Uncertainty and sensitivity analysis of GeoPEARL

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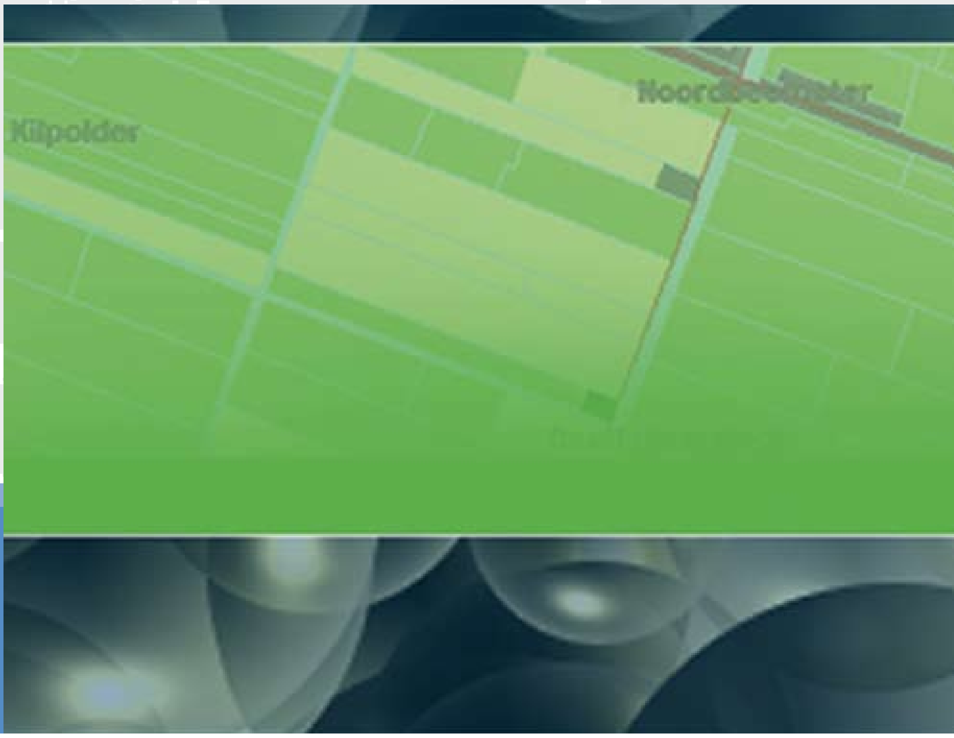

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ABSTRACT

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In the environmental assessments by the Netherlands Environmental Assessment Agency (PBL), the GeoPEARL model is used to calculate the leaching of pesticides to the groundwater at the national scale. In this study, the propagation of errors resulting from the use of a simplified spatial schematisation as well as that of uncertainties in the GeoPEARL input to the predicted leaching concentrations were investigated. Computations using GeoPEARL with the standard schematisation were compared with those obtained with a schematisation at a higher spatial resolution. For all three pesticides considered the nationwide spatial frequency distribution of the median annual leaching concentration (PEC50) and the spatial 90th percentile of the PEC50 (SP90) were hardly affected by spatial aggregation of soil type within larger spatial units. For the assessment of the propagation of uncertainties in the input, only soil properties and the most important pesticide properties, i.e. half-life in soil (DT_{50}) and the coefficient for the sorption on organic matter (K_{om}) were considered. First, the uncertainties in the soil data and the pesticide were quantified. Next, a regular grid sample of points covering the whole of the agricultural area in the Netherlands was randomly selected. At the grid nodes, realisations from the probability distributions of uncertain inputs were generated and used as input to a Monte Carlo uncertainty propagation analysis. Uncertainties in DT_{50} and to a lesser extent K_{om} contributed most to the uncertainty in PEC50 and SP90. The uncertainty about the PEC50 at point locations is greater than that about the SP90. When taking the uncertainties into account, the SP90 of the leaching concentration shifted towards greater values. Recommendations are made for further improvement of the model predictions, in particular by reducing the uncertainty in DT_{50}.

Keywords: error propagation, distribution function, groundwater, half-life, leaching concentrations, pesticide, soil properties, sorption coefficient, spatial aggregate

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Preface

Quality assurance of environmental models used in assessments by the Netherlands Environmental Assessment Agency (PBL) is important. As a result of an inventory of the quality of the models used by Wageningen UR for these assessments, the research programme 'KwaliteitsSlag' was set up to improve the quality of these models. This programme started in 2006 and was financed by PBL and Wageningen UR. One of the projects in this research programme dealt with the uncertainty in the calculation of the leaching of pesticides to the groundwater at the national scale as calculated with the GeoPEARL model.

