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FOOTPRINT

Functional Tools for Pesticide Risk Assessment and Management

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Complete set of European agro-environmental scenarios

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CO	Confidential, only for members of the consortium (including the Commission Services)	

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Foreword

The present report was prepared within the context of the work package WP2 ('High resolution scenario-based spatial zonation') of the FOOTPRINT project (http://www.eu-footprint.org).

The preferred reference to the present document is as follows:
Centofanti T., Hollis J.M., Blenkinsop S., Fowler H.J., Truckell I., Dubus I.G., Reichenberger S. (2007). Identification of agro-environmental scenarios characterizing the variability of the agricultural landscape within Europe. Report DL14 of the FP6 EU-funded FOOTPRINT project [www.eu-footprint.org], 23p.

Thanks are due to all partners of the FOOTPRINT project for fruitful discussion and provision of national census data.

Executive summary

The overall objective of Work Package 2 is to develop and apply a methodology for defining a large number of generic scenarios that characterise the complete spectrum of European agricultural environments. Each scenario represents a unique combination of those agronomic practices, soil and subsoil hydrological characteristics and climates that determine the fate of agriculturally-applied pesticides within Europe. The work reported here describes how this has been achieved using pan-European datasets on soil, climate, cropping and land cover to characterize the diversity of European agricultural and environmental conditions with respect to those parameters that most influence the environmental fate of pesticides. Each pan-European dataset has been intersected, using GIS, to identify the full range of unique combinations of climate, soil and crop types that characterize European agriculture. Full details of derivation and characterization of the component soil, cropping and climate scenarios are given in the FOOTPRINT deliverables DL8, DL9 and DL11, respectively.

The final FOOTPRINT European agro-environmental dataset constitutes a large number of polygons (1 363 138) derived by the fragmentation of each NUTS level 2 polygon into homogenous areas of FOOTPRINT climatic zone, Soil Geographic Database of Europe (SGDBE) soil map unit and CORINE agricultural category. Each polygon has a defined NUTS level 2 code, climate zone code, Soil Map Unit code and CORINE agricultural land code. Attribute data files linked to the spatial data define the fraction of arable crops related to each CORINE arable category as an indicator of its probability of occurrence and the fraction of each FOOTPRINT Soil Type in each Soil Map Unit, derived from the data held in the SGDBE. This fraction indicates the probability of occurrence of each FOOTPRINT Soil Type in each agro-environmental polygon.

A total of 26019 unique combinations of FOOTPRINT climatic zone, NUTS level 2, CORINE agricultural category and Soil Map Unit were identified. However, because of the spatial uncertainty related to the distribution of annual arable crops and soil types within each polygon, the same soil/crop combinations occur in many polygons which have the same climate and CORINE agricultural land category, although the fractions of the soils and arable crops are different.

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The scenarios represent the spatial variation and the heterogeneity of the European landscape with respect to pesticides use and are used to underpin parameterization of the preferential flow path model MACRO and the PRZM runoff and erosion model.

This work is the first ever attempt to quantify such variation at the pan-European scale. Further refinement of the approach could be based on incorporating more comprehensive and finer resolution data on crop and soil distributions as well as identifying locally representative weather datasets for individual soil and land combinations. In addition, integration of socio-economic aspects of farm structure could be used to refine the information on agronomic practices encompassed in the crop growth templates by indicating where differences in socio-economic factors may affect crop management techniques within areas with the same soil and climate.

It is emphasized that although the agro-environmental scenarios developed have primary relevance to pesticide fate, they are also likely to be relevant to other potential environmental pollutants applied as part of agricultural practices within Europe (e.g. nitrate, phosphorus) because most of the driving climatic, soil and cropping characteristics are similar.

1 INTRODUCTION

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It is emphasized that although the agro-environmental scenarios developed have primary relevance to pesticide fate, they are also likely to be relevant to other potential environmental pollutants applied as part of agricultural practices within Europe (e.g. nitrate, phosphorus) because most of the driving climatic, soil and cropping characteristics are similar.

2 MATERIALS AND METHODS

2.1 Definition of FOOTPRINT climatic scenarios

A sensitivity analysis using the preferential flow model MACRO (Larsbo *et al*, 2005) was used to identify the critical climatic factors that influence pesticide fate by leaching and drainage (Nolan *et al.*, 2008). Univariate and multivariate statistics were used to relate predicted pesticide losses to climatic characteristics and 8 key climatic variables influencing pesticide fate were selected on the basis of these analyses. The 8 key climatic variables are: mean April to June temperature (ºC); mean September to November temperature (ºC); mean October to March precipitation (mm); mean annual precipitation (mm); number of days (April to June) where total precipitation >2 mm; number of days (April to June) where total precipitation >20 mm; number of days (April to June) where total precipitation >50 mm; number of days (September to November) where total precipitation >20 mm. A climatic classification for Europe was then constructed on the basis of these 8 key variables (Blenkinsop *et al*., 2007; 2008). Within Europe, each variable was characterized spatially using two data sources: a) CRU TS 2.0 data set (Mitchell *et al*., 2004), and b) European Climate Assessment & Dataset (ECA&D) (Klein Tank *et al*, 2002). The analysis was based on data over the period 1961-1990. In order to take into account the likely correlation between several of the input variables, a dimension reduction procedure was performed using principal component analysis which resulted in the retention of 3 factors. These factors were then used as variables in a cluster analysis (k-means) which objectively grouped grid cells with similar characteristics. The final solution produced 16 groups (the ‘FOOTPRINT climatic zones’) which represents a pragmatic compromise between producing a detailed classification and the need for a manageable number of representative climatic datasets for subsequent modelling work. A brief description of each climate zone and a summary of the EC Member States include in each zone is given in Table 1. The spatial distribution of the 16 FOOTPRINT climatic zones was digitized to provide a polygon dataset for GIS manipulation (Figure 1).

