Universal Soil Loss Equation/MUSLE (Wischmeier and Smith, 1978) and is analoguous to the model used in FOCUS (2001) and PRZM. The model is a modification specifically designed for small watersheds.

The total amount of pesticide reaching the surface water by the pathway of erosion is determined by the erosion load function, which is based on the fraction of application rate bound to the solid phase in the soil and on the ratio of the soil erosion volume to the soil volume in the ploughing layer;

$$L_{erosion}(t) = AR \, \frac{X_e}{A \, d_{usle} \, \rho} \, F_{s,i} \, 10^{-4} \qquad \text{Equation 56}$$

$L_{erosion}(t)$	erosion load function (kg a.i. ha^{-1})
AR	application rate (kg a.i. ha^{-1})
X_e	soil erosion volume (tonnes)
A	area treated (= 1 ha)
d_{usle}	depth of the plough layer (0.1 m)
ρ	soil dry bulk density of the plough layer (kg dm^{-3})
$F_{s,i}$	fraction of application rate bound to the solid phase, at Δt days after the application event (-)
10^{-4}	factor for conversion from m^2 to ha

The erosion load function is calculated for a unit area treated (1 ha). The application rate is stored in the Usage database. Soil density is a function of soil organic matter content (Equation 83). A map of the soil organic carbon content is available for the plough layer (0-0.3 m). This map is taken as a proxy for the organic carbon content in the layer d_{usle}.

The amount of pesticide that is transported into the surface water by soil erosion depends on the proportion of application rate that will reach the ground and will be bound to the solid phase of the soil. Considering the crop interception fraction at the application event day (Section 2.2) and the degradation of the compound during the period between the application event and the erosion event, the fraction bound to the solid phase of the soil is calculated as follows;

$$F_{s,i} = e^{-\frac{\ln(2)}{DegT50_{soil}}(\Delta t)}(1 - CIF_i)\ F_{s,0} \qquad \text{Equation 57}$$

$F_{s,i}$	fraction of application rate bound to the solid phase of the soil, at Δt days after the application event (-)
Δt	time interval between the application event and the erosion event (= 3 d)
$DegT50_{soil}$	degradation half-life of the compound in soil (d)
CIF_i	crop interception fraction at the application event day (-)
$F_{s,0}$	initial fraction of application rate bound to the solid phase of the soil (-)

The initial fraction bound to the solid phase of the soil is calculated according to;

$$F_{s,0} = \frac{K_d}{1 + K_d} \qquad \text{Equation 58}$$

$F_{s,0}$	initial fraction of application rate bound to the solid phase of the soil (-)
K_d	local sorption constant (Equation 48) (-)

A three days time lag between the application event and the erosion event is assumed (Δt = 3 days). Degradation in soil is assumed to follow first order kinetics. The degradation half-life in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value at the monthly average temperature in the climate map unit is obtained using the Arrhenius equation (Equation 45). The soil temperature is assumed to be equal to the air temperature.

The erosion model calculates the volume of erosion of the considered field as follows:

$$X_e = 0.79\,(Q\ q_p)^{0.65}\,A^{0.009}\ usleK\ \ usleLS\ \ usleC\ \ usleP \qquad \text{Equation 59}$$

X_e	soil erosion volume (tonnes)
Q	volume of surface run-off (mm)
q_p	peak storm run-off (mm)
A	area treated (= 1 ha)
usleK	erobility factor (-)
usleLS	topographic factor combining slope length and slope steepness (-)
usleC	vegetation and management factor (-)
usleP	support praxis factor (default 0.5) (-)

The soil erosion volume is calculated for a unit area treated (1 ha). The peak storm run-off value (q_p) can be calculated using the Peak Discharge Method (SCS, 1986). Since this method is quite complicated and a large number of additional parameters are needed, (Strassemeier et al., 2007) assume an equal distribution over 12 hours, for the precipitation event that triggers the erosion event;

$$q_p = \frac{Q}{12} \qquad \text{Equation 60}$$

The support praxis factor (usleP) is set to a constant default value of 0.5 (FOCUS, 2001). The vegetation and management factor (usleC) is shown in Table 15. The so-called erosion crop groups in this table are linked to the HAIR crops in the database. The erodibility factor (usleK) is linked to the soil type as shown in Table 16. According to (Strassemeier et al., 2007), the erodibility factors for the soil textural classes were summarised for the 5 soil textural classes available in the HAIR database (Table 17). The topographic factor (usleLS) is calculated as follows;

$$usleLS = (0.065 + 0.0456\, slope + 0.006541\, slope^2)\left(\frac{\sqrt{A\,10^4}}{22.1}\right)^{sx} \qquad \text{Equation 61}$$

usleLS	topographic factor combining slope length and slope steepness (-)
A	area treated (= 1 ha)
slope	field slope (%)
sx	empirical parameter (Table 14) (-)
10^4	factor for conversion from m^2 to ha

Table 14
The empirical parameter sx has the following values.

Slope (%)	sx
slope ≤ 1	0.2
1 < slope ≤ 3	0.3
3 < slope ≤ 5	0.4
slope > 5	0.5

Table 15
Management factor usleC for erosion crop groups and crop development stages used in HAIR.

Crop group	Fallow stage	Emergence stage, mature stage	Senescence stage
Cereals	0.9	0.2	0.4
Maize	0.9	0.2	0.4
Rape seed	0.9	0.2	0.4
Grass	0.02	0.02	0.02
Sugar beet	0.9	0.2	0.4
Potatoes	0.9	0.2	0.4
Sun flower	0.9	0.2	0.4
Tobacco	0.9	0.2	0.4
Soybean	0.9	0.2	0.4
Cotton	0.2	0.2	0.2
Leguminosae	0.9	0.2	0.4
Field bean	0.9	0.2	0.4
Vegetables, bulb	0.9	0.2	0.4
Vegetables, fruiting	0.9	0.2	0.4
Vegetables, leafy	0.9	0.2	0.4
Vegetables, root	0.9	0.2	0.4
Vine	0.2	0.2	0.2
Hope	0.9	0.2	0.4
Pome/Stone-Fruits	0.9	0.2	0.4
Citrus	0.2	0.2	0.2
Olives	0.2	0.2	0.2

Table 16
Erodibility factor (usleK) for two classes of soil organic carbon content and various soil types used in HAIR.

Textural Class Name	FOC < 2%	FOC ≥ 2%	Texture Class
Clay	0.24	0.21	4
Clay Loam	0.33	0.28	3
Coarse Sandy Loam	0.07	0.07	1
Fine Sand	0.09	0.06	1
Fine Sandy Loam	0.22	0.17	4
Heavy Clay	0.15	0.15	4
Loam	0.34	0.26	3
Loamy Fine Sand	0.15	0.09	1
Loamy Sand	0.05	0.04	1
Loamy Very Fine Sand	0.44	0.25	5
Sand	0.03	0.01	1
Sandy Clay Loam	0.20	0.20	2
Sandy Loam	0.14	0.12	1
Silt Loam	0.41	0.37	3
Silty Clay	0.27	0.26	4
Silty Clay Loam	0.35	0.30	3
Very Fine Sand	0.46	0.37	5
Very Fine Sandy Loam	0.41	0.33	5

Table 17
Average erodibility factors (usleK) for the soil texture classes available in the HAIR database.

Texture Class		FOC < 2%	FOC ≥ 2%
1	Coarse	0.088	0.065
2	Medium	0.2	0.2
3	Medium fine	0.3575	0.3025
4	Fine	0.23	0.1975
5	Very fine	0.437	0.317

The soil texture class map is stored in the HAIR database. For organic soils ("soil texture" class 8) and for missing values (labels 0, 6) the erodibility factor *usleK* is assumed equal to 0.02.

3.3 Risk

3.3.1 Acute risk to algae

The acute biological risk potential for algae is calculated as the ratio of short-term exposure (Equation 32) to the lethal concentration;

$$ETR_{algae,acute,standing\ sw} = \frac{sPEC_{standing\ sw}}{LC50_{algae}} \qquad \text{Equation 62}$$

$ETR_{algae,acute,standing\ sw}$ acute risk indicator for algae, standing water conditions (-)
$sPEC_{standing\ sw}$ short-term exposure concentration, standing water conditions (mg L^{-1})
$LC50_{algae}$ lethal concentration for algae (mg L^{-1})

$$ETR_{algae,acute,flowing\ sw} = \frac{sPEC_{flowing\ sw}}{LC50_{algae}} \qquad \text{Equation 63}$$

$ETR_{algae,acute,flowing\ sw}$ acute risk indicator for algae, flowing water conditions (-)
$sPEC_{flowing\ sw}$ short-term exposure concentration, flowing water conditions (mg L^{-1})
$LC50_{algae}$ lethal concentration for algae (mg L^{-1})

3.3.2 Chronic risk to algae

In an analogue way the chronic biological risk potential for algae is calculated as the ratio of long-term exposure to the no observed effect concentration;

$$ETR_{algae,chronic,standing\ sw} = \frac{lPEC_{standing\ sw}}{NOEC_{algae}} \qquad \text{Equation 64}$$

$ETR_{algae,chronic,standing\ sw}$ chronic risk indicator for algae, standing water conditions (-)
$lPEC_{standing\ sw}$ long-term exposure concentration, standing water conditions (mg L^{-1})
$NOEC_{algae}$ no observed effect concentration for algae (mg L^{-1})

$$ETR_{algae,chronic,flowing\ sw} = \frac{lPEC_{flowing\ sw}}{NOEC_{algae}}$$ Equation 65

$ETR_{algae,chronic,flowing\ sw}$ chronic risk indicator for algae, flowing water conditions (-)
$lPEC_{flowing\ sw}$ long-term exposure concentration, flowing water conditions (mg L^{-1})
$NOEC_{algae}$ no observed effect concentration for algae (mg L^{-1})

For algae a 4 days duration of the standard toxicity test is assumed. This duration is also used to calculate the long-term exposure concentration (Equation 33).

3.3.3 Acute risk to daphnia

The acute biological risk potential for daphnia is calculated as the ratio of short-term exposure (Equation 32) to the lethal concentration;

$$ETR_{daphnia,acute,standing\ sw} = \frac{sPEC_{standing\ sw}}{LC50_{daphnia}}$$ Equation 66

$ETR_{daphnia,acute,standing\ sw}$ acute risk indicator for daphnia, standing water conditions (-)
$sPEC_{standing\ sw}$ short-term exposure concentration, standing water conditions (mg L^{-1})
$LC50_{daphnia}$ lethal concentration for daphnia (mg L^{-1})

$$ETR_{daphnia,acute,flowing\ sw} = \frac{sPEC_{flowing\ sw}}{LC50_{daphnia}}$$ Equation 67

$ETR_{daphnia,acute,flowing\ sw}$ acute risk indicator for daphnia, flowing water conditions (-)
$sPEC_{flowing\ sw}$ short-term exposure concentration, flowing water conditions (mg L^{-1})
$LC50_{daphnia}$ lethal concentration for daphnia (mg L^{-1})

3.3.4 Chronic risk to daphnia

In an analogue way the chronic biological risk potential for daphnia is calculated as the ratio of long-term exposure to the no observed effect concentration;

$$ETR_{daphnia,chronic,standing\ sw} = \frac{lPEC_{standing\ sw}}{NOEC_{daphnia}}$$ Equation 68

$ETR_{daphnia,chronic,standing\ sw}$ chronic risk indicator for algae, standing water conditions (-)
$lPEC_{standing\ sw}$ long-term exposure concentration, standing water conditions (mg L^{-1})
$NOEC_{daphnia}$ no observed effect concentration for daphnia (mg L^{-1})

$$ETR_{daphnia,chronic,flowing\ sw} = \frac{lPEC_{flowing\ sw}}{NOEC_{daphnia}} \quad \text{Equation 69}$$

$ETR_{daphnia,chronic,flowing\ sw}$ chronic risk indicator for algae, flowing water conditions (-)
$lPEC_{flowing\ sw}$ long-term exposure concentration, flowing water conditions (mg L^{-1})
$NOEC_{daphnia}$ no observed effect concentration for daphnia (mg L^{-1})

For daphnia a 21 days duration of the standard toxicity test is assumed. This duration is also used to calculate the long-term exposure concentration (Equation 33).

3.3.5 Acute risk to fish

The acute biological risk potential for fish is calculated as the ratio of short-term exposure (Equation 32) to the lethal concentration;

$$ETR_{fish,acute,s\tan ding\ sw} = \frac{sPEC_{s\tan ding\ sw}}{LC50_{fish}} \quad \text{Equation 70}$$

$ETR_{fish,acute,standing\ sw}$ acute risk indicator for fish, standing water conditions (-)
$sPEC_{standing\ sw}$ short-term exposure concentration, standing water conditions (mg L^{-1})
$LC50_{fish}$ lethal concentration for fish (mg L^{-1})

$$ETR_{fish,acute,flowing\ sw} = \frac{sPEC_{flowing\ sw}}{LC50_{fish}} \quad \text{Equation 71}$$

$ETR_{fish,acute,flowing\ sw}$ acute risk indicator for fish, flowing water conditions (-)
$sPEC_{flowing\ sw}$ short-term exposure concentration, flowing water conditions (mg L^{-1})
$LC50_{fish}$ lethal concentration for fish (mg L^{-1})

3.3.6 Chronic risk to fish

In an analogue way the chronic biological risk potential for fish is calculated as the ratio of long-term exposure to the no observed effect concentration;

$$ETR_{fish,chronic,s\tan ding\ sw} = \frac{lPEC_{s\tan ding\ sw}}{NOEC_{fish}} \quad \text{Equation 72}$$

$ETR_{fish,chronic,standing\ sw}$	chronic risk indicator for algae, standing water conditions (-)
$lPEC_{standing\ sw}$	long-term exposure concentration, standing water conditions (mg L^{-1})
$NOEC_{fish}$	no observed effect concentration for fish (mg L^{-1})

$$ETR_{fish,chronic,flowing\ sw} = \frac{lPEC_{flowing\ sw}}{NOEC_{fish}} \qquad \text{Equation 73}$$

$ETR_{fish,chronic,flowing\ sw}$	chronic risk indicator for algae, flowing water conditions (-)
$lPEC_{flowing\ sw}$	long-term exposure concentration, flowing water conditions (mg L^{-1})
$NOEC_{fish}$	no observed effect concentration for fish (mg L^{-1})

For fish a 28 days duration of the standard toxicity test is assumed. This duration is also used to calculate the long-term exposure concentration (Equation 33).

3.4 Remarks

Loadings due to drainage flow are not considered in the aquatic indicators. This decision was taken by the aquatic work package leader of the original HAIR consortium, but has not been reported in (Strassemeier et al., 2007).

Aquatic risk indicators based on field based application patterns for an entire crop cycle are not supported in HAIR. As a consequence, the SPEAR indicator based on field based application patterns for an entire crop cycle is abandoned.

Strassemeier et al. (2007) suggest to implement the erosion module as optional, and propose to estimate the risk in surface waters caused by compounds bound to eroding soil particles especially in regions with steep slopes. Because no criterion was specified here, and because optional exposure modules may complicate the interpretation of results for non-expert users, we decided to include erosion in the exposure calculation by default. In addition to the risk indicators, the estimated loads by spray drift, run-off, and erosion are printed in the HAIR output file.

A surface water density map is not implemented. As suggested by (Strassemeier et al., 2007), such a map might by used to derive a water index for aggregating risk indicator outcomes and/or for differentiating between seasons of water supply conditions and seasons without water in field ditches. The original HAIR consortium only provided a catchment area map but this map is no good basis for a field ditch density map. The aquatic risk indicators in HAIR express the risk to species in a potential volume of water in a field ditch with standard dimensions.

The term ($d / (Wd - d^2)\ 0.1$) in Equation 31 and Equation 32 for converting loadings per unit of area into concentration in the standard surface water body may have to be replaced by the term ($W / (Wd - d^2)\ 0.1$).

The sign of the exponent in Equation 31 is changed in order to obtain a decrease of concentration in time (cf. Eq. 5 in Strassemeier et al., 2007).

Eq. 36 in (Strassemeier et al., 2007) for calculating soil temperature based on daily air temperature is not used because daily air temperatures were not supplied by the original HAIR consortium. The soil temperature is assumed equal to the monthly average air temperature within the climate zone.
Additional specifications were needed in order to be able to select the appropriate drift function for all possible combinations of application crop, distance between the crop edge and the water body, and crop development stage.

The use of Equation 55 is restricted to the climate map units with annual average precipitation $P \geq 470$ mm. (cf. Eq. 34 in Strassemeier et al., 2007),

Equation 61 is the correct version of the original equation in Wischmeier and Smith (1978) after conversion of the dimensions of area treated from sqft into ha (cf. Eq. 34 in Strassemeier et al., 2007),

Soil data for the depth of the plough layer (0.1 m, several Equations in the run-off and erosion module) were not available. In these cases the soil properties for the layer 0-0.3 were taken.

4 Groundwater indicator

4.1 Introduction and scope

The indicator for the risk of leaching towards deep groundwater layers is based on the long-term average leaching concentration in the soil solution at 1 m depth. Exposure is calculated based on the nominal leaching concentration, the net soil deposition fraction and the application rate. Toxicity is expressed by the drinking water criterion (0.1 μg L^{-1} for all compounds). The groundwater indicator was developed by the original HAIR consortium, Work Package 8 (Van der Linden et al., 2007).

The groundwater indicator is calculated for pesticides applied to outdoor crops and indoor crops and for all methods of application currently used in HAIR (Table 2). Although the indicator is based on the leaching model GeoPEARL for outdoor crops, we assume that indoor leaching conditions are comparable to the outdoor conditions at the same location. The leaching concentration can't be calculated at annual precipitation amounts < 330 mm. At these locations, the risk is set equal to zero.

The regression equation for calculating the long-term average leaching concentration is described in Section 4.2. The exposure is calculated for each application event. For single applications the date of the application event is the application date. For multiple applications, the application events are distributed over time in a symmetric fashion around the application date, taking into account the number of application events and the time interval between subsequent events (Section 1.5.1).

4.2 Exposure

The nominal leaching concentration is calculated based on a regression equation, with the regression terms depending on compound properties and soil data;

$$\ln C_L = \alpha_0 - \alpha_1 X_1 - \alpha_2 X_2$$ Equation 74

$$X_1 = \frac{k\,\theta\,L}{q}$$ Equation 75

$$X_2 = \frac{k\,\rho\,f_{om}\,K_{om,compound}\,L}{q}$$ Equation 76

C_L	nominal leaching concentration at depth L (µg dm^{-3} per unit soil deposition rate)
α_0, α_1, α_2	regression coefficients (Table 19) (-)
k	first order degradation rate coefficient as influenced by temperature (d^{-1})
θ	long-term average soil moisture content (dm^3 dm^{-3})
L	depth at which the leaching is evaluated (constant depth L = 1 m)
q	volume flux of water at depth L (m d^{-1})
ρ	soil dry bulk density (kg dm^{-3})
f_{om}	soil organic matter fraction (kg kg^{-1})
$K_{om,compound}$	sorption coefficient (dm^3 kg^{-1})

Regression terms

The degradation rate constant is based on the half-life for degradation in soil;

$$k = \frac{\ln(2)}{DegT50_{soil}} \quad \text{Equation 77}$$

k	degradation rate coefficient (d^{-1})
$DegT50_{soil}$	half-life for degradation in soil (d)

The degradation half-life in the Compound database is defined at reference temperature 20 °C = 293.15 K. The corresponding value at the annual average temperature is obtained using the Arrhenius equation;

$$DegT50_{soil} = f_T \; DegT50_{soil,ref} \quad \text{Equation 78}$$

$$f_T = \exp\left(\frac{-E_{trans}}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T_{annual}}\right)\right) \quad \text{Equation 79}$$

f_T	temperature correction factor (-)
$DegT50_{soil,ref}$	half-life of the compound at reference temperature (d)
$DegT50_{soil}$	half-life adjusted for temperature (d)
E_{trans}	molar enthalpy of transformation (J mol^{-1}), (54000 J mol^{-1})
R	molar gas constant (J mol^{-1} K^{-1}), (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (K), (value 293.15 K ≡ 20 °C)
T_{annual}	long term average temperature (K)

Annual average temperature and monthly average temperature data are stored in the HAIR database (Section 1.5.3).

The leaching is evaluated at a constant depth (L = 1.0 m). A regression equation is used, with the long-term average soil water content explained by the soil moisture content at field capacity;

$$\theta = 0.01479 + 0.9885\,\theta_{fc} \quad \text{Equation 80}$$

Θ_{fc}	soil moisture content at field capacity Θ_{fc} ($dm^3\ dm^{-3}$)
Θ	long-term average soil moisture content ($dm^3\ dm^{-3}$)

The soil moisture content at field capacity (Θ_{fc}) is available for 5 soil texture classes and for organic soils (Table 18). The soil texture class map is stored in the HAIR database.

Table 18
Soil moisture content at field capacity for 5 soil texture classes and for organic soils.

ID	Texture, soil type	Θ_{fc}	Description
1	Coarse	0.2761	Coarse (clay < 18 % and sand > 65 %)
2	Medium	0.3478	Medium (18% < clay < 35% and sand > 15%), or (clay < 18% and 15% < sand < 65%)
3	Medium Fine	0.3821	Medium fine (clay < 35 % and sand < 15 %)
4	Fine	0.4485	Fine (35 % < clay < 60 %)
5	Very Fine	0.5380	Very fine (clay > 60 %)
8	Organic soil	0.6650	No texture (because of organic layer)

The long-term average flux of water at leaching depth is defined as the annual precipitation surplus.
A regression equation is used, with *q* explained by the average annual precipitation amount;

$$q = \frac{-0.2849 + \frac{0.8634P}{1000}}{365} \qquad P \geq 330$$ Equation 81

q	flux of water at depth L ($m\ d^{-1}$)
P	the average annual precipitation amount ($mm\ yr^{-1}$)
1000	conversion from ($mm\ yr^{-1}$) to ($m\ yr^{-1}$)
365	conversion from ($m\ yr^{-1}$) to ($m\ d^{-1}$)

Equation 81 can't be used at annual precipitation amounts P < 330 mm. At these locations the leaching concentration is set equal to zero.

The soil organic carbon map for the top meter is stored in the HAIR database. Soil organic carbon percentage is converted into the organic matter fraction;

$$f_{om} = \frac{1.724\ F_{OC}}{100}$$ Equation 82

F_{OC}	soil organic carbon content (0-1 m-ss.) (%)
f_{om}	soil organic matter fraction ($kg\ kg^{-1}$)
1.724	conversion factor from organic carbon into organic matter (-)

A regression equation is used, with the soil bulk density explained by the soil organic matter fraction;

$$\rho = 1.80 + 1.24 f_{om} - 2.91 f_{om}^{\ 0.5}$$ Equation 83

f_{om}	soil organic matter fraction (kg kg^{-1})
ρ	soil dry bulk density (kg dm^{-3}).

The soil pH for the plough layer (0-0.3 m) is stored in the HAIR database at 10K resolution.

The groundwater indicator can be calculated for compounds with two types of sorption behaviour:

a. compounds with normal sorption behaviour to organic matter, and
b. compounds with pH dependent sorption behaviour;

The type of sorption behaviour is defined in the Compound database by the boolean pH_dependent_sorption.

In Case (a), the normal sorption coefficient K_{om} is used;

$$K_{om,compound} = K_{om}$$ Equation 84

In Case (b), the combined sorption constant $K_{om,com}$ is calculated using the compound properties and the soil pH at the gridcell;

$$K_{om,compound} = K_{om,com}$$ Equation 85

$$K_{om,com} = \frac{K_{om,acid} + \frac{(M-1)}{M} 10^{pH-pK_a} K_{om,base}}{1 + \frac{(M-1)}{M} 10^{pH-pK_a}}$$ Equation 86

$K_{om,com}$	combined sorption constant (dm^3 kg^{-1})
$K_{om,acid}$	sorption constant of the acidic molecule (dm^3 kg^{-1})
$K_{om,base}$	sorption constant of the conjugated base (dm^3 kg^{-1})
M	molar mass of the compound (g mol^{-1})
pH	soil pH at the gridcell (-)
pK_a	dissociation constant of the compound (-)

Regression coefficients

In HAIR the regression coefficients for predicting the 50th percentile leaching concentration are used (Table 19). These regression coefficients are available for 2 application seasons and 4 regions based on annual precipitation and annual average temperature. The season is based on the application event day. The precipitation and temperature class boundaries are consistent with the climate zones defined in HAIR (Section 2.2).

Table 19
Regression coefficients (50th percentile leaching concentrations; Van der Linden et al., 2007).

Temperature – and precipitation range #	Climate zone ID	Spring (March until September)			Autumn (September until March)		
		α_0	α_1	α_2	α_0	α_1	α_2
T ≤ 12.5, P ≤ 800	1, 2, 4, 5	5.19	0.53	0.53	5.3	0.19	0.57
T ≤ 12.5, P > 800	7, 8, 10, 11, 13, 14	4.75	0.55	0.58	4.88	0.19	0.62
T > 12.5, P ≤ 800	3, 6	4.74	0.33	0.35	5.01	0.14	0.38
T > 12.5, P > 800	9, 12, 15	4.84	0.7	0.59	4.92	0.29	0.6

#) T = temperature (°C), P = precipitation (mm yr^{-1})

4.3 Leaching risk

The exposure concentration is the long-term average concentration in the soil solution leaching at 1 m depth towards deeper groundwater layers. Exposure is calculated based on the nominal leaching concentration, the net soil deposition fraction and the application rate. Toxicity is represented by the drinking water criterion;

$$RI_{groundwater} = \frac{\left(\sum_{i=1}^{n} C_{L_i} \ NSDF_i\right) AR}{DWC} \qquad \text{Equation 87}$$

$C_{L,i}$	nominal leaching concentration (μg L^{-1} per unit soil deposition rate)
$NSDF_i$	net soil deposition fraction (Equation 12) (-)
AR	application rate (kg a.i./ha)
DWC	drinking water criterion (0.1 μg/L)
i	index denoting the application event number

The calculation of the net soil deposition fraction is explained in Section 2.3.

4.4 Remarks

The soil pH map replaces the base saturation map that was delivered by the original HAIR consortium.

5 Terrestrial risk indicators

5.1 Introduction

The terrestrial risk indicator group in HAIR includes acute- and chronic risk indicators for birds and for mammals (Section 5.2), acute- and chronic risk indicators for earthworms (Section 5.3), and the aqute hazard quotient for bees (Section 5.4).

5.2 Birds and Mammals risk indicators

5.2.1 Introduction and scope

Birds and mammals in fields that are sprayed with pesticides may be exposed to the active ingredient in several ways: directly by spraying droplets, through the ingestion of contaminated food or drinking water, and/or through foraging on pesticide granules or treated seeds. The birds and mammals indicators in HAIR2010 consider exposure by ingestion of contaminated food items and foraging on treated seeds.

The birds and mammals indicators evaluate the effect of a single or a multiple application of a pesticide on the survival of birds and mammals (acute) or in the longer term on reproduction (chronic). The indicators are based on the indicators for birds and mammals described by the original HAIR consortium (Flari et al., 2007) and the way this was elaborated by (Kruijne et al., 2007). The indicators are in agreement with the evaluation scheme for a Reasonable Worst Case (RWC) scenario as set out by the EPPO (2003) for terrestrial vertebrates and related to other evaluation schemes and guidance documents (e.g., European Commission, 2002a). The method results in the calculation of Exposure Toxicity Ratio's (ETR).

The algorithms for calculating the indicators for birds and mammals and for acute and chronic exposure are partly the same. The difference is mostly in the definition of food items and some other input parameter values. All four indicators are implemented as separate routines: birds acute, mammals acute, birds chronic and mammals chronic.

The indicators evaluate the acute and chronic effects caused by a single or multiple application of a pesticide. The indicators apply to all outdoor crops and do not apply to indoor crops. The acute indicators apply to spraying applications and seed treatment applications (Method of application codes GS, GSUP, MANUAL, MANUP, and ST, Table 2). The chronic indicators for birds and for mammals apply to spraying applications only, not to seed treatments.

5.2.2 Exposure

The algorithms for calculation of the indicators for birds and mammals are based on exposure scenarios. A combination of a type of treated crop and a method of application determines which indicator species are selected for the exposure scenario. For each of the indicator species, a number of properties of the species and its food are looked up in different tables, for example body weight, physiological properties such as assimilation efficiency of the food, and moisture and energy content of the food.

The relevant tables in the document by Flari et al. (2007), sometimes modified, are included in Annex 6. The species groups and food items selectable for spraying and seed treatment applications are defined in Table 6-1a for birds and Table 6-1b for mammals. For spraying applications, more than one indicator species may be selected. All these selections, given by Flari et al. (2007) are stored in the HAIR database. All user input is stored in the usage database and the Compound database.

The application crop specified in the Usage database is related to a HAIR crop. Because all exposure calculations in HAIR are based on one single crop definition, the crop groups mentioned by Flari et al. (2007) were translated to these HAIR crops.

Acute indicators, spraying applications
The HAIR crop attribute Birds_GS_SCEN (Table 1-2, Annex 1) refers to the species groups and the corresponding food items in Table 6-1a, Annex 6. The HAIR crop attribute Mammals_GS_SCEN refers to the species groups and the corresponding food items in Table 6-1b. The relation between the crop groups mentioned in the birds and mammals exposure scenarios for spraying applications (Flari et al., 2007) and the HAIR crops is shown inTable 20.

Table 20
Relation between the crop groups mentioned in the birds and mammals exposure scenarios for spraying applications (Flari et al., 2007) and the crops defined in HAIR (the scenario ID for each HAIR crop can be found in Table 1-2, Annex 1).

ID	Crop groups in the exposure scenarios	HAIR crop
1	Cereals (early)	winter cereals
2	Cereals (late)	spring cereals
3	Vegetables, leafy crops, root crops (early)	all crops not equal to {1, 2, 5, 6, or 0}
4	Vegetables, leafy crops, Root crops (late)	
5	Orchards, Vines, Hops (all year)	permanent crops
6	Grassland	grass, green fodder
0	(dummy value used for HAIR crops out of scope)	greenhouse crops, fallow land

The exposure is estimated by calculating the Daily Dietary Dose for each bird or mammalian species and for different food items as follows:

$$DDD_j = \frac{\sum_{i=1}^{n}\left[\left(\frac{DFI_i}{BW_j}\right)\times C_i\right]}{n}$$ Equation 88

DDD_j Daily Dietary Dose for a bird or mammalian indicator species (mg a.i. kg BW^{-1} d^{-1})
DFI_i Daily Food Intake for the food item (g fresh weight food d^{-1})
BW_j body weight of the indicator species (g)
C_i concentration of a.i. in the food item (mg a.i. kg fresh weight food^{-1})
n number of food items (-)
j index denoting the species number
i index denoting the food item number

The daily dietary dose (*DDD*) is calculated as the sum for different food items. For all indicator species except skylark the number of food items is 1. The diet of the skylark consists of 33% herbage, 33% seeds and 33% small insects. The calculated total daily dietary dose in Equation 88 is divided by the number of food items, in this case $n = 3$ for the skylark (each food item represents 33%) and $n = 1$ for all other species. This operation replaces the proportionality factor PD (proportion in diet; Equation 5a.1.1 in Flari et al. (2007) and e.g. EPPO (2003; p. 229).

The Daily Food Intake of a food item in the diet of a bird or mammal is calculated based on the Daily Expenditure Energy of the species group, and the food energy, moisture content, and assimilation efficiency of the food item

$$DFI_i = \frac{DEE}{\left[\left(FE_i \times \left(1 - \left(\frac{MC_i}{100}\right)\right) \times \left(\frac{AE_i}{100}\right)\right)\right]} \qquad \text{Equation 89}$$

DFI_i	Daily Food Intake for the food item (g fresh weight food d^{-1})
DEE	Daily Expenditure Energy (kJ d^{-1})
FE_i	Food Energy of the food item (kJ g dry weight food^{-1})
MC_i	Moisture Content of the food item (%)
AE_i	Assimilation Efficiency of the food item (%)
i	index denoting the food item number

The Daily Expenditure Energy is a function of body weight;

$$DEE = 10^{(Log\,\alpha + \beta\,Log\,BW)} \qquad \text{Equation 90}$$

BW	body weight of the indicator species (g)

The parameters Log α and β are available for bird taxonomic groups and mammalian taxonomic groups (Tables 6-2a and 6-2b). The average body weight of the indicator species is given in Tables 6-1a & b.

The Food Energy and Moisture Content of the food items are given in Table 6-3. The assimilation efficiency for bird food items is given in Table 6-4 and for mammalian food items in Table 6-5. Because the Assimilation Efficiency data are given for other types of food items than the Food Energy and Moisture Content data, a lookup table is needed to relate the “AE-food item” to the “FE- and MC-food item”. These factors are given Table 6-6 for birds and Table 6-7 for mammals.

The concentration of active ingredient in a food item is calculated according to

$$C_i = AR\ RUD_{i,acute}\ CIF_{average}\ MAF_{acute} \qquad \text{Equation 91}$$

C_i	concentration of active ingredient in the food item (mg a.i. kg fresh weight food^{-1})
AR	application rate (kg a.i. ha^{-1})
$RUD_{i,acute}$	Residue Unit Dose of the food item, acute exposure (mg a.i. kg fresh weight food^{-1}) at unit application rate (= 1 kg a.i. ha^{-1})

$CIF_{average}$	average Crop Interception Factor of the application events in the gridcell (-).
MAF_{acute}	Multiple Application Factor, acute exposure (-)

The Residue Unit Dose of the food item is the fraction of the pesticide in the food item following an application, normalised for an application rate of 1 kg a.i. ha^{-1}. The RUD values used for the food items of birds and mammals are given in Table 6-8 (based on 90^{th}-percentiles of residue values for the acute indicators).

In case of a multiple application the average Crop Interception Factor is used. This is calculated using the arithmetic mean.

$$CIF_{average} = \frac{\sum_{i=1}^{i=n} CIF_i}{n}$$ Equation 92

$CIF_{average}$	Average Crop Interception Factor for the application and the crop calendar region (-)
CIF_i	Crop Interception Factor at the application event date in the crop calendar region (-)
n	number of application events (-)

More information on the calculation of the Crop Interception Factor is provided in (Section 2.2).

The Multiple Application Factor depends on the number of application events and the application interval. Flari et al. (2007) provided tables for MAF values for the acute indicators (in connection with 90^{th} percentiles residue values for the RUD) and chronic indicators (in connection with 50^{th} percentiles residue values for the RUD) based on the EU guidance document (2002). In this case formulas are preferred for HAIR instead of using tables. The calculation of the MAF for the chronic indicator is described by Equation 93. This equation was provided by the EU (2002). However, a formula for the acute indicator was not presented. We therefore fitted Equation 93 (with an unknown constant *k* instead of the value 0.069) to the data in (Flari et al.,2007; Table 5a.1.11) to interpolate MAF values for other spraying intervals than 7, 10 or 14 days. This yielded the following formula (non-linear regression; 94.2% of the variance accounted for);

$$MAF_{acute} = \frac{(1-e^{-0.10\, n\, AI})}{(1-e^{-0.10\, AI})} \qquad AI > 1$$
$$MAF_{acute} = 1 \qquad AI = 1$$ Equation 93

MAF_{acute}	Multiple Application Factor, acute exposure (-)
n	number of application events (-)
AI	application interval (d)

Note that MAF_{acute} = 1 if insects are (part of) the diet (i.e. when FE_MC_FoodItem ID = 2 or 6: Table 6-3).

Acute indicators, seed treatment applications

As for spraying applications, the HAIR crop attribute Birds_ST_SCEN refers to the species groups and the corresponding food items in Table 6-1a. The HAIR crop attribute Mammals_ST_SCEN refers to the species groups and the corresponding food items in Table 6-1b. The relation between the crop groups in the birds and mammals exposure scenarios for seed treatment applications and the HAIR crops is shown in Table 21.

For birds there are 5 scenarios (see Table 6-1a, Annex 6). Records in (Flari et al., 2007; Table 5a.1.2) for the same granivorous bird indicator species but for different crops are merged in Table 6-1a. For mammals there is 1 scenario (see Table 6-1b). The species diet consists of 1 food item: weed seeds (food item ID = 9) in case of oilseed rape (birds scenario ID = 7) or cereal seeds (food item ID = 4) for the rest of crops (birds scenario ID = 8, .., 11, mammals scenario ID = 7).

Table 21
Relation between the crop groups mentioned in the birds and mammals exposure scenarios for seed treatments (Flari et al., 2007) and the crops defined in HAIR (the scenario ID for each HAIR crop can be found in Table 1-2, Annex 1).

ID	Crop group of the exposure scenarios	HAIR crops
7	Maize, Oilseed rape, Rest of crops	Cereals, Oil seed, etc ....
8	Winter barley	Common wheat and spelt: Winter, Durum wheat: Winter, Barley: Winter
9	Peas	Pulses
10	Spring barley	Barley: Spring
11	Sugar beet (pelleted)	Sugar beet
0	(dummy value used for HAIR crops out of scope)	Greenhouse crops, fallow land; permanent crops, etc.

The application rate of seed treatments is expressed in the same way as for spraying applications, i.e., as kg a.i. per hectare. However, this rate may need to be calculated from the concentration in the seeds and the seeding rate, before it can be put in the right units in the usage database.

For seed treatment, crop interception is not relevant. Equation 91 s therefore rewritten as

$$C_i = AR\ RUD_{i,acute}\ MAF_{acute} \qquad \text{Equation 94}$$

C_i concentration of active ingredient in the food item (mg a.i. kg fresh weight food^{-1})
AR application rate (kg a.i. ha^{-1})
$RUD_{i,acute}$ Residue Unit Dose of the food item, acute exposure (mg a.i. kg fresh weight food^{-1}) at unit application rate (= 1 kg a.i. ha^{-1})
MAF_{acute} Multiple Application Factor, acute exposure (-)

Calculation of exposure and exposure toxicity ratios for seed treatments is done in the same way as for the spraying applications.

Chronic indicators, spraying applications
The calculation of the chronic indicators for birds and mammals is basically done in the same way as the calculation of the acute indicators. Here, only the modifications will be summarized (from Flari et al., 2007).

The formula for the calculation of the concentration of the active ingredient in the food item (Equation 91) is replaced by

$$C_i = AR \quad RUD_{i,chronic}\ CIF_{average}\ MAF_{chronic}\ f_{twa} \qquad \text{Equation 95}$$

C_i	concentration of active ingredient in the food item (mg a.i. kg fresh weight food^{-1})
AR	application rate (kg a.i. ha^{-1})
$RUD_{i,chronic}$	Residue Unit Dose of the food item, chronic exposure (mg a.i. kg fresh weight food^{-1}) at unit application rate (= 1 kg a.i. ha^{-1})
$CIF_{average}$	average Crop Interception Factor of the application events in the gridcell (-).
$MAF_{chronic}$	Multiple Application Factor, chronic exposure (-)
f_{twa}	time-weighted averaged factor (-)

The RUD values used for the food items of birds and mammals for calculation of the chronic indicators are given in Table 6-8, together with the RUD_{acute}. Where the acute indicators for birds and mammals use the 90th-percentiles of the known residue values, the chronic indicators use the 50th-percentiles.

The value for the Multiple Application Factor, chronic exposure, is calculated as

$$MAF_{chronic} = \frac{(1-e^{-0.069\, n\, AI})}{(1-e^{-0.069\, AI})} \qquad AI > 1$$
$$MAF_{chronic} = 1 \qquad AI = 1$$

Equation 96

$MAF_{chronic}$	Multiple Application Factor, chronic exposure (-)
n	number of application events (-)
AI	application interval (d)

$MAF_{chronic}$ = 1 if insects are (part of) the diet.

The time-weighted averaged factor f_{twa} is calculated from the degradation time of the compound on vegetation and a duration. In absence of data on the half-life of compounds on vegetation, as is presently the case for many pesticides, a default value of 10 days is used (so *k* becomes 0.069 in Flari et al., 2007; Equation 5b.1.3). For explanation see (EU, 2002). According to the same documents the default value for the duration should be 21 days when the application interval of a multiple application is equal to or longer than 21 d. This yields a fixed value for the f_{twa} = 0.53. When the interval between the applications is shorter that 21 days, the length of the interval should be used as the duration (Robert Luttik, *personal communication*).

Summarising,

$$f_{twa} = \frac{1-e^{-0.069 AI}}{0.069 AI} \qquad AI < 21$$

$$f_{twa} = 0.53 \qquad AI \geq 21$$

Equation 97

f_{twa}	time-weighted averaged factor (-)
AI	application interval (d)

5.2.3 Acute risk to birds

The exposure toxicity ratio is calculated as the highest exposure for any of the indicator species j and the acute toxicity;

$$ETR = \frac{\underset{j=1}{\overset{n}{MAX}}(DDD_j)}{LD50_{birds}} \qquad \text{Equation 98}$$

For birds, the toxicity parameter is the LD50 from acute oral tests (in mg a.i. kg body weight^{-1}): column "LD50 bird acute mg_kgbw" in the Compound database.

5.2.4 Chronic risk to birds

The exposure toxicity ratio is calculated as;

$$ETR = \frac{\underset{j=1}{\overset{n}{MAX}}(DDD_j)}{NOED_{birds}} \qquad \text{Equation 99}$$

For the birds chronic indicator, the toxicity endpoint that should be used is the No Observed Effect Dose (NOED, in mg kg body weight^{-1} d^{-1}). The values for the NOED can be found in the column "NOED bird chronic mg_kgbw" in the Compound database. Toxicity tests should be conducted according to standardised guidelines (OECD etc.).

5.2.5 Acute risk to mammals

The exposure toxicity ratio is calculated as the highest exposure for any of the indicator species j and the acute toxicity;

$$ETR = \frac{\underset{j=1}{\overset{n}{MAX}}(DDD_j)}{LD50_{mammals}} \qquad \text{Equation 100}$$

For mammals, the toxicity is the LD50 (in mg a.i. kg^{-1} body weight d^{-1}): column "LD50 mammal acute mgai_kgbw" in the Compound database. Toxicity tests should be conducted according to standardised guidelines such as those by the OECD. For an overview, see (EFSA, 2009; Chapter 2).

5.2.6 Chronic risk to mammals

The exposure toxicity ratio is calculated as;

$$ETR = \frac{\underset{j=1}{\overset{n}{MAX}}(DDD_j)}{NOED_{mammals}}$$ Equation 101

For the mammals chronic indicator, the toxicity endpoint that should be used is the No Observed Effect Dose (NOED, in mg kg body weight $^{-1}$ d^{-1}). The values for the NOED can be found in the column "NOED mammal chronic mg_kgbw" in the Compound database. Toxicity tests should be conducted according to standardised guidelines (OECD etc.).

5.2.7 Conversion of toxicity data

In risk assessment, it is necessary to have all toxicity endpoints in mg a.i. kg BW^{-1} d^{-1}, i.e. in a daily dose format to be consistent with the units used in the exposure assessment. Endpoints from mammalian toxicity studies are usually presented in this way. However most avian reproduction studies and some mammalian reproduction- or development studies tend to be reported in terms of parts per million (ppm) or mg a.i. kg diet^{-1} (LC50s, NOECs) and therefore their endpoints need to be converted into daily dose.

Table 22 presents a standard set of factors that can be used to provide internal consistency when converting concentrations in diet into mg kg BW^{-1} d^{-1} dose levels for birds and mammals. This should be used only in the absence of specific information in a study report or summary (it can, however, be used to give a rough check of values cited in a study). Only routine study types, species and ages have been considered.

Table 22
Toxicity data conversion factors of parts per million (ppm) to (mg kg BW^{-1} day^{-1}).

Species	Age/study	Conversion factor
Rat	28 d and 90 d	0.1
Rat	Two-generation study first mating	0.08
Rat	Two-generation study overall (females)	0.12
Mouse	28 d and 90 d	0.2
Dog	Dog adult/all	0.025
Bird	Reproduction study	0.1
Bird	LC50 (5 day dietary study)	0.35

5.2.8 Remarks

Deviations from the HAIR deliverable on terrestrial indicators (Flari *et al.*, 2007).

Only one probability level is used for calculating exposure: i.e. the reasonable worst case (RWC) and not the Most Likely Case (MLC). RWC is also the scenario that is commonly used for registration purposes in Europe (Robert Luttik, personal communication).

In the RWC scenario avoidance (AV), proportion of diet obtained in the treated area (PT) and proportion of food items in the diet of the bird or mammal (PD) are all assumed to be equal to 1 (Flari et al., 2007: Table 5.1.12). Thus these parameters were not included in the calculations.

Only spraying and seed treatment are considered. Granule treatments are not evaluated. Seed treatment is considered for acute risk, not for chronic risk indicators. Slug pellet treatments are not evaluated either. Only exposure through food is considered. Exposure through drinking water in field or surface water is not evaluated. Reasons to restrict the scope of the birds and mammals indicators were problems with parameterisation and limited data availability.

Chronic indicators are not calculated for seed treatment applications because of lack of information. The risk of such treatments on the longer term depends on both the degradation of the compounds in the seeds and on the disappearance of the seeds in the field. At present there is insufficient information, notably on the disappearance rate of the seeds themselves (Robert Luttik, personal communication).

Contrary to their use for registration purposes, Assessment Factors, i.e., safety factors applied to toxicity data, e.g., to correct LD50 or NOED values, are not used for indicators in HAIR.

5.3 Earthworm risk indicators

5.3.1 Introduction and scope

Earthworms are exposed to pesticides when these are sprayed or otherwise applied to crops or directly onto soils.

The acute risk indicator considers the effect of a single or a multiple application of a pesticide within a single growing season (crop cycle) on the survival of earthworms (lethal endpoint) after 2 weeks of exposure in the top 5 cm of the soil. The chronic risk indicator considers the effect of a single or a multiple application of a pesticide within a single growing season (crop cycle) on the growth and/or reproduction of earthworms (sublethal endpoint) after 4 weeks of exposure in the top 5 cm of the soil.

Both indicators apply to all outdoor crops and do not apply to indoor crops. The earthworm risk indicators apply to all (outdoor) application methods.

The earthworm risk indicators are based on Flari et al. (2007). The indicators are also in agreement with the evaluation scheme of the EPPO (2003b) for the acute and the chronic effects on earthworms and related to other evaluation schemes and guidance documents (e.g., European Commission, 2002; Zorn et al., 2010).

5.3.2 Exposure

The earthworm acute and chronic risk indicators are calculated separately. The acute indicator applies to the effect on survival, whereas the chronic indicator applies to the effect on reproduction or growth. Both are based on the same exposure; i.e. the total predicted environmental concentration in soil following the last application event.