In this report the results of a study on the uncertainty in leaching concentrations over time at a specific location and in the spatial leaching concentration over the entire agricultural area are presented. Further, the effects of a simplification in the chemical-physical soil map on the spatial leaching concentrations at the national scale is assessed.

Summary

In the environmental assessments by the Netherlands Environmental Assessment Agency (PBL), the GeoPEARL model is used to calculate the leaching of pesticides to the groundwater at the national scale. The target quantity to report the risk of leaching at a specific location is the 50th percentile over time of the predicted annual average concentration in soil (PEC50). The concentration is taken at 1 m soil depth, which is considered to be representative for the concentration in the upper groundwater. In the new Dutch decision tree for leaching of pesticides to groundwater within the registration procedure of pesticides, the 90th percentile of the spatial frequency distribution (spatial P90 or SP90) of the PEC50 is taken in its area of use.

In this report the effect of a simplification in the Dutch physical-chemical soil map on the spatial leaching concentrations was assessed. First, a detailed physical-chemical soil map was prepared based on the 1:50 000 soil map of the Netherlands. Input data on soil properties for GeoPEARL were derived from the simplified soil map as used in the current PBL assessments and from the detailed physical-chemical soil map. The 90th percentile leaching concentrations at a depth of 1 m calculated for both physical-chemical soil maps were compared. The results show that the spatial P90s for the Netherlands as a whole calculated with both soil maps do not differ much. However, the spatial P90s for smaller areas (regions) may differ substantially.

In this report also the propagation of uncertainty about important soil and pesticide properties to the PEC50 and SP90 was studied. The soil properties taken into consideration were clay content, silt content, sand content, organic matter content, hydraulic characteristics, and thickness of the soil horizons. The probability distributions for texture, horizon thickness and organic matter were derived from data in the Dutch Soil Information System. Data on the water retention and hydraulic conductivity characteristics of soils were taken from the Staring Series, which is a database containing multiple measurements of 36 different building blocks (for top- and subsoil). The set of curves of a building block was treated as a random sample from all curves that populate the building block.

The uncertain pesticide properties considered were the coefficient for the sorption on organic matter and the half-life of transformation in soil. The uncertainty in the pesticide properties was characterised by their variability between soils, which was derived from literature studies.

Stochastic simulations at six point locations showed that uncertainty about PEC50 at point locations is large, also at the 0.1 μg/L level. The spatial pattern of the median leaching concentration over time (PEC50) in the Monte Carlo simulations corresponded well with the spatial pattern predicted in an ordinary deterministic GeoPEARL run. Both in the stochastic simulation and in the deterministic simulation, there is a strong correlation between PEC50 and organic matter. For the

PEC50, the pesticide transformation half-life (DT_{50}) is the main source of uncertainty. The contributions of the sorption coefficient (K_{om}) and organic matter to the total uncertainty were smaller, but meaningful. The contribution of uncertainty in texture and soil physical properties to the total uncertainty is generally small.

The uncertainty about the spatial P90 (SP90) – which is the regulatory endpoint in Dutch pesticide registration – is smaller than the uncertainty about PEC50 at point locations. The width of the interquartile range is computed to be 15% of the median spatial P90 for pesticides A and B and approximately 40% in the case of pesticide D.

For the 90th percentile leaching concentration in space, the most important source of uncertainty on the model output was DT_{50} and to a lesser degree K_{om}. Moreover, the estimated 90th percentile concentrations are substantially larger when uncertainty of pesticide and soil properties is considered. The important implication for regulation is that the SP90 is systematically underestimated when uncertainty is ignored. However, when uncertainty is included in the analysis, it may be sensible to use a less extreme percentile for regulatory evaluation, such as the 80th percentile.

In this study several assumptions were made. Firstly, it was assumed that the Dutch 1:50 000 soil map was free of errors. This results in an underestimation of the contribution of the uncertainty about the basic soil properties to the total uncertainty about the pesticide leaching. Secondly, lateral and vertical correlations (between soil layers) in the uncertainty of the soil and pesticide properties were ignored. Taking these correlations into account will likely result in an increase in the uncertainty in the SP90. Before this can be done, statistical models and software that describe this correlation need to be improved.

The degradation half-life is by far the most important source of uncertainty of both the PEC50 at individual locations and the spatial P90. Strategies to reduce the overall uncertainty should therefore first be directed towards obtaining better estimates of the degradation half-life and its dependence on soil type.