To represent the weather variation in each climate zone, an objective methodological analysis (Blenkinsop *et al*., 2007; 2008) was used to select an ECA & D station displaying ‘average characteristics’ in relation to other stations present in the FCZ. Data from this station or from an equivalent MARS grid (MARS, 2007) was then used to create a 26-year daily weather dataset of precipitation, mean, maximum and minimum temperature, potential evapotranspiration, wind speed and solar radiation.

Table 1. Summary description of the 16 FOOTPRINT European climatic zones identified by the cluster analysis and indication of European member states where each climatic zone can be found.

FOOTPRINT climatic zone	Description	Member States
1.North Mediterranean	Warm and moderate precipitation	France, Germany, Italy, Slovenia, Spain
2. Temperate maritime	Temperate maritime climate	Belgium, Denmark, France, Germany, Latvia, Lithuania, Luxembourg, Netherland, Poland, Sweden ,United Kingdom
3. Sub-alpine continental	Warm, moderate rainfall but low winter rainfall, moderate frequency of extremes	Austria, Czech Republic, Germany, Hungary, Italy, Slovenia
4. North European and continental	Cool and dry	Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden
5. Continental 3	Most warm and dry	Not in the European Union
6. Alpine	Cool and wet, relatively more extremes	Austria, France, Germany, Italy, Slovenia
7. Modified upland temperate maritime	More frequent extremes	United Kingdom
8. Mediterranean 1	More extreme rainfall	France, Greece, Italy, Malta, Spain
9. Mediterranean 2	Warmer, lower rainfall with more dry days but higher winter rainfall	Greece, Italy, Portugal, Spain
10. North European	Cool and dry	Finland, Sweden
11. Modified temperate maritime 1	Warmer and wetter but fewer wet spring days	France, Portugal, Spain, United kingdom
12. Wet mountainous maritime	Very wet, more frequent extremes	United Kingdom
13. Wet maritime	On exposes western coasts, more frequent extremes	Ireland, United Kingdom
14. Continental 1	Warm and dry with moderate frequency of extremes	Austria, Czech Republic, Germany, Hungary, Poland, Slovakia
15. Continental 2	Warm and dry, but more frequent wet days	Czech Republic, Germany, Greece, Hungary, Poland, Slovakia
16. Modified temperate maritime 2	Cool with moderate precipitation	Ireland, Sweden, United Kingdom