The Predicted Initial Environmental Concentration (PIEC) in soil following a single application event at time t_i is calculated as

$$PIEC_{soil,t_i} = \frac{AR\ NSDF_i 100}{d\ \rho}$$ Equation 102

$PIEC_{soil,t\_i}$ Predicted Initial Environmental Concentration in soil at time t_i (mg kg soil^{-1})
AR application rate (kg a.i. ha^{-1})
$NSDF_i$ Net Soil Deposition Fraction (-)
d mixing depth (= 0.05 m).
ρ soil bulk density (kg m^{-3})
t_i application event day (-)
i index for the application event number

The application rate, application time, number of applications, application interval are stored in the Usage database. The application event dates are calculated based on the application time and the application interval (Section 1.5.1).The calculation of the net soil deposition fraction is described in Chapter 2.

The soil dry bulk density is calculated from the soil organic matter fraction with a pedotransfer function (Equation 83), after conversion of the soil organic carbon content into the soil organic matter content (Equation 82). The soil organic carbon map is stored in the HAIR database. Soil properties for the layer 0-0.05 m were not available, so the layer 0-0.3 m is taken instead of the mixing depth.

For a multiple application, the indicator is calculated using the initial concentration immediately following the last application event (see Figure 10), taking into consideration the contributions of the previous application events. The predicted environmental concentration (PEC) at time t_n as a consequence of an application event at time t_i, is described by

$$PEC_{soil,i} = PIEC_{soil,t_i}\ e^{-k(t_n - t_i)}$$ Equation 103

$PEC_{soil,i}$ Predicted Environmental Concentration in soil at time t_n resulting from application event i at time t_i (mg kg soil^{-1})
$PIEC_{soil,t\_i}$ Predicted Initial Environmental Concentration in soil at time t_i (mg kg soil^{-1})
k disappearance rate constant (d^{-1})

$$k = \frac{\ln 2}{DegT50_{soil}}$$ Equation 104

$$DegT50_{soil} = f_T\ DegT50_{soil,ref}$$ Equation 105

$$f_T = \exp\left(\frac{-E_{trans}}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T_{month}}\right)\right)$$ Equation 106

with

f_T	temperature correction factor (-)
$DegT50_{soil,ref}$	degradation half-life of the compound in soil at reference temperature (d)
E_{trans}	molar enthalpy of transformation (54000 J mol^{-1})
R	molar gas constant (value 8.314 J mol^{-1} K^{-1})
T_{ref}	reference temperature (value 293.15 K ≡ 20 °C)
T_{water}	soil temperature (K)

The total predicted environmental concentration in soil at the nth application (t_n) as a consequence of all application events is then calculated as

$$PEC_{soil,total} = PEC_{soil,1} + PEC_{soil,2} + \ldots + PEC_{soil,n} \qquad \text{Equation 107}$$

$PEC_{soil,total}$	Predicted total Environmental Concentration in soil at time t_n resulting from all application events (mg kg soil^{-1})
$PEC_{soil,i}$	Predicted Environmental Concentration in soil at time t_n resulting from application event i at time t_i (mg kg soil^{-1})

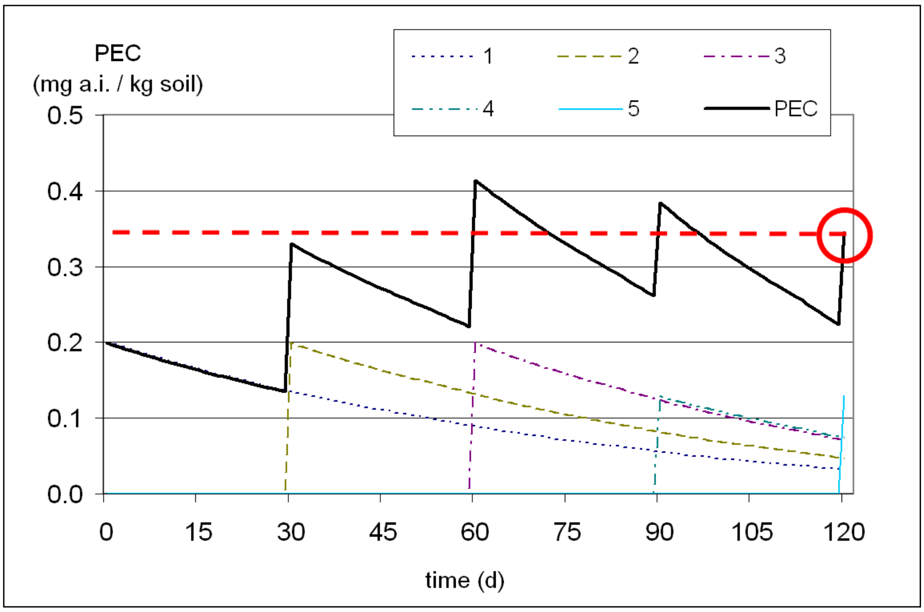

Figure 10
Example application with 5 application events and a 30-days application interval, with the calculated initial concentration in the soil after the last application event ($PEC_{soil,total}$). The calculation period starts at the day of the first application event and ends at the day of the last application event. $PEC_{soil,total}$ is the predicted exposure concentration used in both the earthworm acute and chronic risk indicator.

5.3.3 Acute risk to earthworms

The $LC50_{earthworm}$ is used to calculate the acute risk indicator. The $LC50_{earthworm}$ may need to be corrected for absorption based on the octanol water partition coefficient of the compound;

$$LC50_{earthworm,corrected} = LC50_{earthworm} \qquad \log(K_{ow}) \leq 2$$

Equation 108

$$LC50_{earthworm,corrected} = LC50_{earthworm} CF \qquad \log(K_{ow}) > 2$$

$LC50_{earthworm}$ Concentration causing 50% mortality after 14 d (mg a.i. kg soil^{-1})
$\log(K_{ow})$ logarithm of the octanol water partition coefficient (-)
CF correction factor (= 0.5)

The $LC50_{earthworm}$ and the $\log(K_{ow})$ are stored the Compound database. The correction factor CF is in agreement with the EPPO (2003) guideline.

Finally, the acute risk indicator for earthworms is calculated as

$$ETR_{earthworms,lethal} = \frac{PEC_{soil,total}}{LC50_{earthworm,corrected}}$$

Equation 109

$PEC_{soil,total}$ Predicted total Environmental Concentration in soil at time t_n resulting from all application events (mg kg soil^{-1})
$LC50_{earthworm,corrected}$ $LC50_{earthworm}$ corrected for adsorption (mg a.i. kg soil^{-1})

5.3.4 Chronic risk to earthworms

The lowest NOEC for growth or reproduction for earthworms in soil is used to calculate the chronic risk indicator. The $NOEC_{earthworm}$ may need to be corrected for absorption based on the octanol water partition coefficient of the compound;

$$NOEC_{earthworm,corrected} = NOEC_{earthworm} \qquad \log(K_{ow}) \leq 2$$

Equation 110

$$NOEC_{earthworm,corrected} = NOEC_{earthworm} CF \qquad \log(K_{ow}) > 2$$

$NOEC_{earthworm}$ Highest test concentration causing no effect on growth or reproduction after 28 d (mg a.i. kg soil^{-1})
$\log(K_{ow})$ logarithm of the octanol water partition coefficient (-)
CF correction factor (= 0.5)

The $NOEC_{earthworm}$ and the $\log(K_{ow})$ are stored the Compound database.

Finally, the chronic risk indicator for earthworms is calculated as

$$ETR_{earthworms,sublethal} = \frac{PEC_{soil,total}}{NOEC_{earthworm,\,corrected}}$$ Equation 111

$PEC_{soil,total}$ Predicted total Environmental Concentration in soil at time t_n resulting from all application events (mg kg $soil^{-1}$)

$NOEC_{earthworm,corrected}$ $NOEC_{earthworm}$ corrected for adsorption (mg a.i. kg $soil^{-1}$)

5.3.5 Remarks

The earthworm risk indicators are based on the cumulative concentration of the compound after the last application event of the season. From a risk management point of view, the indicator should be based on the highest cumulative initial concentration during the season, i.e. the highest peak in Figure 10. However, by using the last peak concentration the earthworm risk indicators are in agreement with several guidlines used for registration (European Commission; 2002, EPPO; 2003, Zorn et al.; 2010).

The test to assess the $LC50_{earthworm}$ (14 d) and $NOEC_{earthworm}$ (28 d) should preferably be performed according to international guidelines such as those by the OECD (1984ab) or ISO (1993). The standards species are the earthworms *Eisenia fetida* and *Eisenia andrei*. In sublethal tests adult worms are usually exposed for 28 days to contaminated soils. At the end of this period their growth is measured. Any cocoons that are produced are kept in the same soil for another month to assess the number of juveniles that hatch (fecundity). The lowest NOEC should be used for the HAIR Compound database.

The $PIEC_{soil}$ and $LC50_{earthworm}$, and the $PEC_{soil,total}$ and $NOEC_{earthworm}$ values should be expressed as mg kg dry weight $soil^{-1}$.

Contrary to their use for registration purposes, assessment factors, i.e. safety factors applied to toxicity data, are not used for indicators in HAIR.

The adjectives acute and chronic used for the risk indicators in HAIR refer to the endpoints used and not to the exposure duration. In case of the eartworm indicators, the acute risk refers to the leathal endpoint (mortality) and chronic risk refers to the sublethal endpoints reproduction and growth.

Deviations from the HAIR deliverable on terrestrial indicators (Flari et al., 2007)
The initial concentration following a single application is called Predicted Initial Environmental Concentration (PIEC) instead of $PEC_{soil,initial}$. PIEC is an accepted description for this parameter (Zorn et al., 2010).

The Net Soil Deposition Factor (NSDF) is used instead of the fraction of pesticide reaching the soil (f). The NSDF is calculated from the Crop Interception Factor (CIF) and the cumulated volatilisation from the soil (Chapter 2).

The soil bulk density is not a constant, but is calculated from the soil organic matter fraction in the gridcell. The soil organic matter map is not available for the mixing depth d = 0.05 m. The soil organic matter fraction in the plough layer (0-0.3 m) is used instead.

The $NOEC_{earthworm}$ values are not based on a 21-day test but on a test with a 28-day exposure of adults and another 28 days of exposure of any produced cocoons.

Similar to the $LC50_{earthworm}$ used to calculate the acute earthworm indicator, the NOEC for the chronic indicator is corrected when $\log K_{ow} > 2$. For the $NOEC_{earthworm}$, this was not prescribed in the original deliverable (Flari et al., 2007).

5.4 Bees hazard quotient

5.4.1 Introduction and scope

Bees are exposed to pesticides when these are applied to flowering crops, to non-flowering crops with flowering weeds or when spray drift is deposited on (flowering) field margins. The acute indicator considers the acute effect of spray droplets from a single application event on the survival of the bees. The indicator is based on the document by Flari et al. (2007), but includes several modifications.

The method results in the calculation of a Hazard Quotient (HQ) with different units for exposure and toxicity, and is therefore not to be regarded as an Exposure Toxicity Ratio. The indicator is more complicated than the evaluation scheme of the EPPO (2003) for the acute effects on bees and related schemes and guidance documents (e.g., European Commission, 2002; Zorn et al., 2010) because the method involves a suite of special situations having to do with crop, compound or field properties.

In general two conditions must be met for a pesticide application in order to cause a risk to bees: (1) bees must be active (this would exclude the winter season in colder climate zones) and (2) there must be stages of the crops or weeds present in the field or in the field margin that attract bees (this excludes non-flowering stages for most crops except field beans).

This indicator assesses the acute mortality caused by a single or a multiple application of a pesticide. For some methods of application the indicator is set at a fixed value indicating a negligible risk. The scope of the indicator includes all outdoor crops and their methods of application (Table 2). The indicator does not apply to indoor crops and their methods of application (codes LVM, SPRGRH).

The presence or absence of a field margin is incorporated in HAIR. However, the presence or absence of flowering weeds within this margin is not evaluated.

5.4.2 Acute hazard

The hazard quotient for direct over spraying of a flowering field or flowering weed in a field is calculated as

$$HQ_{field} = \frac{AR}{LD_{50}} \times 1000$$ Equation 112

For spray drift towards a flowering field margin next to the field.

$$HQ_{drift} = \frac{\frac{P}{100} \times AR}{LD_{50}} \times 1000 \qquad \text{Equation 113}$$

P	drift percentage (Equation 40)
AR	application rate (kg a.i. ha^{-1}).
LD_{50}	lethal dose (µg a.i. bee^{-1})
1000	conversion from (kg) to (g)

The factor 1000 is used to convert the application rate from kg a.i. ha^{-1}, as used in HAIR, to g a.i. ha^{-1}, used for calculation of the HQ by the EPPO (2003) and others (EU, 2002; Flari et al., 2007).

For a multiple application, the HQ of one application event, the one with the highest risk, is reported. This is based on the assumption that surviving individual bees do not really accumulate pesticide in their body over time from multiple application events and/or that previously unexposed bees are present in the crop treated or in the field margin when the next application event occurs. HQ_{field} and HQ_{drift} can vary between different application events belonging to the same application; HQ_{field} because flying bees and/or sensitive crop stages may be either present or absent during different application events, HQ_{drift} only because of the presence/absence of actively flying bees.

The EPPO (2003) uses a lower and a higher risk threshold for the HQ of 50 and 2500 respectively. These thresholds are used here to reset the value of the HQ for certain low or high risk situations, depending on:
1. the method of application (spray, granules, seed treatment, etc.),
2. the mode of action of the pesticide (systemic effect, insect growth regulator; defined in the Compound database),
3. the application crop (field beans, for example, are attractive to bees even when not flowering, see Annex 1).
4. the growth stage of the crop at the application event,

The parameters method of application, application crop, application time and application interval are stored in the Usage database. These factors are incorporated in the flow chart (Figure 12). When there is no risk, the HQ is set to a No Risk Value (NRV = 49), just below threshold of 50 (EPPO, 2003; Flari et al., 2007). In case of high risk, a High Risk Value (HRV = 2501) is used, just above the threshold of 2500 (EPPO, 2003; Flari et al., 2007).

The presence of bees is assessed by evaluating the application date. From March 1st to September 30st it is assumed that flying bees may be present in the area. So at present, no distinction is made between different climate zones for this criterion.

The width of the field margin is stored in the Usage database (default = 6 m). The presence of flowering weeds in the crop treated is also stored in the Usage database, but as a Boolean parameter (True / False). Because there is currently little or no information on the presence of flowering weeds in the crops themselves, the default value in the Usage database incidates there are no flowering weeds present (the Boolean “Flowering weeds in crop” = False). The default value is editable.

The drift percentage P is calculated using the equations for calculating drift onto the water surface in a field ditch (Section 3.2.2). The drift deposition is calculated for a field margin located between the distances G_{min} and ($G_{min} + F$) from the crop edge (Figure 11). As proposed by Flari et al. (2007), the default value for the field margin width F = 6 m. The user may edit the field margin width for each individual application in the Usage database. According to (Strassemeijer et al., 2007) the function parameters applicable to the drift crop group "Arable crops + vegetables < 0.5" are used for calculating drift deposition onto the field margin, irrespective of the crop treated. The corresponding value of the minimum distance between the crop edge and the first edge of the field margin G_{min} = 1 m (Table 11). This minimum distance is not editable because the drift function is not applicable at shorter distances.

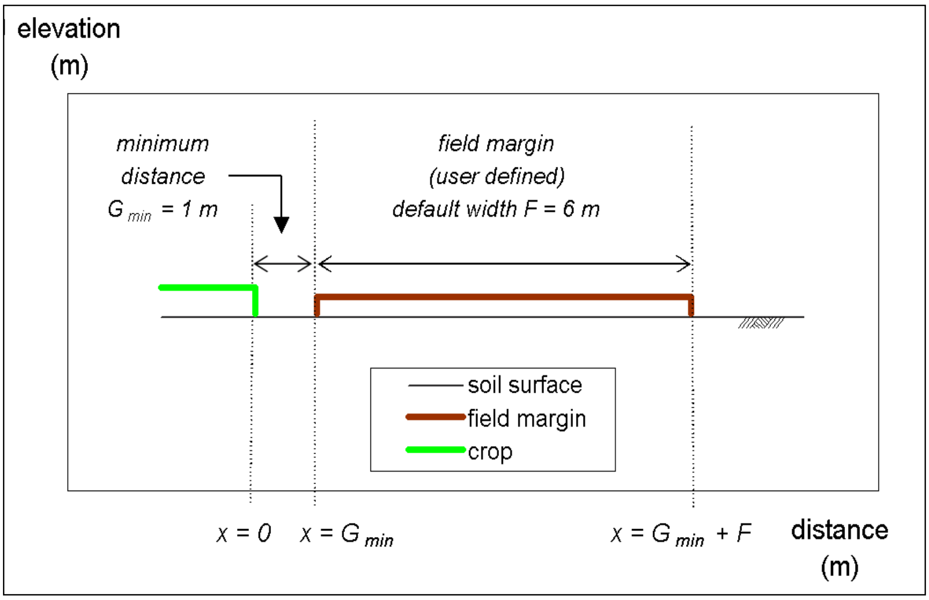

Figure 11
Schematic representation of the field margin adjacent to the crop edge. The field margin width (F) is stored in the Usage database. The default value F = 6 m. The distance between the crop edge and the first edge of the field margin G_{min} = 1 m (Table 11).

HQ_{drift} is calculated under the assumption that the field margin contains weeds that are flowering at the moment of the application. This type of information is not often available. However, if (a) a field margin is not present, if (b) the user knows or assumes that flowering weeds are not present in the margin, or if (c) the user is not interested in HQ_{drift}, the width of the field margin needs to be set equal to 0 m in the Usage database.

Crop stages with a high risk to bees are identified on a HAIR crop basis. For each HAIR crop, the crop development stages of attractiveness to bees are identified in the HAIR database with a Boolean parameter (Table 1-2, Annex 1).

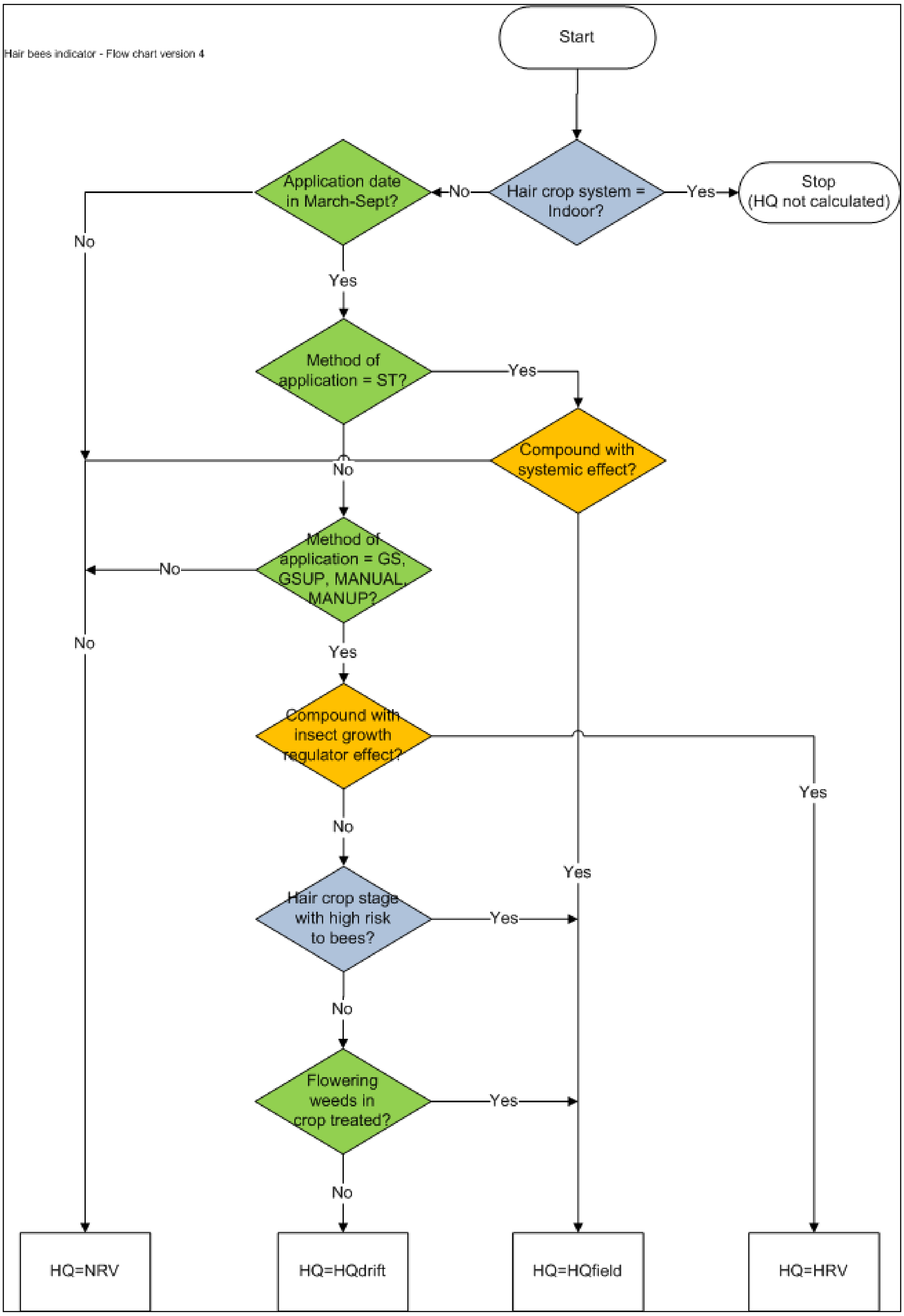

Figure 12
Schematic presentation of the bees acute indicator. Codes for the application methods according to Table 2. The application date, the method of application and the boolean parameter "Flowering weeds in crop" (present default = False) are stored in the Usage database (green color). The Insect growth regulator - and Systemic Effect boolean parameters are stored in the Compound database (yellow color). The HAIR crop features are stored in the HAIR database (blue color).

5.4.3 Remarks

The test to assess the LD50 (48 h) should preferably be performed according to international guidelines such as those by the OECD (1998ab) or EPPO (2001). Dosing is performed either by oral or contact application. If both of these are available, the lowest value should be used (EPPO, 2003). The standards species is *Apis melifera*. The test is conducted with worker bees. The LD50 is expressed as μg bee^{-1}.

The Hazard Quotient used here is different from the exposure toxicity ratio (ETR) used in other (terrestrial) indicators, since exposure and effect concentrations are not expressed in the same units. These HQ and ETR values cannot be compared to each other.

Contrary to their use for registration purposes, Assessment Factors, i.e., safety factors applied to toxicity data, are not used for indicators in HAIR.

Deviations from the original HAIR project (Flari et al., 2007)
The names and symbols of the parameters in Equation 112 and Equation 113 deviate slightly from the original equations. These equations are modified for an application rate expressed in kg a.i. ha^{-1} instead of g a.i ha^{-1} according to the definitions in the Usage database. By introducing a factor 1000 in Equation 112 and Equation 113 the outcome of the calculations is kept in agreement with the HQ calculations by the EPPO (2003) and Flari et al. (2007) and with the threshold values suggested in these documents.

The tables supplied by Flari et al. (2007) with exceptions to the HQ calculation are integrated in the flow chart presented in Figure 12. The presence of flowering crops in adjacent fields is not evaluated, because it is assumed that adjacent fields treated will themselves be represented as applications in the Usage database anyway.

Flowering stages in the crops are identified by the HAIR crop development stage. The start and duration of a specific crop development stage varies with the crop calendar region, so a single crop in different regions may be attractive to bees in different periods of the year. The crop calendars for the FOCUS interception crops grown in each crop calendar region are included in Annex 2.

6 Occupational risk indicators

6.1 Introduction

The set of 9 indicators calculated under the heading 'occupational indicators' were originally described by (Garreyn et al., 2007) as part of the EU HAIR project (Work Package 10).

They comprise a set of acute and chronic indicators aiming to estimate the risk to several groups of humans who may be exposed to pesticides:

- operators: people handling pesticides in the preparation (mixing and loading) of pesticides to be applied to crops, or involved in the actual application of the pesticides to the field;
- re-entry workers: people who enter a field or a greenhouse for various tasks such as weeding, inspection of crops, harvesting;
- bystanders: members of the public who by chance happen to be nearby a field or greenhouse during or immediately after a pesticide is being applied;
- residents: members of the public who live nearby an agricultural field and may therefore be repeatedly exposed to pesticides applied to the nearby field.

An additional indicator is calculated for children, which are considered to be a more sensitive population group due to their lower body weight, higher rate of ventilation and the possibility of additional exposure to pesticides due to their tendency to put their hands and possibly foreign objects into their mouth.

Although the risk for people working in glasshouses for activities like inspection and harvesting of crops is already addressed by the 'general' indicator for re-entry workers, the HAIR consortium proposed an alternative indicator specifically dealing with risks for people in glasshouses, which is called the indicator for greenhouse workers. Although based on the same dermal and inhalation exposure routes as the re-entry indicator, the details of the calculations in the greenhouse indicator are slightly different and therefore yield numerical outputs different from the re-entry indicator.

Since the set of risk indicators also considers the risk to residents and bystanders, the term 'occupational risk indicators' is somewhat a misnomer. However, since this name was originally chosen by the HAIR consortium it was decided to continue its use in order to avoid confusion. Consumer risk, as a result of consumption of food products contaminated by PPP, is not considered by occupational risk indicators.

Acute and chronic risk indicators
The distinction between acute and chronic indicators is largely based on an expectation about the duration of the exposure. The indicators dealing with operators, re-entry workers and greenhouse workers distinguish between acute and chronic exposures solely on the basis of the number of applications occurring. If a pesticide is applied to a crop only once, then the resulting exposure is deemed acute and only the acute risk indicators are calculated (the chronic risk indicator is set to a value of zero). If a pesticide is applied to a crop in a number of multiple applications at a regular interval, then the resulting exposure is deemed chronic and only the chronic risk indicators are calculated and the acute risk indicators are set to a value of zero. In line with the application definition (Section 1.5.1) we make the distinction between single applications and multiple applications in this chapter.

Similarly, the indicators for bystander and children are acute in nature, only dealing with single applications. The indicator for residents is calculated only for multiple applications, and is therefore chronic in nature.

This distinction between acute and chronic indicators on the basis of the number of applications is based on (Garreijn et al., 2007), where acute and chronic indicators are described in separate sections and the number of applications is assumed to be 1 for acute indicators and > 1 for chronic indicators.

There is, however, some ambiguity what should be understood by 'the number of applications'. For field based use data referring to a single field, it is obvious whether the use of a compound in a specific crop occurs once or several times over a year in that field. The occurrence of multiple applications in that field would then cause the calculation of the chronic indicator.

However, calculations of the HAIR occupational indicators will most times be based on regional or national scale (grouped) use data. Regional use data reflect an average application pattern over all fields growing a crop in that region.

Multiple records of application of an active ingredient in a specific crop, describing the use of the active ingredient in different fields at different times, may be grouped into one record for the entire region. Such regional (grouped) use data may contain an average number of applications, when both multiple and single applications occur in the field-collected source data (Thomas, 2007). The same applies to surrogate use data derived from sales data, approval regulations and label recommendations, as described in (Thomas, 2007, Chapter 3).

Therefore multiple records resulting from usage in different fields at different times can not readily be distinguished from multiple records resulting from true multiple usage in some or all of the fields. For this reason, it is assumed that multiple use in a field occurred only for the records in the Usage database that specify a number of applications > 1. The result is that only for records specifying > 1 applications chronic occupational indicators are calculated in the HAIR software. In many cases this may result in an underestimation of chronic toxicity, since some situations where multiple applications occurred will be 'hidden' in the usage records specifying a single application. On the other hand, including the records specifying single application into the calculation of chronic occupational indicators would most likely result in an overestimation of chronic toxicity and an underestimation of acute toxicity. From the above it follows that the extent of the underestimation of chronic toxicity will be very dependent on the accuracy to which records in the Usage database reflect the actual occurrence of multiple applications in single fields, which may differ widely between regional and national data sets from different regions and member states.

Within the framework of HAIR, the systemic Acceptable Operator Exposure Level/AOEL (mg a.i. kg body weight^{-1} d^{-1}) is used as the toxicological reference against which the estimated human exposure is compared, i.e. the value of the various human risk indicators are calculated as the ratio between the estimated exposure and the AOEL. Garreyn et al. (2007) point out that in the HAIR database only short-term AOELs are provided, which can be 'applied in order to cover effects that may arise from a single exposure or repeated (isolated) single exposures (i.e. at intervals that enable clearance of the active substance from the body).' Furthermore they state that 'AOELs based on long-term toxicity studies should be used in the chronic risk assessment. This applies for these cases where operators or re-entry workers are exposed for more than three months per year.' Since the calculated risk indicators, including the chronic ones, do not cover periods over 3 months, all calculations are based on short-term AOELs.

Exposure routes considered
All of the occupational indicators consider a combination of
1. dermal exposure through contact of the skin with a plant protection product, and
2. exposure through inhalation of vapor.

All of the occupational indicators enable consideration of the use of personal protection equipment (PPE). However, for the typical regional type of use data relevant knowledge will usually be very limited. Operators and re-entry workers are assumed to use PPE throughout the calculations, reducing their exposure by 90%. Non-workers, i.e. bystanders, children and residents, are not assumed to use any PPE at all and are therefore assumed to undergo the maximal potential exposure.

The efficiency of the uptake of compounds through skin and in the lung is estimated through the use of dermal and inhalation absorption factors. Dermal absorption is estimated as default 100%, except for compounds with high molecular weight (M > 500 g mol^{-1}) and extremely low or high lipophilicity (log(K_{ow}) either below -1 or above 4), for wich dermal absorption is assumed to be 10% (de Heer et al., 1999). Inhalation absorption is estimated as default 100% for all compounds.

Table 23
Data availability for factors determining exposure and methods of applications present in two example Usage databases.

Method of Application		Remarks	Present in example Usage database		Data availability
Code	Description		UK	NL	
GS	Vehicle ground boom and other downward spraying	Downward	Yes	Yes	Exposure factors for most types of formulations available
GSUP	Outdoor upward spraying	Upward	No	Yes	
SS	Soil sterilant treatment		Yes	Yes	No exposure factors available
ST	Seed treatment		Yes	Yes	No exposure factors available
GB	Granular broadcast	Downward, mechanical	Yes	Yes	Exposure factors for most types of formulations available
GI	Granular incorporated	Downward, mechanical	Yes	Yes	Exposure factors for most types of formulations available
LVM	Low volume misting	Used in occupational indicators	No	Yes	FST value available
RFG	Roof fogging	*(Currenctly not used HAIR)*	No	No	FST value available
MANUAL	Handheld spraying	Downward	No	Yes	
MANUP	Handheld upward spraying	Upward	No	Yes	
SPRGRH	Spraying techniques typical for greenhouses	Assumed: always downward	No	Yes	No FST value available
DUST	Dusting	Not yet used in indicators	No	Yes	No exposure factors available

Consistency of units
In the original document on occupational indicators by Garreyn et al. (2007) not all indicators were consistent with regard to units of parameters in equations, e.g. for some indicators application rate had to be entered into the equations as kg a.i. ha^{-1}, whereas the equations for other indicators assumed that the application rate was entered as mg a.i. m^{-2}. The equations in the present document have, where necessary, been adapted to ensure consistent parameter dimensions throughout the equations used (i.e. application rate in kg a.i. ha^{-1}).

6.2 Operators indicators

6.2.1 Acute risk for operators

Operators are presumed to be exposed during the mixing of pesticides, during loading of the spraying equipment and during the actual spraying of the active substance. The total exposure is the sum of exposures during mixing/loading and during application. The risk indicator is calculated for each event by dividing the calculated exposure by the Acceptable Operator Exposure Level.

The acute indicator applies to situations where only one application is performed, the corresponding chronic indicator applies to situations where multiple applications on a single field occur.

Scope
Both operator indicators apply to outdoor crops and do not apply to indoor crops (greenhouses and other protected crop systems). In addition, the operator indicators are not applicable to soil sterilants, and seed treatment (method of application codes ST, SS). The acute risk indicator for operators applies to single applications, and not to multiple applications.

Both operator indicators are calculated in exactly the same way, using the same equations and data, the only distinction being single or multiple application.

Main equations, calculation algorithm

$$\begin{gathered} Ab_{body} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{body} = Ab_{body,low}\} ELSE\{Ab_{body} = Ab_{body,high}\} \end{gathered}$$ Equation 114

$$\begin{gathered} Ab_{hand} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{hand} = Ab_{hand,low}\} ELSE\{Ab_{hand} = Ab_{hand,high}\} \end{gathered}$$ Equation 115

Ab_{body}	Dermal absorption factor (-)
$Ab_{body,low}$	Low body absorption factor (-)
$Ab_{body,high}$	High body absorption factor (-)
M	Molecular weight (g mol^{-1})
Log Kow	Logarithm of the octanol-water partition coefficient (-)
Ab_{hand}	Hand absorption factor (-)
$Ab_{hand,low}$	Low hand absorption factor (-)
$Ab_{hand,high}$	High hand absorption factor (-)

$$\begin{aligned} IE_{mix/load} &= (MixLoadInhal * PPE_{inhal} * Ab_{inhal}) \\ &+ (MixLoadHand * PPE_{hand} * Ab_{hand}) \end{aligned}$$ Equation 116

$IE_{mix/load}$	Internal exposure mixer/loader (mg a.i. person^{-1} d^{-1})
MixLoadInhal	Exposure mixer/loader through inhalation (mg a.i. kg body weight^{-1})
MixLoadHand	Exposure mixer/loader through hand (mg a.i. kg body weight^{-1})
PPE_{inhal}	Personal protection inhalation (-)

PPE_{hand} Personal protection gloves (-)
Ab_{inhal} Inhalation absorption factor (-)
Ab_{hand} Hand absorption factor (-)

$$IE_{applic} = (ApplicInhal * PPE_{inhal} * Ab_{inhal}) + (ApplicHand * PPE_{hand} * Ab_{hand}) + (ApplicDermal * PPE_{cloths} * PPE_{body} * Ab_{body}) \quad \text{Equation 117}$$

IE_{applic} Internal exposure applicator (mg a.i. person^{-1} d^{-1})
PPE_{inhal} Personal protection inhalation (-)
PPE_{hand} Personal protection gloves (-)
PPE_{cloths} Personal protection cloths (overall) (-)
PPE_{body} Personal protection body (-)
ApplicInhal Exposure applicator through inhalation (mg a.i. kg body weight^{-1})
ApplicHand Exposure applicator through hand (mg a.i. kg body weight^{-1})
ApplicDermal Exposure applicator through skin (mg a.i. kg body weight^{-1})
Ab_{inhal} Inhalation absorption factor (-)
Ab_{hand} Hand absorption factor (-)
Ab_{body} Dermal absorption factor (-)

Acute internal exposure, single applications:

$$IE_{operator,acute} = (IE_{mix/load} + IE_{applic}) * \frac{AR * A}{BW_{worker}} \quad \text{Equation 118}$$

$IE_{operator,acute}$ Internal, acute exposure for operator (mg a.i. person^{-1} d^{-1})
$IE_{mix/load}$ Internal exposure mixer/loader (mg a.i. person^{-1} d^{-1})
IE_{applic} Internal exposure applicator (mg a.i. person^{-1} d^{-1})
AR Application rate (kg a.i. ha^{-1})
A Area treated (ha)
BW_{worker} Body weight worker (kg)

The acute risk indicator:

$$RI_{operator,acute} = IE_{operator,acute} / AOEL \quad \text{Equation 119}$$

$IE_{operator,acute}$ Internal, acute exposure for operator (mg a.i. person^{-1} d^{-1})
$RI_{operator,acute}$ Risk indicator operator,acute (-)
AOEL Acceptable Operator Exposure Level (mg a.i. kg body weight^{-1} d^{-1})

Derived parameter values
The parameters MixLoadInhal, MixLoadHand, ApplicInhal, ApplicHand and ApplicDermal are stored in the HAIR database (Table 24). Selection of the appropriate value is made on the basis of method of application and type of formulation, both of which are stored in the Usage database.

The values used for the dermal absorption coefficients Ab_{body} and Ab_{hand} are derived from physico-chemical properties (molecular mass and octanol-water partition coefficient, both stored in the Compound database). A value of $Ab_{body,low}$ is assumed when M > 500 g mol^{-1} and $\log(K_{ow})$ is either smaller than -1 or higher than 4. Otherwise a value of $Ab_{body,high}$ is assumed. The same rule applies to Ab_{hand} (Table 25).

Inhalation absorption is estimated as default 100% for all compounds.

Table 24
Application factors for various combinations of method of application and type of formulation (stored in the HAIR database, based on the POEM table in Garreijn et al., 2007).

Method of application	Formulation type	MixLoadInhal	MixLoadHand	ApplicInhal	ApplicHand	ApplicDermal
GS	EC	0.005	20	0.008	2	0.6
GSUP	EC	0.005	20	0.03	11	63
MANUAL	EC	0.1	120	0.01	100	250
MANUP	EC	0.1	120	1	65	1100
GS	WP	1	100	0.008	2	0.6
GSUP	WP	1	100	0.03	11	63
MANUAL	WP	1	100	0.01	100	250
MANUP	WP	1	100	1	65	1100
GS	Granular	0.1	1	0.008	2	0.6
GSUP	Granular	0.1	1	0.03	11	63
MANUAL	Granular	0.1	21	0.01	100	250
MANUP	Granular	0.1	21	1	65	1100
GB	Granular	0.1	2	1.00E-09	1.00E-09	1.00E-09
GI	Granular	0.1	2	1.00E-09	1.00E-09	1.00E-09

Table 25
Input parameters for the risk indicators for operators (HAIR database).

Name	Value
$Ab_{body, low}$	0.1
$Ab_{body ,high}$	1.0
$Ab_{hand, low}$	0.1
$Ab_{hand, high}$	1.0
Ab_{inhal}	1.0
BW_{worker}	70
PPE_{body}	0.2
PPE_{cloths}	0.5
PPE_{hand}	0.1
PPE_{inhal}	0.1

6.2.2 Chronic risk for operators

Operators are presumed to be exposed during the mixing of pesticides, during loading of the spraying equipment and during the actual spraying of the active ingredient. The total exposure is the sum of exposures during mixing/loading and during application. The risk indicator is calculated for each event by dividing the calculated exposure by the Acceptable Operator Exposure Level.

The chronic risk indicator applies to situations where multiple applications are performed, the corresponding acute risk indicator applies to situations where a single application on a single field occurs.

Scope
Both operator indicators apply to outdoor crops and do not apply to indoor crops (greenhouses and other protected crop systems). In addition, the operator indicators are not applicable to soil sterilants, and seed treatment (method of application codes ST, SS). The chronic risk indicator for operators applies to multiple applications, and not to single applications.

Both operator indicators are calculated in exactly the same way, using the same equations and data, the only distinction being single or multiple application.

Main equations, calculation algorithm

The dermal absorption factor Ab_{body} (-): Equation 114

The hand absorption factor Ab_{hand} (-): Equation 115

The internal exposure mixer/loader $IE_{mix/load}$ (mg a.i. person^{-1} d^{-1}): Equation 116

The internal exposure applicator IE_{applic} (mg a.i. person^{-1} d^{-1}): Equation 117

Chronic internal exposure (number of application events > 1):

$$IE_{operator,chronic} = \frac{n}{DaysPerYear} * (IE_{mix/load} + IE_{applic}) * \frac{AR * A}{BW_{worker}} \quad \text{Equation 120}$$

$IE_{operator,chronic}$	Internal, chronic exposure for operator (mg a.i. person^{-1} d^{-1})
n	number of application events (-)
DaysPerYear	number of days in a year (= 365)
$IE_{mix/load}$	Internal exposure mixer/loader (mg a.i. person^{-1} d^{-1})
IE_{applic}	Internal exposure applicator (mg a.i. person^{-1} d^{-1})
AR	Application rate (kg a.i. ha^{-1})
A	Area treated (ha)
BW_{worker}	Body weight worker (kg)

The chronic risk indicator value:

$$RI_{operator,chronic} = IE_{operator,chronic} / AOEL \quad \text{Equation 121}$$

$IE_{operator,chronic}$	Internal, chronic exposure for operator (mg a.i. person^{-1} d^{-1})
$RI_{operator,chronic}$	Risk indicator operator, chronic (-)
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body weight^{-1} d^{-1})

Derived parameter values
The parameters MixLoadInhal, MixLoadHand, ApplicInhal, ApplicHand and ApplicDermal are stored in the HAIR database (Table 24). Selection of the appropriate value is made on the basis of method of application and type of formulation, both of which are stored in the Usage database.

The values used for the dermal absorption coefficients Ab_{body} and Ab_{hand} are derived from physico-chemical properties (molecular mass and octanol-water partition coefficient, both stored in the Compound database). A value of $Ab_{body,low}$ is assumed when M > 500 g mol^{-1} and $\log(K_{ow})$ is either smaller than -1 or higher than 4. Otherwise a value of $Ab_{body,high}$ is assumed. The same rule applies to Ab_{hand} (Table 25).

6.2.3 Remarks

The difference between acute and chronic exposure is the number of applications that occur on a field. The exposure due to multiple applications is considered to contribute to chronic toxicity, whereas single applications (n = 1) contribute to acute toxicity only. Chronic exposures are averaged over a 365-day period, and should be compared to a chronic AOEL. However, chronic AOEL data are not available. Acute exposures are not averaged and are compared to an acute AOEL (which is the value generally available in the Compound database).

Detailed information on the usage of personal protection equipment is not available; it is assumed that all operators use PPE. Using PPE reduces the risk 10-fold (from 1 to 0.1), except for using body (non-hand) PPE which reduces the risk 5-fold (from 1.0 to 0.2).

Wearing normal clothing (overalls) during application is assumed to already reduce exposure of the body by 50% (hence the multiplication factor PPE_{cloths} = 0.5, Equation 117, right hand side, 3rd term).

Use of (non-hand) body PPE further reduces risk by another 80% (default value for PPE_{body} = 0.2).

Exposure factors (ApplicDermal, MixLoadHand etc.) are dependent upon type of formulation, the type of application equipment (method of application), whether the application occurs indoor or outdoor, and on spraying direction (up/down). In Table 24 exposure factors are given for all relevant combinations of formulation type and method of application, for which the HAIR consortium provided information.

For an application in the Usage database, the required information is found in:
- HAIR application crop name: Usage database
- Method of application: Usage database
- Decision of indoor or outdoor application is not relevant, since this indicator is not calculated for greenhouse crops and other indoor crop systems;
- Decision on upward or downward technique is based on method of application stored in the Usage database; all methods of application are assumed to be downward, except GSUP and MANUP which are upward;
- Decision whether the treatment concerns a mechanical or manual application is based on the method of application given in the usa database: all methods of application are assumed to be mechanical except MANUAL and MANUP which are manual.
- Formulation type: Usage database
- On the basis of this information exposure factors can be selected (MixLoadInhal, MixLoadHand, ApplicInhal, ApplicHand, ApplicDermal) for each type of formulation relevant for the used method of application.

6.3 Re-entry workers

6.3.1 Acute risk for re-entry workers

Re-entry workers are exposed to pesticides during their working activities, but are not involved in the actual application process. Entering pesticide-treated fields or greenhouses to perform tasks such as pruning, inspecting, thinning or harvesting can occur several times during the growing season. Dermal exposure possibly occurs through contact with leaves and soil. Soil contact is only relevant for very specific scenarios where no or hardly any contact with treated foliage occurs, e.g. the use of compost treated with insecticide or manual harvesting of root crops. For this reason dermal exposure through soil contact is not taken into account.

Scope
Both risk indicators for re-entry workers apply to open field and greenhouse (indoor) applications. The acute risk indicator for re-entry workers only applies to single applications, and does not apply to multiple applications.

Both risk indicators for re-entry workers are calculated using almost the same equations and data. Besides of the distinction between single or multiple applications, inhalation is not considered in the chronic risk indicator for re-entry workers for compounds with vapor pressure $P_{vap} \leq 1.35\ 10^{-3}$ mPa (at 20°C). The scope of the acute risk indicator for re-entry workers does include compounds with such low vapor pressures.

Main equations, calculation algorithm

$$Ab_{dermal} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{dermal} = Ab_{dermal,low}\} ELSE\{Ab_{dermal} = Ab_{dermal,high}\}$$ Equation 122

Ab_{dermal}	Dermal absorption factor (-)
$Ab_{dermal,low}$	Low dermal absorption factor (-)
$Ab_{dermal,high}$	High dermal absorption factor (-)
M	Molecular weight (g mol^{-1})
Log Kow	Logarithm of the octanol-water partition coefficient (-)

$$DERMAL_{re-entry} = 0.01 * \frac{AR}{LAI} * TF * WR * PPE_{body}$$ Equation 123

$DERMAL_{re-entry}$	Dermal exposure (mg a.i. person^{-1} d^{-1})
AR	application rate (kg a.i. ha^{-1})
LAI	Leaf area index (-)
TF	Transfer factor (cm^2 h^{-1})
WR	Work rate, duration of re-entry (h d^{-1})
PPE_{body}	Factor for protection (-)

$$INHALE_{re-entry} = AR * TSF * WR$$ Equation 124

$INHALE_{re-entry}$	Inhalation exposure (mg a.i. person^{-1} d^{-1})
AR	application rate (kg a.i. ha^{-1})

TSF Task specific factor (-)
WR Work rate, duration of re-entry (h d^{-1})

$$IE_{re-entry} = \frac{DERMAL_{re-entry} * Ab_{dermal} + INHALE_{re-entry} * Ab_{inhale}}{BW_{worker}} \quad \text{Equation 125}$$

$IE_{re-entry}$	Internal exposure re-entry worker (mg a.i. $person^{-1}$ d^{-1})
$RI_{re-entry,acute}$	Risk indicator for re-entry, acute (-)
$DERMAL_{re-entry}$	Dermal exposure (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal}	Dermal absorption factor (-)
BW_{worker}	Body weight worker (kg)
$INHALE_{re-entry}$	Inhalation exposure (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale}	Inhalation factor (-)

Acute risk indicator for re-entry worker:

$$RI_{re-entry,acute} = \frac{IE_{re-entry}}{AOEL} \quad \text{Equation 126}$$

$RI_{re-entry,acute}$	Risk indicator for re-entry, acute (-)
$IE_{re-entry}$	Internal exposure re-entry worker (mg a.i. $person^{-1}$ d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})

6.3.2 Chronic risk for re-entry workers

Re-entry workers are exposed to pesticides during their working activities, but are not involved in the actual application process. Entering pesticide-treated fields or greenhouses to perform tasks such as pruning, inspecting, thinning or harvesting can occur several times during the growing season. Dermal exposure possibly occurs through contact with leaves and soil. Soil contact is only relevant for very specific scenarios where no or hardly any contact with treated foliage occurs, e.g. the use of compost treated with insecticide or manual harvesting of root crops. For this reason dermal exposure through soil contact is not taken into account.

Scope
Both risk indicators for re-entry workers apply to open field and greenhouse (indoor) applications. The chronic risk indicator for re-entry workers only applies to multiple applications, and does not apply to single applications.