As GeoPEARL requires a lot of computation time, it is recommended to check whether part of the analyses could be done with a simpler model. A prerequisite is that the simple model captures the most important processes and shows the same behaviour as the complex model.

The soil organic matter map can be improved by including the soil data in the TAGA-archives. This will result in a more accurate soil organic matter map and will yield improved spatial patterns of PEC50.

For an overall assessment of the effect of uncertainties in the model input on the target output, uncertainty in other input data, such as the bottom boundary condition, the dispersion length, land use data and drainage data should be investigated. By ranking the effects of all sources of uncertainty, the weakest parts of the GeoPEARL model chain can be identified and a prioritization can be presented for further improvement of the model.

1 Introduction

1.1 Uncertainty about pesticide leaching

In the Netherlands a policy plan on sustainable crop protection has been adopted to ensure that environmental risks due to the use of crop protection products (pesticides) are minimised (LNV, 2004). The Netherlands Environmental Assessment Agency (PBL) is responsible for evaluating the progress made in achieving the objectives of this plan. Pesticide leaching to the groundwater is one of the aspects considered, because groundwater is a major source of drinking water in the Netherlands. The PBL uses a metamodel of the GeoPEARL model to assess the leaching of pesticides to the groundwater (Van der Linden et al., 2006). GeoPEARL is a spatially distributed pesticide leaching model (Tiktak et al., 2002; 2003), which combines a one-dimensional, process-based leaching model to spatial data available in Geographical Information Systems.

GeoPEARL also plays a central role in Dutch pesticide registration procedures (Van der Linden et al., 2004). In contrast to earlier procedures (Van der Linden and Boesten, 1989), pesticide leaching is evaluated in the entire intended use area of the product. A pesticide can only be registered if the concentration of the pesticide is below 0.1 µg/L for more than 90% of the intended use area of the product. This regulatory endpoint can be directly inferred from the cumulative frequency distribution of the predicted leaching concentration in the intended use area (Figure 1.1).

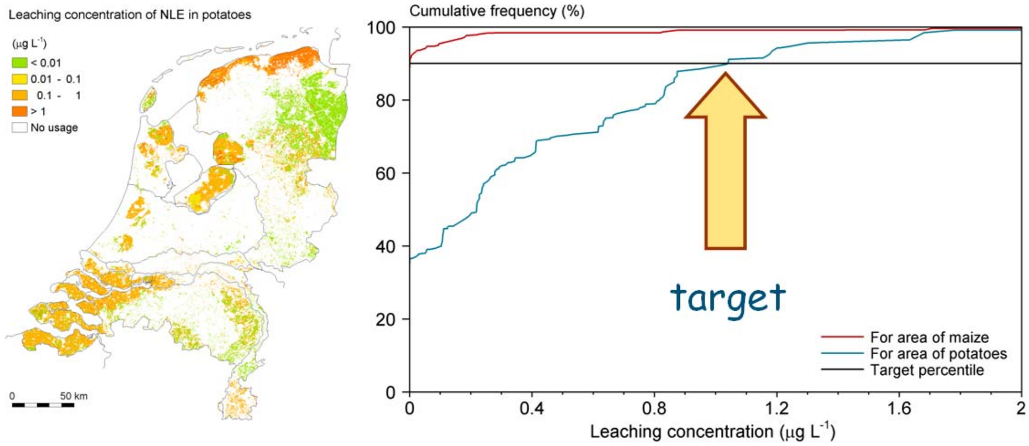

Figure 1.1. Percentiles of the leaching concentration in the intended use area can be inferred from the cumulative frequency distribution of a leaching map. Example with pesticide "NLE" in potatoes (as in Tiktak et al., 2003).

Until now, uncertainty is not explicitly addressed in the risk assessment. However, understanding the consequences of uncertainty is needed to improve risk assessment as a decision-support tool (Brown and Heuvelink, 2005; Refsgaard and Henriksen, 2004). The different sources of uncertainty in pesticide fate modelling have been described by Dubus et al. (2003). Uncertainty is first present in the primary data (physical, chemical and environmental conditions). There is also uncertainty in the estimation of model input parameters from these primary data. This includes for example the estimation of pesticide half-life (DT_{50}) from laboratory data, even though harmonization of the boundary conditions and settings can limit this source of uncertainty (FOCUS, 2006). Uncertainty in environmental assessments also arises from the use of pedotransfer functions (Tiktak et al., 1999; Dubus et al., 2003) or the use of spatial interpolation of spatially referenced parameters (Brus and Jansen, 2004; Brown and Heuvelink, 2005). Model structure, the numerical solution of the model and the spatial schematisation provide additional sources of uncertainty (Addiscott et al., 1995).