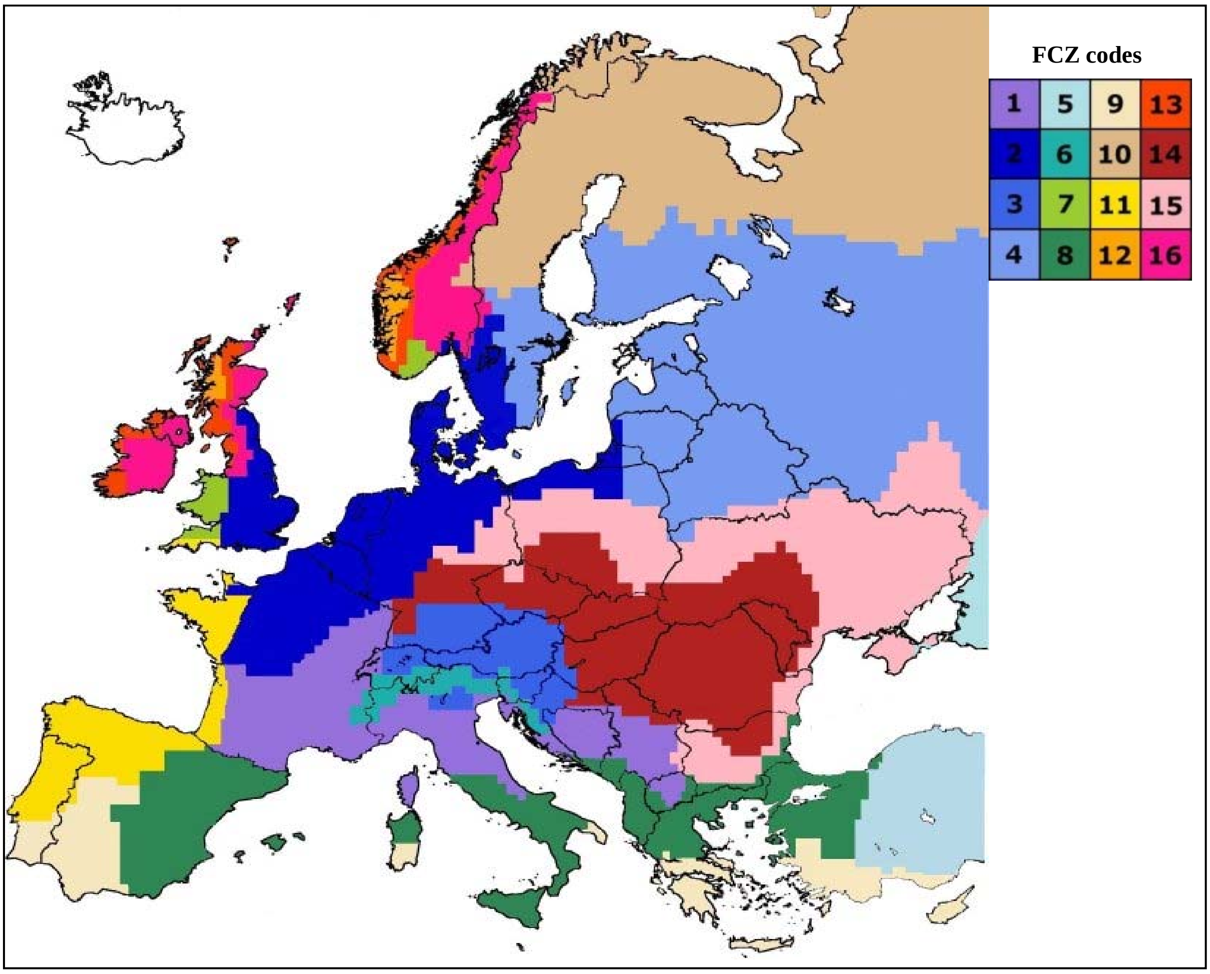

Figure 1. Distribution of the 16 FOOTPRINT climate zones within Europe

2.2 Definition of FOOTPRINT agronomic characteristics

Agronomic scenarios are defined in this work as areas in Europe where the dates of specific crop growth stages and data on specific crop cover area and management practices associated with them, are similar.

The identification of such areas is based on the intersection of two datasets. The precise location of broadly different categories of agricultural land was defined using the CORINE (2000) land cover database at a spatial resolution of 250 m x 250 m. Only CORINE land cover classes that represent agricultural land were selected to define agronomic scenarios and the following categories were used: Non-permanently irrigated (arable) land, permanently irrigated (arable) land, vineyards, fruit tree and berry plantations, olives, pasture, agro-forestry, annual crops associated with permanent crops, land principally occupied by agriculture with significant areas of natural vegetation and complex cultivation patterns. All other CORINE land cover categories were amalgamated as ‘non-agricultural land’ and not further differentiated.

In the resulting spatial database, whereas categories such as vineyards, olives, fruit trees and berry plantations and pasture represent land on which the agricultural crops are relatively permanent, categories that are characterized as partly or wholly arable represent land on which crops may vary from year to year. Within such categories therefore, the probability that a specific arable crop occurs at a certain location was determined using agricultural statistics for the EU administrative areas at NUTS (Nomenclature of Territorial Units for Statistics) level 2. This is the finest resolution at which pan-EU statistical data on crop cover area is available. Data on specific crop cover area and arable land area at the NUTS level 2 were obtained from the EUROSTAT dataset (EUROSTAT, 2006) and, where necessary, these were augmented with national cropping statistics. The following crops were used in this analysis: barley; cotton; durum wheat; flax; fodder root and brassicas; fresh vegetables, melons and strawberry; green fodder; maize fodder, maize grain; oats; other cereals; potato; pulse; rape seed; rye; soft wheat; soya; sugar beet; sunflower; tobacco. At the time of analysis, the most recent complete set of statistics at NUTS level 2 was for the year 2003 and hence data used to characterise the agro-environmental scenarios are for this year only. For each NUTS level 2 area, the probability that any specific arable crop occurs on a CORINE ‘arable’ polygon in that area was calculated using the EUROSTAT 2003 individual arable crop areas expressed as a percentage of the total arable land area. Using GIS, the spatial distribution of each NUTS level 2 area was intersected with the modified CORINE 2000 land cover dataset. This procedure resulted in a fine resolution (250 m x 250 m) dataset that characterizes the spatial distribution of agricultural land within Europe and, for arable land areas, gives an estimated probability of occurrence of specific arable crops.

However, analysis of the area (in hectares) of CORINE category arable land, pasture, olives and vines within each NUTS level 2 unit showed that the area totals often differed significantly from the areas of equivalent crops given in the EUROSTAT agricultural statistics. It is known that there are uncertainties in the allocation of CORINE satellite data to a specific land cover category and a correction factor was therefore applied to the calculated percentage crop areas. For each NUTS 2 level unit, this factor was calculated as the ratio of the EUROSTAT arable (or grassland or olives or vines) area (ha) to the CORINE arable (or grassland or olives or vines) area (ha). An example of the resulting cropping data set that characterizes each NUTS level 2 is shown in Table 2.

Finally, each crop in each NUTS 2 unit was allocated an agronomic template identifying seasonal ‘window’ dates for sowing, germination, shooting, flowering and harvest, along with likely periods for pesticide application.

Table 2. Example of the crop cover data set for selected crops that characterize the agronomic aspects of NUTS level 2 unit ES61 (Andalucia, Spain).