Both risk indicators for re-entry workers are calculated using almost the same equations and data. Besides of the distinction between single or multiple applications, inhalation is not considered in the chronic risk indicator for re-entry workers for compounds with vapor pressure $P_{vap} \leq 1.35\ 10^{-3}$ mPa (at 20°C). For compounds with such a low vapor pressure, exposure through inhalation is assumed to be zero.

Main equations, calculation algorithm

The dermal absorption factor Ab_{dermal} (-): Equation 122

$$DERMAL_{re-entry} = 0.01 * n * \frac{AR}{LAI} * TF * WR * PPE_{body} * \frac{WD}{DaysPerYear} \qquad \text{Equation 127}$$

$DERMAL_{re-entry}$	Dermal exposure (mg a.i. $person^{-1}$ d^{-1})
n	number of application events (-)
AR	application rate (kg a.i. ha^{-1})
LAI	Leaf area index (-)
PPE_{body}	Factor for protection (-)
TF	Transfer factor (cm^2 h^{-1})
WR	Work rate, duration of re-entry (h d^{-1})
DaysPerYear	number of days in a year (= 365)

$$INHALE_{re-entry} = 0 \qquad P_{vap} \leq 1.35\ 10^{-3} mPa$$

$$INHALE_{re-entry} = n * AR * TSF * WR \qquad P_{vap} > 1.35\ 10^{-3} mPa \qquad \text{Equation 128}$$

$INHALE_{re-entry}$	Inhalation exposure (mg a.i. $person^{-1}$ d^{-1})
P_{vap}	saturated vapour pressure (mPa)
n	number of application events (-)
AR	application rate (kg a.i. ha^{-1})
TSF	Task specific factor (-)
WR	Work rate, duration of re-entry (h d^{-1})

The Internal exposure re-entry worker, $IE_{re-entry}$(mg a.i. $person^{-1}$ d^{-1}): (Equation 125)

Chronic risk indicator for re-entry worker:

$$RI_{re-entry,chronic} = \frac{IE_{re-entry}}{AOEL} \qquad \text{Equation 129}$$

$RI_{re-entry,acute}$	Risk indicator for re-entry, acute (-)
$IE_{re-entry}$	Internal exposure re-entry worker (Equation 125) (mg a.i. $person^{-1}$ d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})

6.3.3 Remarks

The acute risk indicator for re-entry workers applies to situations where only one application is performed, the chronic risk indicator for re-entry workers applies to situations where multiple applications on a single field occur.

Inhalation exposure resulting from applications to outdoor crops, including exposure through inhalation of dust, is not taken into account because of the very low expected exposures.

The calculation of inhalation exposure resulting from applications to indoor crops is presently limited to the methods of application low volume misting (code LVM) and roof fogging (code RFG), since data necessary for the calculation is not available for other application techniques.

Pesticide concentrations on leaves decrease in time, and the dermal exposure of the worker is therefore dependent on the time between re-entry and application of the pesticide. Since no information with regard to the time between re-entry and application is available, a worst case scenario is assumed, where re-entry occurs shortly after application.
Exposure through re-entry is assumed to occur only once per growing season per application.

Table 26
Input parameters for the risk indicators for re-entry workers (HAIR database).

Name	Value
$Ab_{dermal, low}$	0.1
$Ab_{dermal ,high}$	1.0
Ab_{inhal}	1.0
BW_{worker}	70
PPE_{body}	0.1
WR	8
TSF (Method of application code LVM)	0.03
TSF (Method of application code RFG)	0.15

The value for the Task Specific Factor (TSF) is on the basis of the method of application in the Usage data-base. Values for TSF are at present only available for the methods of application low volume misting (code LVM) and roof fogging (code RFG). For all other methods of application TSF is set to zero. Moreover, the application method RFG is currently not used in HAIR.

6.4 Greenhouse workers

6.4.1 Acute risk for greenhouse workers

Greenhouse workers are exposed through dermal and inhalation exposure. The dermal exposure for the greenhouse worker is estimated in the same way as for the re-entry worker.

Inhalation exposure is calculated according to the principle in USES, based on average vapor concentrations after application.

Scope
Both risk indicators for greenhouse workers apply only to indoor crops (greenhouses and other protected crop systems). The acute risk indicator for greenhouse workers applies only to single applications and does not apply to multiple applications. For outdoor crops and multiple applications the acute risk indicator for greenhouse workers is assumed zero.

Main equations, calculation algorithm

$$Ab_{dermal} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{dermal} = Ab_{dermal,low}\} ELSE\{Ab_{dermal} = Ab_{dermal,high}\}$$ Equation 130

Ab_{dermal}	dermal absorption factor (-)
$Ab_{dermal,low}$	low dermal absorption factor (-)
$Ab_{dermal,high}$	high dermal absorption factor (-)
M	molecular weight (g mol^{-1})
Log Kow	logarithm of the octanol-water partition coefficient (-)

$$DERMAL_{greenhouse} = 0.01 * \frac{AR}{LAI} * TF * WR * PPE_{greenhouse}$$ Equation 131

$DERMAL_{greenhouse}$	dermal exposure greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
LAI	leaf area index (-)
TF	transfer factor (cm^2 h^{-1})
WR	work rate, duration of re-entry (h d^{-1})
$PPE_{greenhouse}$	factor for protection, greenhouse worker (-)

$$V_{gh} = W_{gh} * L_{gh} * H_{gh}$$ Equation 132

V_{gh}	volume of greenhouse (m^3)
W_{gh}	width of greenhouse (m)
L_{gh}	length of greenhouse (m)
H_{gh}	average height of greenhouse (m)

$$k_{dep} = 5.5E4 * \frac{ISA}{V_{gh}}$$ Equation 133

k_{dep}	deposition rate (s^{-1})
ISA	inner surface area (m^2)
V_{gh}	volume of greenhouse (m^3)

$$C_0 = AR * 1E5 * \frac{1}{H_{gh}}$$ Equation 134

C_0	initial concentration in greenhouse (mg a.i. m^{-3})
AR	application rate (kg a.i. ha^{-1})
H_{gh}	average height of greenhouse (m)

$$C_{gh} = \frac{recover * C_0 * (1 - e^{-ExposureDuration*(k_{dep} + k_{ven})})}{ExposureDuration * (k_{dep} + k_{ven})}$$ Equation 135

C_{gh} concentration in greenhouse (mg a.i. m^{-3})
recover recovery factor (-)
C_0 initial concentration in greenhouse (mg m^{-3})
ExposureDuration exposure duration (s)
k_{dep} deposition rate (s^{-1})
k_{ven} ventilation rate (s^{-1})

$$C_{SAT} = \frac{P_{vap} * M * 1000}{R * T_{gh}}$$ Equation 136

C_{SAT} saturation concentration in air (mg a.i. m^{-3})
P_{vap} saturated vapour pressure (mPa)
M molar mass (g mol^{-1})
R molar gas constant (8.314 J mol^{-1} K^{-1})
T_{gh} temperature in the greenhouse (K)

$$C_{expose} = MIN(C_{gh}, C_{SAT})$$ Equation 137

C_{expose} exposure concentration in greenhouse (mg a.i. m^{-3})
C_{gh} concentration in greenhouse (mg a.i. m^{-3})
C_{SAT} saturation concentration in air (mg a.i. m^{-3})

$$INHALE_{greenhouse} = \frac{C_{expose} * InhalationRate_{Adult} * WR}{1000}$$ Equation 138

$INHALE_{greenhouse}$ Inhalation exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
C_{expose} exposure concentration in greenhouse (mg a.i. m^{-3})
$InhalationRate_{Adult}$ inhalation rate for adults (m^3 d^{-1})
WR Work rate (h d^{-1})

$$IE_{greenhouse,acute} = \frac{DERMAL_{greenhouse} * Ab_{dermal} + INHALE_{greenhouse} * Ab_{inhale}}{BW_{worker}}$$ Equation 139

$IE_{greenhouse,acute}$ internal exposure for greenhouse worker, acute (mg a.i. $person^{-1}$ d^{-1})
$DERMAL_{greenhouse}$ dermal exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal} dermal absorption factor (-)
$INHALE_{greenhouse}$ inhalation exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale} inhalation factor (-)
BW_{worker} body weight worker (kg)

Acute risk indicator for greenhouse worker;

$$RI_{greenhouse,acute} = \frac{IE_{greenhouse,acute}}{AOEL}$$ Equation 140

$RI_{greenhouse,acute}$	risk indicator for greenhouse worker, acute (-)
$IE_{greenhouse,acute}$	internal exposure re-entry worker, acute (mg a.i. person^{-1} d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body weight^{-1} d^{-1})

Table 27
Input parameters for the actute risk indicator for greenhouse workers (HAIR database).

Name	Value
$Ab_{dermal, low}$	0.1
$Ab_{dermal ,high}$	1.0
Ab_{inhal}	1.0
BW_{worker}	70
ExposureDuration	28800 s
H_{gh}	4.5
InhalationRateAdult	1.25
ISA	450
k_{ven}	1.67 10^{-4}
L_{gh}	100
PPE	0.1
R	8.314
$Temp_{gh}$	293.15
W_{gh}	100
WR	8
YED	0.571

Table 28
Recovery values are choosen based on method of application and vapor pressure class.

Method of application	Vapor pressure class*	Recovery (-)
LVM	Low	0.10
LVM	Moderate	0.04
LVM	High	0.51
RFG	Low	0.10
RFG^	Moderate	0.71
RFG	High	0.51
SPRGRH	Low	0.10
SPRGRH	Moderate	0.02
SPRGRH	High	0.51

* High vapor pressure: > 10 mPa; moderate vapor pressure: 0.01 – 10 mPa; low vapor pressure: < 0.01 mPa

^ the application method RFG is currently not used in HAIR

6.4.2 Chronic risk for greenhouse workers

Greenhouse workers are exposed through dermal and inhalatory exposure. The dermal exposure for the greenhouse worker is estimated in the same way as for the re-entry worker.

Inhalation exposure is calculated according to the principle in EUROPOEM.

Scope
Both risk indicators for greenhouse workers apply only to indoor crops (greenhouses and other protected crop systems). The chronic risk indicator for greenhouse workers applies only to multiple applications and does not apply to single applications. For outdoor crops and single applications the chronic risk indicator for greenhouse workers is assumed zero.

Main equations, calculation algorithm
The dermal absorption factor Ab_{dermal} (-): Equation 130

$$DERMAL_{greenhouse} = 0.01 * n * \frac{AR}{LAI} * TF * WR * PPE_{greenhouse} * \frac{WD}{DaysPerYear}$$ Equation 141

$DERMAL_{greenhouse}$	dermal exposure greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
n	number of application events (-)
AR	application rate (kg a.i. ha^{-1})
LAI	leaf area index (-)
TF	transfer factor (cm^2 h^{-1})
WR	work rate (h d^{-1})
$PPE_{greenhouse}$	factor for protection, greenhouse worker (-)
WD	work days (d)
DaysPerYear	number of days in a year (= 365)

$$INHALE_{greenhouse} = AR * n * TSF * WR * \frac{WD}{DaysPerYear} * YED_{greenhouse}$$ Equation 142

$INHALE_{greenhouse}$	Inhalation exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
n	number of application events (-)
TSF	Task specific factor (-)
WR	Work rate (h d^{-1})
WD	work days (d)
DaysPerYear	number of days in a year (= 365)
$YED_{greenhouse}$	average working life/average life expectancy (-)

The value for TSF (Task Specific Factor) is determined in the same way as for the re-entry worker, on the basis of the method of application in the Usage database (Section 6.3.3).

$$IE_{greenhouse,chronic} = \frac{DERMAL_{greenhouse} * Ab_{dermal} + INHALE_{greenhouse} * Ab_{inhale}}{BW_{worker}}$$ Equation 143

$IE_{greenhouse,chronic}$	internal exposure for greenhouse worker, chronic (mg a.i. $person^{-1}$ d^{-1})
$DERMAL_{greenhouse}$	dermal exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal}	dermal absorption factor (-)
$INHALE_{greenhouse}$	inhalation exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale}	inhalation factor (-)
BW_{worker}	body weight worker (kg)

Acute risk indicator for greenhouse worker;

$$RI_{greenhouse,chronic} = \frac{IE_{greenhouse,chronic}}{AOEL}$$ Equation 144

$RI_{greenhouse,chronic}$	risk indicator for greenhouse worker, chronic (-)
$IE_{greenhouse,chronic}$	internal exposure, greenhouse worker, chronic (mg a.i. $person^{-1}$ d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})

Table 29
Input parameters for the chronic risk indicator for greenhouse workers (HAIR database).

Name	Value
$Ab_{dermal, low}$	0.1
$Ab_{dermal ,high}$	1.0
Ab_{inhal}	1.0
BW_{worker}	70
DaysPerYear	365
$PPE_{greenhouse}$	0.1
WD	200
WR	8
$YED_{greenhouse}$	0.571

6.4.3 Remarks

A map of the greenhouse crops and other indoor crops in the EU is not yet available. In order to be able to test and to demonstrate the acute and chronic risk indicators for greenhouse workers, a map of the greenhouse crops in the Netherlands was included in the HAIR database (Section 1.5.3). Currently, the risk indicators for greenhouse workers can only be calulated for the Netherlands.

6.5 Bystanders

6.5.1 Acute risk for bystanders

Bystanders may be exposed during applications to field crops and to greenhouses and other indoor crop systems.

Exposure near a field occurs through dermal exposure to spray drift (small droplets drifting through the air depositing on the skin of the bystander, and through inhalation of vapor originating from the field.

Spray drift near a field is calculated based on the Ganzelmeyer tables also used for the aquatic risk indicators (Section 3.2.2). However, whereas the aquatic indicators use a cumulative drift percentage which applies to the entire width of a small surface water (ditch), the bystander indicator uses a drift percentage at a fixed distance (E = 8 m) away from the application. Since the acute risk indicator for bystanders applies to single applications, the 90-percentile drift functions are used (Table 12).

Inhalation exposure next to sprayed fields is assumed to be equal to inhalation exposure for operators (Section 6.2.1), but lasting only 1 minute (operators are assumed to be exposed for 6 hours per day).

Bystanders living near to greenhouses are assumed not to be exposed through drift. Inhalation exposure next to greenhouses is assumed to last for 1 minute.

The exposure calculated does not account for multiple applications, since it is considered unlikely that the same bystander will be present during each separate application.

The acute risk indicator for bystanders is calculated by dividing the calculated exposure by the Acceptable Operator Exposure Level.

Scope

This acute risk indicator for bystanders applies to outdoor crops and to indoor crops (greenhouses and other covered crop systems).

For field applications dermal exposure occurs only during sprayed applications (codes GS, GSUP, LVM, MANUAL, MANUP, SPRGRH). For indoor crops dermal exposure is considered to be zero. Inhalation exposure may occur during all types of applications.

Main equations, calculation algorithm

Exposure in the open field (non-greenhouse applications)

$$\begin{gathered} Ab_{dermal} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{dermal} = Ab_{dermal,low}\} ELSE\{Ab_{dermal} = Ab_{dermal,high}\} \end{gathered} \qquad \text{Equation 145}$$

Ab_{dermal}	dermal absorption factor (-)
$Ab_{dermal,low}$	low dermal absorption factor (-)
$Ab_{dermal,high}$	high dermal absorption factor (-)
M	molecular weight (g mol^{-1})
Log Kow	logarithm of the octanol-water partition coefficient (-)

Spray drift exposure is calculated at fixed distance $E = 8$ m from the from the crop edge. The appropriate functions parameters are selected for the FOCUS drift crop and the crop development stage, as explained in Section 3.2.2. Considering that the distance $E = 8$ m from the crop edge is within the hinge distance defined for all combinations shown in Table 12;

$$Drift = A\ E^{B} f_{r} \qquad \text{Equation 146}$$

drift	percentage of application rate deposited (-)
A, B	regression parameters (Equation 38) (-)
E	distance (8 m)
f_r	drift mitigation factor for improved spraying equipment; user defined (-)

$$DERMAL_{bys\tan der,open} = AR * Drift * ExposedArea \qquad \text{Equation 147}$$

$DERMAL_{bystander,open}$	dermal exposure, field application, bystander (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
ExposedArea	exposed area of neck, hands and arms (m^2)

$$INHALE_{bystasnder,open} = \frac{1}{MinutesPerSixHours} * (ApplicInhal * PPE_{inhal}) * AR * A \qquad \text{Equation 148}$$

$INHALE_{bystander,open}$	inhalation exposure (mg a.i. $person^{-1}$ d^{-1})
MinPerSixHours	minutes per 6 hours
ApplicInhal	Exposure applicator through inhalation (mg a.i. kg body $weight^{-1}$)
PPE_{inhal}	Personal protection inhalation (-)
AR	application rate (kg a.i. ha^{-1})
A	area treated (= 1 ha)

Exposure near greenhouses

$$DERMAL_{bys\tan der,gh} = 0 \qquad \text{Equation 149}$$

$DERMAL_{bystander,gh}$	dermal exposure, greenhouse application, bystander (mg a.i. $person^{-1}$ d^{-1})
TF	transfer factor (cm^2 h^{-1})
WR	work rate (h d^{-1})
$PPE_{greenhouse}$	factor for protection, greenhouse worker (-)
WD	work days (d)
DaysPerYear	number of days in a year (= 365)

In the calculation of inhalation exposure an exposure duration of 60 seconds is assumed, equal to the exposure in the open field. The maximum exposure concentration that would occur when ventilating immediately after application is assumed.

$$A_{gh} = W_{gh} * H_{gh}$$ Equation 150

A_{gh}	area of greenhouse (m)
W_{gh}	width of greenhouse (m)
H_{gh}	average height of greenhouse (m)

$$k_{dep} = 5.5E4 * \frac{ISA}{V_{gh}}$$ Equation 151

k_{dep}	deposition rate (s^{-1})
ISA	inner surface area (m^2)
V_{gh}	volume of greenhouse (m^3)

$$C_0 = AR * 1E5 * \frac{1}{H_{gh}}$$ Equation 152

C_0	initial concentration in greenhouse (mg a.i. m^{-3})
AR	application rate (kg a.i. ha^{-1})
H_{gh}	average height of greenhouse (m)

$$C_{gh} = \frac{recover * C_0 * (1 - e^{-ExposureDuration*(k_{dep}+k_{ven})})}{ExposureDuration * (k_{dep} + k_{ven})}$$ Equation 153

C_{gh}	concentration in greenhouse (mg a.i. m^{-3})
recover	recovery factor (-)
C_0	initial concentration in greenhouse (mg m^{-3})
ExposureDuration	exposure duration (s)
k_{dep}	deposition rate (s^{-1})
k_{ven}	ventilation rate (s^{-1})

$$C_{SAT} = \frac{P_{vap} * M * 1000}{R * T_{gh}}$$ Equation 154

C_{SAT}	saturation concentration in air (mg a.i. m^{-3})
P_{vap}	saturated vapour pressure (mPa)
M	molar mass (g mol^{-1})
R	molar gas constant (8.314 J mol^{-1} K^{-1})
T_{gh}	temperature in the greenhouse (K)

$$C_{inside} = MIN(C_{gh}, C_{SAT})$$ Equation 155

C_{inside} concentration in greenhouse (mg a.i. m^{-3})
C_{gh} concentration in greenhouse (mg a.i. m^{-3})
C_{SAT} saturation concentration in air (mg a.i. m^{-3})

$$C_{expose} = \frac{C_{inside} * \left[\frac{k_{vent}}{k_{vent} + k_{dep}} \right] * V_{gh}}{Time * K_{gh} * A_{gh} * U} \qquad \text{Equation 156}$$

C_{expose} exposure concentration in greenhouse (mg a.i. m^{-3})
C_{inside} concentration in greenhouse (mg a.i. m^{-3})
k_{dep} deposition rate (s^{-1})
k_{ven} ventilation rate (s^{-1})
V_{gh} volume of greenhouse (m^3)
K_{gh} greenhouse construction factor (-)
A_{gh} area of greenhouse (m)
U wind velocity above greenhouse (m s^{-1})

$$INHALE_{bystander,greenhouse} = \frac{C_{expose} * IR * Time}{1000 * SecPerDay} * HrsPerDay \qquad \text{Equation 157}$$

$INHALE_{bystander,greenhouse}$ Inhalation exposure, greenhouse worker (mg a.i. $person^{-1}$ d^{-1})
C_{expose} exposure concentration in greenhouse (mg a.i. m^{-3})
IR inhalation rate (m^3 h^{-1})
Time time (h)
HrsPerDay hours per day
SecPerDay seconds per day

Based on the type of crop (open field crops or greenhouse crops) the internal exposure ($IE_{bystander}$) is calculated as the sum of dermal and inhalation exposure relevant to the application.

$$IE_{bystander} = \frac{(DERMAL_{bystander} * Ab_{dermal} + INHALE_{bystander} * Ab_{inhale})}{BW_{bystander}} \qquad \text{Equation 158}$$

$IE_{bystander}$ internal exposure for bystander, acute (mg a.i. $person^{-1}$ d^{-1})
$DERMAL_{bystander}$ dermal exposure, bystander (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal} dermal absorption factor (-)
$INHALE_{bystander}$ inhalation exposure, bystander (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale} inhalation factor (-)
BW_{worker} body weight bystander (kg)

Acute risk indicator for bystanders;

$$RI_{bystander} = IE_{bystander} / AOEL \qquad \text{Equation 159}$$

$RI_{bystander}$	risk indicator for bystander, acute (-)
$IE_{bystander}$	internal exposure for bystander, acute (mg a.i. person^{-1} d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body weight^{-1} d^{-1})

The exposure factors MixLoadInhal and ApplicInhal are dependent upon type of formulation, the type of application equipment (method of application), indoor/outdoor application and spraying direction (up/down). In HAIR the distinction between indoor and outdoor crop systems and between upward and downward spraying technique is made based on the method of application. This information is part of the application definition and stored in the Usage database.

In Table 24 the exposure factors are given for all combinations of method of application and formulation type. If necessary and when possible, this table may be extended with additional information on exposure factors in the future.

For each application in the Usage database, the required information can be found:
– HAIR application crop name: Usage database
– Method of application: Usage database
– Exposure factors (MixLoadInhal, MixLoadHand, ApplicInhal, ApplicHand, ApplicDermal) for each type of formulation relevant for the used method of application: HAIR database

Table 30
Input parameters for the acute risk indicator for bystanders (HAIR database).

Name	Value
$Ab_{dermal, low}$	0.1
$Ab_{dermal ,high}$	1.0
Ab_{inhal}	1.0
$BW_{bystander}$	70
ExposedArea	0.425
ExposureDuration	60
GanzF	1
GanzX	8
H_{gh}	4.5
HrsPerDay	24
IR	1.25
ISA	450
k_{ven}	1.67 10^{-4}
K_{gh}	0.5
L_{gh}	100
MinutesPerSixHours	360
PPE_{inhal}	1
R	8.314
SecPerDay	86400
$Temp_{gh}$	293.15
U	3
W_{gh}	100

Recovery values are choosen based on method of application and vapor pressure class (Table 28).

6.6 Child bystanders

6.6.1 Acute risk for child bystanders

The acute risk indicator for child bystanders is a special case of the acute risk indicator for bystanders; children are more vulnerable because they have a lower body weight and have a higher rate of inhalation. Moreover, additional exposure through additional routes is considered:

- dermal exposure resulting from crawling on a lawn contaminated by spray drift, and
- exposure resulting from ingestion of turf residues (hand-to-mouth and object-to-mouth activity) contaminated through spray drift.

Exposure near a field occurs through both dermal and inhalation exposure. Exposure near a greenhouse occurs through inhalation exposure only.

Spray drift near a field is calculated based on the Ganzelmeyer tables also used for the aquatic risk indicators (Section 3.2.2). However, whereas the aquatic indicators use a cumulative drift percentage which applies to the entire width of a small surface water (ditch), the child bystander indicator uses a drift percentage at a fixed distance (E = 8 m) from the crop edge as well as from the lawn treated. Since the acute risk indicator for child bystanders applies to single applications, the 90-percentile drift functions are used (Table 12).

Inhalation exposure for children next to sprayed fields is calculated in the same way as outlined for bystanders.

The exposure calculated does not account for multiple applications, since it is considered unlikely that the same child bystander will be present during each separate application event.

The acute risk indicator for child bystanders is calculated by dividing the calculated exposure by the Acceptable Operator Exposure Level.

Inhalation exposure next to sprayed fields is assumed to be equal to inhalation exposure for operators (Section 6.2.1), but lasting only 1 minute (operators are assumed to be exposed for 6 hours per day).

Scope

The acute risk indicator for child bystanders applies both to outdoor crops and to indoor crops (greenhouses and other covered crop systems).

For field applications dermal exposure occurs only during sprayed applications (codes GS, GSUP, LVM, MANUAL, MANUP, SPRGRH). No dermal exposure is calculated for applications dealing with granules, pouring, dipping or when using treated seeds. For indoor crops dermal exposure is considered to be zero. Inhalation exposure may occur during all types of applications.

Main equations, calculation algorithm

Exposure in the open field, non-greenhouse

$$\begin{aligned} &Ab_{dermal} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ &THEN\{Ab_{dermal} = Ab_{dermal,low}\} ELSE\{Ab_{dermal} = Ab_{dermal,high}\} \end{aligned}$$ Equation 160

Ab_{dermal}	dermal absorption factor (-)
$Ab_{dermal,low}$	low dermal absorption factor (-)
$Ab_{dermal,high}$	high dermal absorption factor (-)
M	molecular weight (g mol^{-1})
Log Kow	logarithm of the octanol-water partition coefficient (-)

Spray drift exposure is calculated at fixed distance *E* = 8 m from the from the crop edge. The appropriate functions parameters are selected for the FOCUS drift crop and the crop development stage, as explained in Section 3.2.2. Considering that the distance *E* = 8 m from the crop edge is within the hinge distance defined for all combinations shown in Table 12;

$$Drift = A\, E^{B} f_{r}$$ Equation 161

drift	percentage of application rate deposited (-)
A, B	regression parameters (Equation 38) (-)
E	distance (8 m)
f_r	drift mitigation factor for improved spraying equipment; user defined (-)

$$DERMAL_{child,direct} = AR * Drift * ExposedAreaChildBody$$ Equation 162

$DERMAL_{child,direct}$	dermal exposure, child, direct by spray drift (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
drift	percentage of application rate deposited (-)
ExposedAreaChildBody	Body area child exposed to drift (m^2)

$$DERMAL_{child,lawn} = 10^{-4} * AR * Drift * TTR_{turf} * TF_{child} * DED_{child}$$ Equation 163

$DERMAL_{child,lawn}$	dermal exposure, child, lawn (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
drift	percentage of application rate deposited (-)
TTR_{turf}	turf transferable residue (-)
TF_{child}	transfer factor (cm^2 h^{-1})
DED_{child}	daily exposure duration (h d^{-1})

$$DERMAL_{child,turf} = 10^{-4} * AR * Drift * TTR_{turf} * SE * ExposedAreaChildFingers * Nevents * DED_{child}$$ Equation 164

$DERMAL_{child,turf}$	dermal exposure, child, turf (mg a.i. $person^{-1}$ d^{-1})
AR	application rate (kg a.i. ha^{-1})
drift	percentage of application rate deposited (-)
TTR_{turf}	turf transferable residue (-)
SE	saliva extraction factor (-)
ExposedAreaChildFingers	area of fingers (cm^2)
Nevents	number of hand/mouth events per hr (h^{-1})
DED_{child}	daily exposure duration (h d^{-1})

$$DERMAL_{child,object} = 10^{-4} * AR * Drift * TTR_{object} * IngestionRate$$ Equation 165

$DERMAL_{child,object}$	dermal exposure, child, object (mg a.i. person^{-1} d^{-1})
AR	application rate (kg a.i. ha^{-1})
drift	percentage of application rate deposited (-)
TTR_{object}	object transferable residue (-)
IngestionRate	ingestion rate (cm^2 grass d^{-1})

$$DERMAL_{child,open} = DERMAL_{child,direct} + DERMAL_{child,lawn} + DERMAL_{child,turf} + DERMAL_{child,object}$$ Equation 166

$DERMAL_{child,,open}$	dermal (skin) exposure, child, open field application (mg a.i. person^{-1} d^{-1})
$DERMAL_{child,direct}$	dermal exposure, child, direct by spray drift (mg a.i. person^{-1} d^{-1})
$DERMAL_{child,lawn}$	dermal exposure, child, lawn (mg a.i. person^{-1} d^{-1})
$DERMAL_{child,turf}$	dermal exposure, child, turf (mg a.i. person^{-1} d^{-1})
$DERMAL_{child,object}$	dermal exposure, child, object (mg a.i. person^{-1} d^{-1})

$$INHALE_{child,open} = \frac{1}{MinutesPerSixHours} * ApplicInhal * AR * A$$ Equation 167

$INHALE_{child,open}$	inhalation exposure (mg a.i. person^{-1} d^{-1})
MinPerSixHours	minutes per 6 hours
ApplicInhal	Exposure applicator through inhalation (mg a.i. kg body weight^{-1})
AR	application rate (kg a.i. ha^{-1})
A	area treated (= 1 ha)

Exposure near greenhouses

$$DERMAL_{child,greenhouse} = 0$$ Equation 168

$DERMAL_{child,greenhouse}$	dermal (skin) exposure, child, greenhouse application (mg a.i. person^{-1} d^{-1})

In the calculation of inhalation exposure an exposure duration of 60 seconds is assumed, equal to the exposure in the open field. The maximum exposure concentration that would occur when ventilating immediately after application is assumed. The exposure concentration is calculated according to the acute risk indicator for bystanders (Section 6.5.1, Equation 150 to Equation 156).

$$INHALE_{child,greenhouse} = \frac{C_{expose} * InhalationRate_{Child} * Time}{1000 * SecPerDay} * HrsPerDay$$ Equation 169

$INHALE_{child,greenhouse}$ Inhalation exposure, child bystander (mg a.i. $person^{-1}$ d^{-1})
C_{expose} exposure concentration in greenhouse (mg a.i. m^{-3})
$InhalationRate_{child}$ inhalation rate child (m^3 h^{-1})
Time time (h)
HrsPerDay hours per day
SecPerDay seconds per day

Based on the crop system (outdoor or indoor) the internal exposure (IE_{child}) is calculated as the sum of dermal and inhalation exposure relevant to the application. The value of the acute risk indicator for child bystanders is obtained by comparing internal exposure to the Acceptable Operator Exposure Level.

$$IE_{child} = \frac{(DERMAL_{child} * Ab_{dermal} + INHALE_{child} * Ab_{inhale})}{BW_{child}}$$ Equation 170

IE_{child} internal exposure for child bystander, acute (mg a.i. $person^{-1}$ d^{-1})
$DERMAL_{child}$ dermal exposure, bystander (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal} dermal absorption factor (-)
$INHALE_{child}$ inhalation exposure, child bystander (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale} inhalation factor (-)
BW_{worker} body weight child (kg)

Acute risk indicator for child bystanders;

$$RI_{child} = IE_{child} / AOEL$$ Equation 171

$RI_{child\ bystander}$ risk indicator for child bystander, acute (-)
$IE_{child\ bystander}$ internal exposure for child bystander, acute (mg a.i. $person^{-1}$ d^{-1})
AOEL Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})

The exposure factor ApplicInhal is dependent upon type of formulation, the type of application equipment (method of application), indoor/outdoor application and spraying direction (up/down). In HAIR the distinction between indoor and outdoor crop systems and between upward and downward spraying technique is made based on the method of application. This information is part of the application definition and stored in the Usage database.

In Table 24 the exposure factors are given for all combinations of method of application and formulation type. If necessary and when possible, this table may be extended with additional information on exposure factors in the future.

For each application in the Usage database, the required information can be found:
- HAIR application crop name: Usage database
- Method of application: Usage database
- Exposure factors for each type of formulation relevant for the used method of application: HAIR database

Table 31
Input parameters for the acute risk indicator for child bystanders (HAIR database).

Name	Value
$Ab_{dermal, low}$	0.1
$Ab_{dermal ,high}$	1.0
Ab_{inhal}	1.0
BW_{child}	15
DED	2
ExposedAreaChildBody	0.2
ExposedAreaChildFingers	20
ExposureDuration	60
GanzF	1
GanzX	8
HrsPerDay	24
H_{gh}	4.5
IngestionRate	25
InhalationRateChild	0.36
ISA	450
k_{ven}	$1.67\ 10^{-4}$
K_{gh}	0.5
L_{gh}	100
MinutesPerSixHours	360
Nevents	20
R	8.314
SE	0.50
SecPerDay	86400
$Temp_{gh}$	293.15
TF_{child}	5200
TTR_{object}	0.05
TTR_{turf}	0.05
U	3
W_{gh}	100

Recovery values are choosen based on method of application and vapor pressure class (Table 28).

6.7 Residents

6.7.1 Chronic risk for residents

The chronic risk indicator for residents describes the exposure of people living nearby fields. The risk to people living in the vicinity of greenhouses is not addressed by this indicator. Residents may be subject to a single exposure but also to multiple exposures due to repeated applications to a single crop.

Exposure near a field occurs through dermal exposure to spray drift (small droplets drifting through the air over a distance of 50 m) depositing on the skin of the bystander, and through inhalation of vapor originating on the field.

Spray drift is calculated based on the Ganzelmeyer tables (Section 3.2.2), but in a way slighly different from the drift calculation for the risk indicators for bystanders and for child bystanders (Sections 6.5.1, 6.6.1):

1. The chronic risk indicator for residents applies to a drift percentage at 50 m distance from the edge of the treated field, whereas the risk indicators for bystanders and for child bystanders apply to 8 m distance.
2. For multiple applications the percentile of the spray drift deposition data decreases with the number of applications (Table 32).
3. For multiple applications one drift percentage is used at all application events, instead of a drift percentage at each event. This drift percentage is the value corresponding with the crop stage at the application date.

For single applications the 90-percentile of drift percentage is used, similar to the acute risk indicator for bystanders and the acute risk indicator for child bystanders.

Inhalation exposure is assumed to be the same (and is calculated in the same way) as the operator inhalation exposure, using exposure factors which depend on several crop related factors (type of crop, mechanical or manual application, application direction, indoor or outdoor application) and the type of formulation used.

Residents are assumed to be exposed at the same daily level for 3 months, which according to the HAIR WP10 document is far greater than those living next to a treated field will actually experience.
The risk indicator is calculated for each event by dividing the calculated exposure by the Acceptable Operator Exposure Level.

Table 32
The percentile of the spray drift deposition data depending on the number of applications.

Number of applications	Percentile used
1	90
2	82
3	77
4	74
5	72
6	70
7	69
8 or more	67

Table 33
Drift deposition percentages used for the chronic risk indicator for residents.

FOCUS drift crop group	Crop stage #	percentile							
		90	82	77	74	72	70	69	67
Arable crops and small vegetables (< 0.5 m)	all stages	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03
Large vegetables (> 0.5 m)	all stages	0.1	0.08	0.08	0.08	0.08	0.07	0.07	0.04
Hops	all stages	0.13	0.09	0.08	0.08	0.07	0.07	0.06	0.02
Vines	not in mature stage	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.009
	mature stage	0.1	0.08	0.08	0.08	0.08	0.07	0.07	0.04
Fruits	not in mature stage	0.3	0.22	0.19	0.17	0.17	0.16	0.16	0.15
	mature stage	0.22	0.15	0.13	0.13	0.13	0.11	0.11	0.11

\# referred to as "early" (not in mature stage) and "late" (mature stage) in (Strassemeier et al., 2007).

Scope
The chronic risk indicator for residents applies only to outdoor crops and spraying applications (codes GS, GSUP, LVM, MANUAL, MANUP, SPRGRH). Exposure is not calculated for applications to greenhouse crops, nor for open field granular treatments and seed treatments (codes GB, GI, ST). for these applications, the chronic risk indicator for residents is assumed to be zero.

Main equations, calculation algorithm
Exposure in the open field, non-greenhouse

$$\begin{gathered} Ab_{dermal} : IF((M > 500) AND((\log Kow < -1) OR(\log Kow > 4))) \\ THEN\{Ab_{dermal} = Ab_{dermal,low}\} ELSE\{Ab_{dermal} = Ab_{dermal,high}\} \end{gathered}$$ Equation 172

Ab_{dermal}	dermal absorption factor (-)
$Ab_{dermal,low}$	low dermal absorption factor (-)
$Ab_{dermal,high}$	high dermal absorption factor (-)
M	molecular weight (g mol^{-1})
Log Kow	logarithm of the octanol-water partition coefficient (-)

$$DERMAL_{resident} = n * AR * Drift * ExposedArea * \frac{RD}{DaysPerYear}$$ Equation 173

$DERMAL_{resident}$	dermal exposure, field application, resident (mg a.i. $person^{-1}$ d^{-1})
n	number of application events (-)
AR	application rate (kg a.i. ha^{-1})
ExposedArea	exposed area of neck, hands and arms (m^2)
RD	residence days (d)
DaysPerYear	365

$$INHALE_{resident} = \frac{n}{MinutesPerSixHours} * ApplicInhal * AR * A * DED_{resident} * EF * YED_{resident}$$ Equation 174

$INHALE_{resident}$	inhalation exposure (mg a.i. $person^{-1}$ d^{-1})
MinPerSixHours	minutes per 6 hours
ApplicInhal	exposure applicator through inhalation (mg a.i. kg body $weight^{-1}$)
AR	application rate (kg a.i. ha^{-1})
A	area treated (= 1 ha)
$DED_{resident}$	Daily Exposure Duration (min)
EF	Exposure Frequency, fraction of year exposed (-)
$YED_{resident}$	Yearly Exposure Duration (-)

$$IE_{resident} = \frac{(DERMAL_{resident} * Ab_{dermal} + INHALE_{resident} * Ab_{inhale})}{BW_{resident}}$$ Equation 175

$IE_{resident}$	internal exposure for residents, chronic (mg a.i. $person^{-1}$ d^{-1})
$DERMAL_{resident}$	dermal exposure, resident (mg a.i. $person^{-1}$ d^{-1})
Ab_{dermal}	dermal absorption factor (-)
$INHALE_{resident}$	inhalation exposure, resident (mg a.i. $person^{-1}$ d^{-1})
Ab_{inhale}	inhalation factor (-)
BW_{worker}	body weight resident (kg)

Acute risk indicator for residents;

$$RI_{resident} = IE_{resident} / AOEL$$ Equation 176

$RI_{resident}$	chronic risk indicator for residents (-)
$IE_{resident}$	internal exposure for residents, chronic (mg a.i. $person^{-1}$ d^{-1})
AOEL	Acceptable Operator Exposure Level (mg a.i. kg body $weight^{-1}$ d^{-1})

The exposure factor ApplicInhal is dependent upon type of formulation, the type of application equipment (method of application), indoor/outdoor application and spraying direction (up/down). In HAIR the distinction between indoor and outdoor crop systems and between upward and downward spraying technique is made based on the method of application. This information is part of the application definition and stored in the Usage database.

6.7.2 Remarks

For multiple applications one drift percentage is used at all application events, instead of a drift percentage at each event. This drift percentage is the value corresponding with the crop stage at the application date. With this approximation, a change of exposure level at different application events with a transition of the crop development stage in vines and fruits may be disregarded.

7 Usage data aggregation

This chapter briefly describes some ways to aggregate field based pesticide usage data and/or to disaggregate country based usage and sales data, taking into account the data requirements of the risk indicators built in HAIR. These options are not implemented in HAIR2010, since the Usage database is regarded as an external database.

7.1 Pesticide usage

Three cases of usage data availability for calculating environmental and human risk indicators were described by (Strassemeier et al., 2007);

1. Field based application patterns, with each row in the usage database representing a single application to a specific field. This case was abandoned, because only a few member states will collect usage data at this spatial and temporal detail.
2. Regional grouped application patterns, with each row in the Usage database representing a risk event defined by average application parameters. These risk events are derived from field-collected data, with applications at different locations and at different time combined into one row of data per crop development stage.
3. Regional grouped applications, with each row in the Usage database representing a risk event described by annual average application parameters at country level. These risk events are based on the kind of statistics that are expected to be available from all member states in the near future.

Although field based application patterns are not supported in Hair, the format of the field based use data and regional use data are basically the same (Thomas, 2007). In principle, the routines in Hair for calculating the risk indicators can be used with all cases of usage data availability mentioned here. The Usage database contains no Field ID but the possibility does exist to incorporate such an ID by means of the Application ID that is printed to the HAIR csv output file. An exposure toxicity ratio ETR ≤ 1 calculated for a particular application indicates an acceptable risk, whereas higher values indicate towards a risk that may need to be further investigated.

Regional differences in use patterns resulting from heterogeneity in weather, cropping, and pest, weed and disease pressure are no part of pesticide statistics at country level, unless additional expertise or administrative sources can be included. In addition, the results will be different because the begin- and end dates of crop development stages vary with the crop calendar regions within the EU. In order to facilitate such a regional differentiation of national scale usage and sales data, all the crop calendars defined within the crop calendar regions in the European Union are described in Section 2.2 and in Annex 2. Case 3 seems to be most in line with the usage and sales data that will be available from the databases managed by DG-EUROSTAT (EU Regulation 1185/2009).

Other approaches than the ones mentioned in (Strassemeier et al, 2007, Thomas, 2007) may be followed as well. For example, the risk indicators calculated for the evaluation of the Dutch National Action Plan for sustainable use of pesticides are based on national average applications derived from detailed survey data conducted by Statistics Netherlands. The allocation of average amounts applied to the major Dutch agricultural crops is corrected based on annual sales data per compound provided by the Dutch crop protection association. Each application is defined by an average rate and by method of application, application technique, application time (month), number of applications, and application interval.

According to (Thomas, 2007), a row with regional grouped usage data may contain average values for the parameters

- Application date,
- Dose rate,
- Area treated,
- Number of application events, and
- Application interval.

However, we recommend to set the number of application events and the application interval to values that correspond with the information on the product label, when aggregating field based data or when disaggregating country based sales data. This would prevent from generating regional grouped usage data with unrealistic large numbers of application events and long application intervals. Such applications would lead to unrealistic outcomes of the risk indicators. See also Section 6.1, for a discussion of the distinction between acute and chronic occupational risk based on the number of applicaton events.

It can be expected that in many cases the total amount applied to a crop will be available on annual basis, for the crops mentioned in a National Action Plan. Such national data can be broken down based on the crop maps stored in the HAIR database. In addition, a distribution in time, of similar, field based applications can be converted into different rows of usage data with the same parameter values but with different application date.

If the data are available, one can split up the regional area treated according to;

- Methods of application,
- Formulation types,
- Buffer strip width, and
- Mitigation factor

7.2 Risk indicators

Options for aggregation and break-down of risk indicator outcomes are described in the HAIR2010 User Manual (Vlaming et al., 2011). These options include regions and gridcells, application month, chemical class and chemical use groups.
The HAIR csv output file contains the outcomes per unit of area treated, per combination of an application and gridcell. The calculated area treated per gridcell is included as well. This information can be used for post-processing, e.g. to calculate the area-weighted results.

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Annex 1 Crop classifications

Contents

A list of 205 application crops was created starting with crops in the UK for which MRL's are available, and expanded with crops likely to be encountered around the EU countries on which pesticides might be applied. Only these application crops can be referred to in the Usage database. Application crops are related to internal HAIR crops. All other crops and crop groups used for calculating the risk indicators in HAIR are defined as attributes of these internal HAIR crops. The HAIR crop definition was derived from 3 Farm Structure Survey (FSS) Reporting Regions with different agricultural crop classes at multiple levels. Redundant items were removed from and the distinction between cereal crops with a winter crop calendar and a spring crop calendar was added (Kruijne et al., 2007). The resulting list of 50 HAIR crops is included in Table 1-2.

The relation between application crops and HAIR crops (n : 1) is given in Table 1-1.

Table 1-1

List of Application crops (ID and name) with the corresponding HAIR crop. Application crop can be referred to in the Usage database. All other crops and crop groups used for calculating risk indicators are defined as attributes of these internal HAIR crops.