Jury and Gruber (1989) and Van der Zee and Boesten (1991) have studied the effect of spatial variability on the average leached fractions of the applied dosage of pesticides from fields by stochastic simulation, and they suggested that spatial variability can significantly increase the pesticide leaching. Leterme et al. (2007) studied the effect of spatial variability on pesticide leaching on a regional scale using a similar method and their findings also indicate an increase in the fractions of the dosage of pesticide leached. Stochastic simulations are likely to generate extreme events that are not captured within an 'average' deterministic simulation.

1.2 Model inputs and outputs

This report presents an uncertainty and sensitivity analysis of the GeoPEARL model. The analysis only studies the effect of input uncertainty. GeoPEARL contains a large number of model inputs (Figure 1.2), many of which are spatially distributed. An uncertainty analysis with all these model inputs would require too much computation time, because a single GeoPEARL run requires approximately 24 hours on a single computer. The analysis therefore focuses on the uncertainty of the pesticide half-life (DT_{50}), the coefficient for sorption on organic matter (K_{om}), soil organic matter content, soil texture, thickness of soil horizons, Staring series building blocks and the soil physical properties of the Staring series building blocks. The choice of these (sets of) input parameters follows the conclusions of Tiktak et al. (1994) and Boesten (1991) in previous sensitivity analyses performed on the point-scale models PESTRAS and PESTLA, respectively. These two models are predecessors of the PEARL model. They found the Freundlich exponent, K_{om}, and DT_{50} to be the most sensitive pesticide parameters. Organic matter content was found to be the most important soil parameter. Other sensitive parameters were the soil physical parameters, in particular the *n*-parameter in the Mualem-van Genuchten equation of water retention, and the saturated conductivity parameter K_{sat}. The Freundlich exponent was not included in the analysis presented in this report. Uncertainty in the Freundlich coefficient is considered to be less important than that in the half-life and the sorption coefficient, because the coefficient of variation of the Freundlich exponent is much smaller than that of half-life and sorption coefficient.

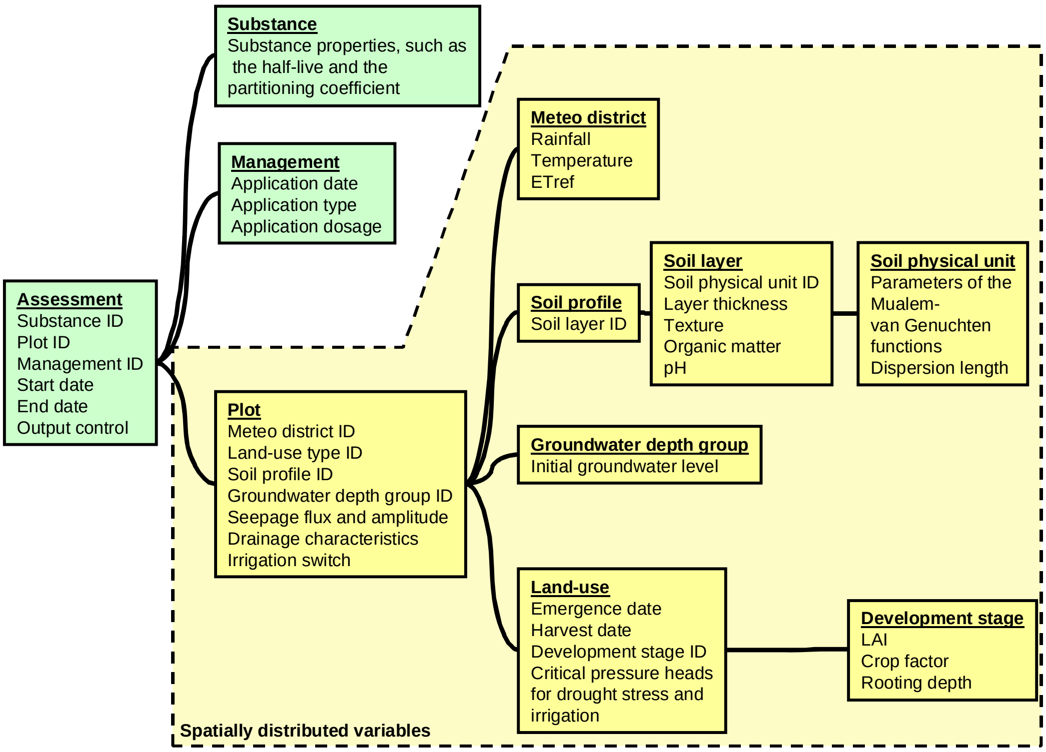

Figure 1.2 Structure of the GeoPEARL database. Fields in yellow refer to spatially distributed inputs, fields in green are assumed spatially constant in deterministic studies.