Crop Type	CORINE 2000 land cover classes	Crop cover area as percentage of arable land area†	Adjusted crop cover percentage using correction factor	Calculated crop cover area (1000ha) †
Barley	Non-(permanently) irrigated arable land	5.11	5.88	97.87
Cotton		4.84	5.57	92.81
Durum wheat		24.86	28.48	475.94
Maize grain		2.45	2.83	47.06
Oil seed		15.47	17.79	296.32
Potato		0.51	0.58	9.74
Soft wheat		3.32	3.81	63.59
Sugar beet		2.24	2.58	43.01
Sunflower		15.45	17.76	295.81
Olive plantations	Olive groves	-	100	1494.01
Vineyards	Vineyards	-	100	44.31

† Data source: EUROSTAT , reference year 2003.

2.3 Definition of FOOTPRINT soil classes

Soil types within Europe were differentiated according to those characteristics that are the drivers for pesticide fate, especially those that are used to parameterize the MACRO (Larsbo *et al*, 2005) and PRZM (Carsel *et al*, 1985) pesticide fate models which are used in FOOTPRINT.

Three main sources of information were used:

- The Soil Geographic Database of Europe (SGDBE, v.1) at 1:1,000,000 scale (Le bas et al., 1998) provides the only harmonized pan-European data that defines soil spatial variability. The database comprises polygon data files that define the location of Soil Map Units (SMUs), each of which comprises a number of defined Soil Types (STUs). The percentage cover of each STU within each SMU and some general attributes of each STU are defined in separate data files.
- The SPADE1 and SPADE2 databases (Hollis *et al*., 2006a), provide detailed profile-level data on soil properties for a wide range of European soil types within the SGDBE.
- The Hydrology of Soil Types (HOST) classification system (Boorman *et al*., 1995; Schneider *et al*, 2007) and the CORPEN system for identification of pollutant transfer pathways in the field. These very similar systems were harmonised to provide a set of conceptual models of hydrological and associated pollutant transfer pathways from the land to water resources, based on local soil and land characteristics.

Using these information sources, each STU in the SGDBE was assigned to a FOOTPRINT soil type based on its associated attribute data. FOOTPRINT soil types were identified according to three components: a) hydrological, which uses the STU attribute data on FAO soil type code, soil parent material type, depth to obstacle to roots, water regime and water management system to identify a HOST/CORPEN conceptual model and allocate each STU to one of 15 FOOTPRINT hydrological classes, coded L to Z. Descriptions of these classes are given in Table 3 along with their significance for deriving hydrologic conditions for the MACRO and PRZM models; b) textural, which defines a ‘topsoil’ and a ‘subsoil’ textural grouping base directly on the TEXT1, TEXT2, TD1 and TD2 attributes of the STU attribute data file. Where detailed particle-size data for an STU were available from the SPADE1 or SPADE2 databases this was used to check and, if necessary, adjust the FST topsoil and subsoil texture codes; c) generalized sorption potential, which allocates STUs to an ‘organic profile class’ based on the SOIL attribute in the STU attribute data file. This attribute gives the FAO soil class which can be pedologically interpreted to infer broad differences in the magnitude and distribution pattern of organic matter within the soil profile. Table 4 gives descriptions of each organic profile code used. The final FOOTPRINT Soil Type code was created by combining the codes for each of the hydrological, textural and organic profile components as shown in Figure 2.

This process resulted in 373 FOOTPRINT Soil Types (FSTs) representing all of the STUs in the SGDBE. Of these 257 represent soils under arable or permanent crops such as olives, fruit trees or vines, 221 represent soils under (permanent) pasture and 50 represent soils that occur solely under non-agricultural uses.

For each ‘agricultural’ FOOTPRINT soil type, a set of land use specific soil properties was created using data on soil horizon type, depths, particle-size distribution, organic carbon content, pH and bulk density derived from the SPADE 1 and SPADE 2 datasets. Although these data do not cover all of the STUs in the SGDBE, there are still over 1,000 complete profiles with an agricultural land use available. All soil profile data for STUs with the same FOOTPRINT soil type code were amalgamated and mean values for each parameter in each similar soil horizon calculated. This process provided data on soil horizon type and depth, particle-size characteristics, organic carbon content, pH and bulk density for most of the FOOTPRINT soil types identified, but some did not have any representative in the SPADE1 or SPADE2 databases. In such cases, synthetic land use specific property data were derived using the three components of the FOOTPRINT soil type code. Thus, soil horizon sequences were derived from those FOOTPRINT soil types with data that had the same hydrological class as the uncharacterized soil type. Particle-size data were derived from those FOOTPRINT soil types with data that had the same topsoil and subsoil textural codes. Stone content, pH and organic carbon content were derived from those FOOTPRINT soil types with data that had the same 'SOIL' and 'organic profile' codes as the uncharacterized soil type. Finally, bulk density was derived using a set of pedo-transfer functions incorporating particle-size distribution, organic carbon content and soil horizon type.

Table 3 Description of the hydrologic component of FOOTPRINT soil type codes and their relationship with hydrologic conditions for the MACRO and PRZM models.