ID	Application crop name	ID	HAIR crop name
203	Winter wheat	1	Common wheat and spelt: Winter
179	Spring wheat	2	Common wheat and spelt: Spring
47	Durum wheat	3	Durum wheat: Winter
168	Rye	4	Rye: Spring
202	Winter barley	5	Barley: Winter
177	Spring barley	6	Barley: Spring
101	Oats	7	Oats: Winter
91	Maize (grain)	8	Grain maize
164	Rice	9	Rice
19	Buckwheat	10	Other cereals
98	Millet	10	Other cereals
110	Other cereals	10	Other cereals
174	Sorghum	10	Other cereals
193	Triticale	10	Other cereals
49	Field beans (fodder)	11	Pulses
82	Lentils	11	Pulses
88	Lupins	11	Pulses
125	Other pulses	11	Pulses
142	Peas (fodder)	11	Pulses
156	Potatoes seed	12	Potatoes
157	Potatoes ware	12	Potatoes
11	Beetroot	14	Fodder roots and brassicas
21	Carrots	14	Fodder roots and brassicas

ID	Application crop name	ID	HAIR crop name
23	Cassava	14	Fodder roots and brassicas
25	Celeriac	14	Fodder roots and brassicas
53	Fodder beet	14	Fodder roots and brassicas
69	Horseradish	14	Fodder roots and brassicas
71	Jerusalem artichokes	14	Fodder roots and brassicas
115	Other fodder crops	14	Fodder roots and brassicas
126	Other root & tuber vegetables	14	Fodder roots and brassicas
136	Parsley root	14	Fodder roots and brassicas
137	Parsnips	14	Fodder roots and brassicas
159	Radishes	14	Fodder roots and brassicas
169	Salsify	14	Fodder roots and brassicas
183	Sugar beet	14	Fodder roots and brassicas
185	Swedes	14	Fodder roots and brassicas
186	Sweet potatoes	14	Fodder roots and brassicas
194	Turnips	14	Fodder roots and brassicas
204	Yams	14	Fodder roots and brassicas
190	Tobacco	15	Tobacco
68	Hops	16	Hops
54	Fodder rape	18	Oil seed or fibre plants: Rape and turnip: Summer
55	Fodder turnips	18	Oil seed or fibre plants: Rape and turnip: Summer
102	Oilseed rape (summer)	18	Oil seed or fibre plants: Rape and turnip: Summer
205	Oilseed rape (winter)	18	Oil seed or fibre plants: Rape and turnip: Summer
184	Sunflowers	19	Oil seed or fibre plants: Sunflower
175	Soya beans	20	Oil seed or fibre plants: Soya
39	Cotton seed	21	Other oil-seed or fibre plants
67	Hemp seed	21	Other oil-seed or fibre plants
86	Linseed	21	Other oil-seed or fibre plants
99	Mustard seed	21	Other oil-seed or fibre plants
123	Other oilseeds	21	Other oil-seed or fibre plants
140	Peanuts	21	Other oil-seed or fibre plants
155	Poppy seed	21	Other oil-seed or fibre plants
171	Sesame seed	21	Other oil-seed or fibre plants
44	Cumin seed	22	Aromatic-; medicinal and culinary plants
66	Hemp	22	Aromatic-; medicinal and culinary plants
72	Juniper seed	22	Aromatic-; medicinal and culinary plants
95	Mangolds	22	Aromatic-; medicinal and culinary plants
96	Medicinal and culinary plants	22	Aromatic-; medicinal and culinary plants
100	Nutmeg	22	Aromatic-; medicinal and culinary plants
129	Other spices	22	Aromatic-; medicinal and culinary plants
145	Pepper, black and white	22	Aromatic-; medicinal and culinary plants
195	Vanilla pods	22	Aromatic-; medicinal and culinary plants
118	Other industrial plants	23	Other industrial plants
5	Asparagus	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
6	Aubergines (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
17	Broccoli (including calabrese)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
18	Brussels sprouts	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
20	Cardoons	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
24	Cauliflower	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
26	Celery (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
33	Chilli peppers	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
34	Chinese cabbage (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
40	Courgettes	24	Outdoor: Open field: Fresh vegetables; melons; strawberries

ID	Application crop name	ID	HAIR crop name
43	Cultivated mushrooms	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
48	Fennel (bulb)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
57	Garlic	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
58	Gherkins	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
59	Globe artichokes	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
65	Head cabbage	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
73	Kale (includes collards)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
75	Kohlrabi	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
80	Leeks	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
97	Melons	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
103	Okra	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
106	Onions (harvested dry)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
108	Other bulb vegetables	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
112	Other cucurbits-edible peel	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
113	Other cucurbits-inedible peel	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
114	Other flowering brassicas	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
116	Other head brassicas	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
119	Other leafy brassicas	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
122	Other miscellaneous fruit	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
128	Other solanacea	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
131	Other stem vegetables	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
134	Papaya	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
146	Peppers (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
150	Pineapples	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
153	Pomegranates	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
163	Rhubarb	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
173	Shallots	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
178	Spring onions	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
180	Squashes	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
181	Strawberries (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
187	Sweetcorn	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
192	Tomatoes (outdoor)	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
198	Watermelons	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
200	Wild mushrooms	24	Outdoor: Open field: Fresh vegetables; melons; strawberries
10	Beet leaves (chard)	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
28	Celery leaves	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
30	Chervil	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
32	Chicory	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
36	Chives	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
77	Lambs lettuce	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
78	Land cress	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
79	Leaves and stems of brassica	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
83	Lettuce (outdoor)	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
84	Lettuce (protected)	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
117	Other herbs	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
121	Other lettuce-like leaf vegetables	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
130	Other spinach-like leaf vegetables	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
135	Parsley	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
165	Rocket	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
170	Scarole (broad-leaf endive)	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
176	Spinach	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries
197	Watercress	25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries

ID	Application crop name	ID	HAIR crop name
27	Celery (protected)	26	Under glass: Vegetables; flowers and permanent crops
7	Aubergines (protected)	27	Under glass: Fresh vegetables; melons; strawberries
35	Chinese cabbage (protected)	27	Under glass: Fresh vegetables; melons; strawberries
42	Cucumbers (protected)	27	Under glass: Fresh vegetables; melons; strawberries
147	Peppers (protected)	27	Under glass: Fresh vegetables; melons; strawberries
161	Raspberries (protected)	27	Under glass: Fresh vegetables; melons; strawberries
182	Strawberries (protected)	27	Under glass: Fresh vegetables; melons; strawberries
191	Tomatoes (protected)	27	Under glass: Fresh vegetables; melons; strawberries
51	Flowers and ornamentals (outdoor)	28	Outdoor: Flowers and ornamental plants
52	Flowers and ornamentals (protected)	29	Under glass: Flowers and ornamental plants
90	Maize (fodder)	31	Forage plants: green fodder
16	Broad beans	35	Arable land: Other crops
56	French beans	35	Arable land: Other crops
93	Mange toute	35	Arable land: Other crops
120	Other legume vegetables	35	Arable land: Other crops
143	Peas (vining)	35	Arable land: Other crops
167	Runner beans	35	Arable land: Other crops
172	Set aside	36	Fallow land without subsidies
62	Grass less than 5 years old	38	Permanent grassland and meadow
148	Permanent grassland	38	Permanent grassland and meadow
166	Rough grazing	38	Permanent grassland and meadow
2	Apples (culinary)	39	Fruit and berry plantations excluding nuts
3	Apples (dessert)	39	Fruit and berry plantations excluding nuts
4	Apricots	39	Fruit and berry plantations excluding nuts
8	Avocados	39	Fruit and berry plantations excluding nuts
12	Blackberries	39	Fruit and berry plantations excluding nuts
13	Blackcurrants	39	Fruit and berry plantations excluding nuts
14	Blueberries	39	Fruit and berry plantations excluding nuts
29	Cherries	39	Fruit and berry plantations excluding nuts
41	Cranberries	39	Fruit and berry plantations excluding nuts
46	Dewberries	39	Fruit and berry plantations excluding nuts
60	Gooseberries	39	Fruit and berry plantations excluding nuts
70	Hybridberries	39	Fruit and berry plantations excluding nuts
74	Kiwi fruit	39	Fruit and berry plantations excluding nuts
87	Litchis	39	Fruit and berry plantations excluding nuts
124	Other pome fruit	39	Fruit and berry plantations excluding nuts
127	Other small fruit & berries (other than wild)	39	Fruit and berry plantations excluding nuts
132	Other stone fruit	39	Fruit and berry plantations excluding nuts
139	Peaches (incl nectarines & similar hybrids)	39	Fruit and berry plantations excluding nuts
141	Pears	39	Fruit and berry plantations excluding nuts
152	Plums	39	Fruit and berry plantations excluding nuts
158	Quinces	39	Fruit and berry plantations excluding nuts
160	Raspberries (outdoor)	39	Fruit and berry plantations excluding nuts
162	Red & white currants	39	Fruit and berry plantations excluding nuts
1	Almonds	40	Fruit and berry plantations: Nuts
15	Brazil nuts	40	Fruit and berry plantations: Nuts
22	Cashew nuts	40	Fruit and berry plantations: Nuts
31	Chestnuts	40	Fruit and berry plantations: Nuts
37	Coconuts	40	Fruit and berry plantations: Nuts
64	Hazelnuts	40	Fruit and berry plantations: Nuts
89	Macadamia nuts	40	Fruit and berry plantations: Nuts
133	Other tree nuts	40	Fruit and berry plantations: Nuts

ID	Application crop name	ID	HAIR crop name
144	Pecans	40	Fruit and berry plantations: Nuts
149	Pine nuts	40	Fruit and berry plantations: Nuts
151	Pistachios	40	Fruit and berry plantations: Nuts
196	Walnuts	40	Fruit and berry plantations: Nuts
61	Grapefruit	41	Citrus plantations
81	Lemons	41	Citrus plantations
85	Limes	41	Citrus plantations
92	Mandarins (inc clementines & similar hybrids)	41	Citrus plantations
107	Oranges	41	Citrus plantations
111	Other citrus fruits	41	Citrus plantations
154	Pomelos	41	Citrus plantations
105	Olives (table consumption)	42	Olive plantations: table olives
104	Olives (oil extract)	43	Olive plantations: oil production
201	Wine grapes	44	Vineyards: quality wine
188	Table grapes	46	Vineyards: table grapes
63	Hardy nursery stock	48	Nurseries
9	Bananas	49	Other permanent crops
38	Cotton	49	Other permanent crops
45	Dates	49	Other permanent crops
50	Figs	49	Other permanent crops
76	Kumquats	49	Other permanent crops
94	Mangoes	49	Other permanent crops
109	Other cane fruit	49	Other permanent crops
138	Passion fruit	49	Other permanent crops
189	Tea (dried lvs & stalks, fermented or otherwise, C. sinesis)	49	Other permanent crops
199	Wild berries & wild fruit	49	Other permanent crops

Table 1-2a, b, c, d
Internal table with HAIR crop attributes

Field names (Table CROPS_HAIR, HAIR database v5)

- HAIR_CROP_ID
- HAIR_CROP_NAME
- CROP_MAP_ID
- _CROP_MAP_CODE
- _CROP_MAP_NAME
- CROP_SYSTEM
- FOCUS_INTERCEPTION_CROP_ID
- _FOCUS_INTERCEPTION_CROP_NAME
- FOCUS_DRIFT_CROP_GROUP_ID
- _FOCUS_DRIFT_CROP_GROUP
- CN_CROP_GROUP_ID
- _CN_CROP_GROUP
- EROSION_CROP_GROUP_ID
- _EROSION_CROP_GROUP
- SCEN_BIRDS_GS
- SCEN_MAMMALS_GS
- SCEN_BIRDS_ST
- SCEN_MAMMALS_ST
- LAI
- TRANSFER_FACTOR_cm2_h
- FLOWERING_WEEDS_MARGIN
- FLOWERING_WEEDS_CROP
- FALLOW_STAGE
- EMERGENCE_STAGE
- MATURE_STAGE
- SENESCENCE_STAGE

Table a

HAIR CROP ID	HAIR CROP NAME	CROP MAP ID	CROP MAP CODE	CROP MAP NAME	CROP SYSTEM
1	Common wheat and spelt: Winter	28	SWHE	Common wheat	other
2	Common wheat and spelt: Spring	28	SWHE	Common wheat	other
3	Durum wheat: Winter	3	DWHE	Durum Wheat	other
4	Rye: Spring	24	RYEM	Rye	other
5	Barley: Winter	1	BARL	Barley	other
6	Barley: Spring	1	BARL	Barley	other
7	Oats: Winter	14	OATS	Oats	other
8	Grain maize	8	LMAIZ	Maize	other
9	Rice	20	PARI	Rice	other
10	Other cereals	15	OCER	Other cereals	other
11	Pulses	22	PULS	Dry pulses	other
12	Potatoes	21	POTA	Potatoes	other
13	Sugar beet	26	SUGB	Sugar beet	other
14	Fodder roots and brassicas	23	ROOF	Other root crops	other
15	Tobacco	29	TOBA	Tobacco	other
16	Hops	16	OCRO	Other crops	other
17	Cotton	18	OIND	Other non permanent industrial crops	other
18	Oil seed or fibre plants: Rape and turnip: Summer	10	LRAPE	Rape and turnip rape	other
19	Oil seed or fibre plants: Sunflower	27	SUNF	Sunflower	other
20	Oil seed or fibre plants: Soya	25	SOYA	Soya	other
21	Other oil-seed or fibre plants	11	LTEXT	Fibre and oleaginous crops	other
22	Aromatic-; medicinal and culinary plants	16	OCRO	Other crops	other
23	Other industrial plants	18	OIND	Other non permanent industrial crops	other
24	Outdoor: Open field: Fresh vegetables; melons; strawberries	19	OVTO	Tomatoes and Other fresh Vegetables	other
25	Outdoor: Market gardening: Fresh vegetables; melons; strawberries	19	OVTO	Tomatoes and Other fresh Vegetables	other
26	Under glass: Vegetables; flowers and permanent crops	30	GHCR	Greenhouse crop and other covered crops	greenhouse
27	Under glass: Fresh vegetables; melons; strawberries	30	GHCR	Greenhouse crop and other covered crops	greenhouse
28	Outdoor: Flowers and ornamental plants	4	FLOW	Floriculture	other
29	Under glass: Flowers and ornamental plants	30	GHCR	Greenhouse crop and other covered crops	greenhouse
30	Forage plants: temporary grass	17	OFAR	Fodder other on arable land	other
31	Forage plants: green fodder	17	OFAR	Fodder other on arable land	other
32	Forage plants: Leguminous plants	17	OFAR	Fodder other on arable land	other
33	Forage plants: Other green fodder	17	OFAR	Fodder other on arable land	other
34	Seeds and seedlings	16	OCRO	Other crops	other
35	Arable land: Other crops	16	OCRO	Other crops	other
36	Fallow land without subsidies	6	LFALL	Fallow land	other
37	Kitchen gardens	16	OCRO	Other crops	other

HAIR CROP ID	HAIR CROP NAME	CROP MAP ID	CROP MAP CODE	CROP MAP NAME	CROP SYSTEM
38	Permanent grassland and meadow	5	GRAS	Permanent gras and grazing	other
39	Fruit and berry plantations excluding nuts	7	LFRUI	Fruit tree and berry plantations	other
40	Fruit and berry plantations: Nuts	7	LFRUI	Fruit tree and berry plantations	other
41	Citrus plantations	2	CITR	Citrus fruits	other
42	Olive plantations: table olives	9	LOLIV	Olive groves	other
43	Olive plantations: oil production	9	LOLIV	Olive groves	other
44	Vineyards: quality wine	12	LTWIN	Vineyards	other
45	Vineyards: other wines	12	LTWIN	Vineyards	other
46	Vineyards: table grapes	12	LTWIN	Vineyards	other
47	Vineyards: raisins	12	LTWIN	Vineyards	other
48	Nurseries	13	NURS	Nurseries	other
49	Other permanent crops	16	OCRO	Other crops	other
50	Oil seed or fibre plants: Rape and turnip: Winter	10	LRAPE	Rape and turnip rape	other

Table b

HAIR CROP ID	FOCUS INTERCEPTION CROP ID	FOCUS INTERCEPTION CROP NAME	FOCUS DRIFT CROP GROUP ID	FOCUS DRIFT CROP GROUP	CN CROP GROUP ID	CN CROP GROUP
1	33	winter cereals	1	arable and small vegetables	1	arable crops
2	22	spring cereals	1	arable and small vegetables	1	arable crops
3	33	winter cereals	1	arable and small vegetables	1	arable crops
4	22	spring cereals	1	arable and small vegetables	1	arable crops
5	33	winter cereals	1	arable and small vegetables	1	arable crops
6	22	spring cereals	1	arable and small vegetables	1	arable crops
7	33	winter cereals	1	arable and small vegetables	1	arable crops
8	13	maize	1	arable and small vegetables	1	arable crops
9	13	maize	1	arable and small vegetables	1	arable crops
10	22	spring cereals	1	arable and small vegetables	1	arable crops
11	18	peas (animals)	2	large vegetables	2	row fruits
12	20	potatoes	1	arable and small vegetables	1	arable crops
13	24	sugar beets	1	arable and small vegetables	1	arable crops
14	24	sugar beets	1	arable and small vegetables	1	arable crops
15	26	tobacco	2	large vegetables	1	arable crops
16	10	hops	3	hops	2	row fruits
17	8	cotton	1	arable and small vegetables	1	arable crops
18	14	oilseed rape (summer)	1	arable and small vegetables	2	row fruits
19	25	sunflower	1	arable and small vegetables	1	arable crops
20	25	sunflower	1	arable and small vegetables	1	arable crops
21	25	sunflower	1	arable and small vegetables	1	arable crops
22	26	tobacco	1	arable and small vegetables	1	arable crops
23	26	tobacco	1	arable and small vegetables	1	arable crops
24	11	legumes	1	arable and small vegetables	2	row fruits
25	11	legumes	1	arable and small vegetables	2	row fruits
26	11	legumes	1	arable and small vegetables	2	row fruits

HAIR CROP ID	FOCUS INTERCEPTION CROP ID	FOCUS INTERCEPTION CROP NAME	FOCUS DRIFT CROP GROUP ID	FOCUS DRIFT CROP GROUP	CN CROP GROUP ID	CN CROP GROUP
27	11	legumes	1	arable and small vegetables	2	row fruits
28	17	onions	1	arable and small vegetables	1	arable crops
29	17	onions	1	arable and small vegetables	1	arable crops
30	9	grass + alfalfa	1	arable and small vegetables	1	arable crops
31	9	grass + alfalfa	1	arable and small vegetables	1	arable crops
32	11	legumes	1	arable and small vegetables	1	arable crops
33	11	legumes	1	arable and small vegetables	1	arable crops
34	17	onions	1	arable and small vegetables	1	arable crops
35	17	onions	1	arable and small vegetables	1	arable crops
36	9	grass + alfalfa	1	arable and small vegetables	3	grassland
37	9	grass + alfalfa	1	arable and small vegetables	1	arable crops
38	9	grass + alfalfa	1	arable and small vegetables	3	grassland
39	19	pome/stone fruit early,late	4	fruits	4	fruits
40	19	pome/stone fruit early,late	4	fruits	4	fruits
41	7	citrus	4	fruits	4	fruits
42	16	olives	4	fruits	4	fruits
43	16	olives	4	fruits	4	fruits
44	32	vines	5	vines	2	row fruits
45	32	vines	5	vines	2	row fruits
46	32	vines	5	vines	2	row fruits
47	32	vines	5	vines	2	row fruits
48	17	onions	1	arable and small vegetables	1	arable crops
49	9	grass + alfalfa	1	arable and small vegetables	1	arable crops
50	15	oilseed rape (winter)	1	arable and small vegetables	2	row fruits

Table c

HAIR CROP ID	EROSION CROP GROUP ID	EROSION CROP GROUP	SCEN BIRDS GS	SCEN MAMMALS GS	SCEN BIRDS ST	SCEN MAMMALS ST
1	1	Cereals	1	1	8	7
2	1	Cereals	2	2	7	7
3	1	Cereals	1	1	8	7
4	1	Cereals	2	2	7	7
5	1	Cereals	1	1	8	7
6	1	Cereals	2	2	10	7
7	1	Cereals	1	1	7	7
8	8	Maize	2	2	7	7
9	8	Maize	2	2	7	7
10	1	Cereals	2	2	7	7
11	4	Field bean	4	4	9	7
12	12	Potatoes	4	4	0	0
13	15	Sugar beet	4	4	11	7
14	18	Vegetables, bulb	4	4	0	0
15	17	Tobacco	4	4	0	0
16	6	Hops	4	4	0	0
17	3	Cotton	4	4	0	0
18	13	Rape seed	4	4	7	7
19	16	Sunflower	4	4	7	7
20	14	Soybean	4	4	7	7
21	16	Sunflower	4	4	7	7
22	17	Tobacco	4	4	0	0
23	17	Tobacco	4	4	0	0
24	19	Vegetables, fruiting	4	4	7	7
25	19	Vegetables, fruiting	4	4	7	7
26	20	Vegetables, leafy	0	0	0	0
27	20	Vegetables, leafy	0	0	0	0
28	20	Vegetables, leafy	4	4	0	0
29	20	Vegetables, leafy	0	0	0	0
30	5	Grass	6	6	7	7
31	5	Grass	6	6	7	7
32	7	Leguminosae	4	4	7	7
33	7	Leguminosae	4	4	7	7
34	8	Maize	2	2	7	7
35	8	Maize	2	2	0	0
36	5	Grass	0	0	0	0
37	5	Grass	4	4	7	7
38	5	Grass	6	6	0	0
39	11	Pome/Stone-Fruits	5	5	0	0
40	11	Pome/Stone-Fruits	5	5	0	0
41	2	Citrus	5	5	0	0
42	10	Olives	5	5	0	0
43	10	Olives	5	5	0	0
44	22	Vine	5	5	0	0
45	22	Vine	5	5	0	0
46	22	Vine	5	5	0	0
47	22	Vine	5	5	0	0
48	9	Nurseries	4	4	7	7
49	5	Grass	5	5	0	0
50	13	Rape seed	4	4	7	7

Table d

HAIR CROP ID	LAI	TRANSFER FACTOR cm^2 h	FLOWERING WEEDS MARGIN	FLOWERING WEEDS CROP	FALLOW STAGE	EMERGENCE STAGE	MATURE STAGE	SENESCENCE STAGE
1	2	0	1	1	FALSE	TRUE	FALSE	FALSE
2	2	0	1	1	FALSE	TRUE	FALSE	FALSE
3	2	0	1	1	FALSE	TRUE	FALSE	FALSE
4	2	0	1	1	FALSE	TRUE	FALSE	FALSE
5	2	0	1	1	FALSE	TRUE	FALSE	FALSE
6	2	0	1	1	FALSE	TRUE	FALSE	FALSE
7	2	0	1	1	FALSE	TRUE	FALSE	FALSE
8	2	0	1	1	FALSE	TRUE	FALSE	FALSE
9	2	0	1	1	FALSE	TRUE	FALSE	FALSE
10	2	0	1	1	FALSE	TRUE	FALSE	FALSE
11	2	0	1	1	FALSE	TRUE	TRUE	TRUE
12	2	0	1	1	FALSE	TRUE	FALSE	FALSE
13	2	0	1	1	FALSE	TRUE	FALSE	FALSE
14	2		1	1	FALSE	TRUE	FALSE	FALSE
15	2		1	1	FALSE	TRUE	FALSE	FALSE
16	2		1	1	FALSE	TRUE	FALSE	FALSE
17	2	1000	1	1	FALSE	TRUE	FALSE	FALSE
18	2		1	1	FALSE	TRUE	FALSE	FALSE
19	2		1	1	FALSE	TRUE	FALSE	FALSE
20	2		1	1	FALSE	TRUE	FALSE	FALSE
21	2		1	1	FALSE	TRUE	FALSE	FALSE
22	2		1	1	FALSE	TRUE	FALSE	FALSE
23	2		1	1	FALSE	TRUE	FALSE	FALSE
24	2	2500	1	1	FALSE	TRUE	FALSE	FALSE
25	2	2500	1	1	FALSE	TRUE	FALSE	FALSE
26	2	5000	1	1	FALSE	TRUE	FALSE	FALSE
27	2	5000	1	1	FALSE	TRUE	FALSE	FALSE
28	1	5000	1	1	FALSE	TRUE	FALSE	FALSE
29	2	5000	1	1	FALSE	TRUE	FALSE	FALSE
30	9999		1	1	FALSE	TRUE	FALSE	FALSE
31	9999		1	1	FALSE	TRUE	FALSE	FALSE
32	9999		1	1	FALSE	TRUE	FALSE	FALSE
33	9999		1	1	FALSE	TRUE	FALSE	FALSE
34	9999		1	1	FALSE	TRUE	FALSE	FALSE
35	9999		1	1	FALSE	TRUE	FALSE	FALSE
36	9999		1	1	FALSE	TRUE	FALSE	FALSE
37	9999		1	1	FALSE	TRUE	FALSE	FALSE
38	9999		1	1	FALSE	TRUE	FALSE	FALSE
39	2	3000	1	1	FALSE	TRUE	FALSE	FALSE
40	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
41	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
42	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
43	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
44	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
45	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
46	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
47	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
48	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
49	4	4500	1	1	FALSE	TRUE	FALSE	FALSE
50	4	4500	1	1	FALSE	TRUE	FALSE	FALSE

Annex 2 Crop calendar data

Contents

Figure 2-1a
Crop development stages for the FOCUS interception crops in crop calendar region Chateaudun.

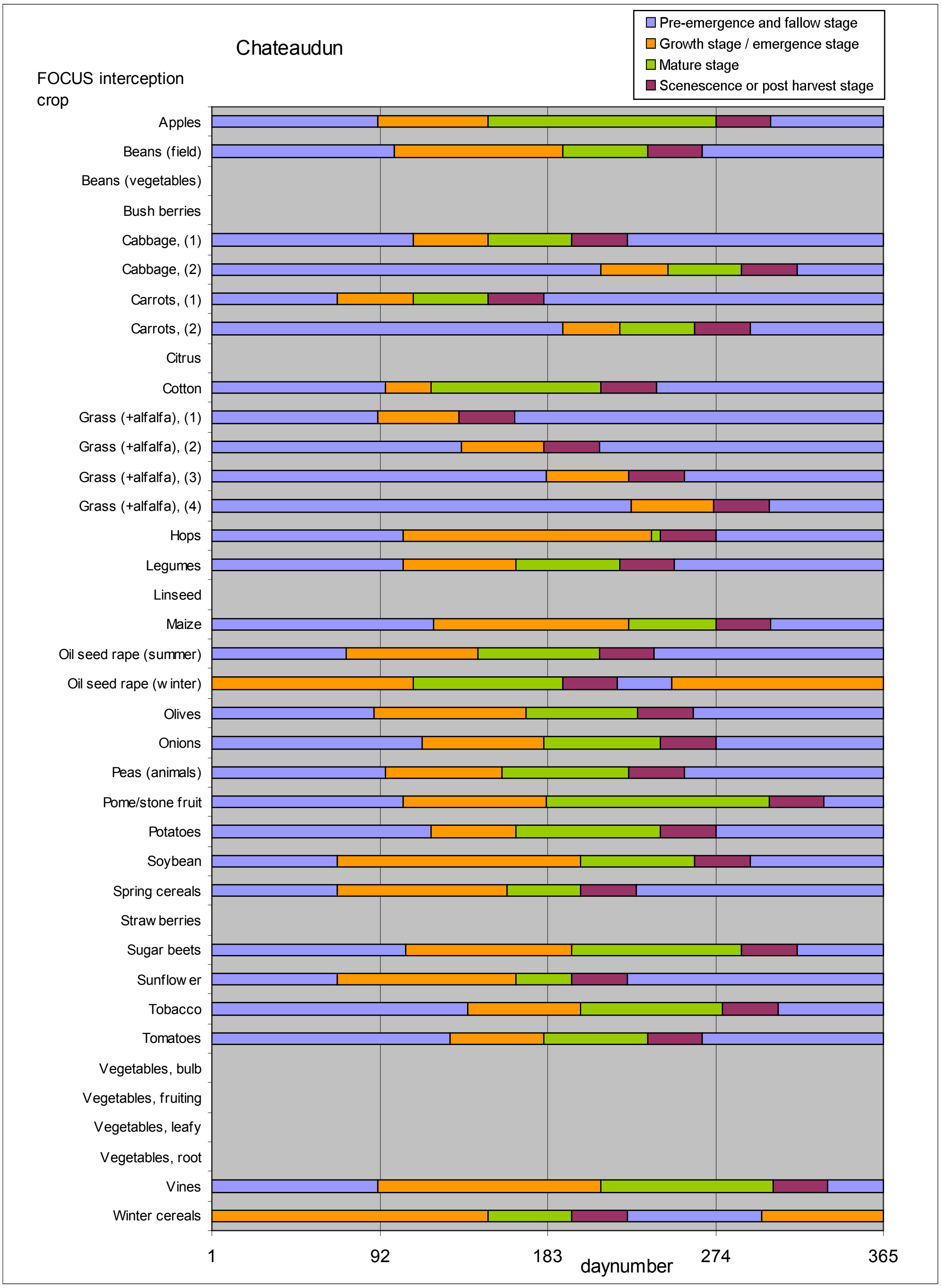


Figure 2-1b
Crop development stages for the FOCUS interception crops in crop calendar region Hamburg.

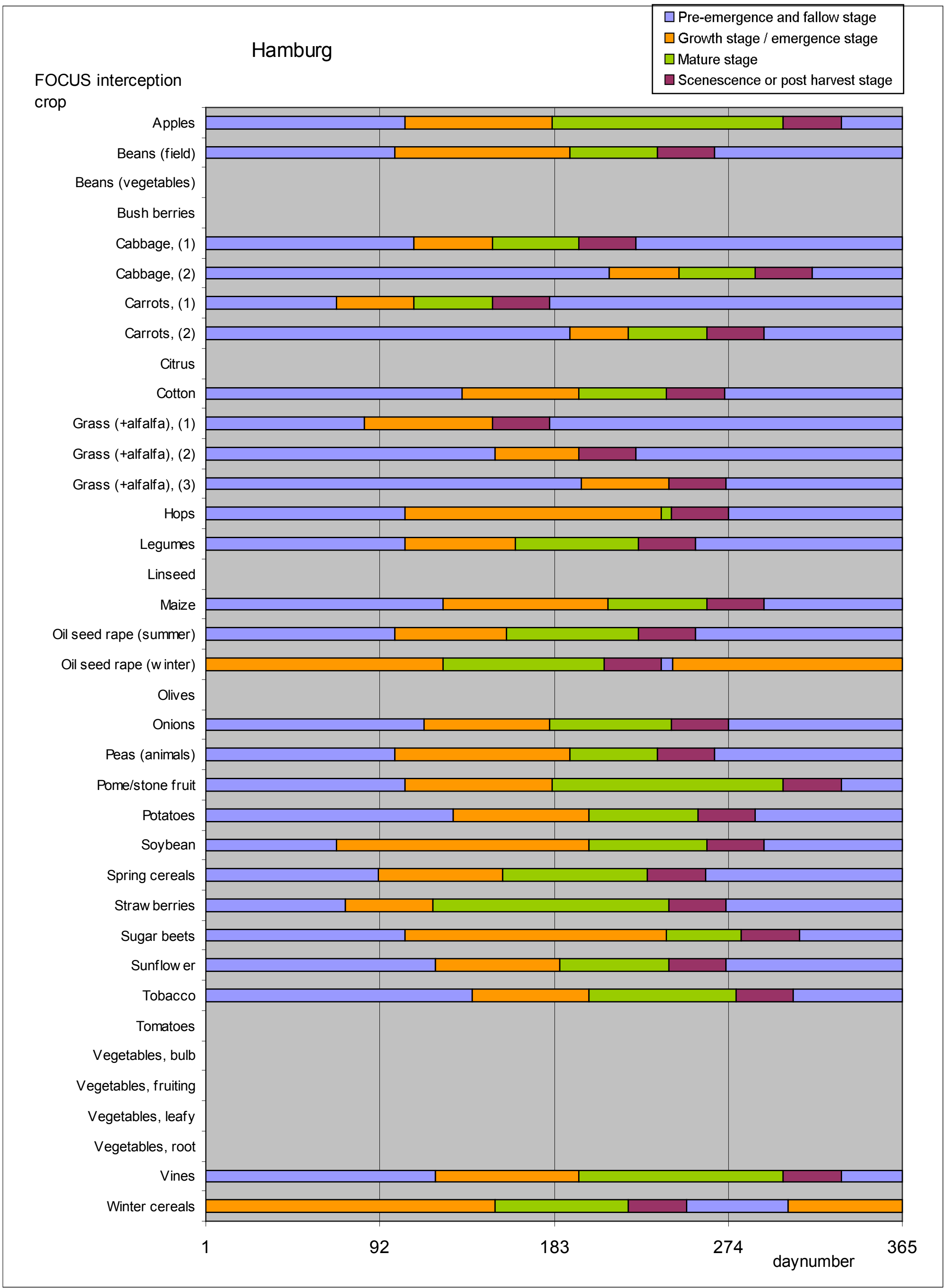


Figure 2-1c
Crop development stages for the FOCUS interception crops in crop calendar region Jokioinen.

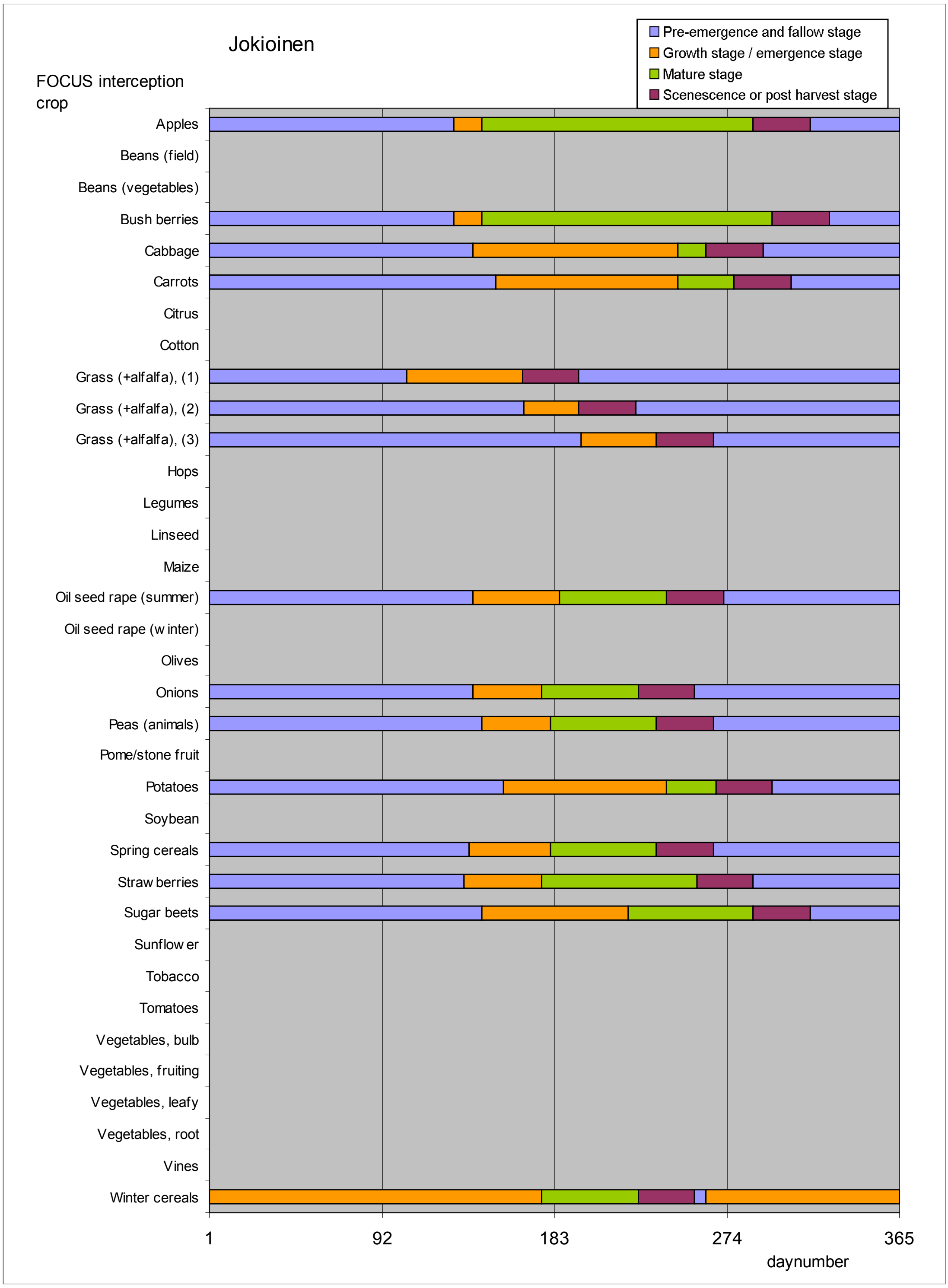


Figure 2-1d
Crop development stages for the FOCUS interception crops in crop calendar region Kremsmunster.

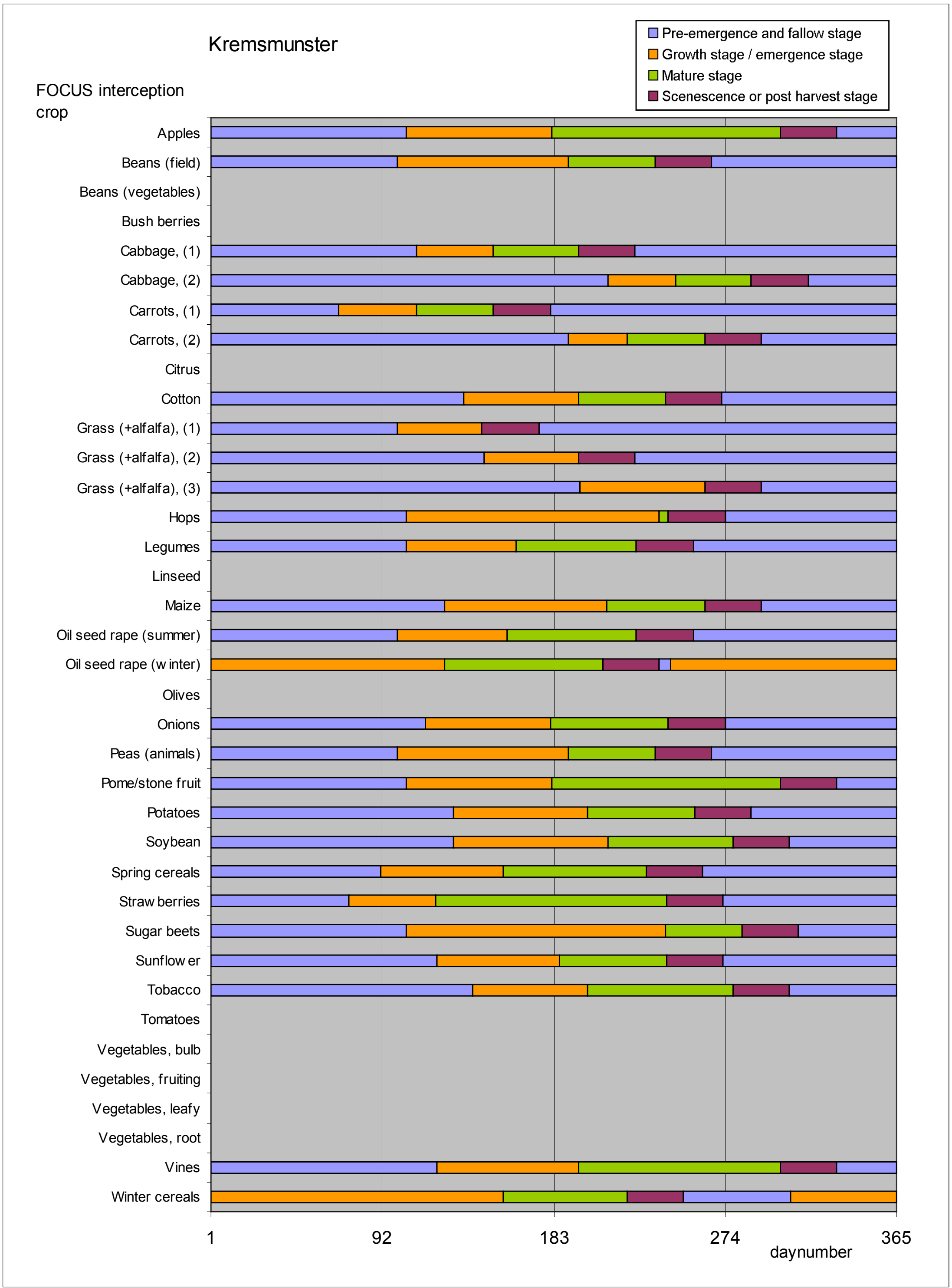


Figure 2-1e
Crop development stages for the FOCUS interception crops in crop calendar region Okehampton.

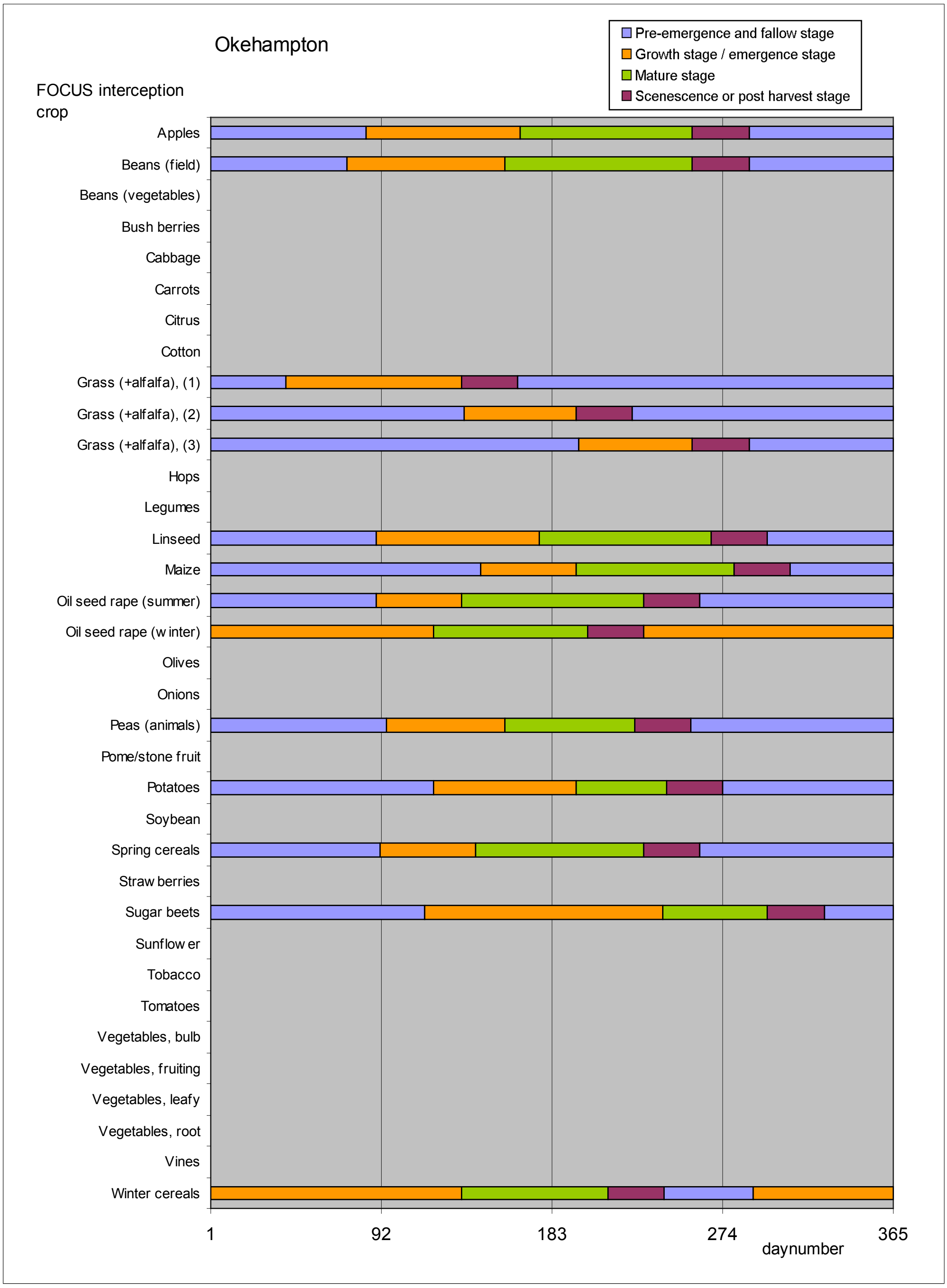


Figure 2-1f
Crop development stages for the FOCUS interception crops in crop calendar region Piacenza.

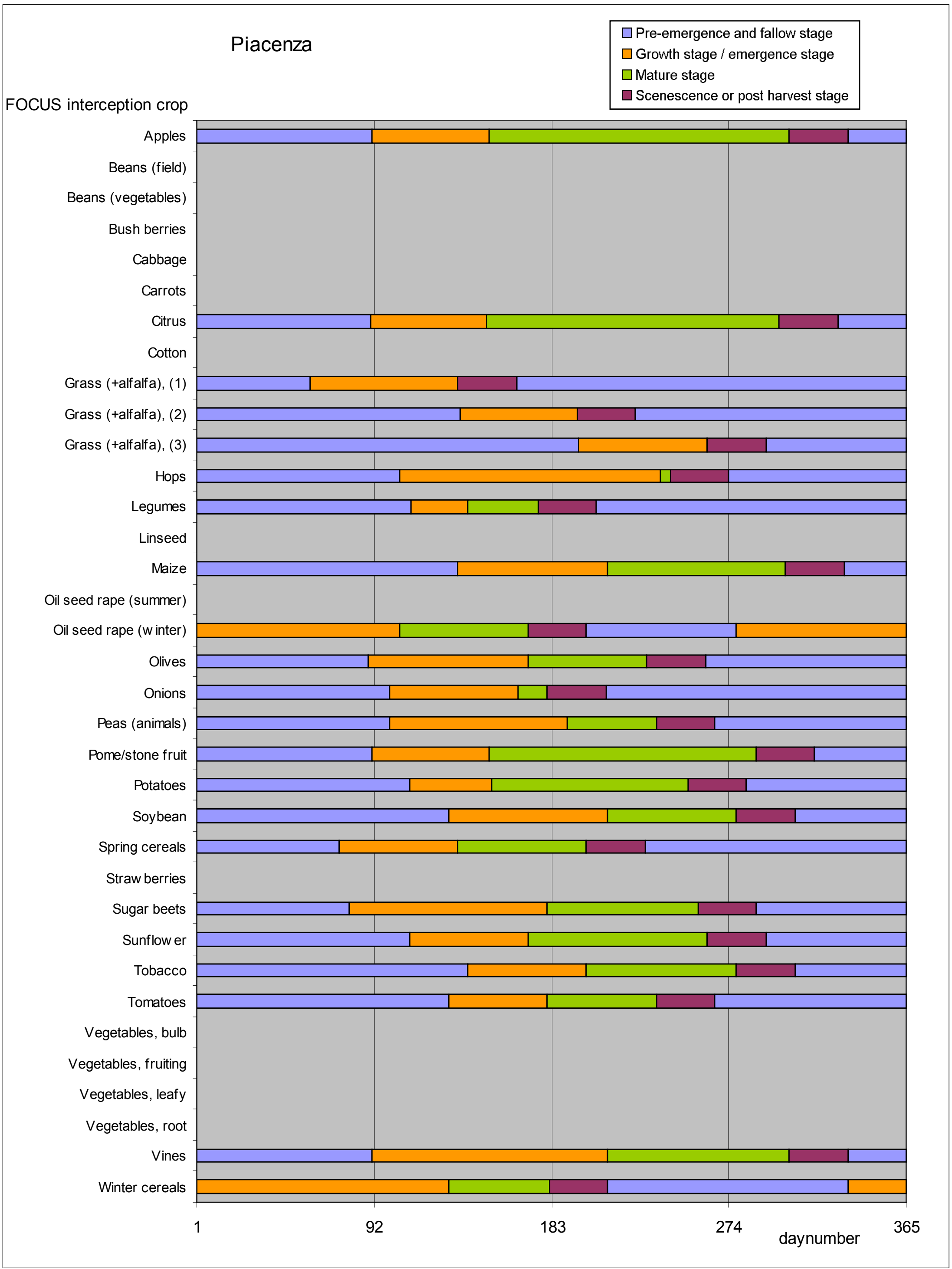


Figure 2-1g
Crop development stages for the FOCUS interception crops in crop calendar region Porto.