The uncertainty analysis focused on the following model outputs:

- The temporal median of the annual average leaching concentration (PEC50) at 1 m depth at point locations within the intended use area. Following FOCUS (2000), the median annual average leaching concentration is derived from a weather time-series of 20 years. So, to calculate the PEC50 at a location, the following procedure is followed: (i) at the location of interest, the point scale model PEARL is run for 20 years with real weather data, (ii) the annual average leaching concentrations are calculated for these 20 years, (iii) PEC50 is computed by taking the median of these 20 averages;
- The 90th percentile of the spatial distribution of PEC50 in the intended use area (SP90). In our analysis, it is assumed that the intended use area is the entire agricultural area within the Netherlands.

1.3 Objectives of research

1.3.1 Analysis of the error resulting from the use of a simplified soil physical-chemical map

Although more detailed spatial information of the soil input is available for the Netherlands, in a standard assessment of the target concentration, computations are done for 6 405 map units, referred to as 'STONE plots' (Kroon et al., 2001). These plots are characterised by unique combinations of subsoils ('hydrotypes'), drainage characteristics, seepage fluxes, groundwater depth classes, land use type, climate district, soil physical type and soil profiles (Figure 1.3). This saves considerable computing time because GeoPEARL needs only be run 6 405 times, since all locations within a STONE-plot have the same input values. However, ignoring spatial variation within plots may lead to bias (Heuvelink and Pebesma, 1999), particularly for non-linear models such as GeoPEARL (Leterme et al., 2007). The bias may be quantified by comparing the standard GeoPEARL results with the results obtained with a more detailed map of model inputs. Because of time constraints, the analysis of the effect of accounting for spatial variation of input variables within the 6 405 STONE-plots was limited to soil input characteristics. More detailed maps of the hydrological and climatic input variables were not used. Instead, these input variables were derived from the STONE map with 6 405 map units (plots). The research presented in the first part of this report (Chapter 2) therefore focuses on the quantification of the error resulting from the use of a spatial schematisation, consisting of 6 405 unique combinations.