FOOTPRINT hydrological code	HOST class	Description	MACRO bottom boundary condition	PRZM Soil Hydrologic Group
L	1, 2, 3, 5, 13	Permeable, free draining soils on permeable sandy, gravelly, chalk or limestone substrates with deep groundwater (below 2m depth).	Unit hydraulic gradient	A
M	4	Permeable, free draining soils on hard but fissured substrates (including karst) with deep groundwater (below 2m depth).	Unit hydraulic gradient	B
N	6	Permeable, free draining soils on permeable soft loamy or clayey substrates with deep groundwater (below 2m depth).	Unit hydraulic gradient	B-C
O	7	Permeable soils on sandy or gravelly substrates with intermediate groundwater (between 1 & 2 m depth)	Zero flow	A
P	8	Permeable soils on soft loamy or clayey substrates with intermediate groundwater (between 1 & 2 m depth)	Zero flow	B-C
Q	9, 10, 11	All soils with shallow groundwater (within 1m depth) and artificial drainage	Zero flow	A
R	17	Permeable, free draining soils with large storage, over hard impermeable substrates below 1 m depth	Zero flow	B
S	19	Permeable, free draining soils with moderate storage, over hard impermeable substrates at between 0.5 & 1 m depth	Zero flow	B-C
T	22	Shallow, permeable, free draining soils with small storage, over hard impermeable substrates within 0.5 m depth	Zero flow	C
U	20	Soils with slight seasonal waterlogging ('perched' water) over soft impermeable clay substrates	Zero flow	B-C
V	23, 25	Soils with prolonged seasonal waterlogging ('perched' water) over soft impermeable clay substrates	Zero flow	C
W	16	Free draining soils over slowly permeable substrates	Percolation rate regulated by water table height	B
X	18	Slowly permeable sois with slight seasonal waterlogging ('perched' water) over slowly permeable substrates	Percolation rate regulated by water table height	B
Y	14, 21, 24	Slowly permeable soil with prolonged seasonal waterlogging ('perched' water) over slowly permeable substrates	Percolation rate regulated by water table height	B-C
Z	12, 15, 26, 27, 28, 29	All undrained peat or soils with peaty tops	Not modelled	D

Table 4. Description of the 'organic profile' component of FOOTPRINT soil type codes and their derivation from the pedological SOIL code from the Soil Geographic Database of Europe (SGDBE).

FOOTPRINT organic profile code	Description	SOIL (from SGDBE)
a	Alluvial soils with an uneven distribution of organic matter down the profile	Fluvisols, fluvic subgroups
g	With a thick (artificially deepened) topsoil relatively rich in organic matter	Plaggen soils
h	With an organic rich topsoil	Chernozems, phaeozems humic & mollic subgroups
i	With a clay increase in the subsoil	Planosols, luvisols, podzoluvisols, luvic & planic subgroups
n	With a 'normal' organic profile	
f	Permafrost soils (non-agricultural) with an uneven distribution of organic matter down the profile	Gelic subgroups
o	Soils in volcanic material with organic rich upper layers	Andisols
p	Podzols' with a relatively organic rich topsoil and an relatively organic rich subsoil layer	Podzols
r	Soils where the organic profile is limited by rock within 1 m depth	Rendzinas rankers and lithosols
t	With a peaty topsoil	Histosols & histic subgroups
u	Undeveloped' soils with relatively small organic matter content.	Regosols

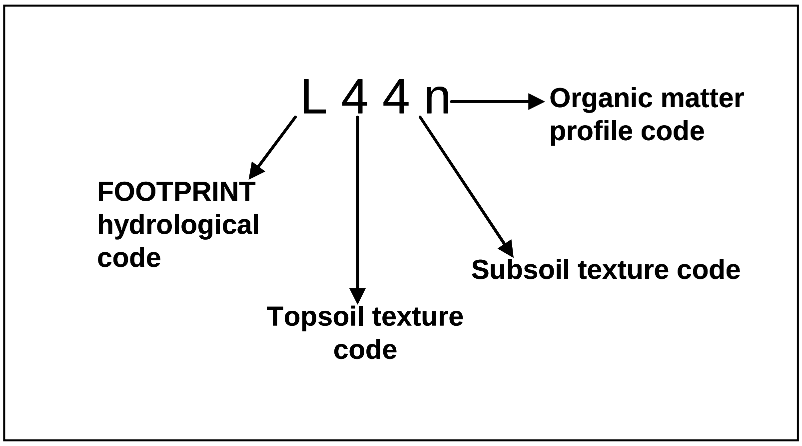

Figure 2 The FOOTPRINT Soil Type code and its components

2.4 Creation of the FOOTPRINT agro-environmental scenarios

Using a Geographic Information System (GIS; ESRI Arcview 9.1), both the FOOTPRINT climate map and the combined CORINE land cover-NUTS level 2 spatial datasets were intersected with the SGDBE Soil Map Unit polygons to create the final FOOTPRINT European agro-environmental dataset.

Because of the different resolution of the CORINE and SGDBE datasets, spatial inconsistencies were observed between those areas which, in the SGDBE (1:1,000,000 scale), are characterized as either 'undefined'; 'not surveyed'; 'soil disturbed by man'; 'water body'; 'glacier'; 'marsh'; or 'out of surveyed area' and equivalent areas in the CORINE data (250 m x 250 m). Where such areas had an attributed CORINE land cover class they were assigned to the Soil Map Unit of the nearest soil polygon rather than their original 'non-soil' designation from the SGDBE. This ensured that all areas identified as 'land' by the fine-resolution CORINE data, had a designated soil type.