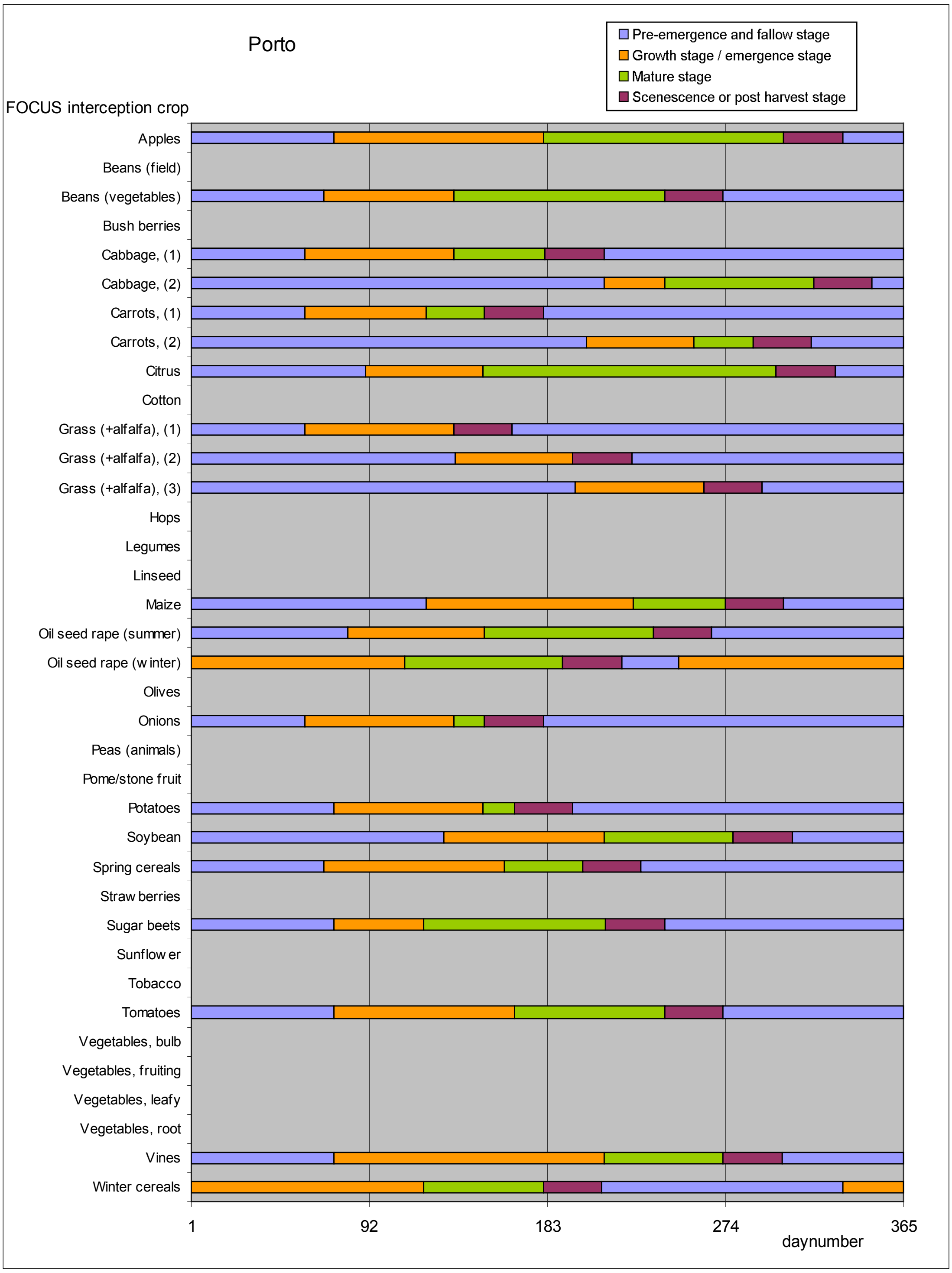


Figure 2-1h
Crop development stages for the FOCUS interception crops in crop calendar region Sevilla.

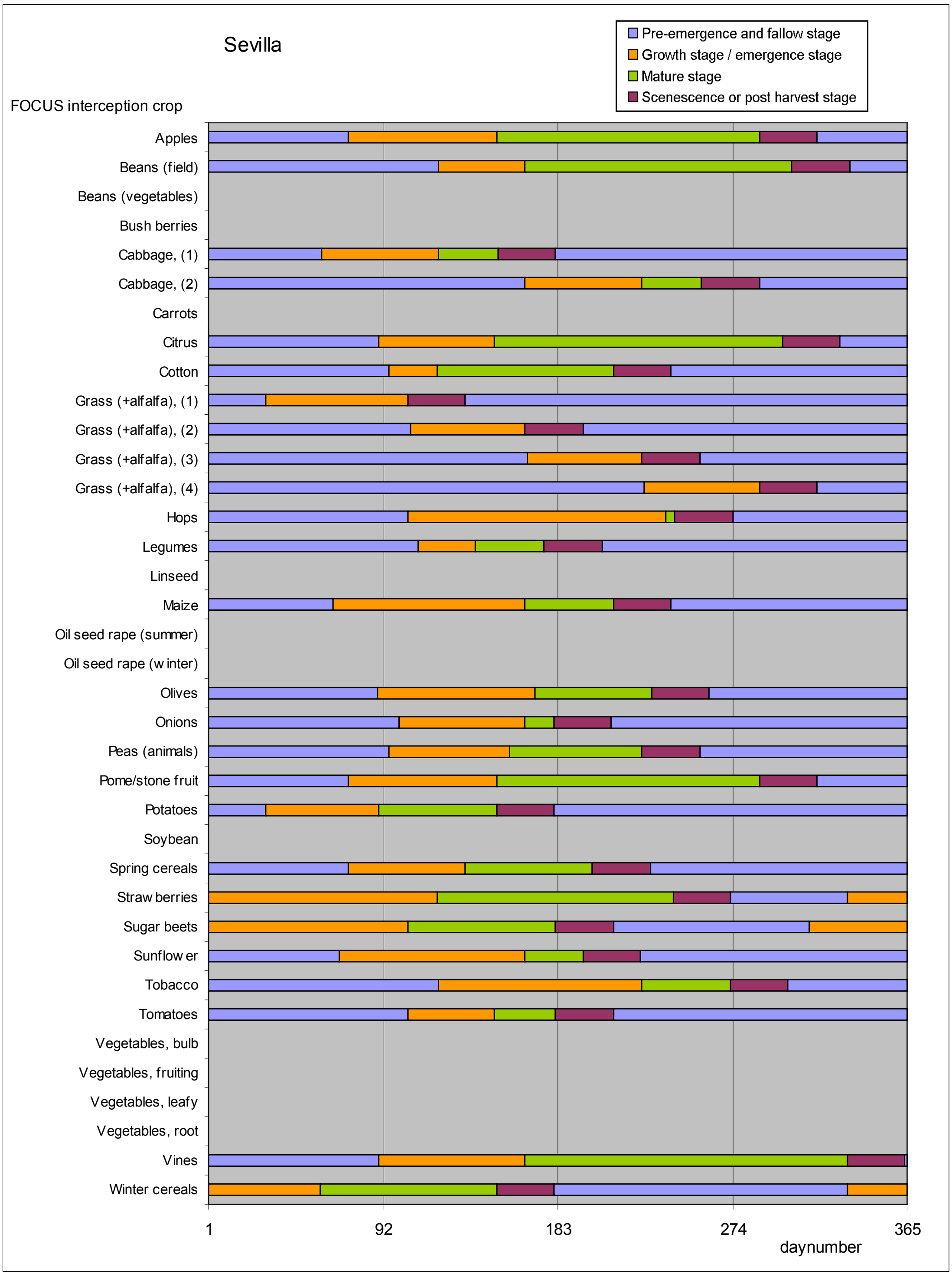


Figure 2-1i
Crop development stages for the FOCUS interception crops in crop calendar region Thiva.

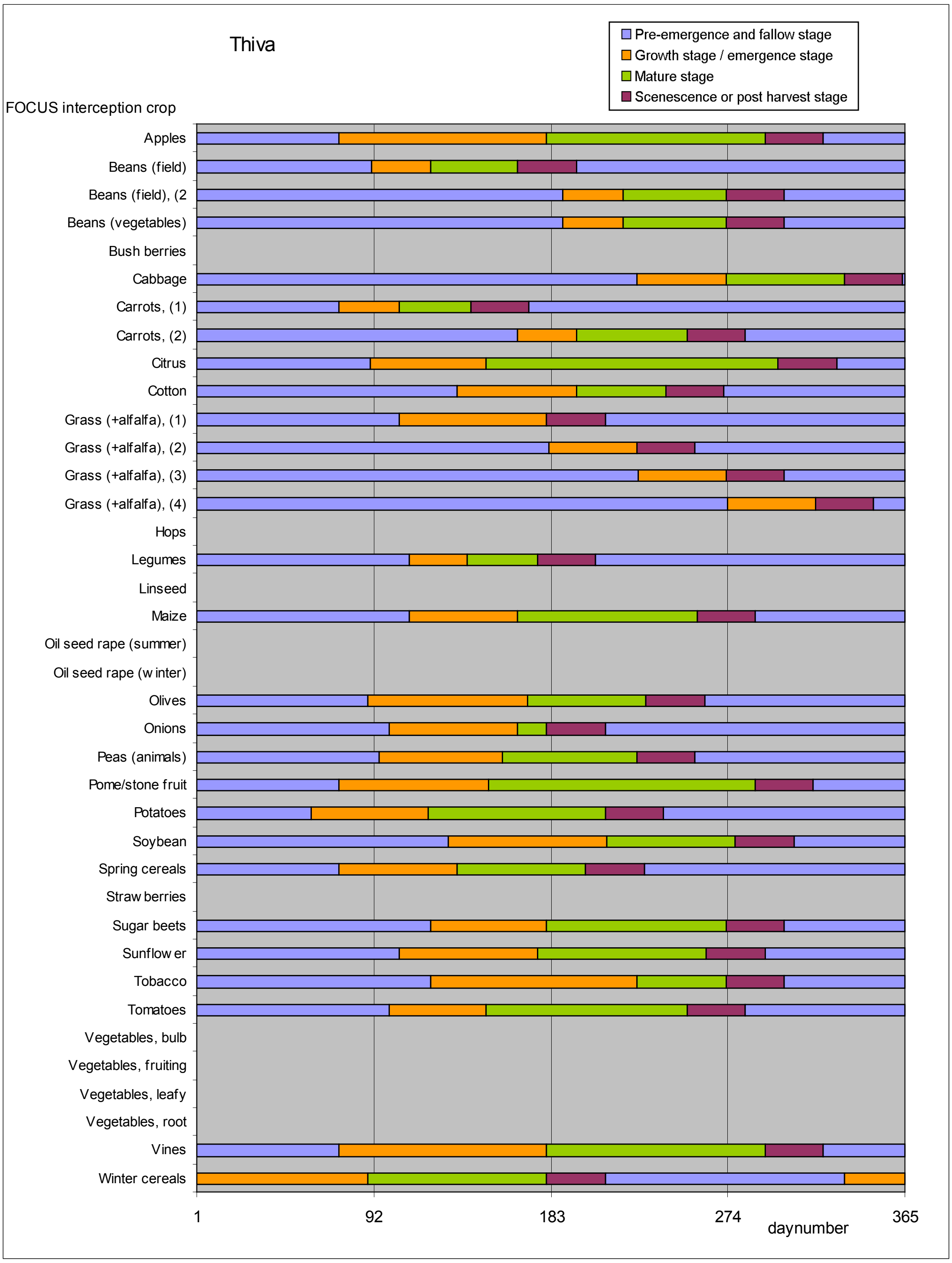


Table 2-2
Distribution of crop areas among the crop calendar regions in the European Union except Cyprus and Malta (in % of total area; Column 3).

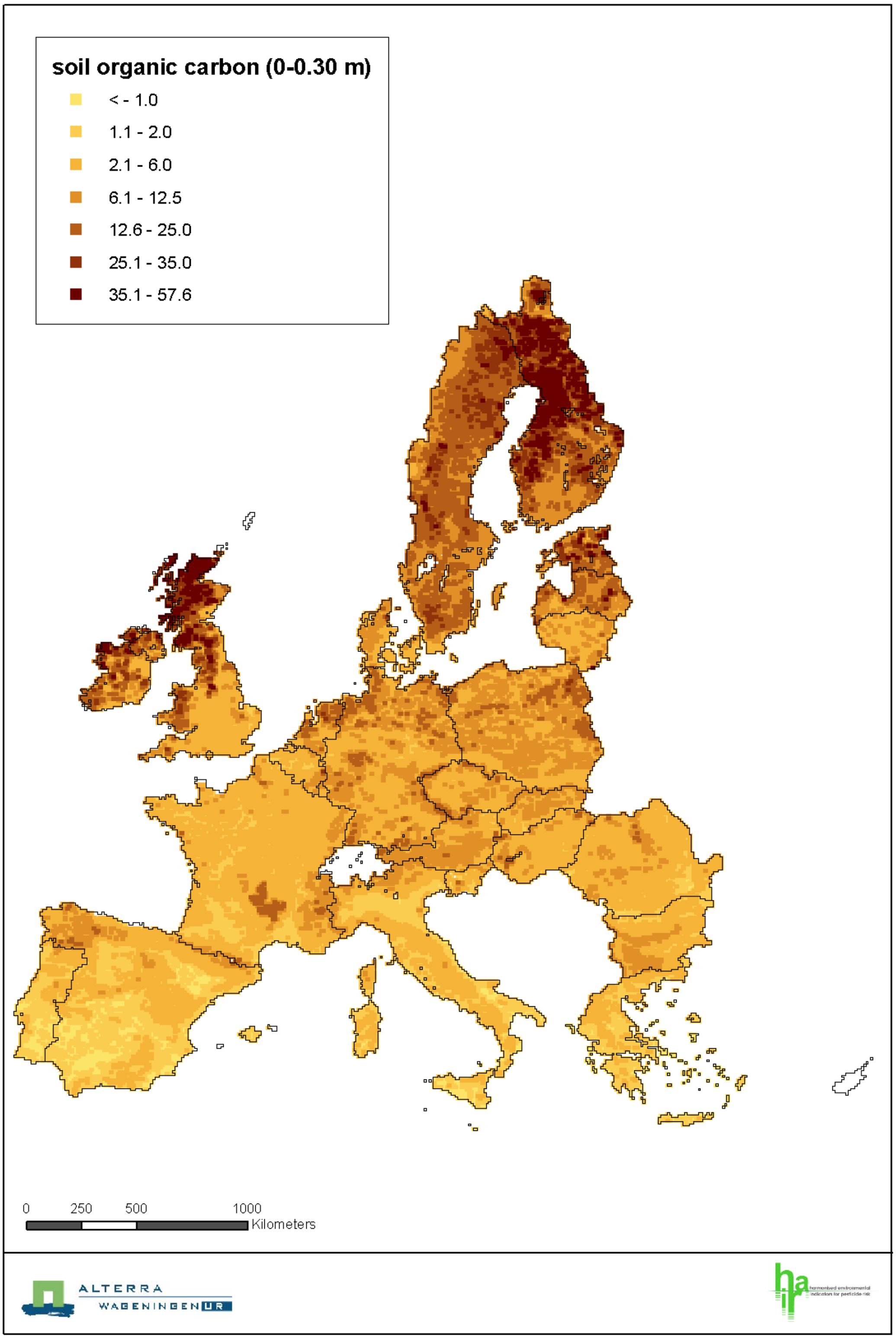
Crop map		Total area (sqkm x 1000)	Climate zone								
			Jokioinen	Chateau-dun	Sevilla	Hamburg	Thiva	Krems-munster	Piacenza	Oke-hampton	Porto
			1, 4, 7, 10, 13	2	3	5	6	8	9	11, 14	12, 15
			precipitation class (P in mm)								
			1, …, 5	1	1	2	2	3	3	4, 5	4, 5
				P ≤ 600	P ≤ 600	600 < P ≤ 800	600 < P ≤ 800	800 < P ≤ 1000	800 < P ≤ 1000	P > 1000	P > 1000
			temperature class (T in ºC)								
			1	2	3	2	3	2	3	2	3
			T <= 5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5
BARL	Barley	140.9	4	40	13	32	2	6	1	2	1
CITR	Citrus fruits	4.4	0	0	83	0	14	0	3	0	1
DWHE	Durum Wheat	36.3	0	5	61	5	19	1	7	0	1
FLOW	Floriculture	0.9	0	18	11	48	5	10	6	1	2
GRAS	Permanent gras and grazing	584.7	2	27	12	29	2	15	2	9	2
LFALL	Fallow land	105.2	2	42	24	20	4	3	3	1	1
LFRUI	Fruit tree and berry plantations	27.1	1	30	37	10	9	3	8	0	2
LMAIZ	Maize	134.4	0	45	3	27	5	7	8	2	2
LOLIV	Olive groves	41.6	0	3	69	1	18	1	7	0	1
LRAPE	Rape and turnip rape	42.5	1	43	1	43	1	7	1	2	0
LTEXT	Fibre and oleaginous crops	10.9	0	28	39	15	12	3	2	0	0
LTWIN	Vineyards	35.2	0	17	33	9	19	4	15	0	2
NURS	Nurseries	1.1	1	18	7	43	8	11	9	1	2
OATS	Oats	50.3	8	55	12	19	2	2	1	1	0
OCER	Other cereals	20.2	0	61	4	20	4	5	2	3	0
OCRO	Other crops	5.6	1	71	11	13	1	2	1	0	0
OFAR	Fodder other on arable land	134.5	7	25	8	31	5	11	4	8	2

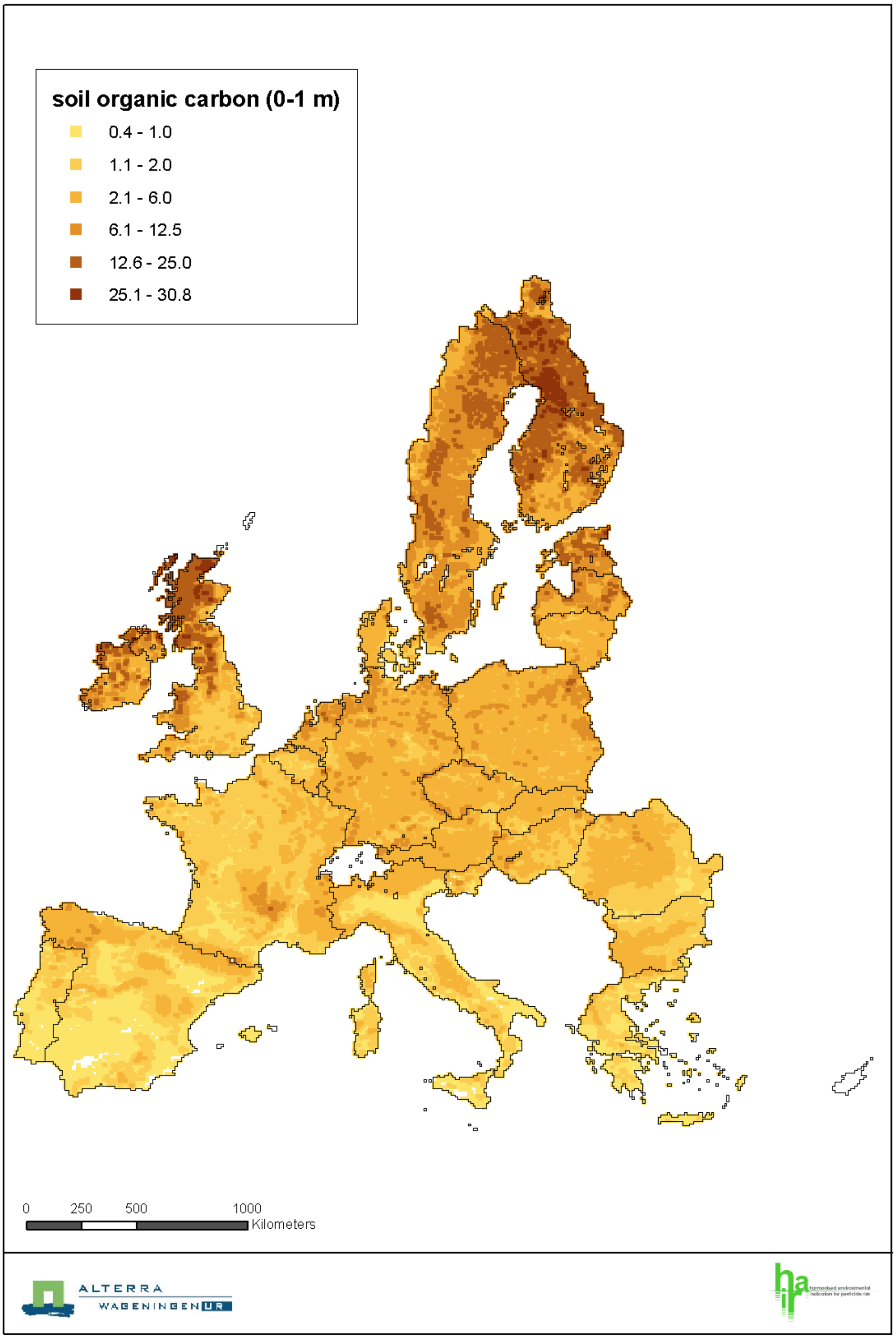
Crop map		Total area (sqkm x 1000)	Climate zone								
			Jokioinen	Chateau-dun	Sevilla	Hamburg	Thiva	Krems-munster	Piacenza	Oke-hampton	Porto
			1, 4, 7, 10, 13	2	3	5	6	8	9	11, 14	12, 15
			precipitation class (P in mm)								
			1, ..., 5	1	1	2	2	3	3	4, 5	4, 5
				P ≤ 600	P ≤ 600	600 < P ≤ 800	600 < P ≤ 800	800 < P ≤ 1000	800 < P ≤ 1000	P > 1000	P > 1000
			temperature class (T in ºC)								
			1	2	3	2	3	2	3	2	3
			T <= 5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5	5 < T ≤ 12.5	T > 12.5
OIND	Other non permanent industrial crops	5.0	1	54	6	28	3	6	1	1	0
OVTO	Tomatoes and Other fresh Vegetables	19.7	1	39	17	21	9	4	5	2	2
PARI	Rice	3.8	0	1	33	0	9	16	39	0	0
POTA	Potatoes	26.6	2	54	2	34	1	4	1	1	1
PULS	Dry pulses	18.3	1	35	17	37	3	5	2	1	0
ROOF	Other root crops	2.9	0	42	3	43	1	8	1	3	1
RYEM	Rye	32.1	1	74	2	19	1	2	1	0	0
SOYA	Soya	4.4	0	27	2	6	22	7	24	2	9
SUGB	Sugar beet	24.2	1	36	5	45	4	6	3	0	0
SUNF	Sunflower	38.7	0	55	20	10	8	3	3	0	0
SWHE	Common wheat	220.3	1	48	5	35	2	6	1	1	0
TOBA	Tobacco	1.9	0	28	40	7	12	2	8	0	2
GHCR	Greenhouse crop and other covered crops	(*)	-	-	-	-	-	-	-	-	-
	Total, arable crops	1773.8	2	35	14	27	4	8	3	4	1

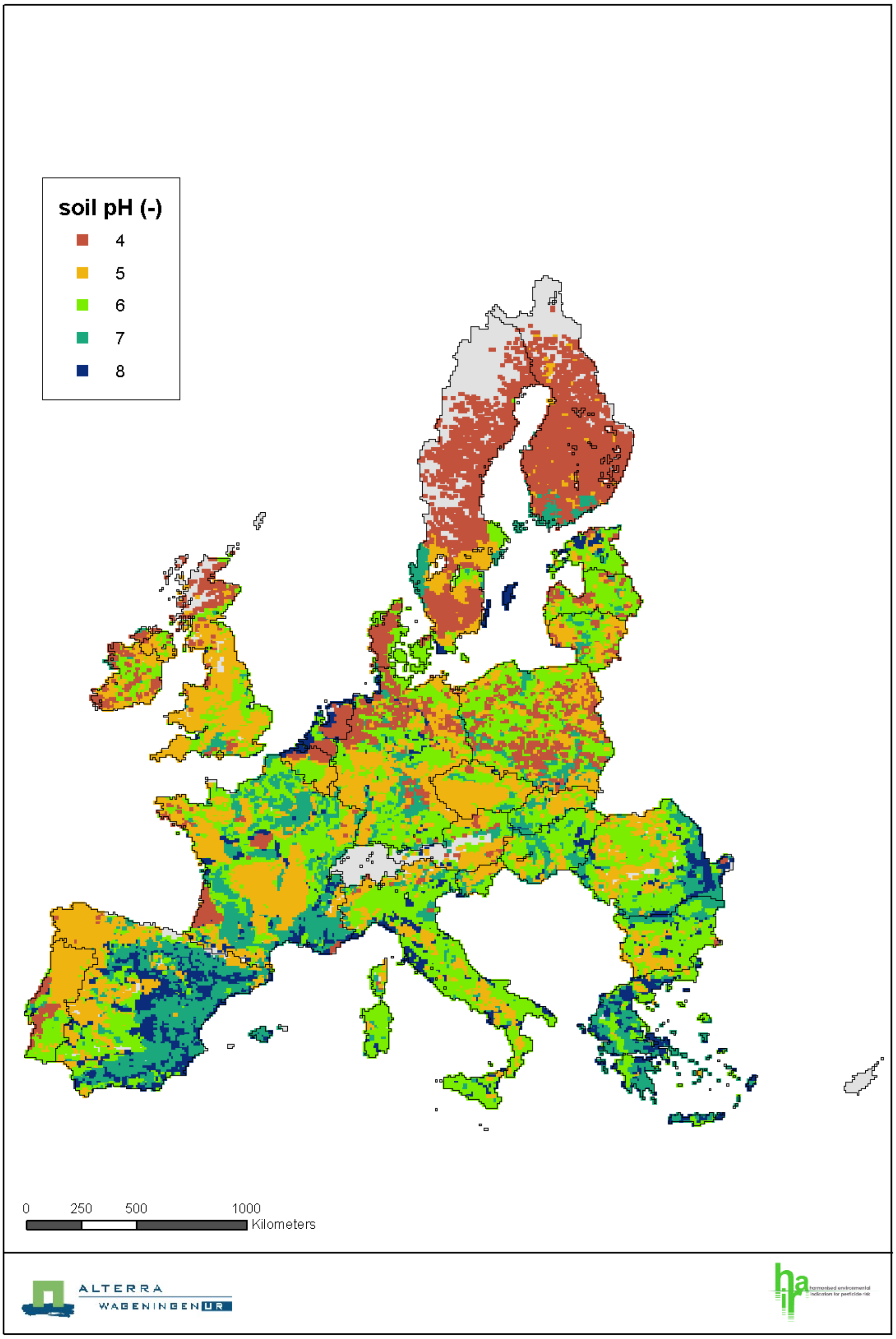
(*) Available for the Netherlands only.

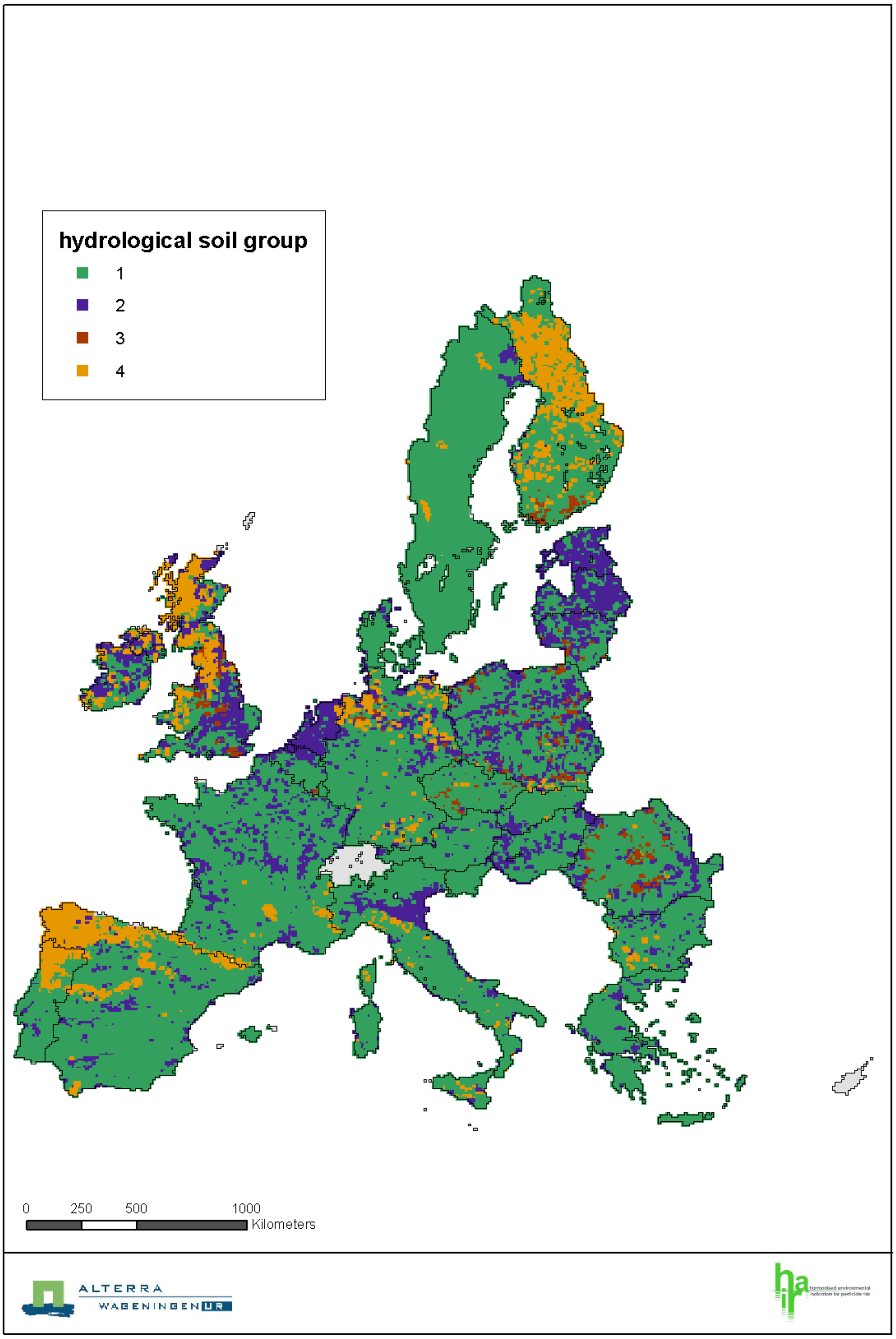
Annex 3 Soil and climate maps

Contents

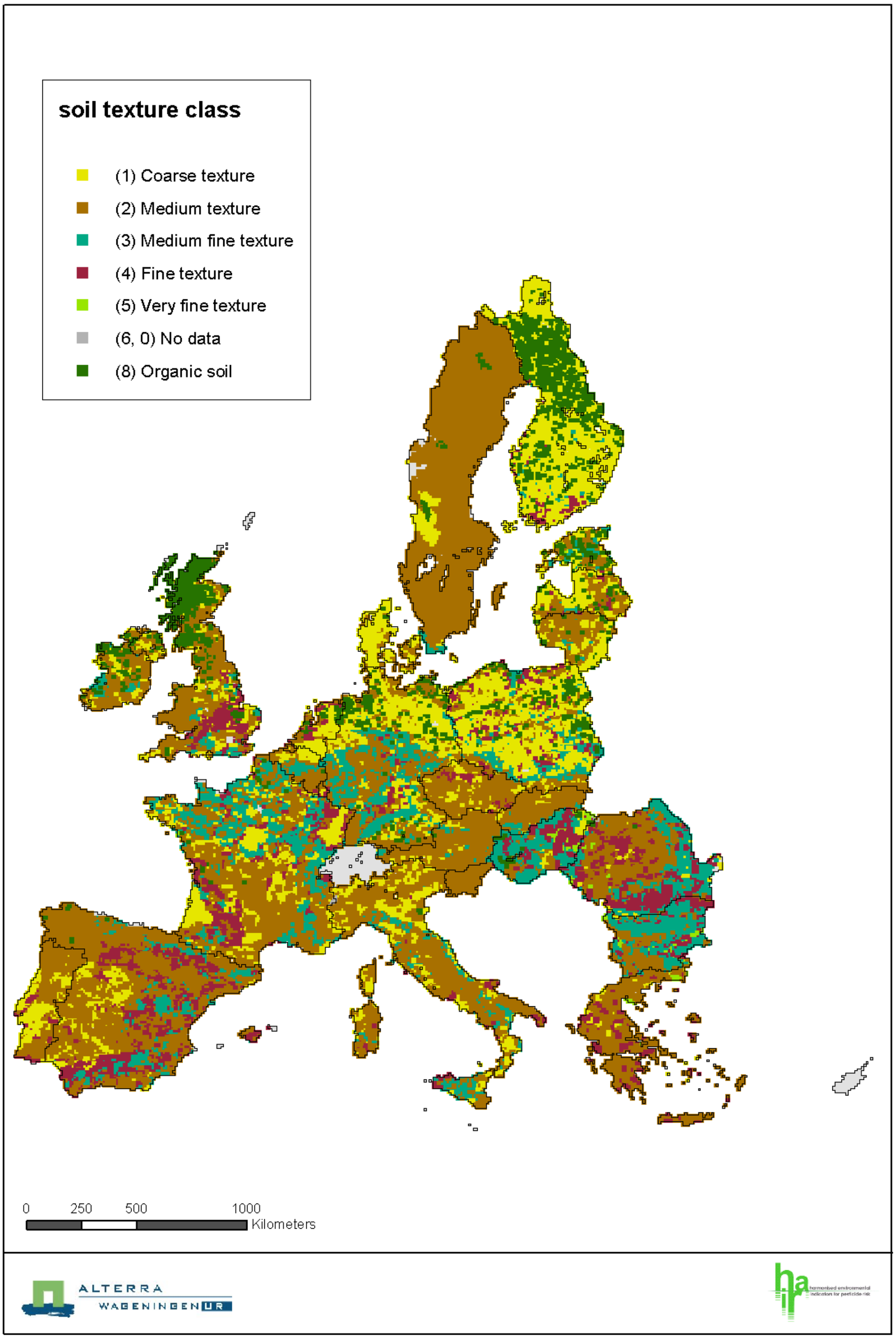

soil organic carbon (0-0.30 m)
< - 1.0
1.1 - 2.0
2.1 - 6.0
6.1 - 12.5
12.6 - 25.0
25.1 - 35.0
35.1 - 57.6
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

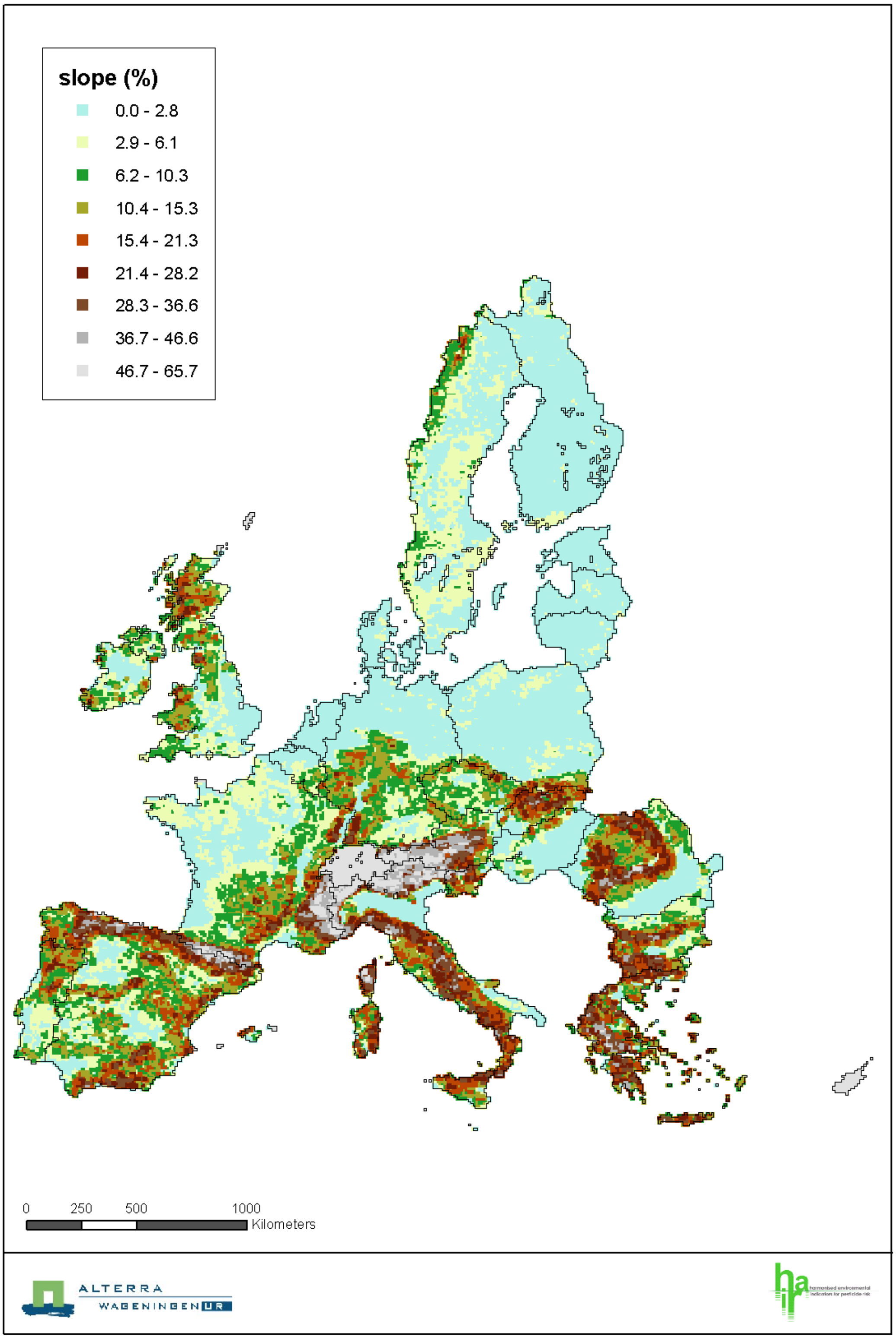

soil organic carbon (0-1 m)
0.4 - 1.0
1.1 - 2.0
2.1 - 6.0
6.1 - 12.5
12.6 - 25.0
25.1 - 30.8
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

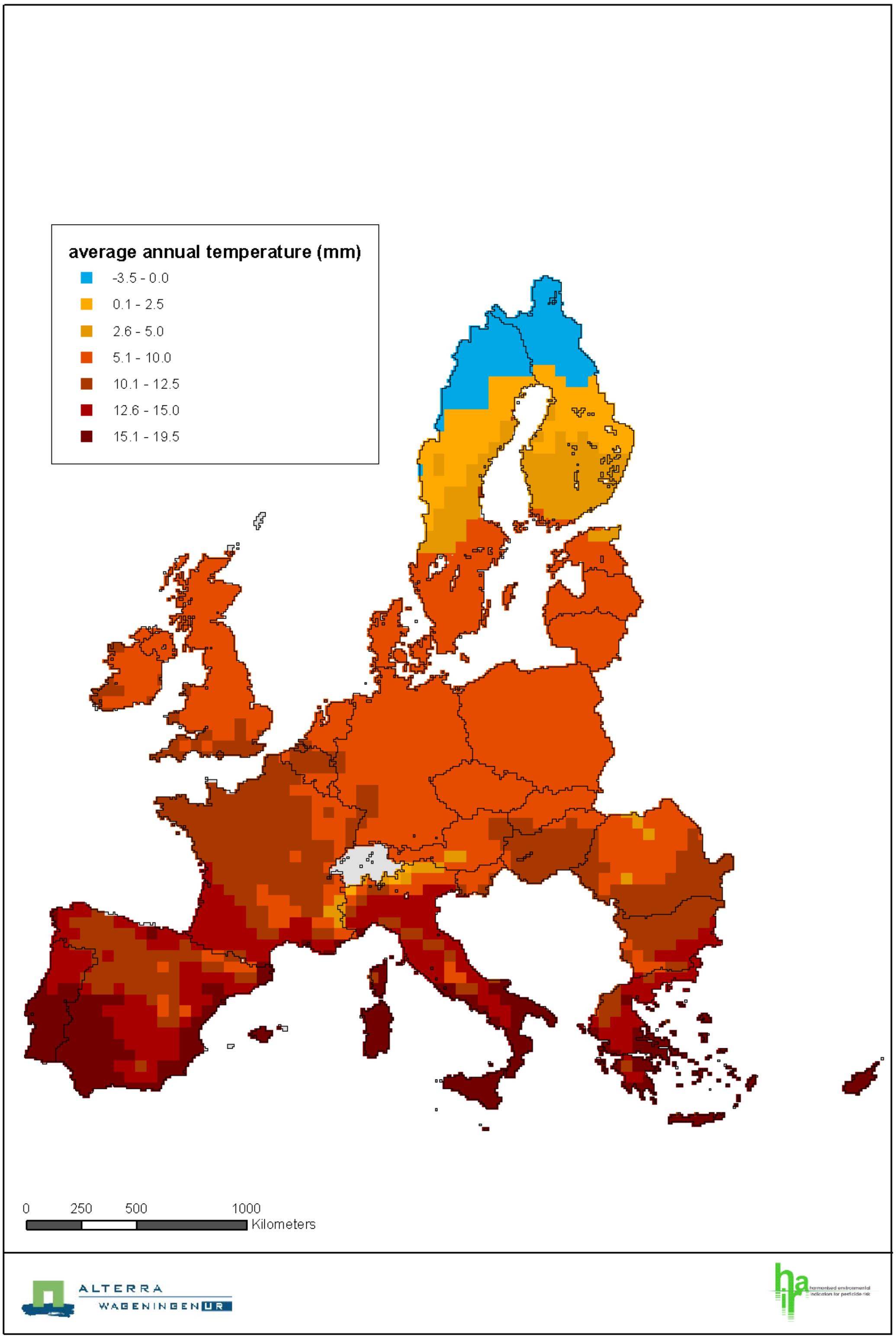

soil pH (-)
4
5
6
7
8
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

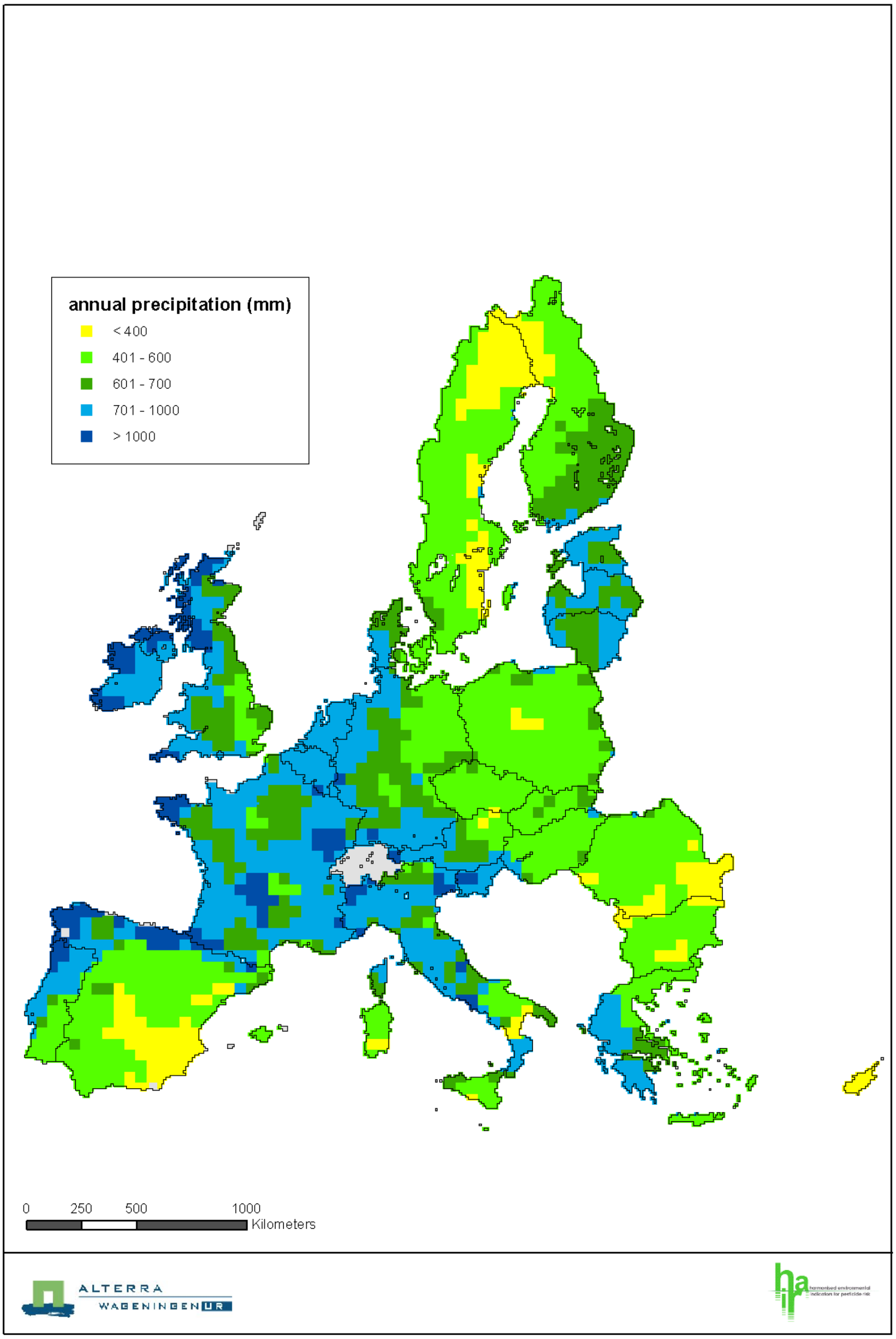


hydrological soil group
1
2
3
4
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


soil texture class
(1) Coarse texture
(2) Medium texture
(3) Medium fine texture
(4) Fine texture
(5) Very fine texture
(6, 0) No data
(8) Organic soil
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


slope (%)
0.0 - 2.8
2.9 - 6.1
6.2 - 10.3
10.4 - 15.3
15.4 - 21.3
21.4 - 28.2
28.3 - 36.6
36.7 - 46.6
46.7 - 65.7
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


average annual temperature (mm)
-3.5 - 0.0
0.1 - 2.5
2.6 - 5.0
5.1 - 10.0
10.1 - 12.5
12.6 - 15.0
15.1 - 19.5
0
250
500
1000
Kilometers