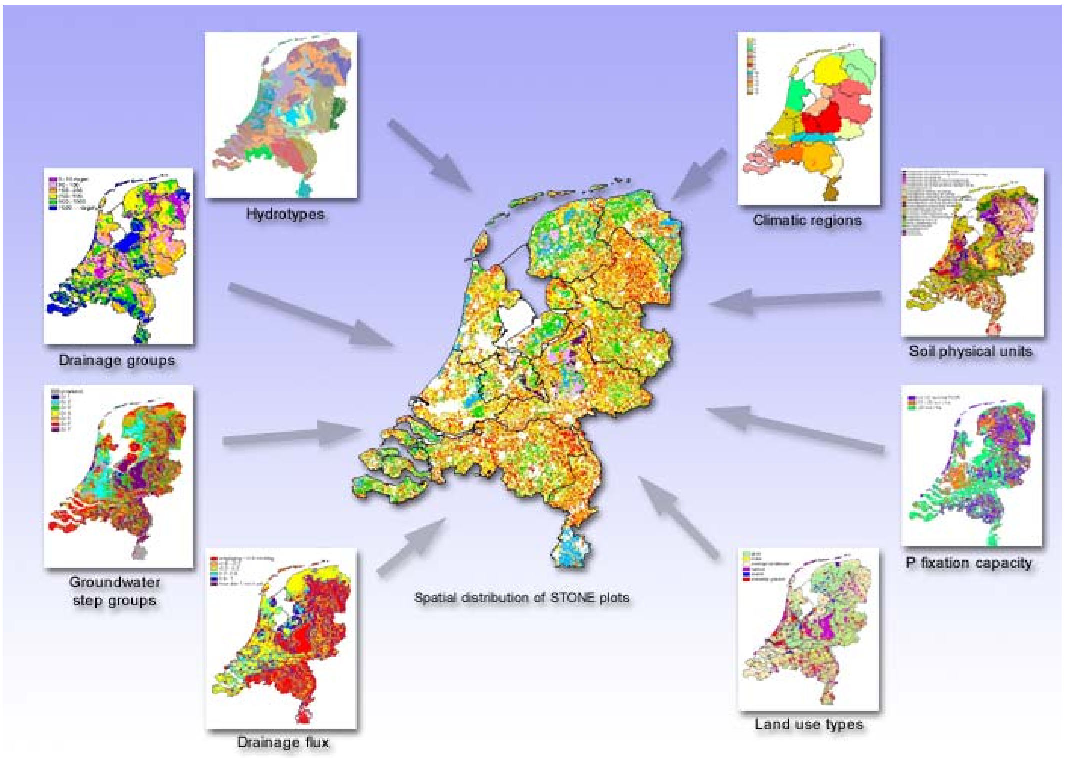

Figure 1.3 Procedure for creating the spatial schematisation for GeoPEARL. This procedure was originally developed for the Dutch Model for Emission of Nutrients, STONE (Kroon et al., 2001)

1.3.2 Uncertainty in leaching concentrations at the field scale and at the scale of the total agricultural area in the Netherlands

The main objective of this study was to analyse the uncertainty in the leaching concentration calculated with the GeoPEARL model at specific locations as well as at the scale of the entire agricultural area within the Netherlands. As a complete analysis for all components in the GeoPEARL model, e.g the lower boundary flux, drainage schematisation, would be very time consuming, the uncertainty analysis focussed on the soil schematisation and the two most important pesticide properties, i.e. the coefficient for the sorption on organic matter and the half-life in soil. The research presented in chapters 3 and 4 therefore focuses on:

1. Quantification of the uncertainty about the median annual average leaching concentration at point locations (PEC50) and about the associated spatial 90th-percentile for the entire Dutch agricultural area (spatial P90, abbreviated here to SP90), as caused by uncertainty of pesticide properties and soil characteristics;
2. Assessment of the contribution of individual uncertain input parameters to the total uncertainty in PEC50 and SP90 (i.e. stochastic sensitivity analysis).

Other important issues addressed in this report are 1) whether ignoring uncertainty in soil characteristics and pesticide properties leads to a systematic error (bias) in the model predictions and 2) what strategy should be followed to reduce the uncertainty of the current GeoPEARL simulations.

1.4 Outline of report

In Chapter 2 the effect of accounting for spatial variation in soil input variables within STONE plots is quantified. This chapter first presents a more detailed map with soil input variables. Using an overlay of the soil map 1:50 000 and the map with the STONE plots, all relevant soil profiles within each STONE plot are characterised. Using the more detailed soil map, the SP90 (i.e., the 90th percentile of the spatial cumulative frequency distribution of the median annual leaching concentration at a depth of 1 m) is assessed for the whole agricultural area. The results of these calculations and the results of the standard schematisation for four different pesticides are also presented.

Chapters 3 and 4 present the uncertainty and stochastic sensitivity analysis. Chapter 3 describes the definition, identification and stochastic simulation of soil and pesticide properties. Statistical and technical procedures of the Monte Carlo uncertainty and sensitivity analysis are also presented. The results of the computations are described and interpreted in Chapter 4. Chapter 4 starts with a discussion of results at point locations. The output variable presented is the median average annual leaching concentration (see Section 1.2). Then, the results of the regulatory endpoint (the spatial 90th percentile of the leaching concentration in the entire agricultural area) are discussed.

In Chapter 5 the results obtained in the entire study are discussed and compared with results from other studies. Finally, in Chapter 6 recommendations are given for further research and on the improvement of the schematisation as well as the model.

2 Analysis of errors in leaching concentrations resulting from the use of the simplified soil physical-chemical map

2.1 Introduction

The most important output variable of GeoPEARL is the 90th percentile of the spatial cumulative frequency distribution of PEC50. To obtain an accurate estimate of this percentile, GeoPEARL is run for a large number of unique combinations of soil type, weather district and groundwater depth group (Tiktak et al., 2002; 2003). The current GeoPEARL version uses the so-called STONE schematisation, which was developed for national predictions of nutrient emissions to surface waters and groundwater (Kroon et al., 2001). In this schematisation, the unique combinations are aggregated to 6 405 larger spatial units, using relation diagrams (see also Tiktak et al., 2003). Within each unit, the dominant soil profile is assumed to be representative for the whole unit. The effect of this assumption on the nationwide spatial frequency distribution of predicted PEC50 is analysed by comparing the output of GeoPEARL obtained with the STONE-plot soil input with the output obtained with soil input that is derived from the soil physical-chemical map of De Vries (1999).