The final FOOTPRINT European agro-environmental dataset constitutes a large number of polygons (1 363 138) derived by the fragmentation of each NUTS level 2 polygon into homogenous areas of FOOTPRINT climatic zone, SGDBE soil map unit and CORINE agricultural category. Each polygon has a defined NUTS level 2 code, climate zone code, Soil Map Unit code and CORINE agricultural land code. Attribute data files linked to the spatial data define the fraction of arable crops related to each CORINE arable category as an indicator of its probability of occurrence, as described in section 2.2, and the fraction of each FOOTPRINT Soil Type in each Soil Map Unit, derived from the data held in the SGDBE. This fraction indicates the probability of occurrence of each FOOTPRINT Soil Type in each agro-environmental polygon. Figure 3 gives a diagrammatic representation of the derivation and content of the European agro-environmental scenarios and an example of the GIS-based geographic representation of the scenarios is shown in Figure 4.

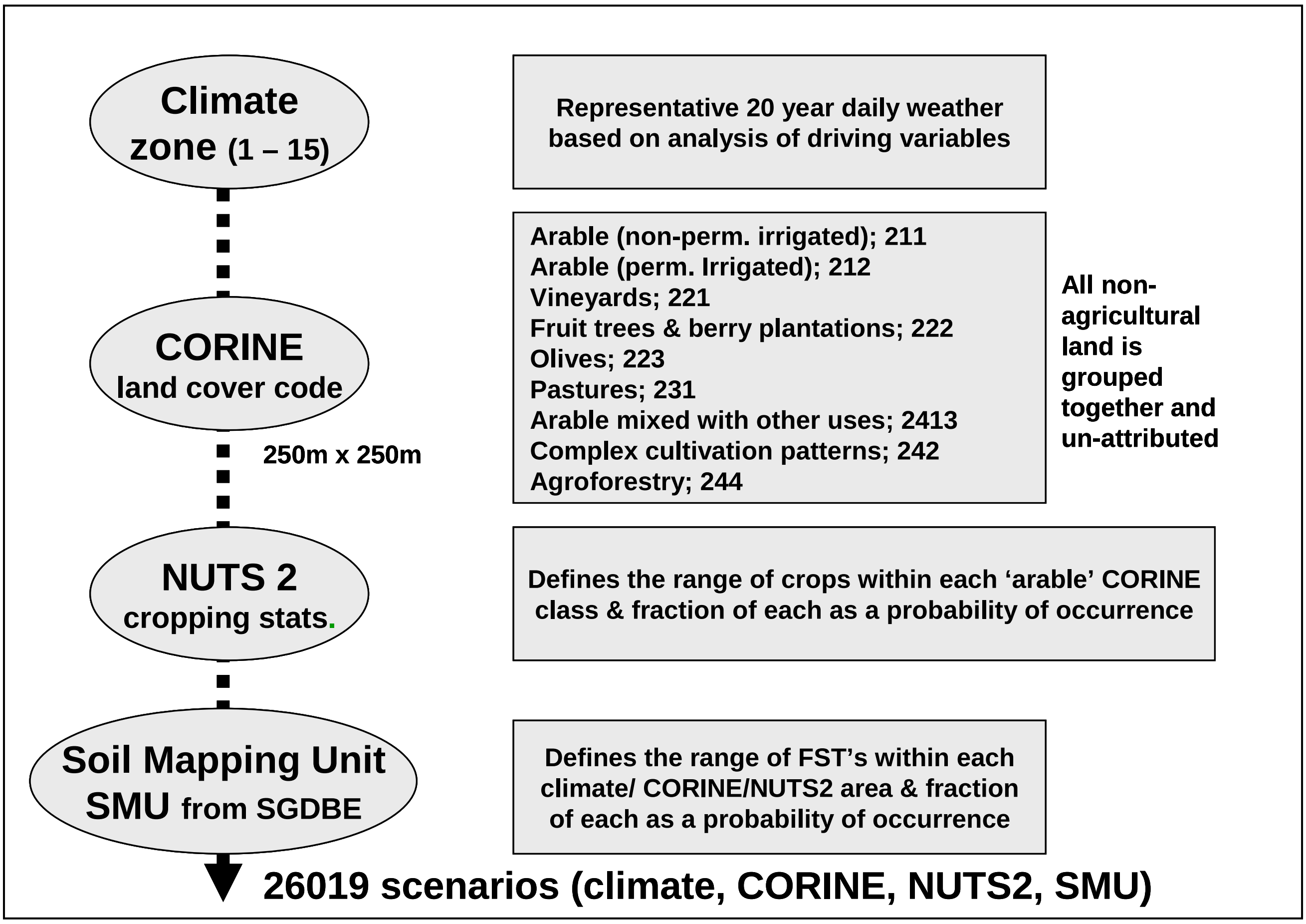

Figure 3 Diagrammatic representation of the derivation and content of the European agro-environmental scenarios