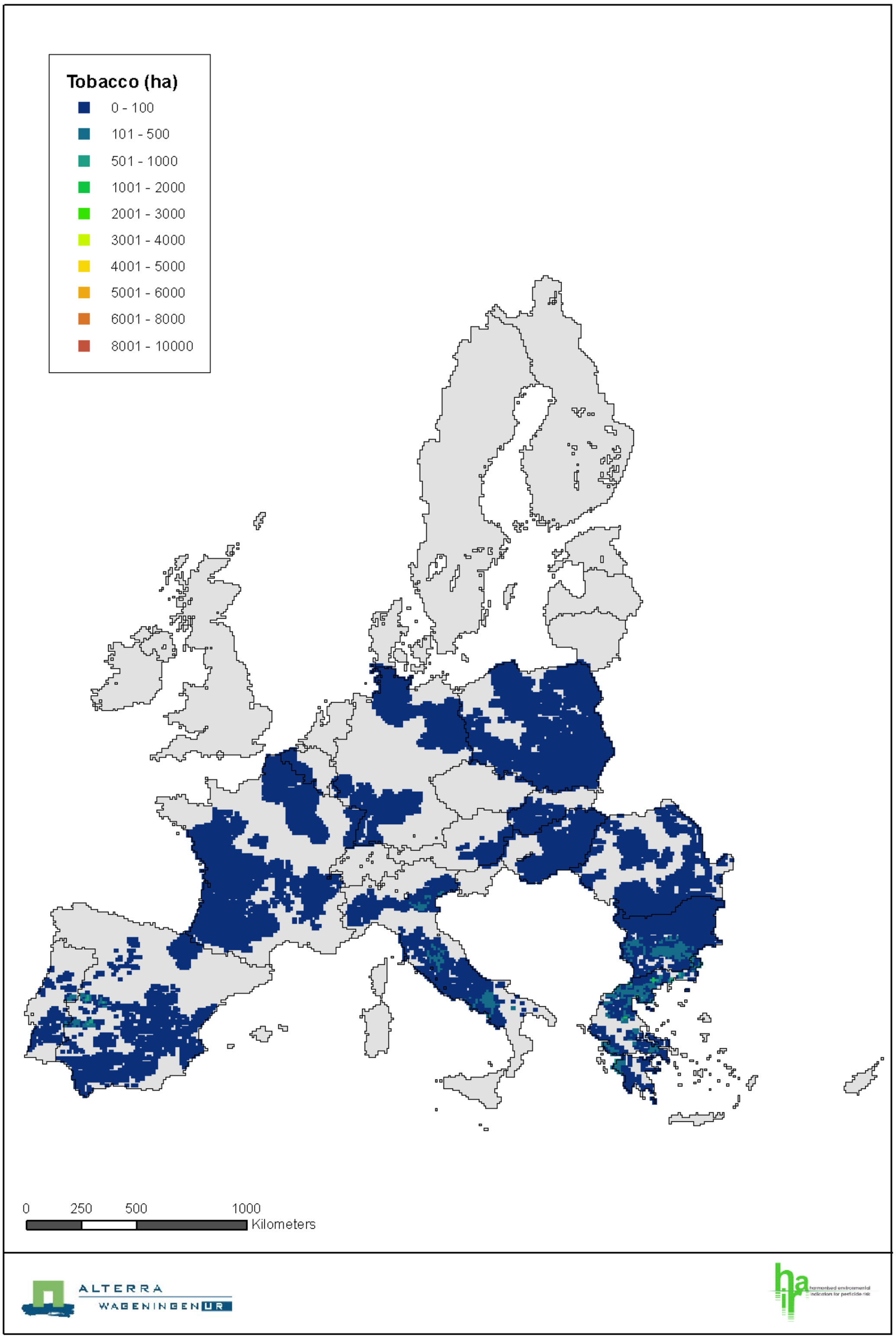

annual precipitation (mm)
< 400
401 - 600
601 - 700
701 - 1000
> 1000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

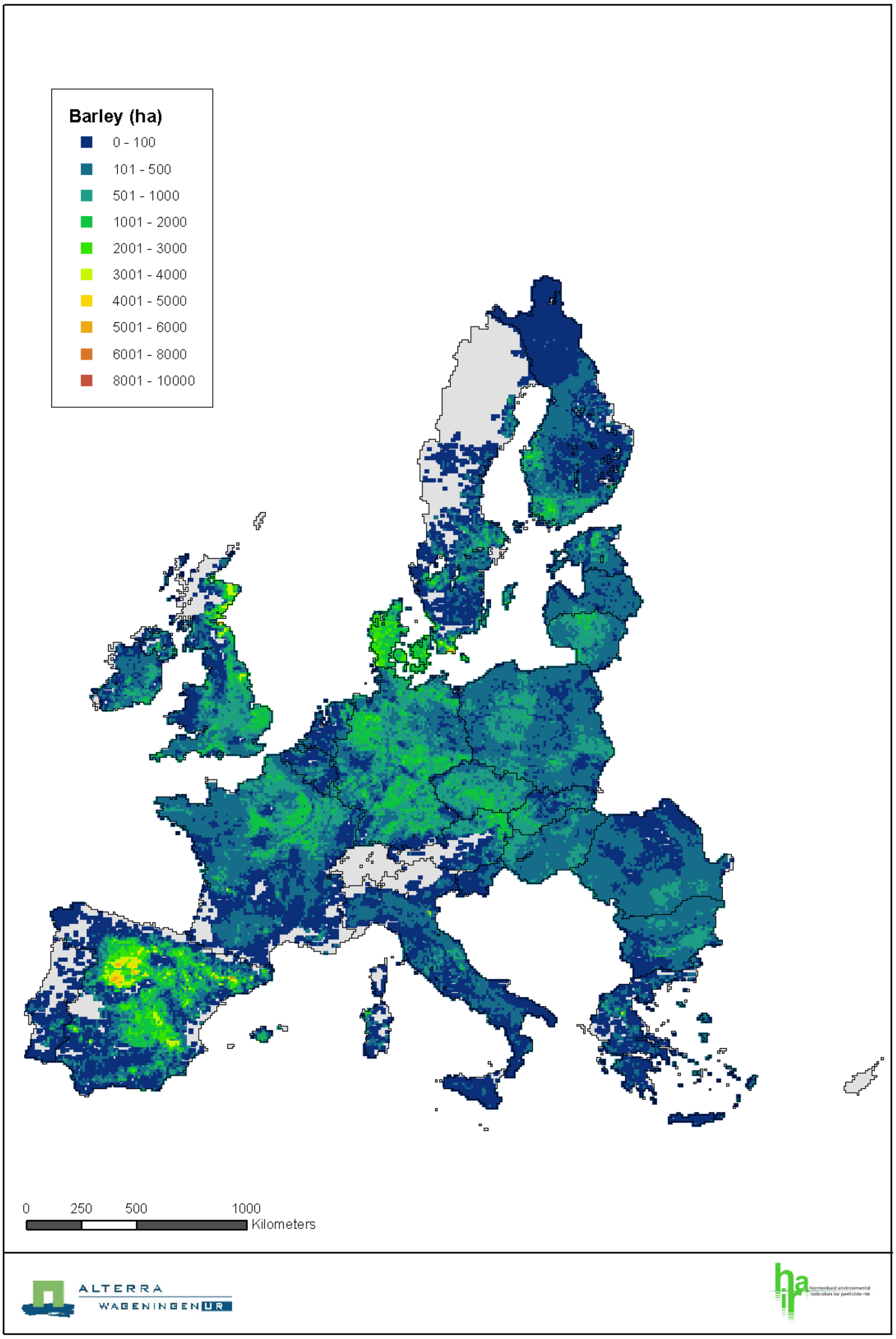
Annex 4 Crop maps

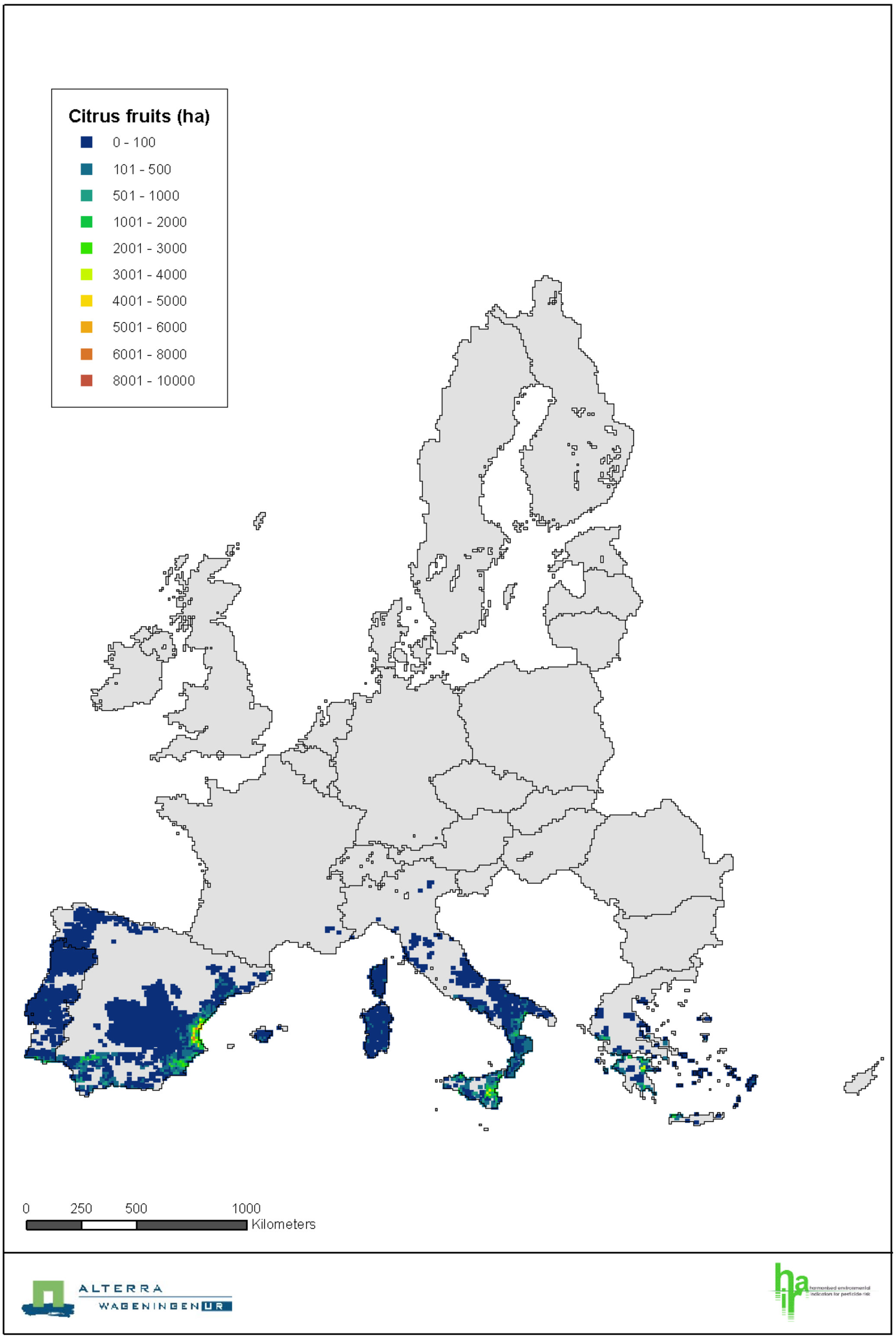
Contents

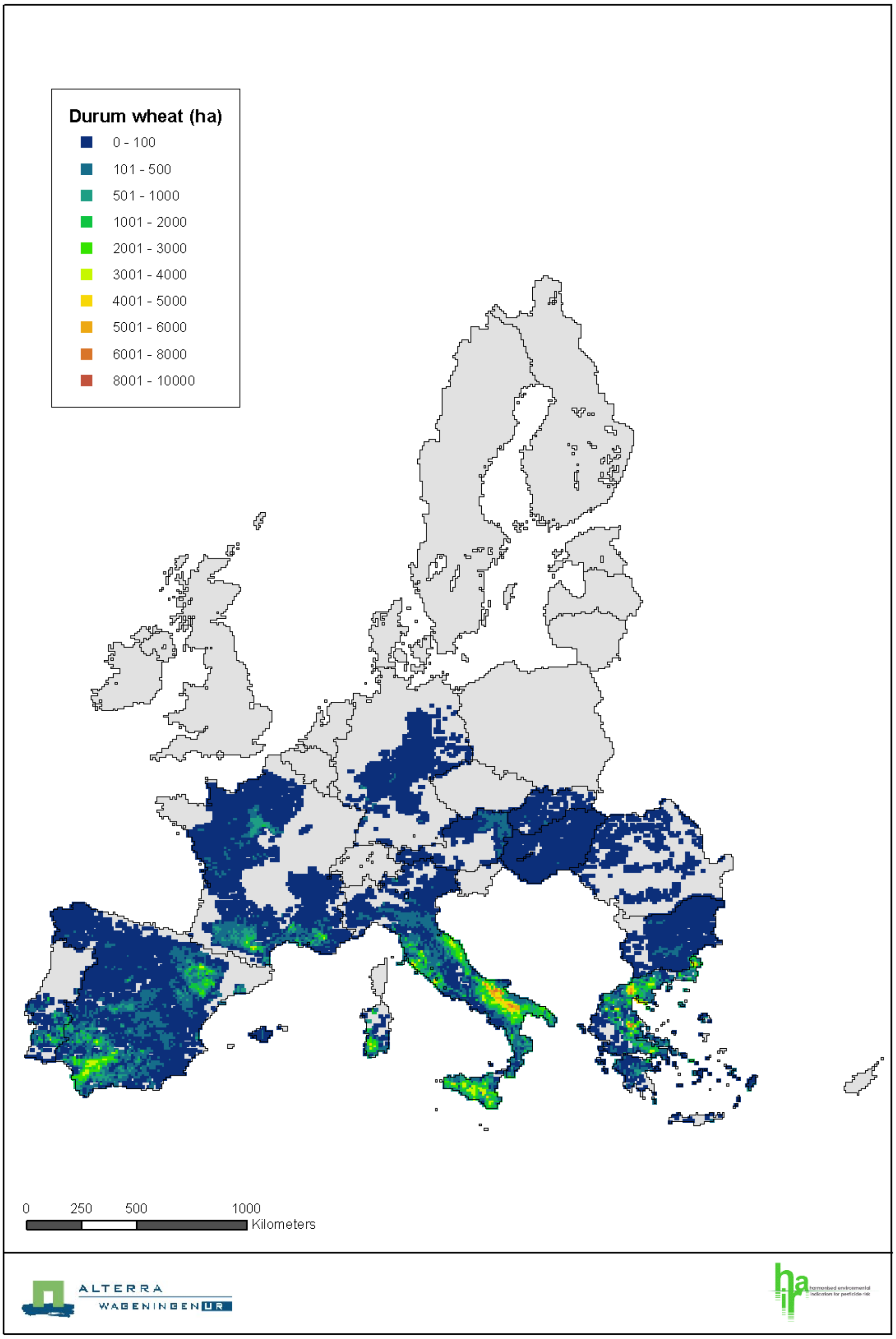
Crop map code	Crop map name
1BARL	Barley
2CITR	Citrus fruits
3DWHE	Durum Wheat
4FLOW	Floriculture
5GRAS	Permanent gras and grazing
6LFALL	Fallow land
7LFRUI	Fruit tree and berry plantations
8LMAIZ	Maize
9LOLIV	Olive groves
10LRAPE	Rape and turnip rape
11LTEXT	Fibre and oleaginous crops
12LTWIN	Vineyards
13NURS	Nurseries
14OATS	Oats
15OCER	Other cereals
16OCRO	Other crops
17OFAR	Fodder other on arable land
18OIND	Other non permanent industrial crops
19OVTO	Tomatoes and Other fresh Vegetables
20PARI	Rice
21POTA	Potatoes
22PULS	Dry pulses
23ROOF	Other root crops
24RYEM	Rye
25SOYA	Soya
26SUGB	Sugar beet
27SUNF	Sunflower
28SWHE	Common wheat
29TOBA	Tobacco
30GHCR [#]	Greenhouse crop and other covered crops

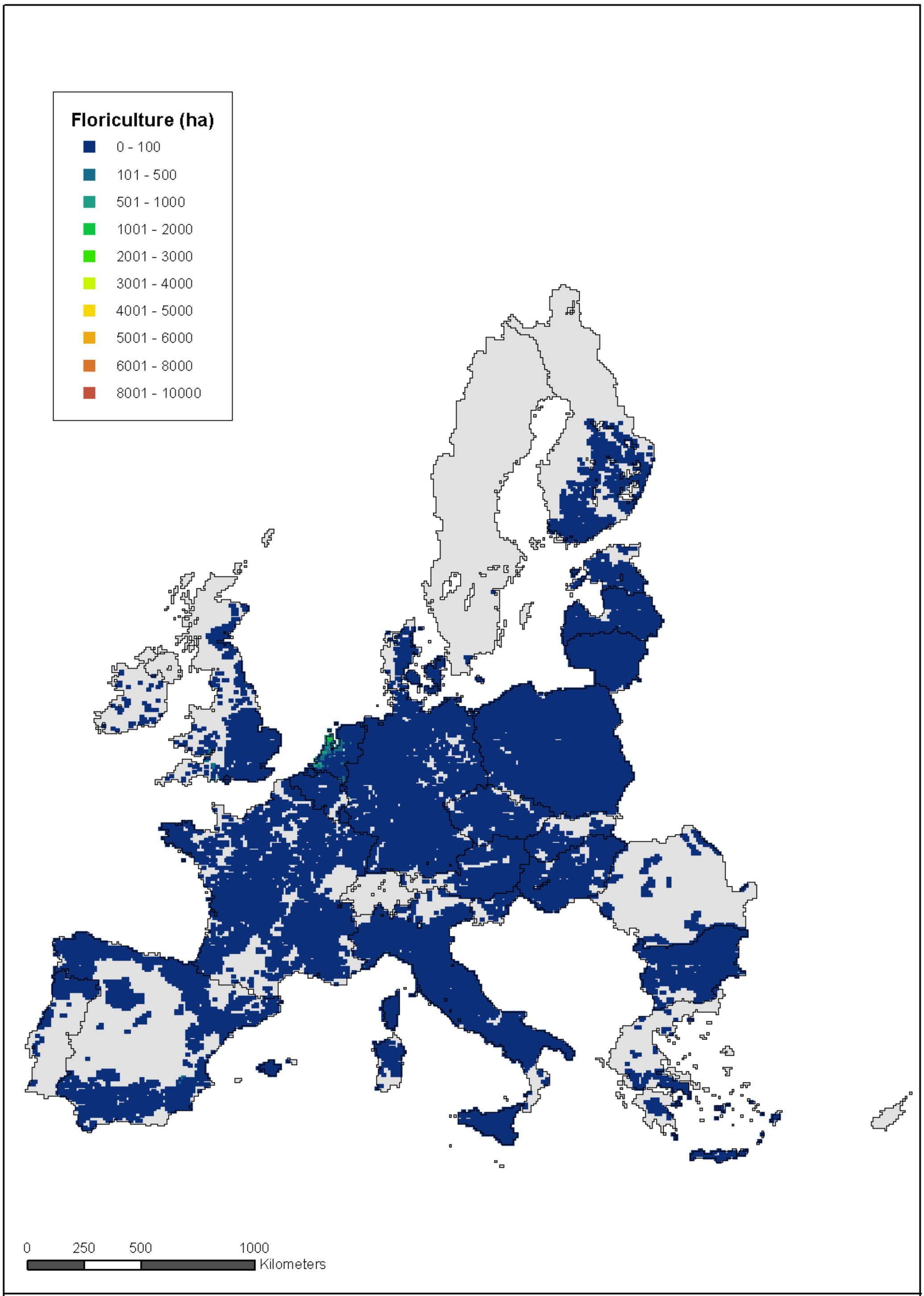
#) Covering the Netherlands, included for example calculations and test purposes.

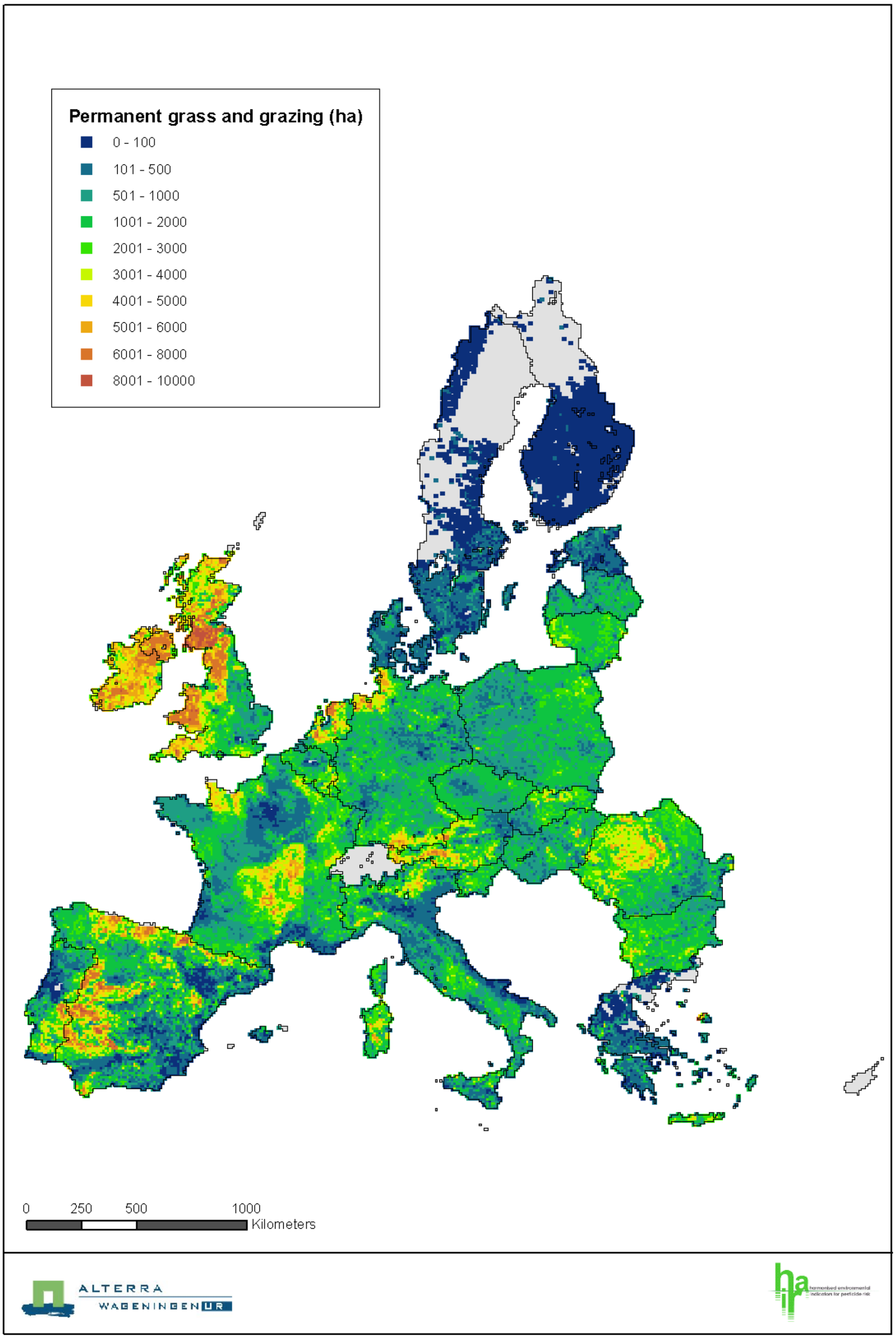

Tobacco (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

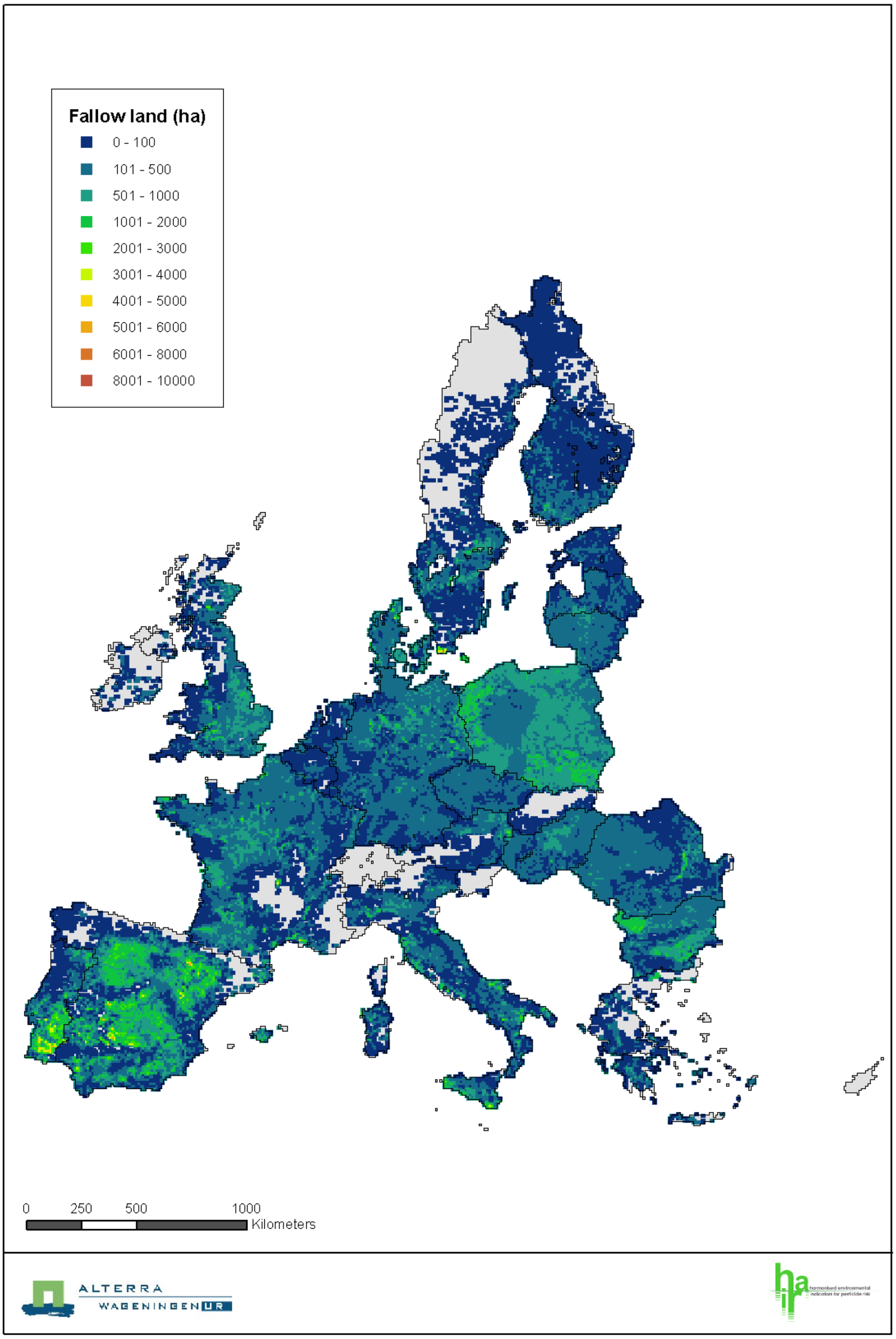

Barley (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

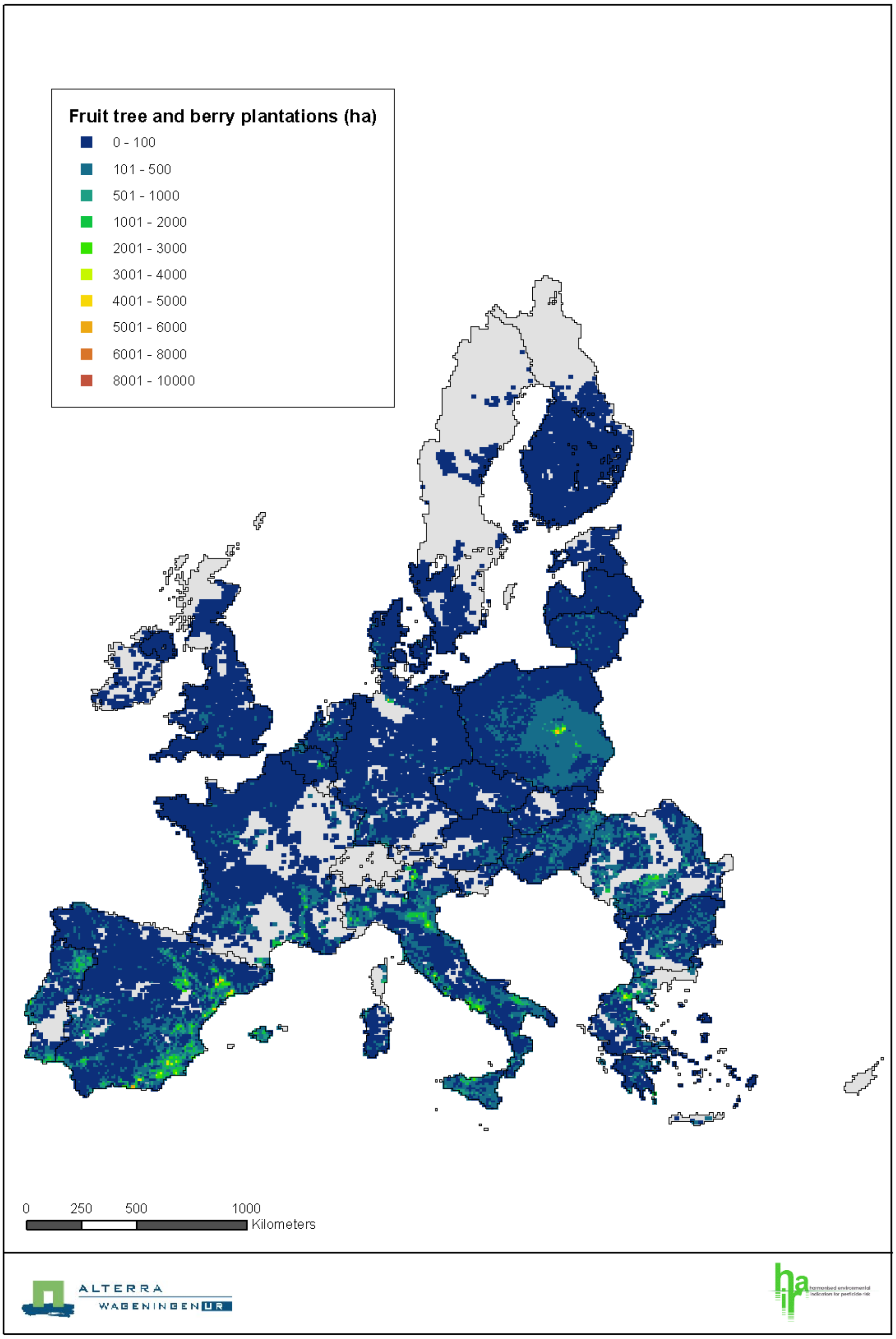

Citrus fruits (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0 250 500 1000
Kilometers
ALTERRA
WAGENINGEN UR

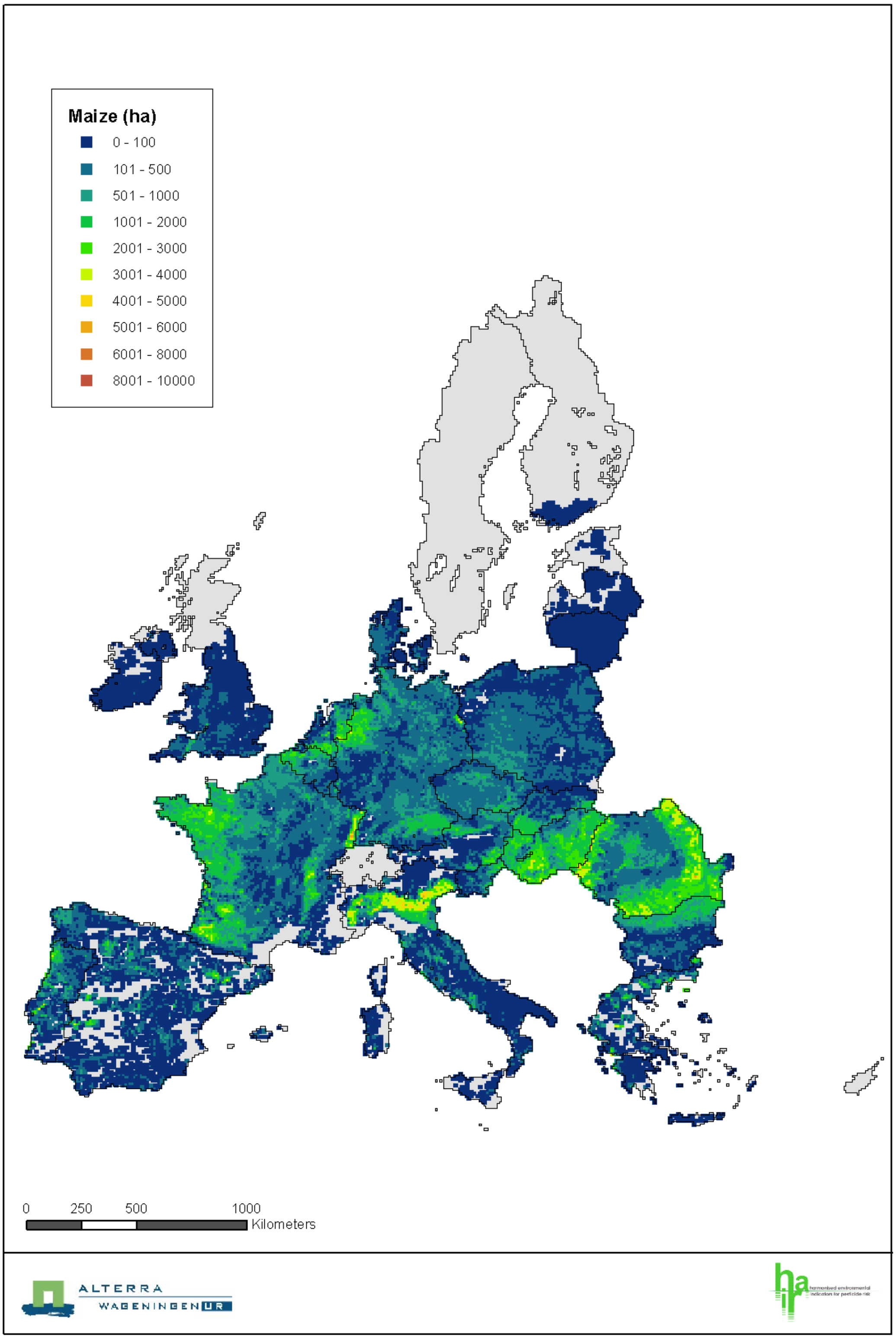

Durum wheat (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

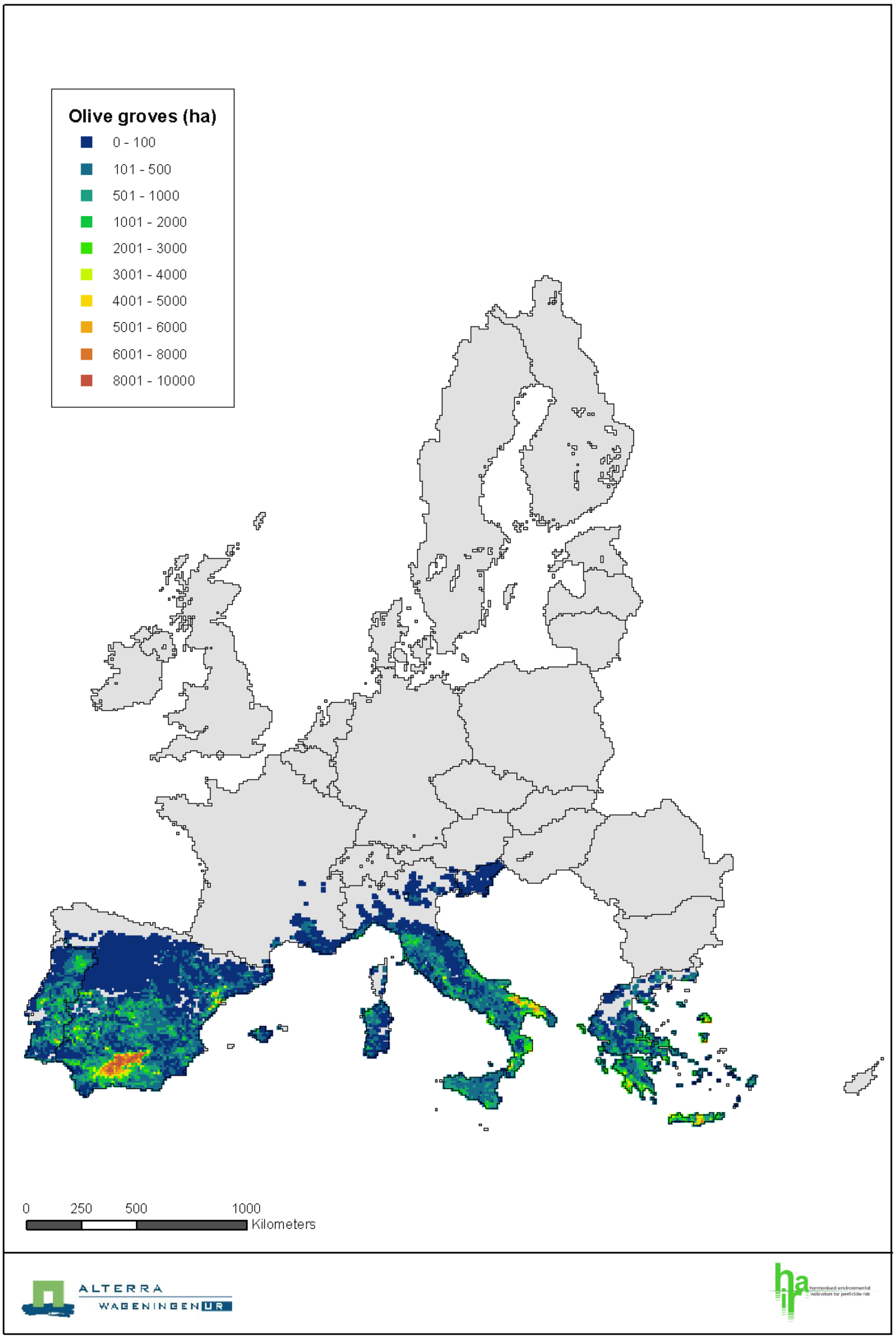

Floriculture (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers

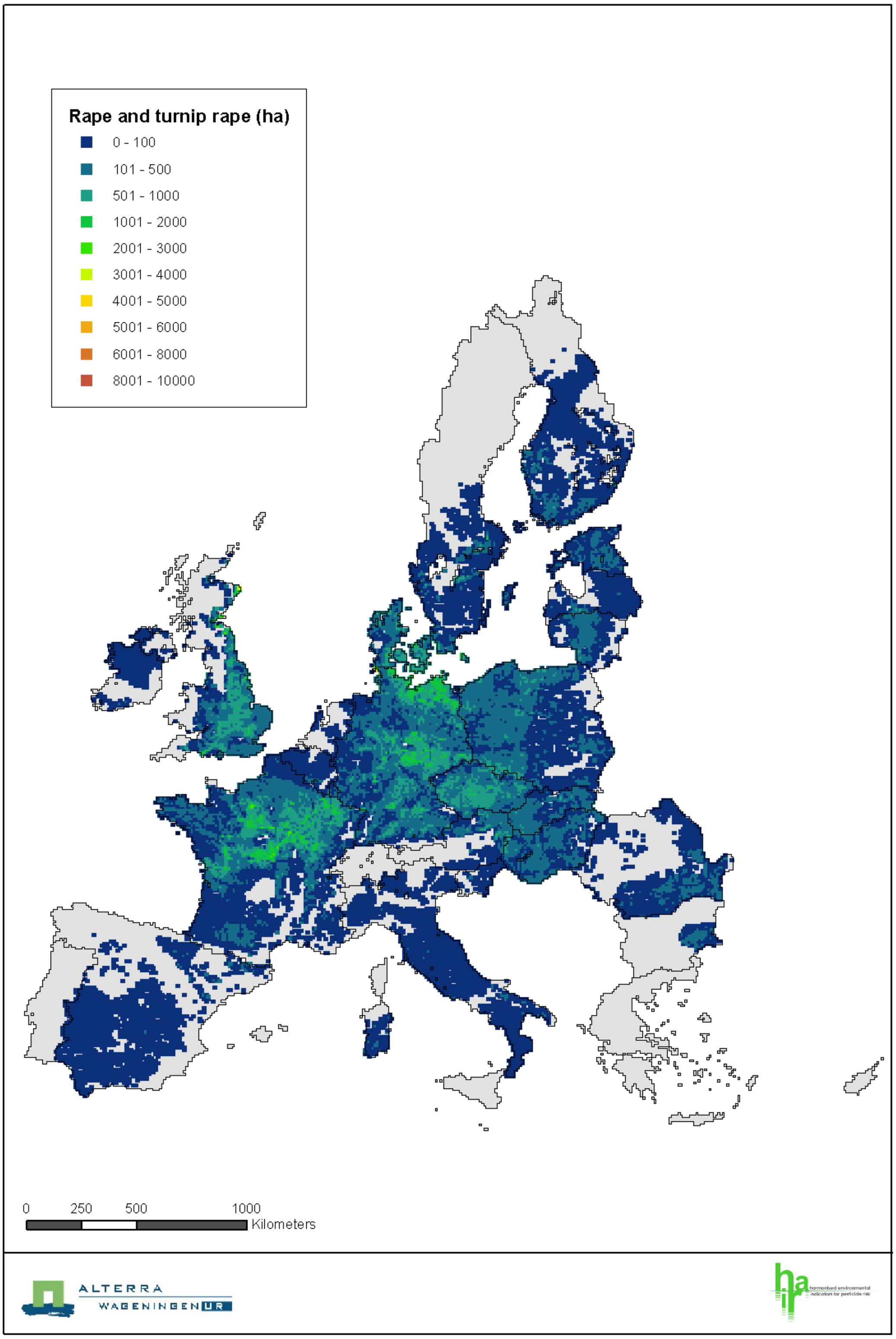

Permanent grass and grazing (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0 250 500 1000
Kilometers
ALTERRA
WAGENINGEN UR


Fallow land (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

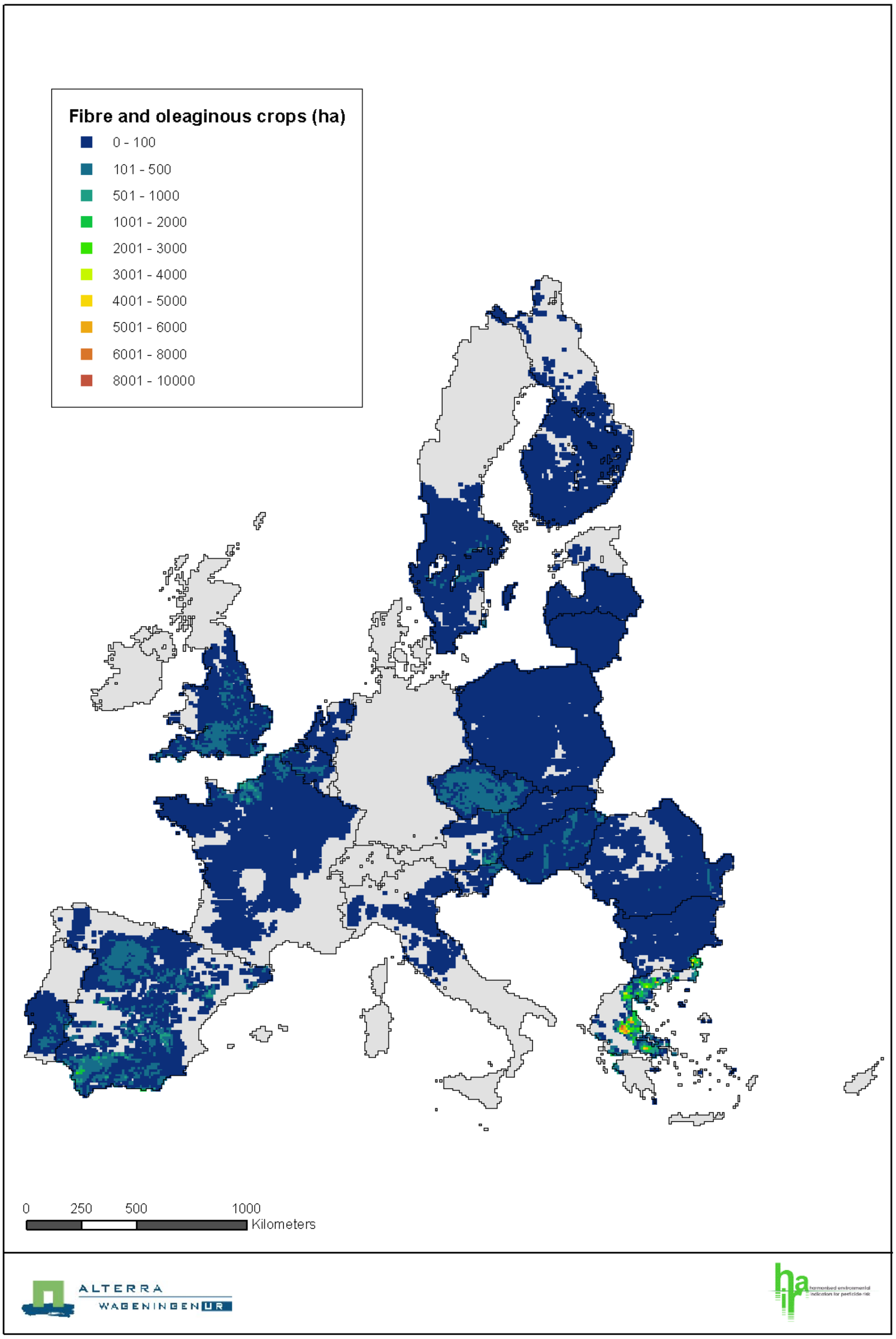

Fruit tree and berry plantations (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