In Section 2.2 a description is given of the procedure to create the original map with STONE-plots containing information on geochemical, geophysical and hydrological properties, and the information that was added in order to complete the 'soil' information required by GeoPEARL. In Section 2.3, the procedure is described to derive a detailed soil physical-chemical map. The output was analysed in detail on the basis of:

- the regulatory endpoint for the GeoPEARL model, which is the 90th percentile of the spatial cumulative frequency distribution of the PEC50;
- spatial patterns of PEC50.

When creating a new map with model inputs, the lower boundary condition of SWAP will be affected. The consequence is that new calculations with NAGROM should preferably be carried out (De Lange, 1996). This step has not been carried out in this study – implying that the current study is limited to the effect of variation of soil input variables within STONE plots only.

2.2 Geochemical-geophysical-hydrological map used by STONE

In this section a description is given of the procedure followed to obtain the geochemical-geophysical-hydrological map as used by the model STONE. The final map is obtained by overlaying three elementary maps: 1) a geophysical-chemical map of the upper layer, referred to hereafter as the soil physical-chemical map (0-120 cm below surface), 2) a geochemical map of subsurface layers (1.20 - 13 m) and 3) a hydrological map (Kroon et al., 2001).

To create the soil physical-chemical map, first the units of the Soil Map of the Netherlands 1: 50 000 are grouped into 21 soil physical units, also referred to as PAWN-units (Figure 2.1, Wösten et al., 1988). With each PAWN-unit a representative soil profile is associated, that is described in terms of a vertical succession of building blocks of the Staring series, including the thickness of the building blocks. The Staring series building blocks are soil horizons, grouped on the basis of soil-physical properties. The 21 soil physical units (PAWN-units) have been subdivided by the Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA) on the basis of the geochemical properties phosphate sorption capacity, mineralisation capacity and cation exchange capacity (CEC). It should be noted that these parameters are not relevant for pesticide leaching.