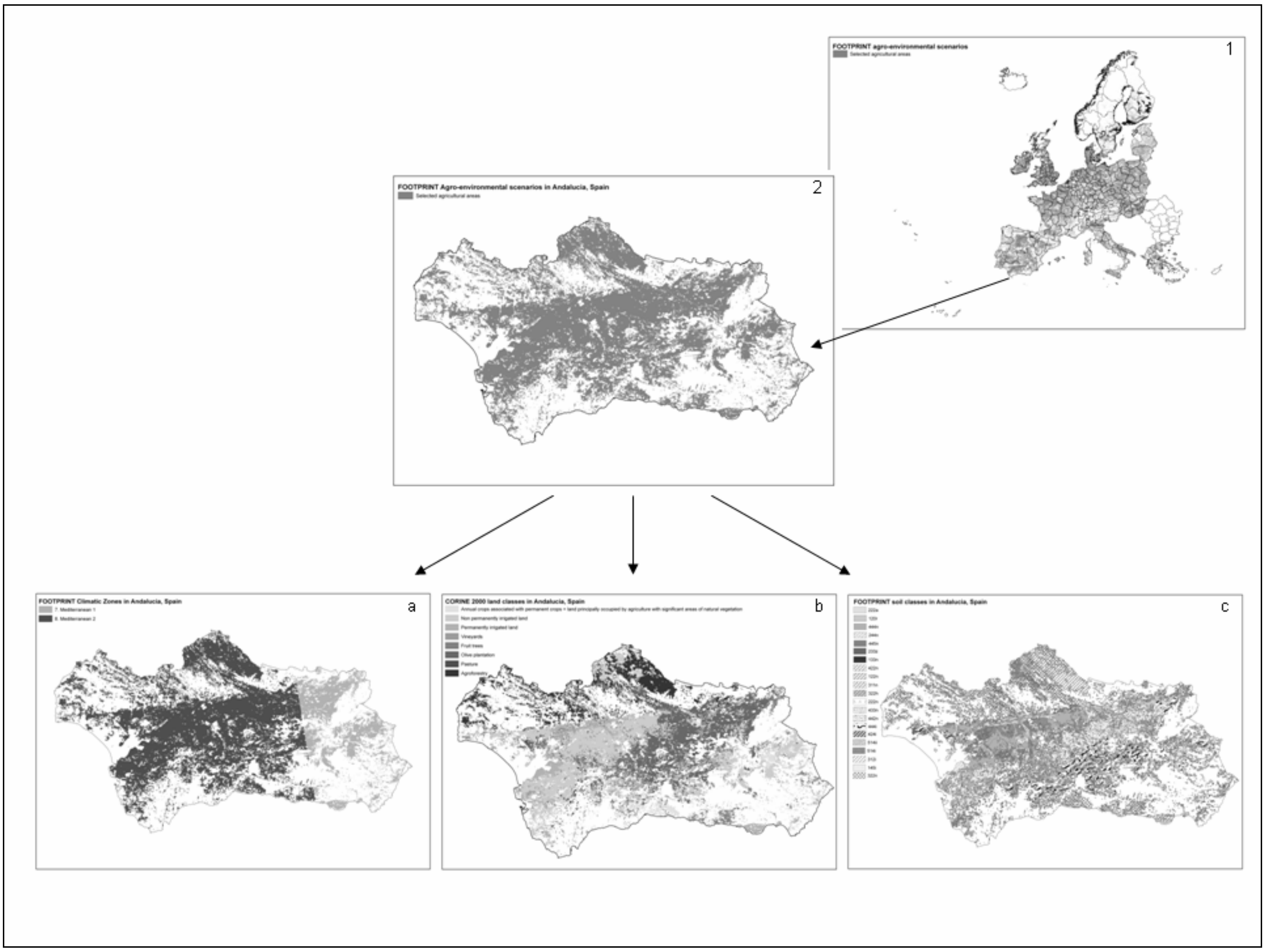

Figure 4 Map of the FOOTPRINT agro-environmental scenarios representative of the European agricultural landscape (1). The agro-environmental scenarios in Andalucía, Spain, are shown as example 2). The agro-environmental scenarios were obtained by the intersection of the FOOTPRINT climatic zones (a), the FOOTPRINT soil classes (b), the selected CORINE 2000 land use classes and European agricultural statistics (c).

3 RESULTS AND DISCUSSION

3.1 FOOTPRINT agro-environmental scenarios

As explained in section 2, each unique combination of CORINE ‘agricultural class’, NUTS level 2 category, climate zone and Soil Map Unit (SMU) represents a single agro-environmental scenario in which the local soil is defined from a range of FOOTPRINT Soil Types with a defined percentage probability of occurrence and, for those scenarios that have a partly or wholly ‘arable’ designation, a defined range of annual crops with an estimated percentage probability of occurrence. A total of 26 019 unique combinations of FOOTPRINT climatic zone, NUTS level 2, CORINE agricultural category and Soil Map Unit were identified. However, because of the spatial uncertainty related to the distribution of annual arable crops and soil types within each polygon, the same soil/crop combinations occur in many polygons which have the same climate and CORINE agricultural land category, although the fractions of the soils and arable crops are different.

3.2 Use of the scenarios for modelling the fate of agrochemicals within Europe

For modelling purposes it is only necessary to take into account the unique combinations of climate, soil and crop that occur within Europe and when this is calculated from the agro-environmental scenario dataset, the total of unique combinations is 35 158. This number takes into account the need for separate model simulation for autumn sown and spring sown varieties of the same crop, as well as early and late sown varieties of crops such as potatoes, soya, etc.