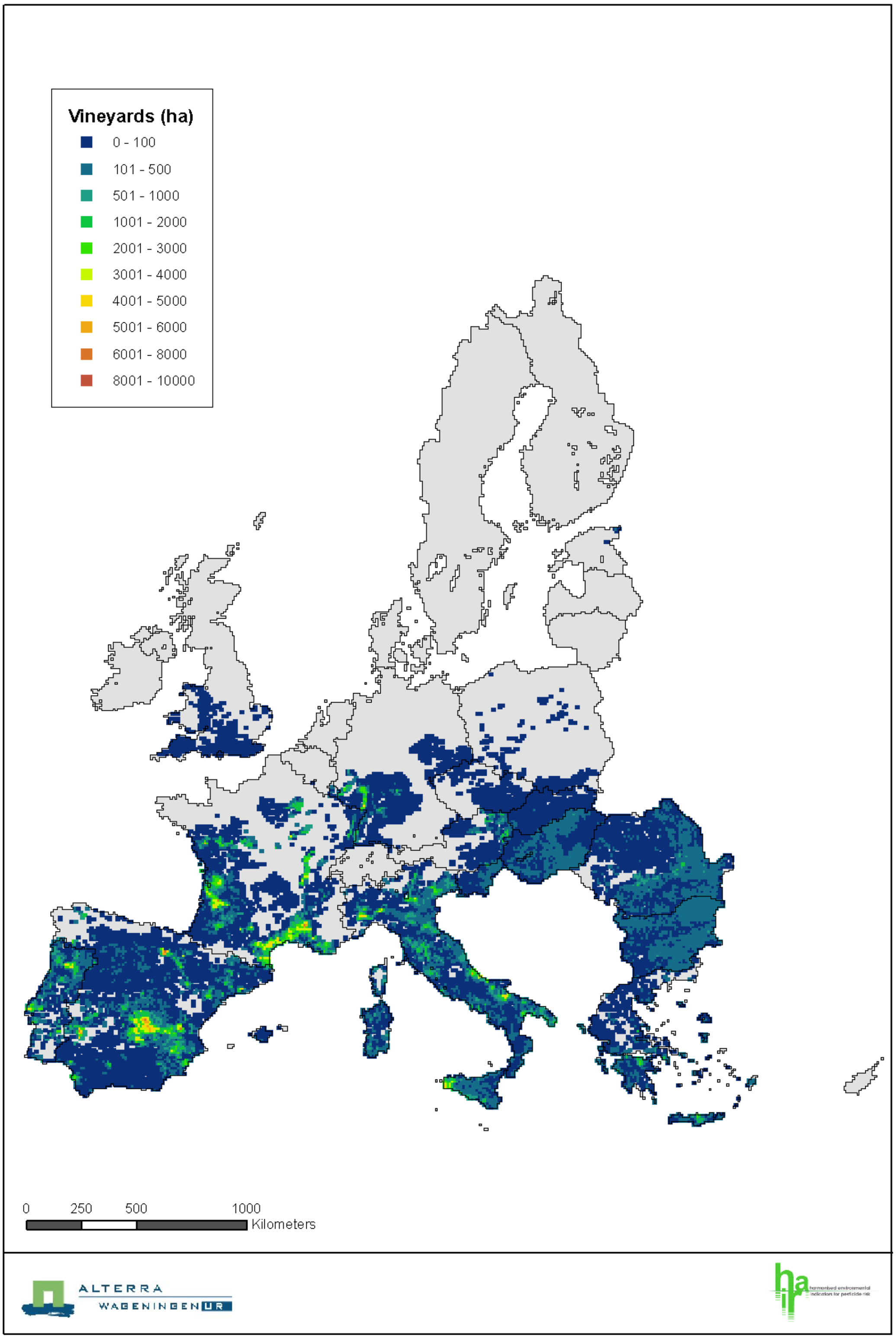

Maize (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

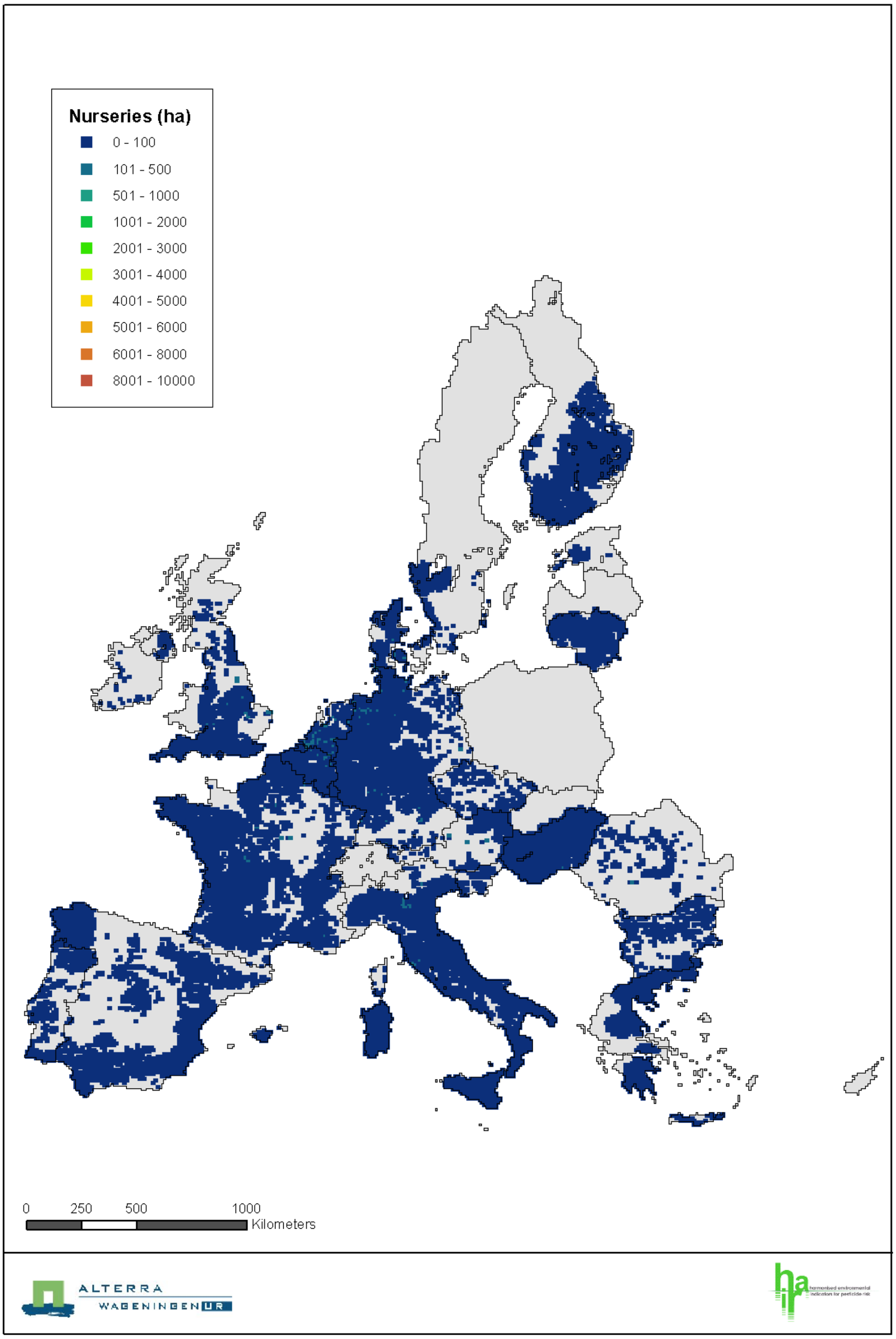

Olive groves (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR



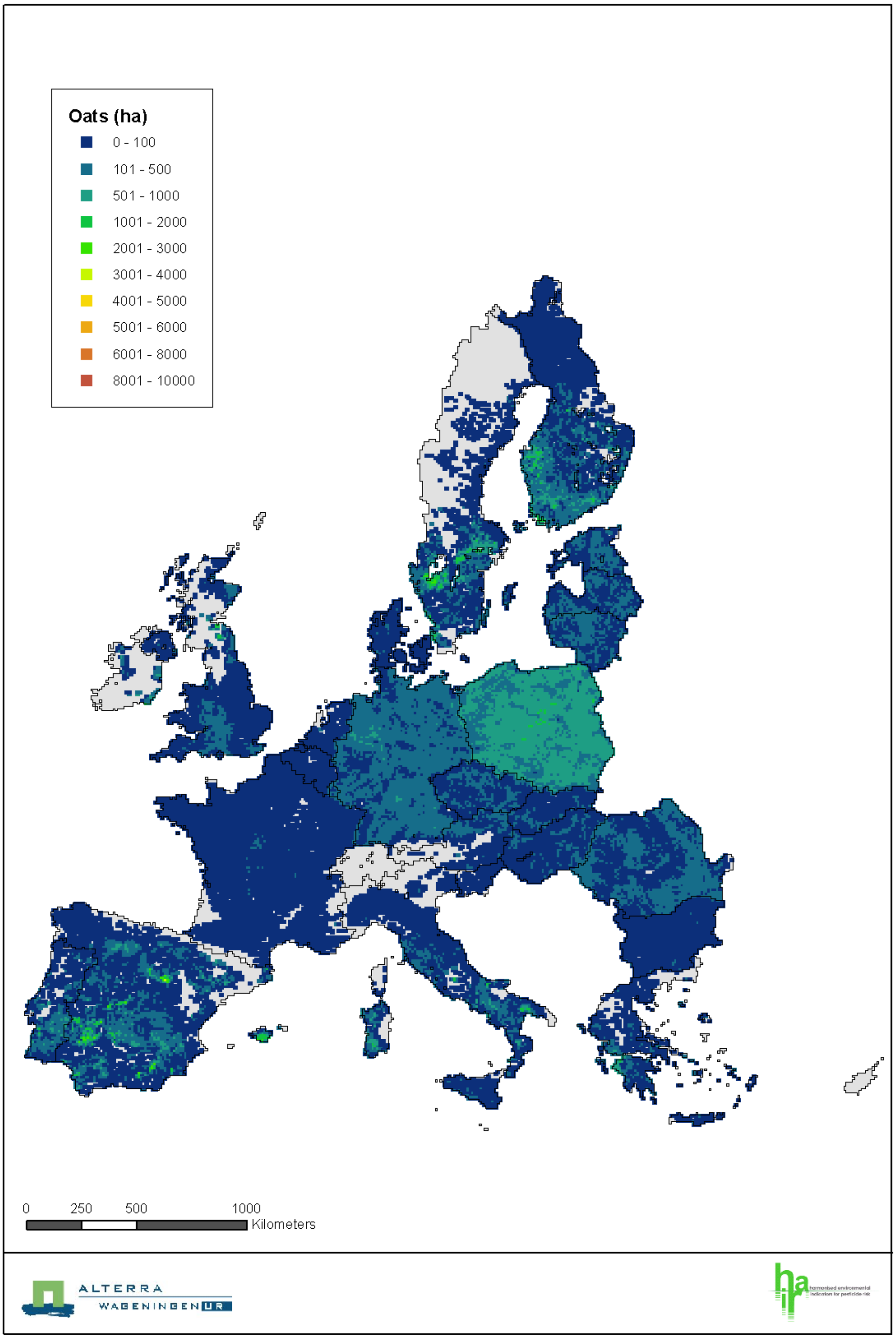
Rape and turnip rape (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


Fibre and oleaginous crops (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

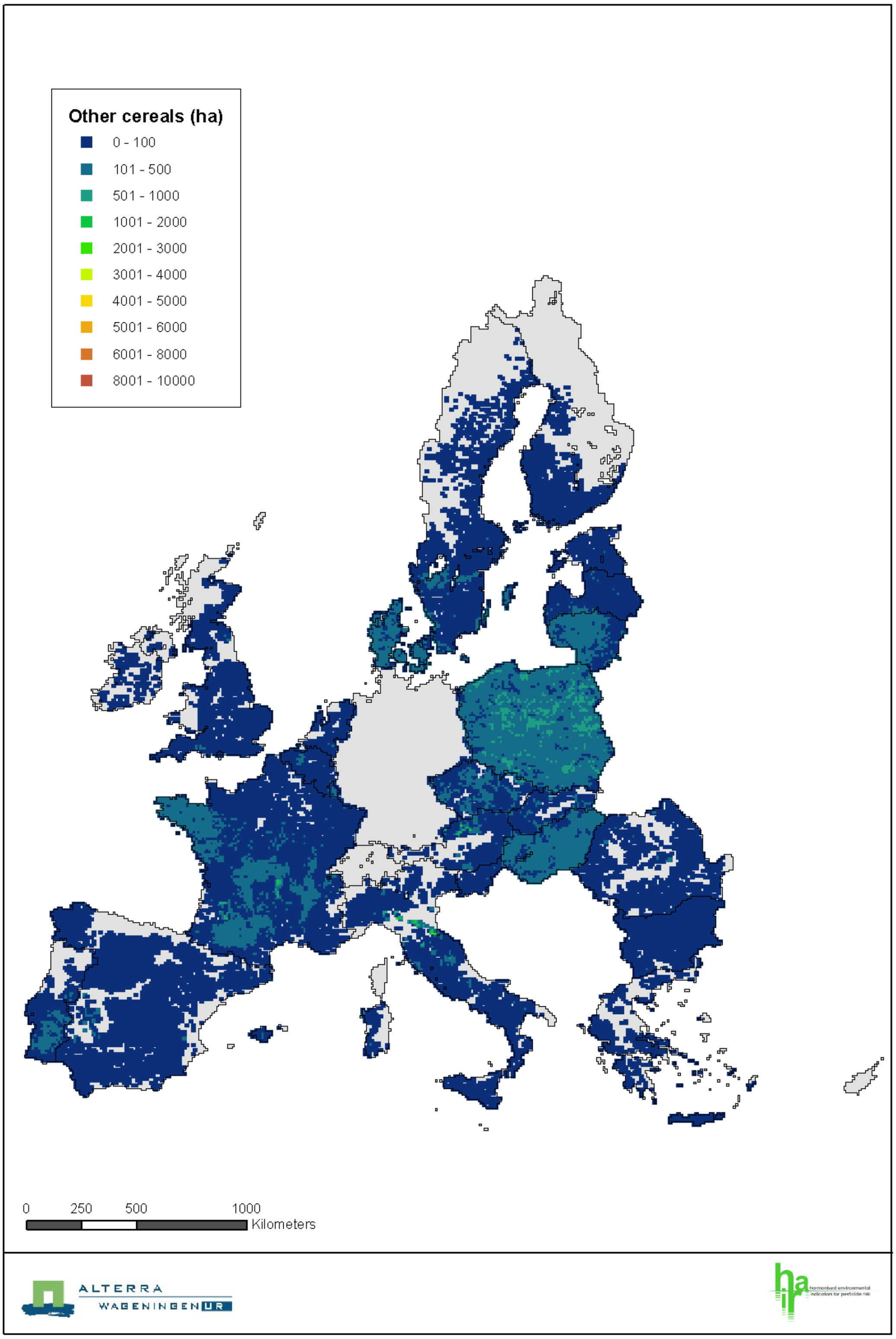

Vineyards (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

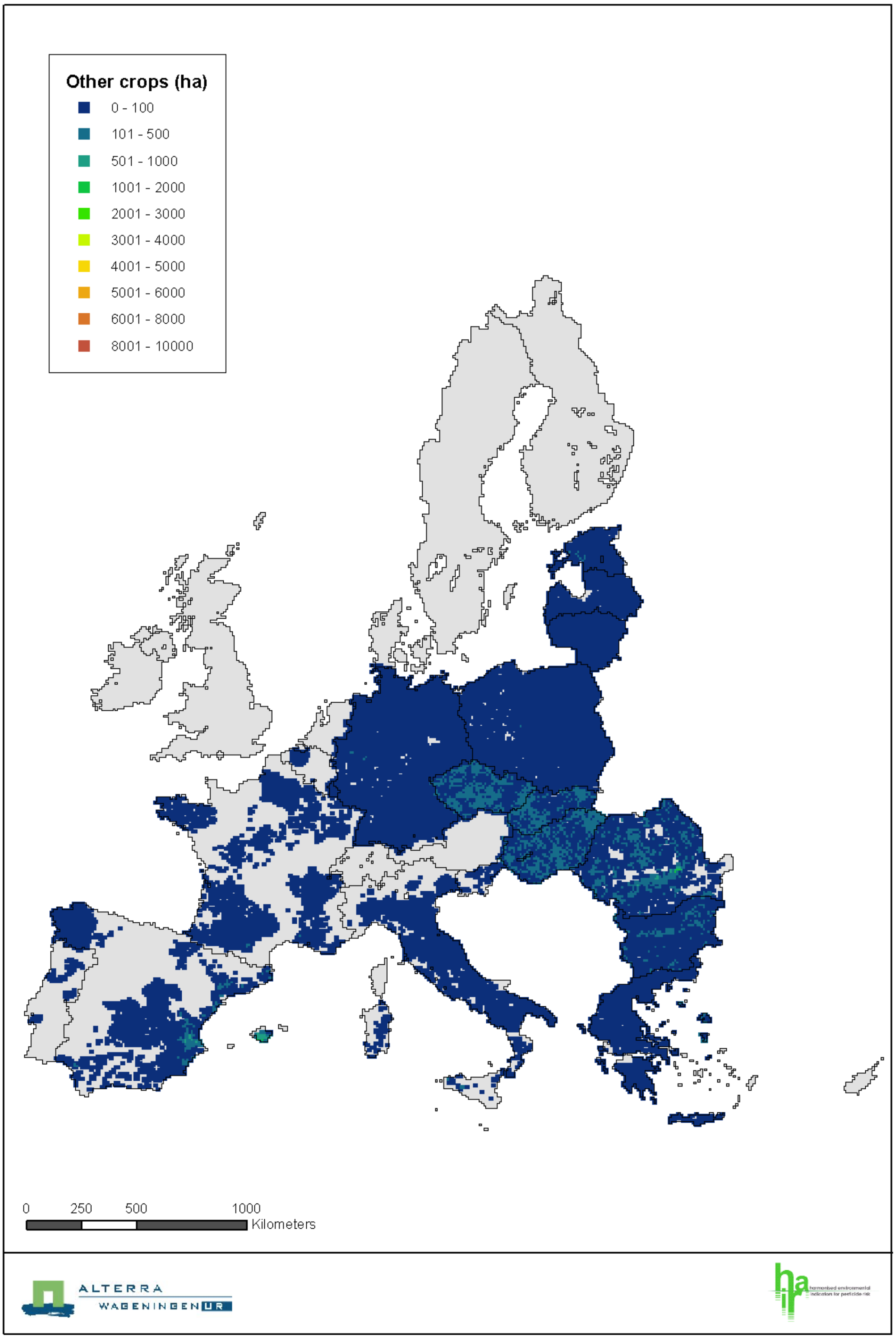


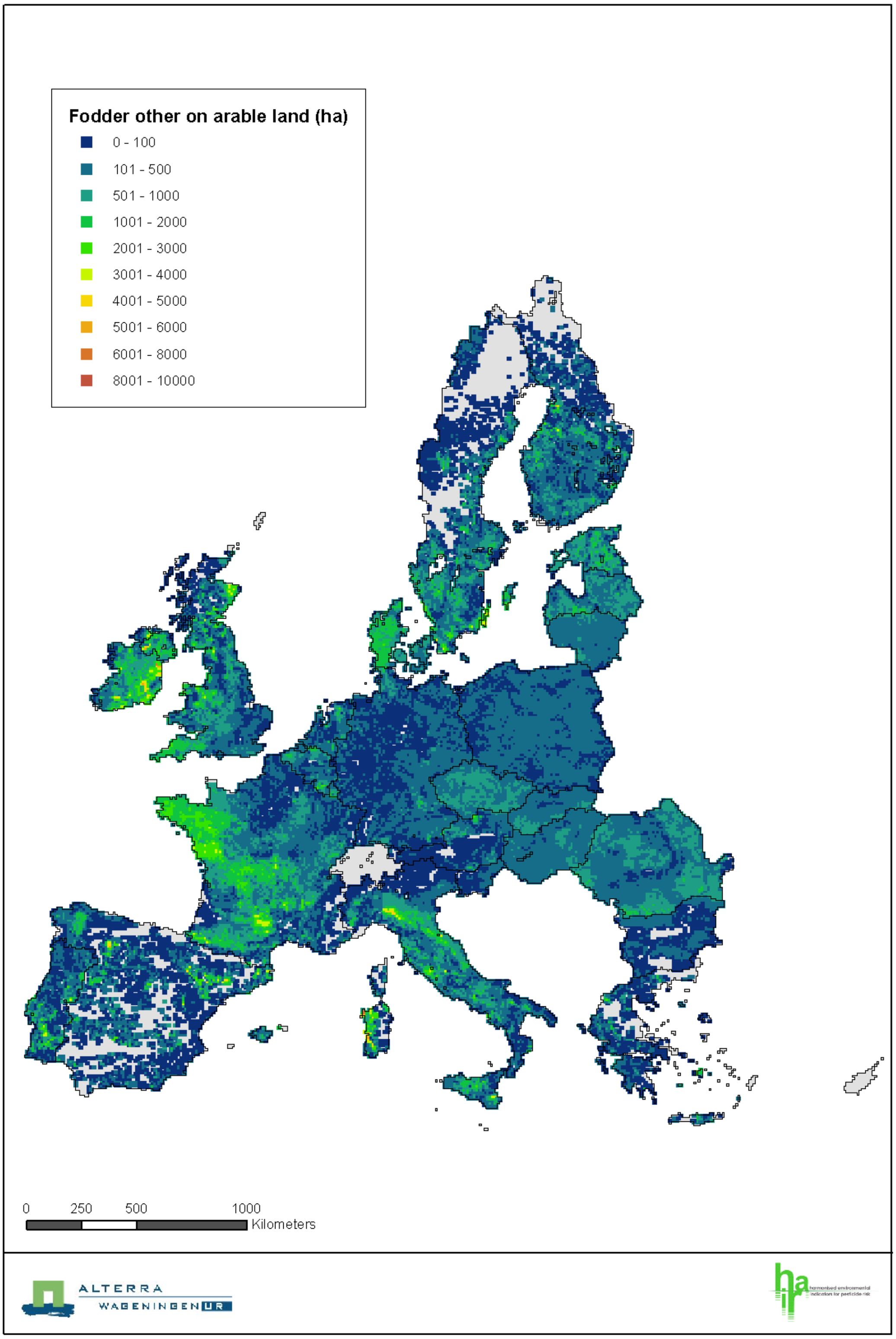
Nurseries (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

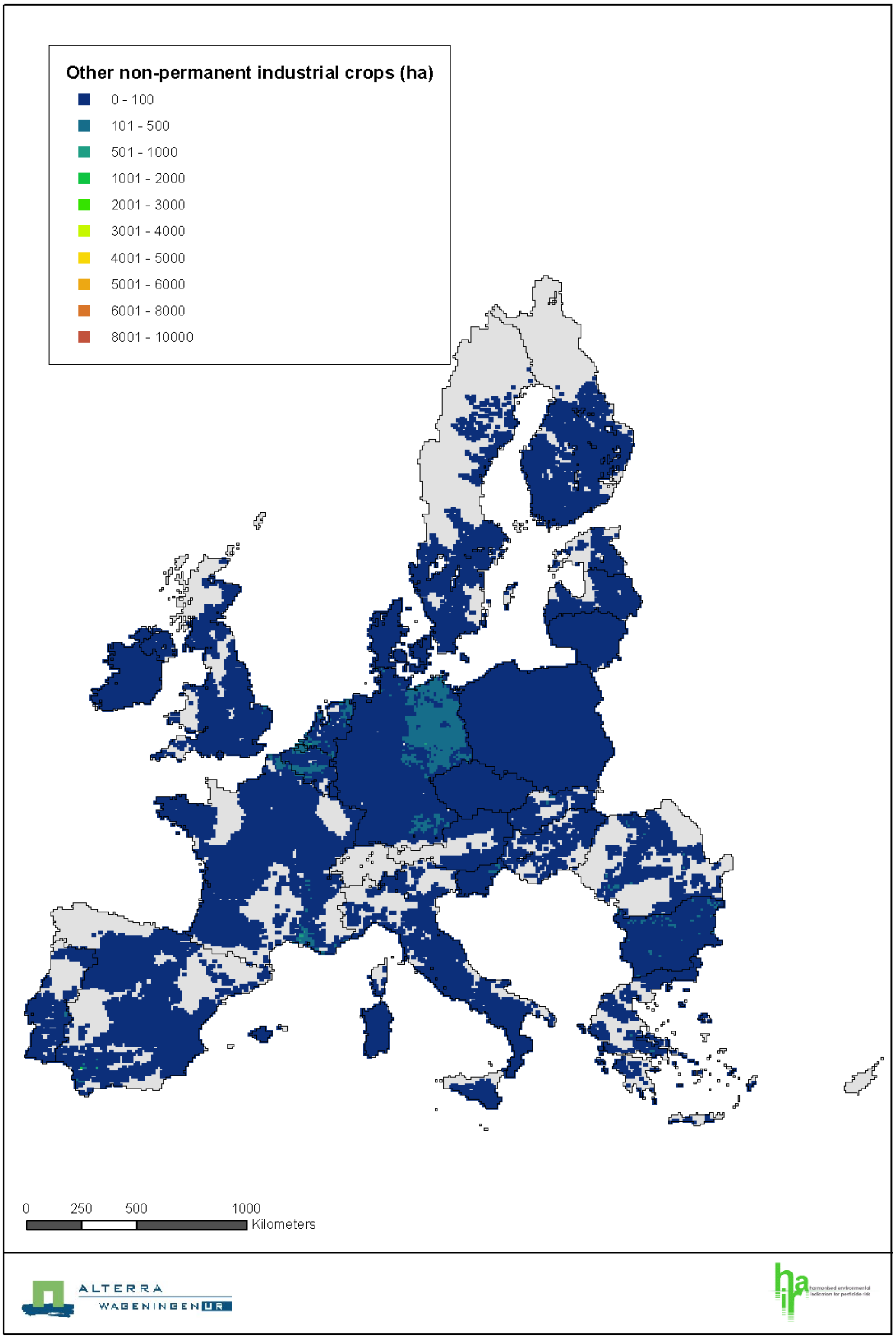


Oats (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

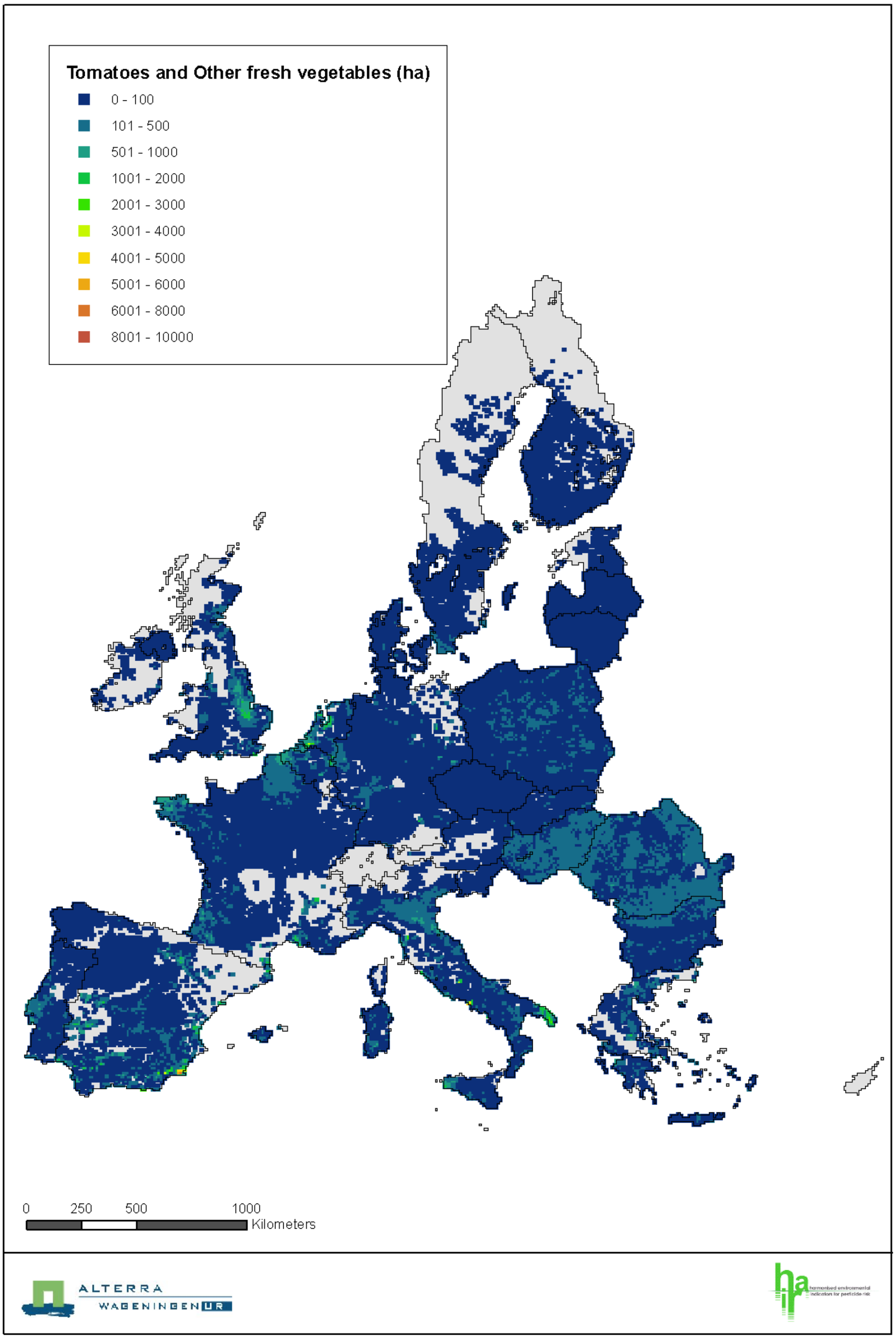

Other cereals (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

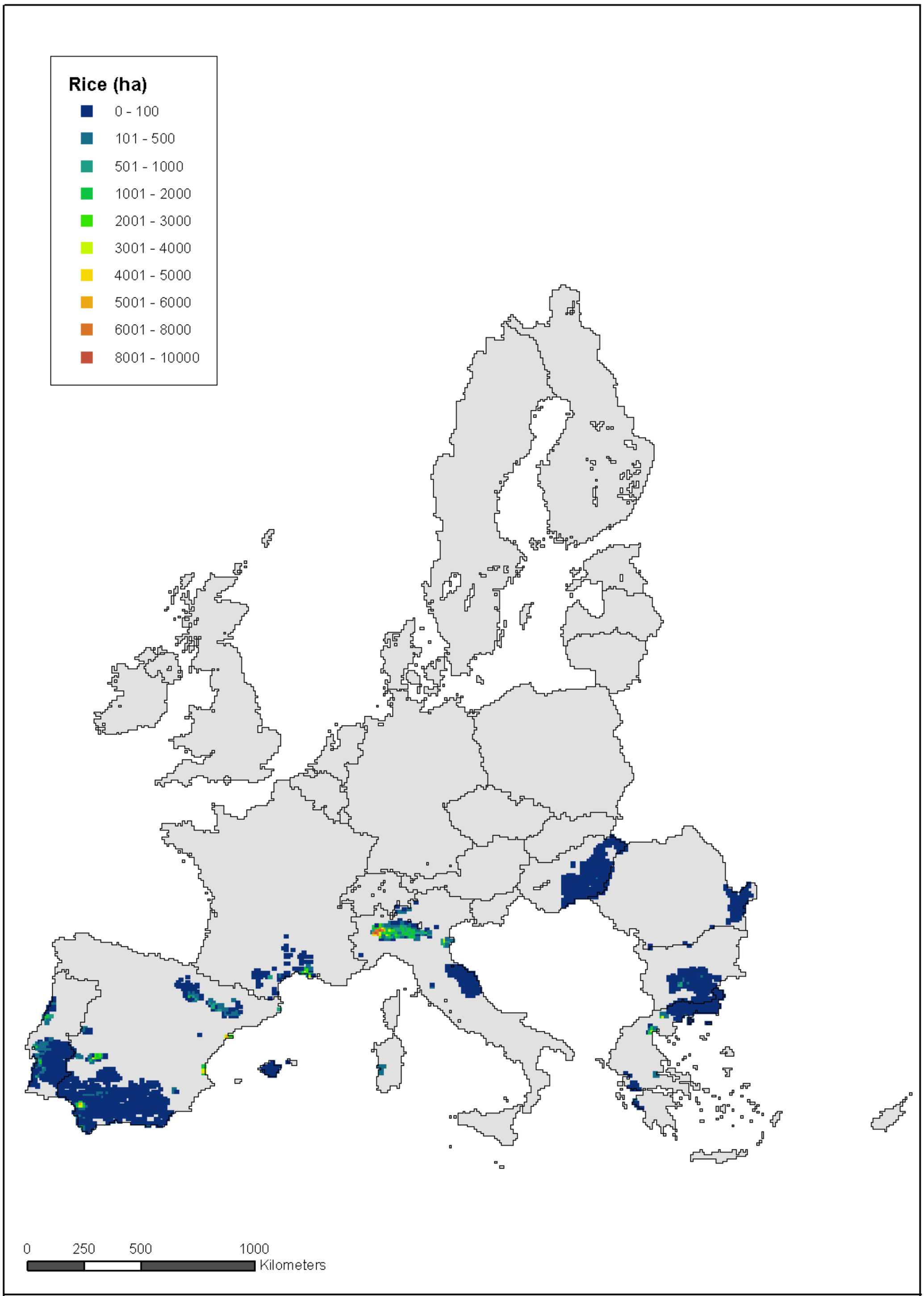

Other crops (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


Fodder other on arable land (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

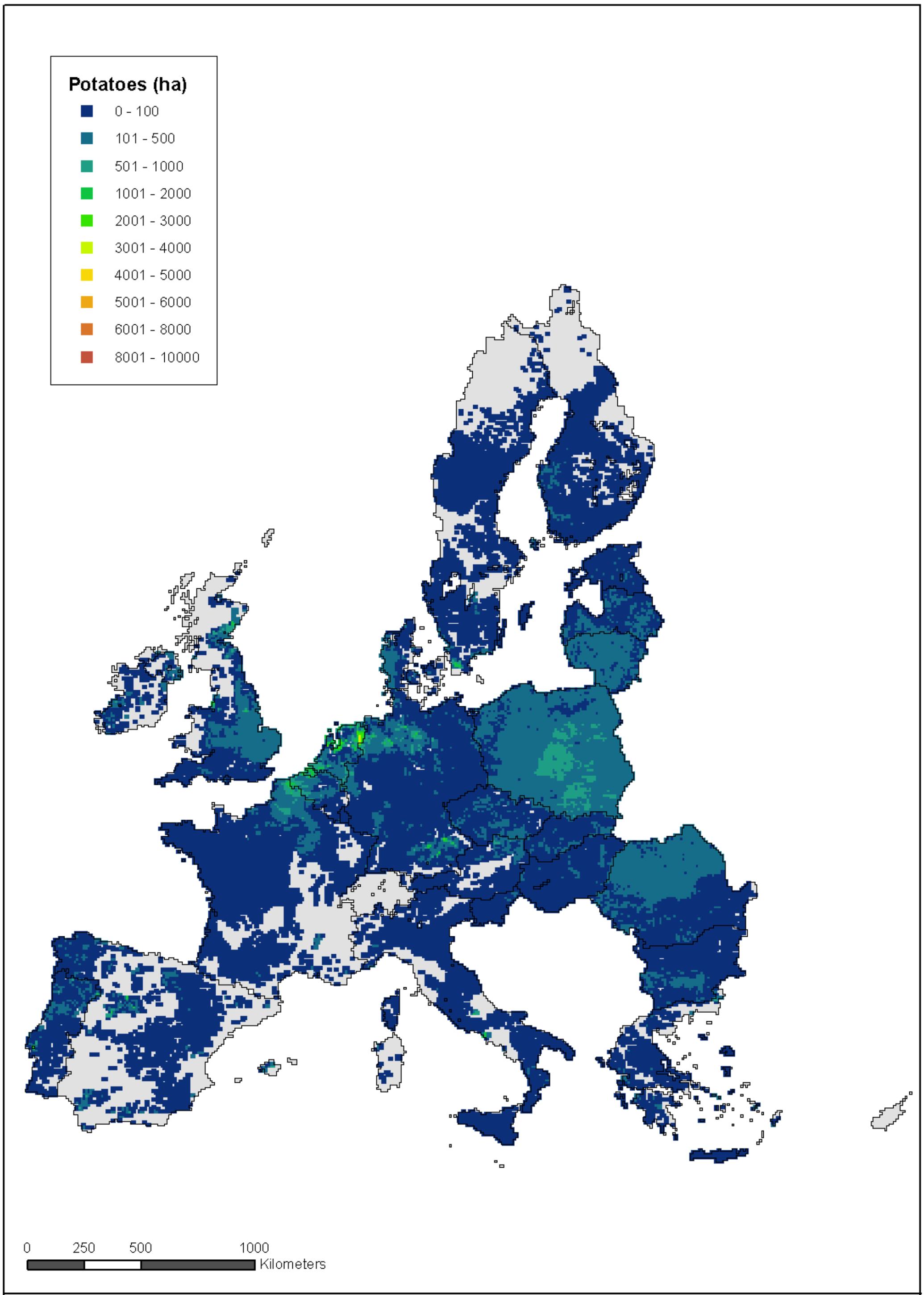


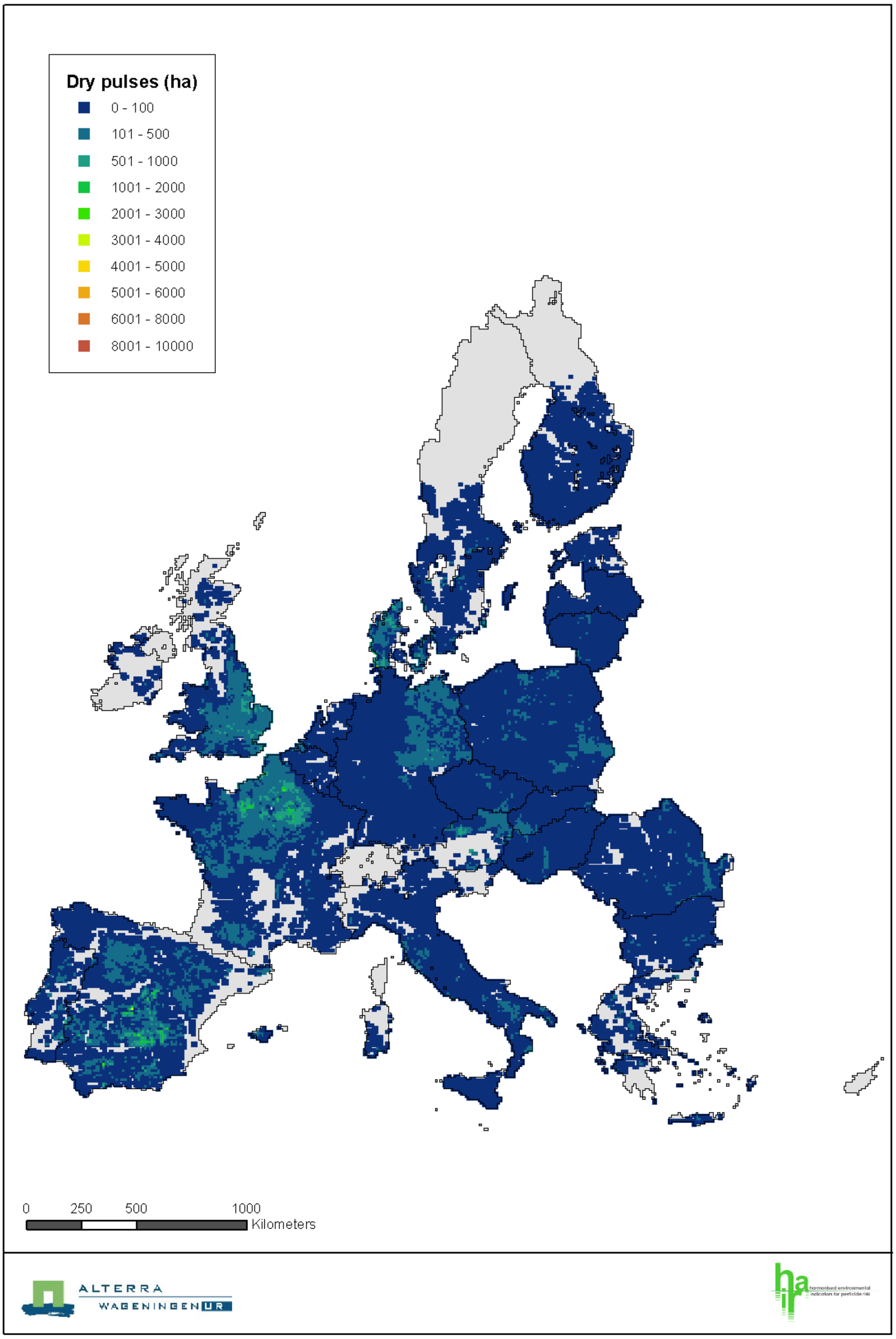
Other non-permanent industrial crops (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0 250 500 1000
Kilometers
ALTERRA
WAGENINGEN UR

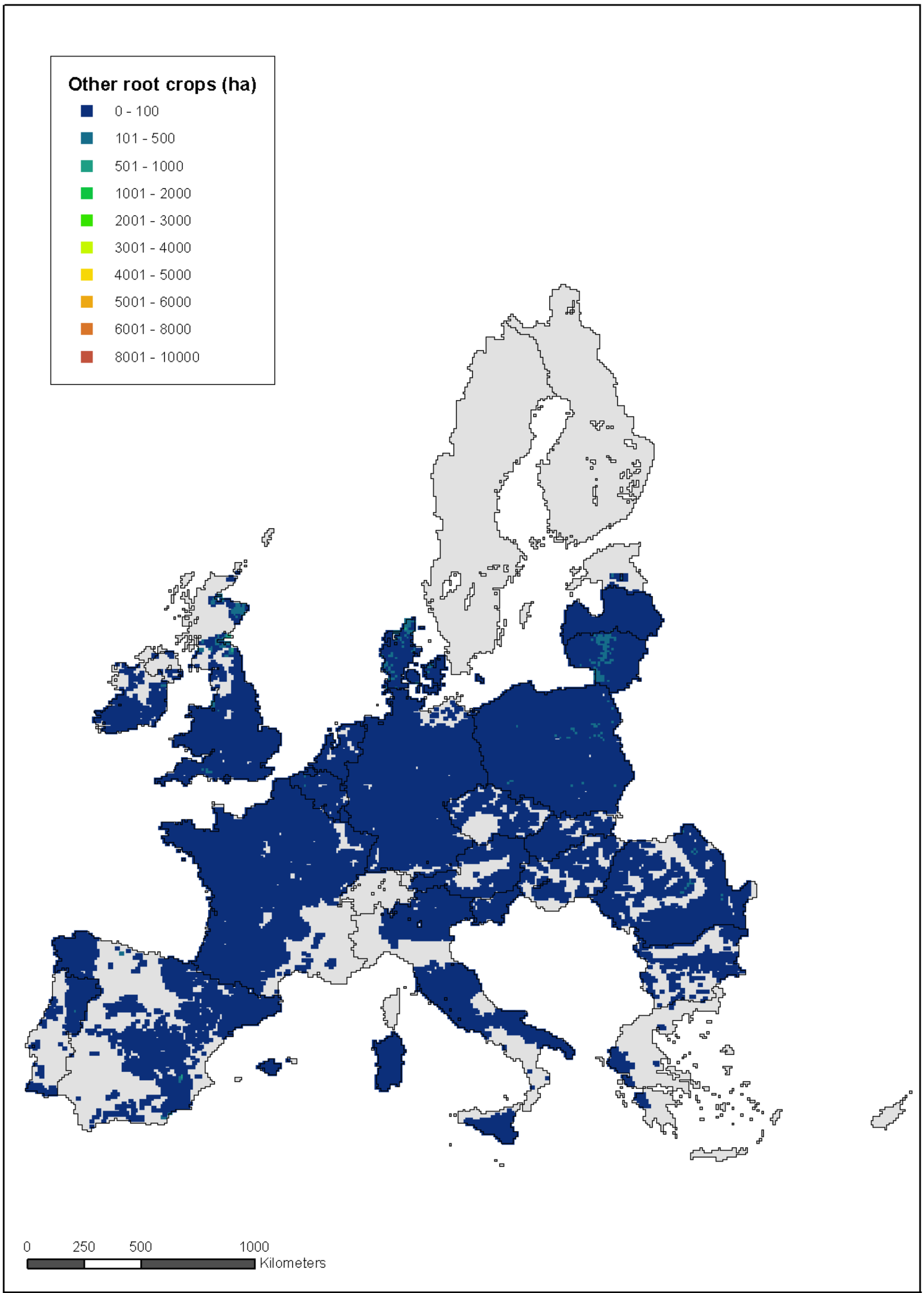

Tomatoes and Other fresh vegetables (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers



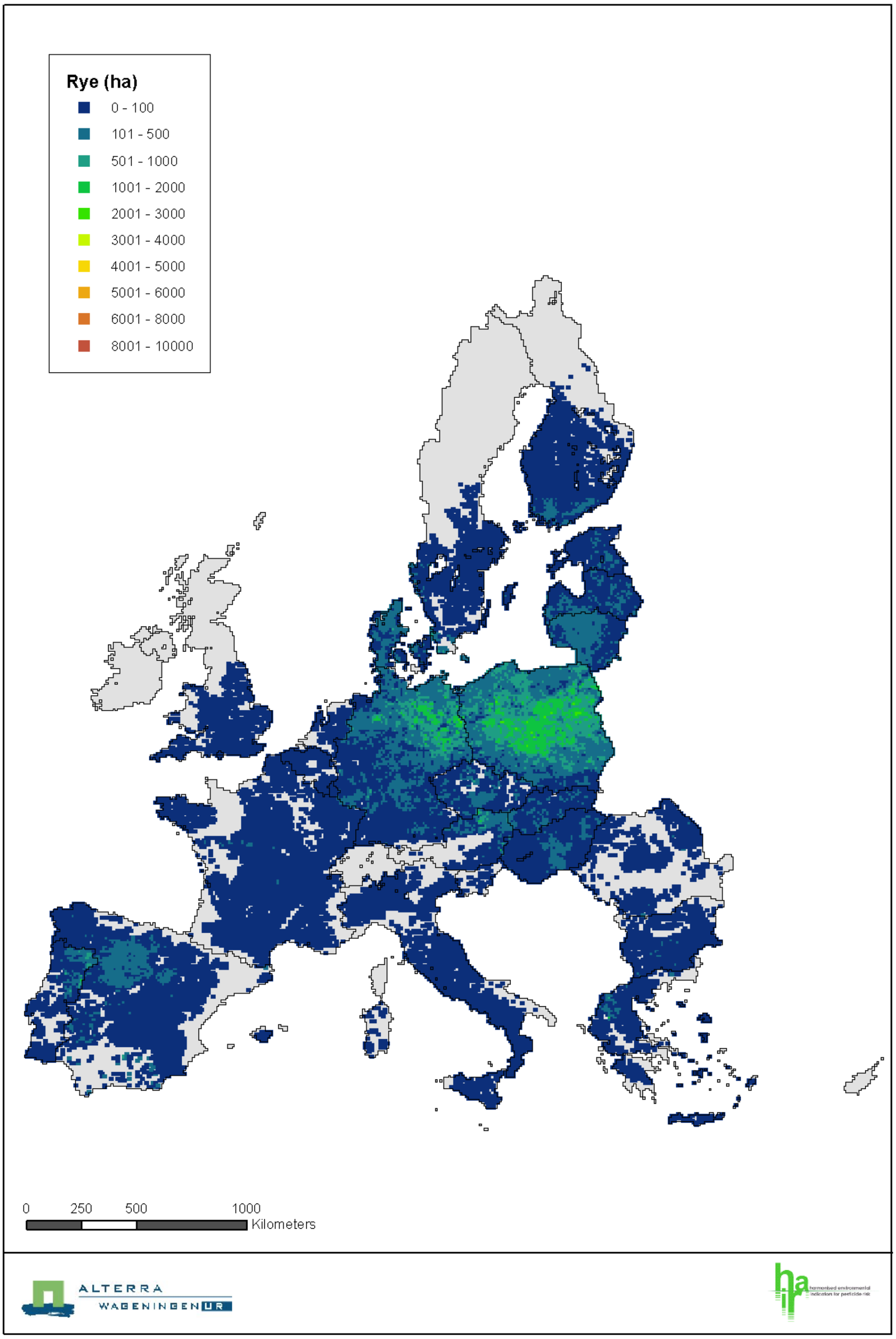
ALTERRA WAGENINGEN UR

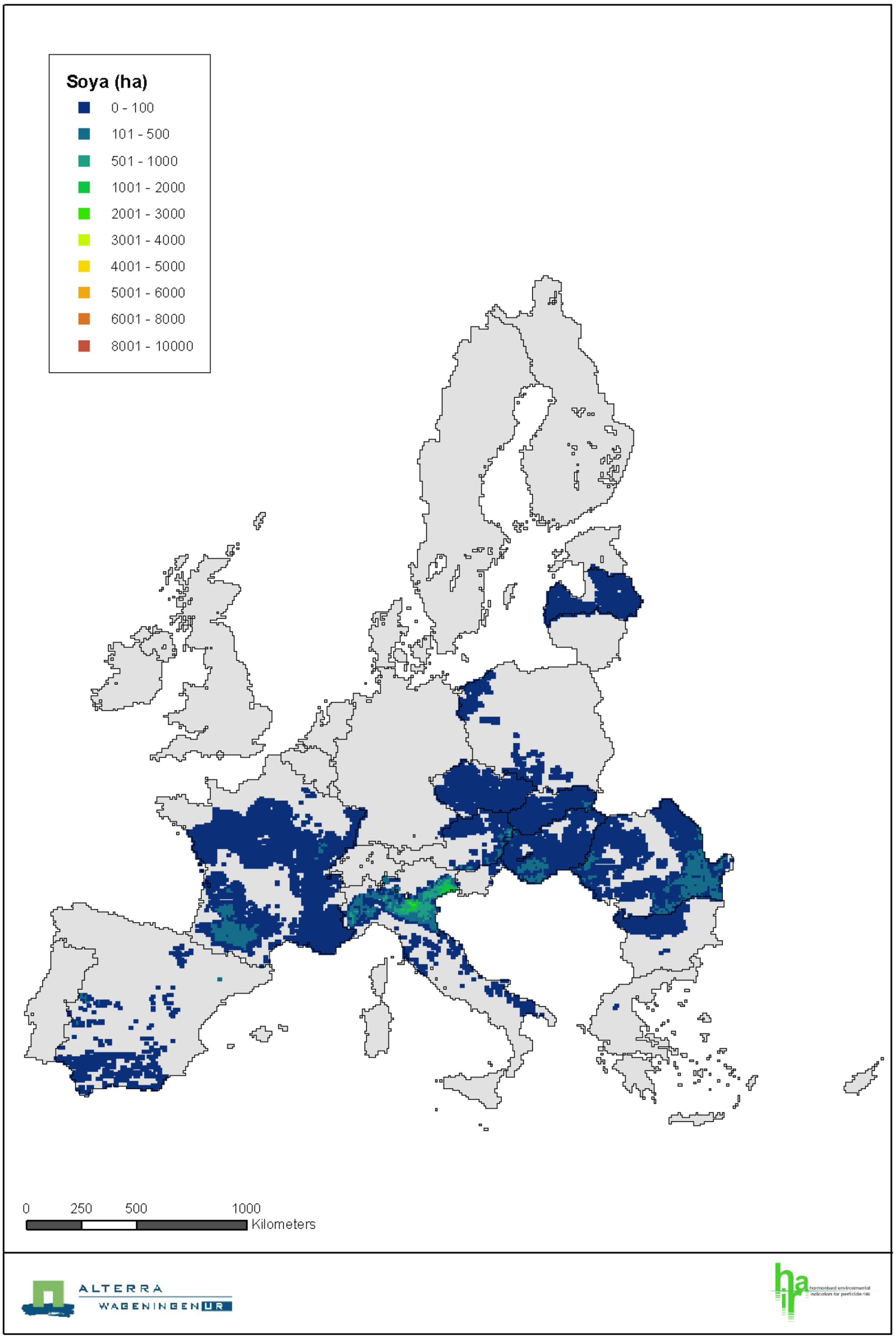

Potatoes (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers

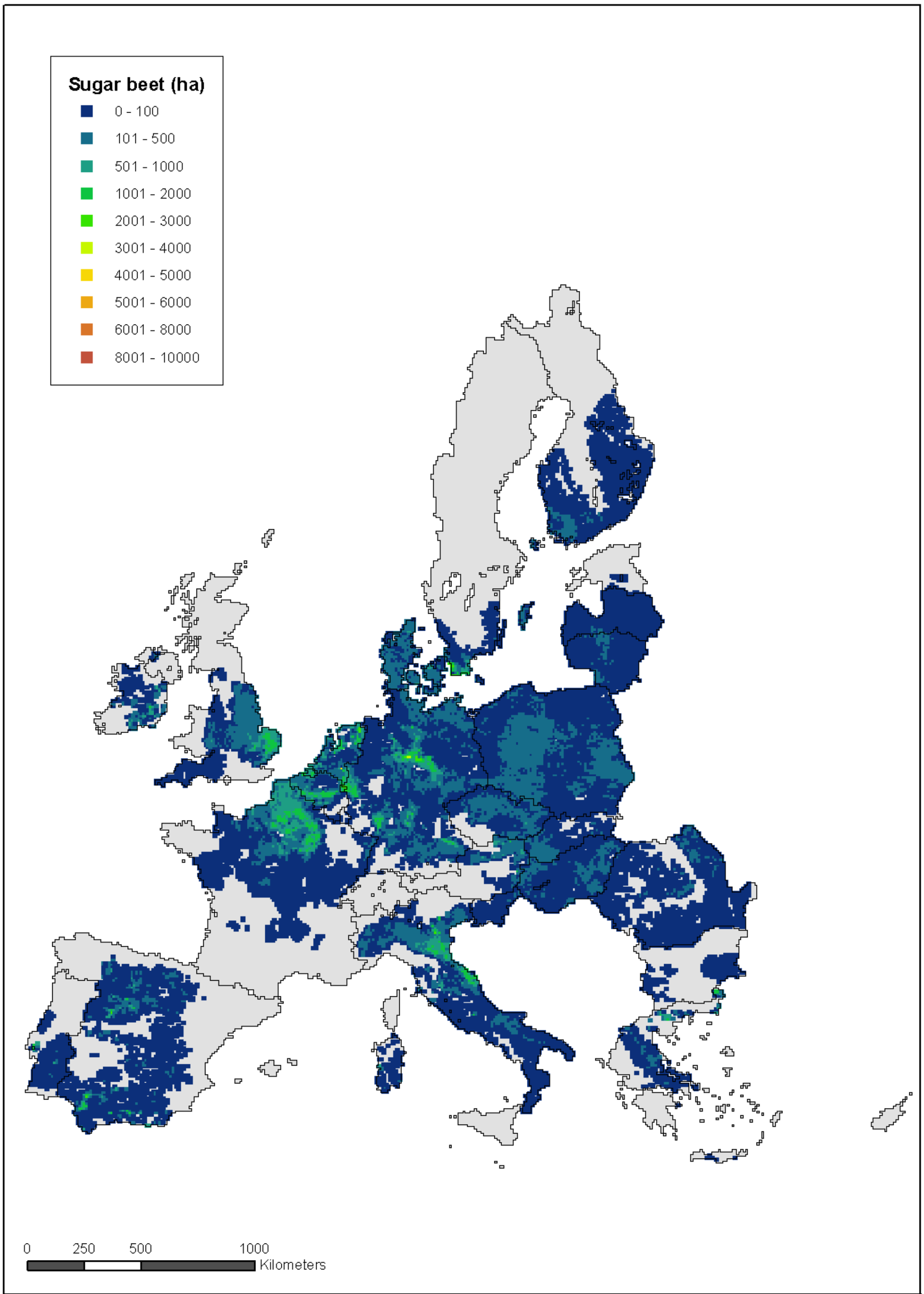

Dry pulses (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR



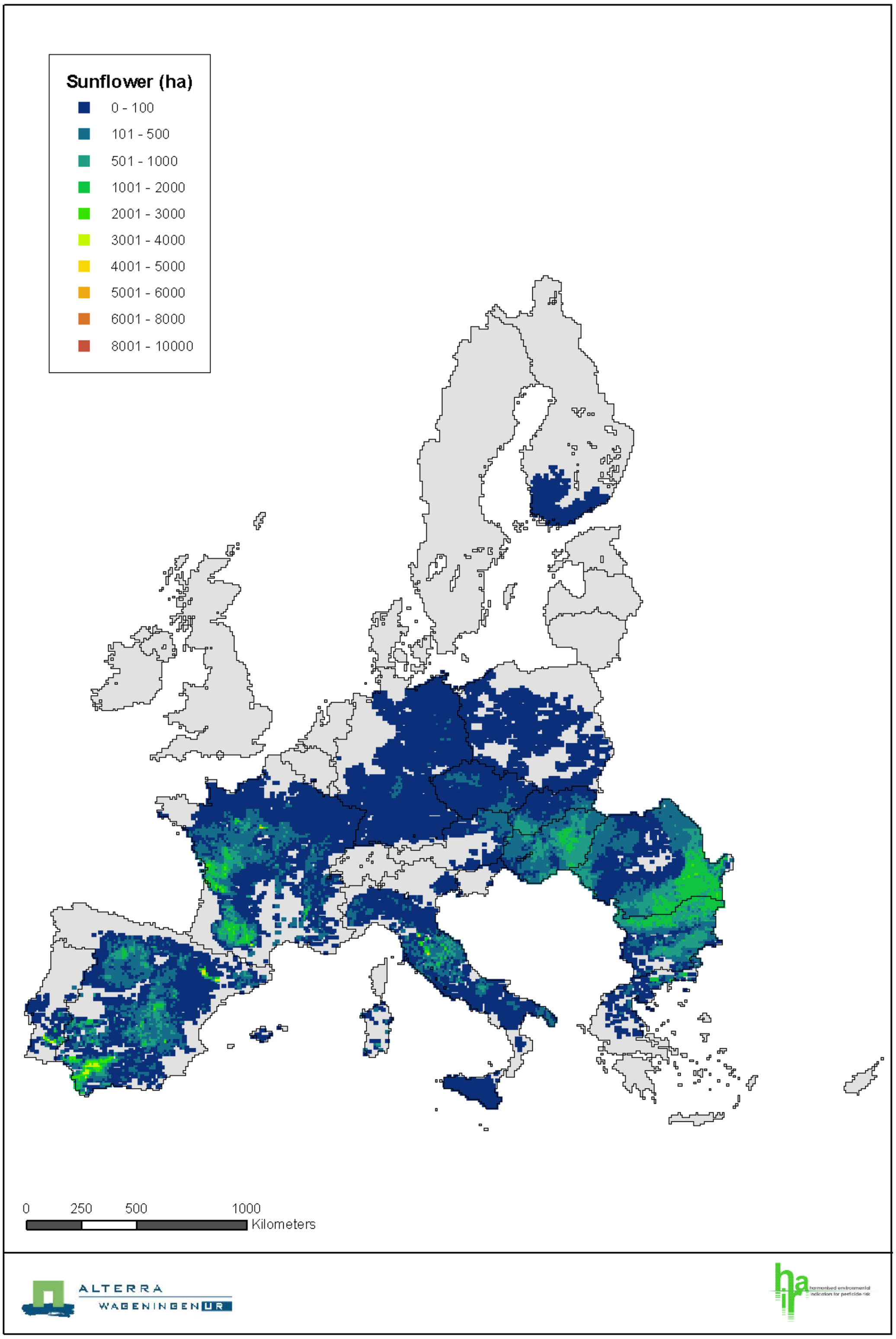
ALTERRA WAGENINGEN UR

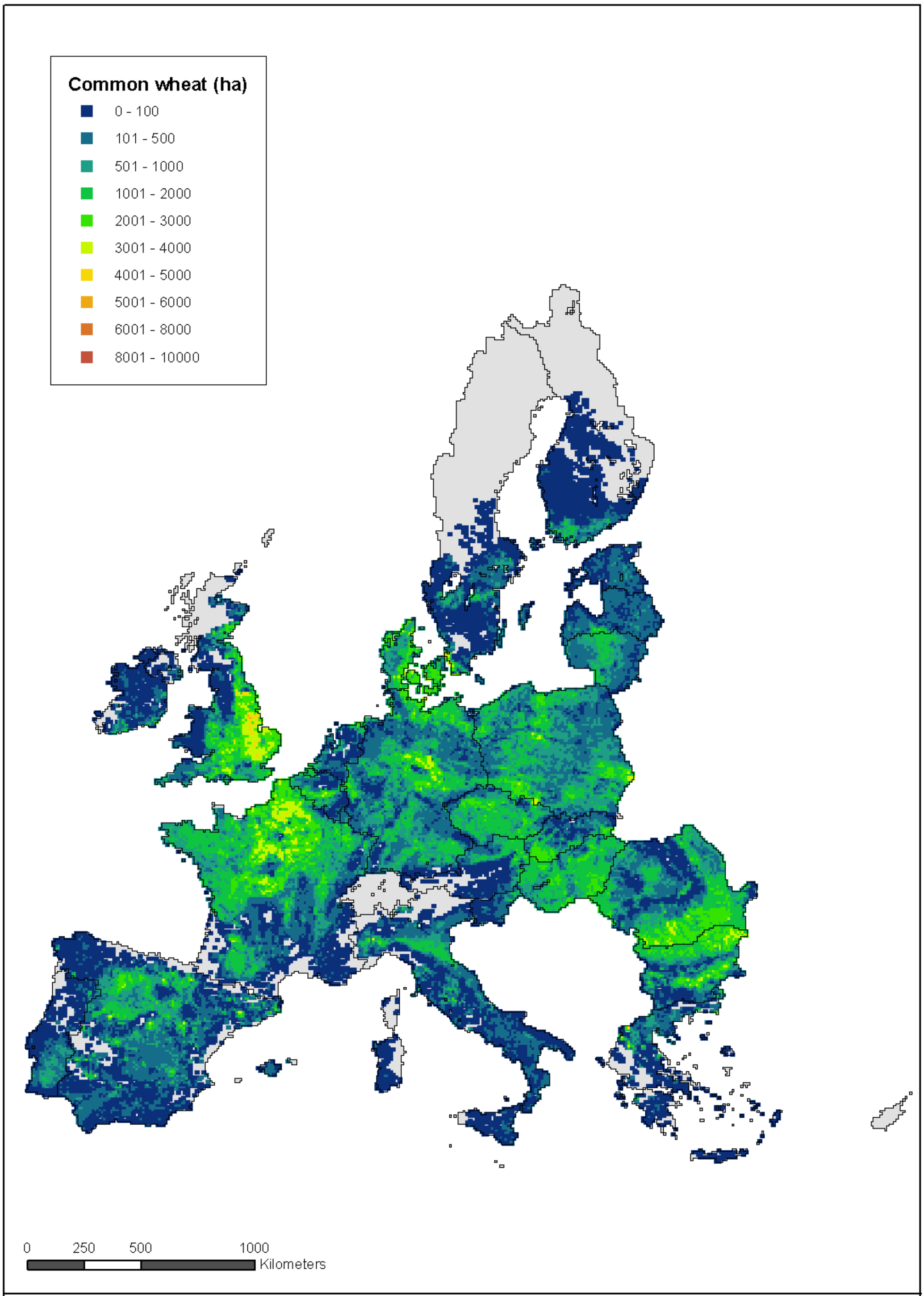

Rye (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR

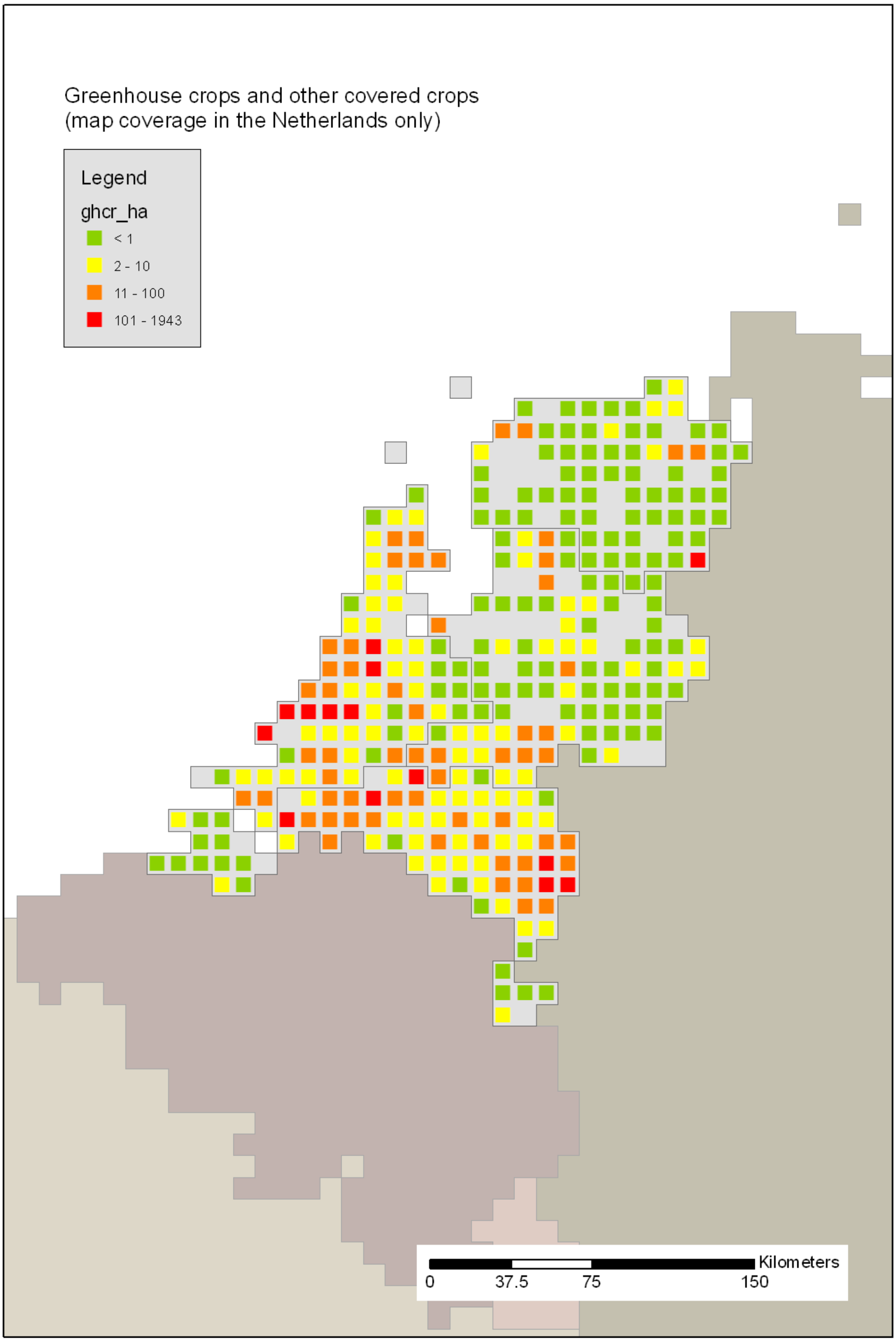

Soya (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0 250 500 1000
Kilometers
ALTERRA
WAGENINGEN UR



ALTERRA WAGENINGEN UR


Sunflower (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers
ALTERRA
WAGENINGEN UR


Common wheat (ha)
0 - 100
101 - 500
501 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 8000
8001 - 10000
0
250
500
1000
Kilometers


Greenhouse crops and other covered crops
(map coverage in the Netherlands only)
Legend
ghcr_ha
< 1
2 - 10
11 - 100
101 - 1943
Kilometers
0
37.5
75
150

Annex 5 NUTS1 regionalisation in HAIR

For statistical purposes, the European Commission uses a standard nomenclature for geo-referencing the administrative divisions of countries called Nomenclature of Territorial Units for Statistics (NUTS). The NUTS_1 regions in HAIR were delivered by the original HAIR consortium (Mulligan and Bouraoui, 2007).

In HAIR the NUTS administrative units (version 2003) are used;

- For region identification in the Usage database (NUTS_1)
- For interactive selection, when the user defines a case in the Graphical User Interface (either regions/NUTS_1 or Member States/NUTS_0)
- For visualisation and presentation of results with HAIR Studio (NUTS_1).

The new HAIR software works with the Regions codes and shapefiles delivered by JRC (as part of the original HAIR project).

Table 5-1
NUTS1 Region code and name, NUTS0 country code and name. Only the codes in column NUTS1 can be used for region identification in the Usage database.

ID	NUTS0	Name	NUTS1	Name
1	AT	Austria	AT1	Ostösterreich
2	AT	Austria	AT2	Südösterreich
3	AT	Austria	AT3	Westösterreich
4	BE	Belgium	BE1_2	Vlaams gewest en Brussel
5	BE	Belgium	BE3	Région Wallonne
6	BG	Bulgaria	BG011	Bulgaria BG011
7	BG	Bulgaria	BG012	Bulgaria BG012
8	BG	Bulgaria	BG013	Bulgaria BG013
9	BG	Bulgaria	BG021	Bulgaria BG021
10	BG	Bulgaria	BG022	Bulgaria BG022
11	BG	Bulgaria	BG023	Bulgaria BG023
12	BG	Bulgaria	BG024	Bulgaria BG024
13	BG	Bulgaria	BG025	Bulgaria BG025
14	BG	Bulgaria	BG031	Bulgaria BG031
15	BG	Bulgaria	BG032	Bulgaria BG032
16	BG	Bulgaria	BG033	Bulgaria BG033
17	BG	Bulgaria	BG034	Bulgaria BG034
18	BG	Bulgaria	BG035	Bulgaria BG035
19	BG	Bulgaria	BG036	Bulgaria BG036
20	BG	Bulgaria	BG041	Bulgaria BG041
21	BG	Bulgaria	BG042	Bulgaria BG042
22	BG	Bulgaria	BG043	Bulgaria BG043
23	BG	Bulgaria	BG044	Bulgaria BG044
24	BG	Bulgaria	BG045	Bulgaria BG045
25	BG	Bulgaria	BG051	Bulgaria BG051
26	BG	Bulgaria	BG052	Bulgaria BG052
27	BG	Bulgaria	BG053	Bulgaria BG053
28	BG	Bulgaria	BG054	Bulgaria BG054
29	BG	Bulgaria	BG055	Bulgaria BG055
30	BG	Bulgaria	BG056	Bulgaria BG056
31	BG	Bulgaria	BG061	Bulgaria BG061
32	BG	Bulgaria	BG062	Bulgaria BG062
33	BG	Bulgaria	BG063	Bulgaria BG063
34	CH (*)	Switzerland	CH01	Switzerland CH01
35	CH (*)	Switzerland	CH02	Switzerland CH02
36	CH (*)	Switzerland	CH03	Switzerland CH03
37	CH (*)	Switzerland	CH04	Switzerland CH04
38	CH (*)	Switzerland	CH05	Switzerland CH05
39	CH (*)	Switzerland	CH06	Switzerland CH06
40	CH (*)	Switzerland	CH07	Switzerland CH07
41	CY (*)	Cyprus	CY	Cyprus
42	CZ	Czech Republic	CZ01	Czech Republic CZ01
43	CZ	Czech Republic	CZ02	Czech Republic CZ02
44	CZ	Czech Republic	CZ03	Czech Republic CZ03
45	CZ	Czech Republic	CZ04	Czech Republic CZ04
46	CZ	Czech Republic	CZ05	Czech Republic CZ05

ID	NUTS0	Name	NUTS1	Name
47	CZ	Czech Republic	CZ06	Czech Republic CZ06
48	CZ	Czech Republic	CZ07	Czech Republic CZ07
49	CZ	Czech Republic	CZ08	Czech Republic CZ08
50	DE	Germany	DE1	Baden-Württemberg
51	DE	Germany	DE2	Bayern
52	DE	Germany	DE3_90_5_6	HamburgBremenBerlin
53	DE	Germany	DE4	Brandenburg
54	DE	Germany	DE7	Hessen
55	DE	Germany	DE8	Mecklenburg-Vorpommern
56	DE	Germany	DE9	Niedersachsen
57	DE	Germany	DEA	Nordrhein-Westfalen
58	DE	Germany	DEB	Rheinland-Pfalz
59	DE	Germany	DEC	Saarland
60	DE	Germany	DED	Sachsen
61	DE	Germany	DEE	Sachsen-Anhalt
62	DE	Germany	DEF	Schleswig-Holstein
63	DE	Germany	DEG	Thüringen
64	DK	Denmark	DK	Danmark
65	EE	Estonia	EE	Estonia
66	ES	Spain	ES11	Galicia
67	ES	Spain	ES12	Principado de Asturias
68	ES	Spain	ES13	Cantabria
69	ES	Spain	ES21	Pais Vasco
70	ES	Spain	ES22	Comunidad Foral de Navarra
71	ES	Spain	ES23	La Rioja
72	ES	Spain	ES24	Aragón
73	ES	Spain	ES3	Comunidad de Madrid
74	ES	Spain	ES41	Castilla y León
75	ES	Spain	ES42	Castilla-La Mancha
76	ES	Spain	ES43	Extremadura
77	ES	Spain	ES51	Cataluña
78	ES	Spain	ES52	Comunidad Valenciana
79	ES	Spain	ES53	Baleares
80	ES	Spain	ES61	Andalucía
81	ES	Spain	ES62	Murcia
82	FI	Finland	FI11_12_2	Etelä-Suomi
83	FI	Finland	FI13	Itä-Suomi
84	FI	Finland	FI14	Väli-Suomi
85	FI	Finland	FI15	Pohjois-Suomi
86	FR	France	FR1	Île-de-France
87	FR	France	FR21	Champagne-Ardenne
88	FR	France	FR22	Picardie
89	FR	France	FR23	Haute-Normandie
90	FR	France	FR24	Centre
91	FR	France	FR25	Basse-Normandie
92	FR	France	FR26	Bourgogne
93	FR	France	FR3	Nord-Pas-de-Calais
94	FR	France	FR41	Lorraine
95	FR	France	FR42	Alsace

ID	NUTS0	Name	NUTS1	Name
96	FR	France	FR43	Franche-Comté
97	FR	France	FR51	Pays de la Loire
98	FR	France	FR52	Bretagne
99	FR	France	FR53	Poitou-Charentes
100	FR	France	FR61	Aquitaine
101	FR	France	FR62	Midi-Pyrénées
102	FR	France	FR63	Limousin
103	FR	France	FR71	Rhône-Alpes
104	FR	France	FR72	Auvergne
105	FR	France	FR81	Languedoc-Roussillon
106	FR	France	FR82	Provence-Alpes-Côte d'Azur
107	FR	France	FR83	Corse
108	GR	Greece	GR11	Anatoliki Makedonia Thraki
109	GR	Greece	GR12	Kentriki Makedonia
110	GR	Greece	GR13	Dytiki Makedonia
111	GR	Greece	GR14	Thessalia
112	GR	Greece	GR21	Ipeiros
113	GR	Greece	GR22	Ionia Nisia
114	GR	Greece	GR23	Dytiki Ellada
115	GR	Greece	GR24	Sterea Ellada
116	GR	Greece	GR25	Peloponnisos
117	GR	Greece	GR3	Attiki
118	GR	Greece	GR41	Voreio Aigaio
119	GR	Greece	GR42	Notio Aigaio
120	GR	Greece	GR43	Kriti
121	HU	Hungary	HU01	Hungary HU01
122	HU	Hungary	HU02	Hungary HU02
123	HU	Hungary	HU03	Hungary HU03
124	HU	Hungary	HU04	Hungary HU04
125	HU	Hungary	HU05	Hungary HU05
126	HU	Hungary	HU06	Hungary HU06
127	HU	Hungary	HU07	Hungary HU07
128	IE	Ireland	IE01	Border Midlands and Western
129	IE	Ireland	IE02	Southern and Eastern
130	IT	Italy	IT11	Piemonte
131	IT	Italy	IT12	Valle d'Aosta
132	IT	Italy	IT13	Liguria
133	IT	Italy	IT2	Lombardia
134	IT	Italy	IT311	Bolzano-Bozen
135	IT	Italy	IT312	Trento
136	IT	Italy	IT32	Veneto
137	IT	Italy	IT33	Friuli-Venezia Giulia
138	IT	Italy	IT4	Emilia Romagna
139	IT	Italy	IT51	Toscana
140	IT	Italy	IT52	Umbria
141	IT	Italy	IT53	Marche
142	IT	Italy	IT6	Lazio
143	IT	Italy	IT71	Abruzzi
144	IT	Italy	IT72	Molise

ID	NUTS0	Name	NUTS1	Name
145	IT	Italy	IT8	Campania
146	IT	Italy	IT91	Puglia
147	IT	Italy	IT92	Basilicata
148	IT	Italy	IT93	Calabria
149	IT	Italy	ITA	Sicilia
150	IT	Italy	ITB	Sardegna
151	LT	Lithuania	LT	Lithuania
152	LU	Luxembourg	LU	Luxembourg
153	LV	Latvia	LV	Latvia
154	MT (*)	Malta	MT	Malta
155	NL	Netherlands	NL1	Noord-Nederland
156	NL	Netherlands	NL2	Oost-Nederland
157	NL	Netherlands	NL3	West-Nederland
158	NL	Netherlands	NL4	Zuid-Nederland
159	PL	Poland	PL01	Poland PL01
160	PL	Poland	PL02	Poland PL02
161	PL	Poland	PL03	Poland PL03
162	PL	Poland	PL04	Poland PL04
163	PL	Poland	PL05	Poland PL05
164	PL	Poland	PL06	Poland PL06
165	PL	Poland	PL07	Poland PL07
166	PL	Poland	PL08	Poland PL08
167	PL	Poland	PL09	Poland PL09
168	PL	Poland	PL0A	Poland PL0A
169	PL	Poland	PL0B	Poland PL0B
170	PL	Poland	PL0C	Poland PL0C
171	PL	Poland	PL0D	Poland PL0D
172	PL	Poland	PL0E	Poland PL0E
173	PL	Poland	PL0F	Poland PL0F
174	PL	Poland	PL0G	Poland PL0G
175	PT	Portugal	PT11	Norte
176	PT	Portugal	PT12	Centro (P)
177	PT	Portugal	PT13	Lisboa e Vale do Tejo
178	PT	Portugal	PT14	Alentejo
179	PT	Portugal	PT15	Algarve
180	RO	Romania	RO01	Romania RO01
181	RO	Romania	RO02	Romania RO02
182	RO	Romania	RO03	Romania RO03
183	RO	Romania	RO04	Romania RO04
184	RO	Romania	RO05	Romania RO05
185	RO	Romania	RO06	Romania RO06
186	RO	Romania	RO07	Romania RO07
187	RO	Romania	RO08	Romania RO08
188	SE	Sweden	SE01	Stockholm
189	SE	Sweden	SE02	Östra Mellansverige
190	SE	Sweden	SE04	Sydsverige
191	SE	Sweden	SE06	Norra Mellansverige
192	SE	Sweden	SE07	Mellersta Norrland
193	SE	Sweden	SE08	Övre Norrland

ID	NUTS0	Name	NUTS1	Name
194	SE	Sweden	SE09	Småland med öarna
195	SE	Sweden	SE0A	Västsverige
196	SI	Slovenia	SI	Slovenia
197	SK	Slovakia	SK01	Slovakia SK01
198	SK	Slovakia	SK02	Slovakia SK02
199	SK	Slovakia	SK03	Slovakia SK03
200	SK	Slovakia	SK04	Slovakia SK04
201	UK	United Kingdom	UK2	Yorkshire and Humberside
202	UK	United Kingdom	UK3	East Midlands
203	UK	United Kingdom	UK6	South West (UK)
204	UK	United Kingdom	UK7	West Midlands
205	UK	United Kingdom	UK9	Wales
206	UK	United Kingdom	UKA	Scotland
207	UK	United Kingdom	UKB	Northern Ireland
208	UK	United Kingdom	UKC	North East
209	UK	United Kingdom	UKD	North West
210	UK	United Kingdom	UKH	Eastern
211	UK	United Kingdom	UKI_J	London South East

(*) Not selectable.

Annex 6 Parameters for birds and mammal indicators

Table 6-1a
Identifiers for the species groups and food items for birds (according to Table 5a.1.1a in Flari et al., 2007). The ID's refer to the species and food item properties in other tables in this Annex (see footnotes).

Method of application code (1)	Treated crop scenario ID (2)	Number of indicator species (3)	Species No. (4)	Species group / taxa for estimating DEE (5)	Species group / taxa for estimating AE (6)	Number of food items in the species diet	Species body weight BW (g)	Bird- and mammal food item ID's (7)		
								i = 1	i = 2	i = 3
Spraying	1	3	1	3	3	1	3000	1		
			2	4	13	1	10	2		
			3	4	13	3	40	8	4	2
	2	1	1	4	13	1	10	2		
	3	2	1	3	21	1	300	5		
			2	4	13	1	10	2		
	4	2	1	3	21	1	300	5		
			2	4	13	1	10	2		
	5	1	1	4	13	1	10	2		
	6	2	1	3	3	1	3000	3		
			2	4	13	1	10	2		
Seed treatment	7	1	1	4	13	1	21.4	9		
	8	1	1	4	13	1	18.2	4		
	9	1	1	4	13	1	27.5	4		
	10	1	1	4	13	1	20	4		
	11	1	1	4	13	1	27.8	4		

(1) The method of application is read from the Usage database / (2) HAIR crop attribute Birds_<Code>_SCEN (see text) / (5) Bird_taxonomic_group_ID (see Table 6-2a) / (6) Bird_Species_order_ID for AE (see Tables 6-4, 6-6) / (7) Bird- and mammal food items for FE, MC (Table 6-3) and RUD data (Table 6-8).

Table 6-1b
Identifiers for the species groups and food items for mammals (according to Table 5a.1.1c in Flari et al., 2007). The ID's refer to the species and food item properties in other tables in this Annex (see footnotes).

Method of application code	Treated crop scenario ID	Number of indicator species	Species No.	Species group / taxa for estimating DEE	Species group / taxa for estimating AE	Number of food items in the species diet	Species body weight BW (g)	Bird- and mammal food item ID's (7)		
(1)	(2)	(3)	(4)	(5)	(6)			i = 1	i = 2	i = 3
Spraying	1	1	1	5	4	1	25	1		
	2	1	1	5	1	1	10	6		
	3	1	1	5	5	1	3000	5		
	4	1	1	5	5	1	3000	5		
	5	1	1	5	4	1	25	3		
	6	1	1	5	4	1	25	3		
Seed treatment	7	1	1	5	4	1	25	4		

(1) The method of application is read from the Usage database / (2) HAIR crop attribute Mammals_<Code>_SCEN (see text) / (5) Mammal_taxonomic_group_ID (see Table 6-2b) / (6) Mammal_Species_order_ID for AE (see Tables 6-5, 6-7) / (7) Bird- and mammal food items for FE, MC (Table 6-3) and RUD data (Table 6-8).

Table 6-2a
(Table 5a.1.3a in Flari et al., 2007).

Bird_taxonomic_group_ID	Bird_taxonomic_group	Log α	β
1	Desert	0.6107	0.7299
2	Hummingbirds	0.7495	1.2064
3	Other birds	0.6768	0.7723
4	Passerines	1.0017	0.7034

Items 1 and 2 do not (anymore) occur in Tables 6-1a and 6-1b.

Table 6-2b
(Table 5a.1.3b in Flari et al., 2007).

Mammalian_Taxonomic_Group_ID	Mammalian_Taxonomic_Group	Log α	β
1	Non eutherians	1.0232	0.5814
2	All eutherians	0.6794	0.7646
3	Desert eutherians	0.512	0.7843
4	Marine eutherians	2.4203	0.4266
5	Other eutherians	0.8459	0.705

Items 1, 2 3 and 4 do not (anymore) occur in Tables 6-1a and 6-1b.

Table 6-3
Food Energy (kJ/g of dry weight food) and Moisture Content (%) of the bird- and mammal food items in Tables 6-1a and A1b (adapted from Table 5a.1.4 in Flari et al., 2007).

ID	FW_MC_FoodItem	Food_energy_FE_kJ_gdw	Moisture_Content_MC_pct
1	Cereal shoots	18	76.4
2	Small insects	21.8	75
3	Short grass	18	82.1
4	Cereal seeds	16.7	13.3
5	Leaves, Leafy crops	11.2	88.6
6	Large insects	21.8	75
8	Non-grass herbs	18	82.1
9	Weed seeds	21	11.9

Soil invertebrates and fish from Table 5a.1.4 in Flari et al. (2007) do not occur in this Table.

Table 6-4
Assimilation Efficiency for bird food items (from Table 5a.1.5 in Flari et al., 2007). When the assimilation efficiency for a food item in a particular mammalian Order is not known, the average AE across all taxonomical groups is used (shown in italics).

Bird_species_order_ID	Bird_species_order	Bird_AE_Fooditem_ID			
		1	2	3	4
		Animal prey	Fruits	Herbage	Seeds
1	Accipitriformes	82	63	44	75
2	Alciformes	76	63	44	75
3	Anseriformes	87	63	41	83
4	Charadriiformes	69	63	44	75
5	Ciconiiformes	80	63	44	75
6	Coliiformes	78	56	44	75
7	Columbiformes	78	63	44	75
8	Falconiformes	84	63	44	75
9	Galliformes	70	57	42	65
10	Gruiformes	34	45	59	75
11	Lariformes	79	63	44	75
12	Opisthocomiformes	78	63	44	75
13	Passeriformes	76	67	76	80
14	Pelecaniformes	80	76	44	75
15	Piciformes	64	63	61	75
16	Procellariiformes	87	63	44	75
17	Psittaciiformes	78	63	44	75
18	Ralliformes	78	63	44	75
19	Sphenisciformes	75	63	44	75
20	Strigiformes	77	63	44	75
21	Struthioniformes	78	63	36	67
22	Trochiliformes	78	63	44	75

Table 6-5
Assimilation Efficiency per mammal food item (from Table 5a.1.6 in Flari et al., 2007). When the assimilation efficiency for a food item in a particular bird Order is not known, the average AE across all taxonomical groups is used (shown in italics).

ID	Mammal Group	Mammal_AE_FoodItem_ID								
		1	2	3	4	5	6	7	8	9
		Ver-tebrates	Insects	Nuts	Seeds	Grasses	Mixed vegetation	Crops Forbs	Tree browse	Hay
1	Shrews	85	88	84	83	46	74	74	32	80
2	Bats	85	88	84	84	84	74	74	32	80
3	Squirrels	85	88	85	84	84	74	74	32	80
4	Small mammals	85	88	83	83	46	74	74	32	80
5	Lagomorphs	85	88	84	84	84	74	74	32	80
6	White tailed deer	85	88	84	84	84	74	74	32	80
7	Ruminants	85	88	84	84	84	74	74	32	80
8	Carnivores	85	88	84	84	84	74	74	32	80

Table 6-6
Relation between bird food items with Assimilation Efficiency data (Table 6-4) and (food) items with Food Energy and Moisture Content data (Table 6-3). The table is based on Table 5a.1.7 in Flari et al. (2007).

ID	FE_MC_FoodItem (Table 6-3)	Bird_AE_Fooditem_ID (Table 6-4)			
		1	2	3	4
		Animal prey	Fruit	Herbage	Seeds
1	Cereal shoots			1	
2	Small insects	1			
3	Short grass			1	
4	Cereal seeds				1
5	Leaves, leafy crops			1	
6	Large insects	1			
7	Fruits		1		
8	Non-grass herbs			1	
9	Weed seeds			1	
10	Long grass			1	

Table 6-7
Relation between (7 out of 9) mammalian food items with Assimilation Efficiency data (Table 6-5) and (food) items with Food Energy and Moisture Content data (Table 6-3). The table is based on Table 5a.1.8 in Flari et al. (2007).

ID	FE_MC_FoodItem (Table 6-3)	Mammal_AE _FoodItem_ID (Table 6-5)								
		1	2	(3)	4	5	6	7	8	(9)
		Verte-brates	Insects	Nuts	Seeds	Grass	Herb-age (*)	Crops	Fruit, Tree browse	Hay
1	Cereal shoots							1		
2	Small insects		1							
3	Short grass					1				
4	Cereal seeds				1					
5	Leaves, leafy crops						1			
6	Large insects		1							
7	Fruits								1	
8	Non-grass herbs						1			
9	Weed seeds				1					
10	Long grass					1				

(*) general of mixed vegetation.

Table 6-8
Residue Unit Doses (RUDs) for bird and mammalian food items. The 90th-percentiles of known residue values are used for the acute indicators and the 50th-percentiles for the chronic indicators (from Table 5a.1.9 and Table 5b1.2 in Flari et al., 2007, respectively).

ID	Food items	RUD_{acute} (mg a.i. per kg fresh weight of food) 90th-percentiles	$RUD_{chronic}$ (mg a.i. per kg fresh weight of food) 50th-percentiles
1	Cereal shoots	142	76
2	Small insects	52	29
3	Short grass	142	76
4	Cereal seeds	11	11
5	Leaves, Leafy crops, Forage crops	87	40
6	Large Insects	14	5.1
7	Fruits, Pods	11	11
8	Non-grass herbs (*)	87	40
9	Weed seeds	52	29
10	Long grass	69	69

(*) assumed to be equal to values for leaves, leafy crops, forage crops (food items ID 5 in this table).

Annex 7 Checklist recommendations Arcadis

Assessments by ARCADIS
The aim of the assessments conducted by ARCADIS Belgium B.V. in 2008 was: (i) to test the set of indicators developed in the original Hair project in order to determine the operability of the indicators, their robustness and sensibility, and (ii) to identify possible bugs in the models or problems with the quality and availability of the data concerning the toxicity of pesticides and the behaviour in the environment.

ARCADIS identified a number of issues concerning the state and quality of the software product (ARCADIS Report, Section 3.3). In summary, it was recommended to;
1. finalise incomplete parts and fix the bugs in the Hair source code,
2. consider less strict rules for the replacement of missing compound properties,
3. provide more guidance on the program features for importing a dataset from an external source,
4. fix the bugs in the presentation tool Hair studio, and
5. improve the user friendliness of the software and the user manual.

1)
In line with the proposal presented by Alterra at the Working Group Meeting on Pesticide Statistics in Poznan (October 2009), 29 risk indicators were selected for HAIR2010 for which data and models are considered sufficiently developed.

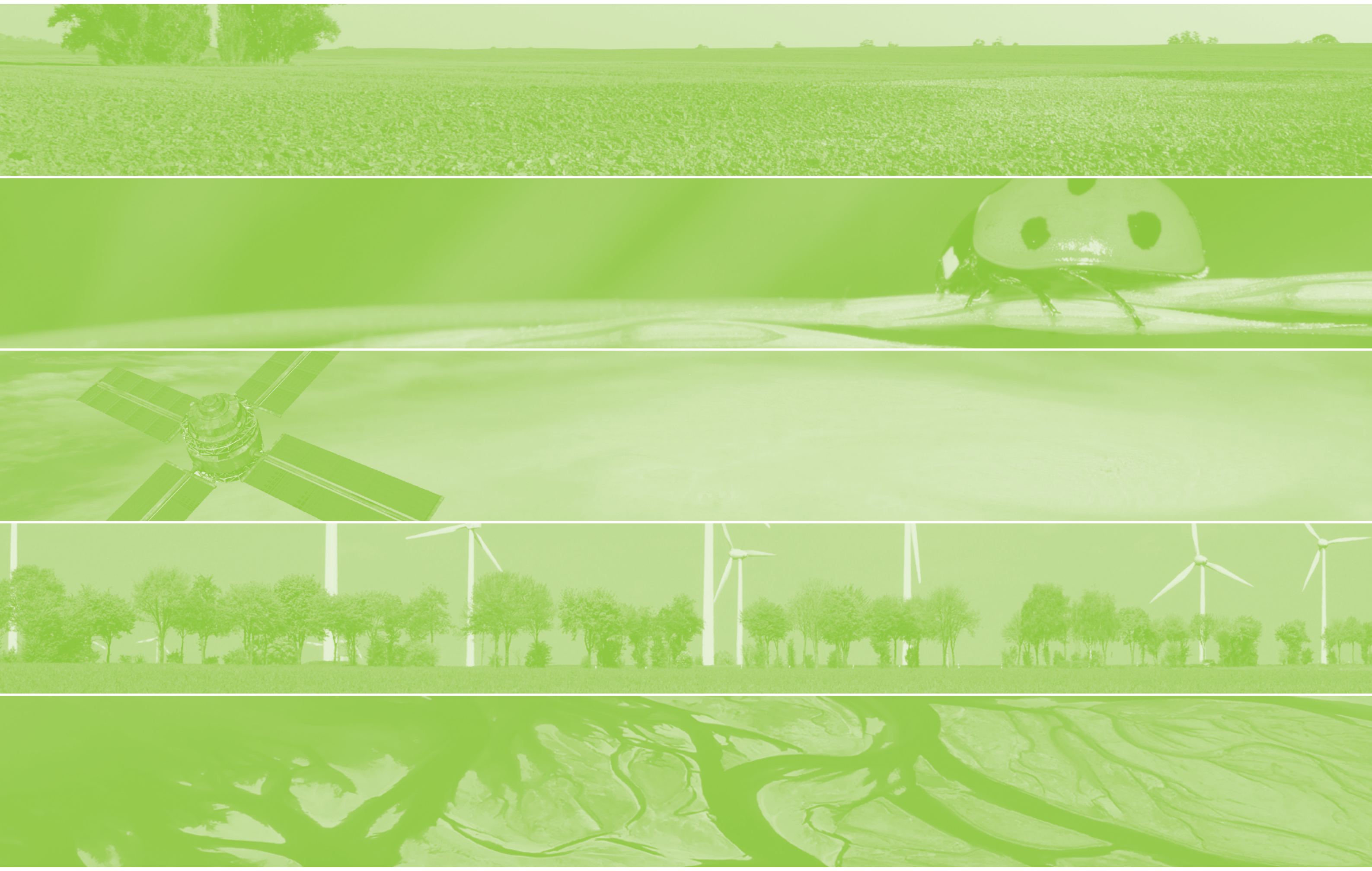
The following risk indicators were abandoned;
- A microbial risk indicator is not included in HAIR2010 (in line with the decisions taken by the original HAIR consortium)
- A risk indicator for non-target plants is not built in HAIR2010 (because of problems with missing input data)
- Aquatic risk indicators based on field based application patterns for an entire crop cycle are not supported in HAIR2010. As a consequence, the SPEAR indicator based on field based application patterns for an entire crop cycle is abandoned.
- Consumer indicators are not included in HAIR2010 because of problems related to the availability of input data.

2)
A robust alternative for the multiple compound related databases was implemented. This enabled the way to apply less strict rules for the replacement of missing compound properties (View Compound status feature, HAIR User Manual, Vlaming et al., 2011).

3)
The structure of the databases in Hair was redesigned. With the Usage database and the Compound database the input data that need to be collected by the user are separated from the input data stored in the HAIR database.

4)
Bugs in Hair Studio were fixed. All the software modules including the relevant documents from the original Hair consortium were reviewed. The modules were intensively tested before the new HAIR2010 was released to the European Commission. Specific remarks and notes on individual indicators are mentioned in the Remarks sections in this report.

5)
An additional HAIR Output Viewer was included to the package. This report and the HAIR User Manual (Vlaming et al., 2011) contain a full description of the software package, and specific attention was paid to the issues reported by ARCADIS.



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