Each of the climate, soil and crop components of the scenarios has an associated set of data which can be used to parameterize environmental fate models. Thus, each climate zone has a representative set of daily weather parameters for precipitation, mean, maximum and minimum temperature, potential evapotranspiration, wind speed, solar radiation for 20 years. Such a long period of daily data should be adequate to encompass most of the temporal variability in weather across the climate zone as well as including a sufficient number of extreme weather events to represent at least a 95^{th} percentile worst case for leaching, drainage or runoff. The crop calendar templates should also provide enough information to derive the crop growth input parameters necessary for modelling. Finally, the soil horizon type and depth, particle-size characteristics, organic carbon content, pH and bulk density data provided for each FOOTPRINT soil type can be used to derive any soil hydraulic characteristics required by models, using ‘pedo-transfer functions’ such as those included in the HYPRES data files (Wosten *et al*, 1998) or derived from national datasets (Mayr & Jarvis, 1999). In addition, the hydrological component of the soil type code can be used to derive the hydrologic conditions to help parameterize leaching, drainage and runoff models such as MACRO and PRZM as illustrated in Table 3.

3.3 Implication for improvement of risk assessment procedures

Current European risk assessment procedures use a limited number of scenarios to represent national and European spatial variability (a single scenario is used in the Netherlands, two scenarios are used in Denmark, and 10 scenarios have been defined at the EU level) (Van Alphen and Stoorvogel, 2002). In Germany Probst et al. (2006) and Herrchen et al. (1995) have identified eight different environmental scenarios in the central lowland region and five small scale national scenarios, respectively.

In contrast to these studies, the work presented here has derived a large number of agro-environmental scenarios representing land areas that are effectively homogeneous with respect to the critical factors that control the fate of agriculturally applied chemicals. The scenarios represent the spatial variation and heterogeneity of the European agricultural landscape and, because they incorporate data on the weather, soil physical, soil hydrological and crop growth characteristics that are required by most soil leaching, drainage and runoff models, they can be used to underpin their parameterization at the pan-European level. As such they provide a basis for developing a comprehensive probabilistic approach to estimating environmental exposure of agricultural applied chemicals within Europe. Probabilistic approaches to risk assessment for pesticides are currently under consideration (Hart, 2001), but a recognized limitation to such approaches is the lack of harmonised data at the pan-European scale, both for estimating exposure and effects. The agro-environmental datasets described here now provide the basis for addressing the exposure side of this problem.

3.4 Possibilities for further improvement of the scenarios

The agro-environmental scenarios described here have highlighted some inter-national variability in the complexity of scenarios as well as showing the high spatial heterogeneity between small areas within the same country. The scenarios have the advantage of using harmonised pan-European datasets in their derivation but, at the regional scale, such an analysis can obviously be improved by incorporating more comprehensive or spatially precise data on weather, soil type and cropping, where it is available.

In addition the agro-environmental scenarios identified represent only one aspect of the variability of agricultural practices in respect to pesticide usage in Europe. Social aspects and economic factors also affect agricultural practices because individual farmer's managerial decisions are usually strongly influenced by local tradition, land inheritance, the national economy and global market forces.

For example, data on farm structure survey in 2003 (EC, 2005) show important differences between the structure of agriculture holdings among the 24 Member States. Southern European countries are characterized by small holdings (5 to 20 ha) which rely heavily on family labour force and are often managed by farmers aged above 60 years. Such holdings have a small economic size and mainly focus on permanent crops such as vineyards, fruit, orchards, and olives. To a lesser extent, such socio-economic agricultural conditions extend into Slovenia and Hungary. In contrast, further north in Europe, a large proportion of holdings are more than 50ha in size with at least about 4% being more than 100ha. On average, holders are between 45 and 64 years old with Poland, Austria, Germany and Finland having 70% of holders aged less than 54. With the exception of Poland, the farm labour force on such farms comes mainly from outside the family and in many cases the holder has another profitable activity besides agriculture. The Netherlands, Denmark, Belgium, UK, and Czech Republic have the highest average economic size followed by Germany, France, Luxembourg, Sweden, Finland and Ireland. Lithuania, Latvia, Slovenia and Poland have the lowest average economic size, with economic production focussed solely on arable crops and grazing.

Such differences in socio-economic factors across Europe are likely to affect crop management techniques within areas with the same soil and climate and thus could be integrated with the biophysically-based scenarios described to develop sound and context-specific ecological risk assessment.

CONCLUSIONS AND PERSPECTIVES

A large number of agro-environmental scenarios representing land areas that are effectively homogeneous with respect to the critical factors that control the environmental fate of agriculturally applied chemicals have been identified. The 26019 scenarios represent the spatial variation and heterogeneity of the European agricultural landscape and can be used to underpin parameterization of pesticide fate models.

As far as we are aware this work is the first attempt to quantify such variation at the pan-European scale. Further refinement of the approach could be based on incorporating more comprehensive and finer resolution data on crop and soil distributions as well as identifying locally representative weather datasets for individual soil and land combinations. In addition, integration of socio-economic aspects of farm structure could be used to refine the information on agronomic practices encompassed in the crop growth templates by indicating where differences in socio-economic factors may affect crop management techniques within areas with the same soil and climate.

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