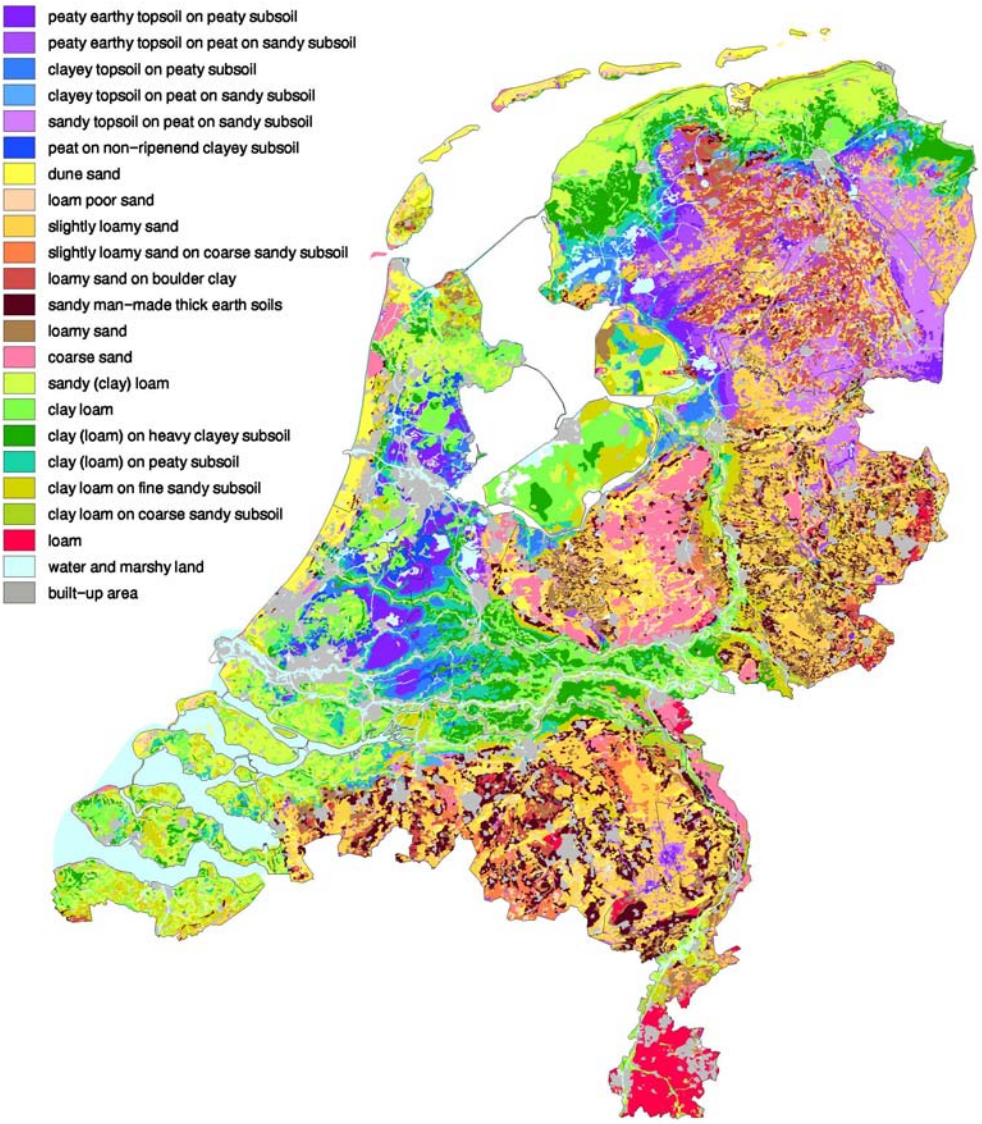

Figure 2.1 Map of the 21 soil physical units, also referred to as PAWN-units (Wösten, et al., 1988).

Finally, an overlay of the map of the resulting geophysical-chemical units and a land use map with units grassland, maize, other agricultural land use, and nature was made. This results, after aggregation[1], in a soil physical-chemical map consisting of 456 map units. For all 456 map units estimates of texture, organic matter content, bulk density, pH, C/N ratio and sesqui-oxide content were added for each layer (Kroon et al., 2001). For this, point-data in the Soil Information System of Alterra, and other information have been used.

The subsurface geochemical map is much less detailed, and consists of 30 map units only. The hydrological base-map consists of 900 map units. After overlaying the three elementary maps, the units of the resulting map were grouped into 6405 map units, referred to as STONE-plots, which in fact is a somewhat misleading term because a STONE-plot may consist of multiple map polygons. With this number of map units, the required computing time for one STONE run is one day on a single personal computer, which was considered acceptable.

The vertical resolution required by STONE is much larger than that of the representative soil profiles of the 21 PAWN-units (see Appendix 2). Therefore, for each STONE-plot the GeoPEARL layers are allocated on the basis of their depth to one of the Staring series building blocks. All layers within the same building block have the same properties.

2.3 Detailed soil physical-chemical map

In 1999 a new map of physical and chemical properties of the 0-120 cm soil layer became available (De Vries, 1999). This section describes this new soil physical-chemical map, and how this map was used to obtain the soil data required as input for GeoPEARL.

The new soil physical-chemical map is obtained by grouping units of the Soil Map of the Netherlands 1 : 50 000 smaller than 1000 ha with related units (De Vries, 1999). This results in a map of 330 units. Similar to the PAWN-units, each map unit is associated with a representative profile description, that is described in terms of a vertical succession of pedogenetic soil horizons. Note the difference with the representative soil profile descriptions of the PAWN-units, which are described in terms of a vertical succession of Staring series building blocks, i.e. soil physical layers. Each pedogenetic soil horizon is described by median values for thickness of soil horizon, organic mater content, clay fraction, loam fraction sand coarseness (M50), pH-KCl, $CaCO_3$, C/N-ratio and bulk density, as well as a measure of the spatial variation of these properties by means of the 10th- and 90th percentiles. These statistics are derived from point-data in the Soil Information System of Alterra, supplemented by information derived from the descriptions of the sheets of the Soil Map of the Netherlands 1 : 50 000.

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[1] Combinations of less than 10 grid cells of 250 m x 250 m have been aggregated.

For application of the new soil physical-chemical map in the model GeoPEARL an overlay of this soil physical-chemical map and the map with the 6 405 STONE-plots was made, resulting in 48 423 map units. Most of the STONE-plots contain more than one unit of the detailed soil physical-chemical map. Instead of 6 405, the new GeoPEARL soil file (schematisation.sol file) contains 48 423 different soil profiles. The required information on the basic soil properties such as soil texture, organic mater content and pH-KCl can be directly derived from the 330 representative soil profile descriptions. For this, the median values were used. To determine the Mualem-Van Genuchten parameters, a classification tree was constructed (See Appendix 1). Given soil texture, organic matter content and the geological formation the Staring series building block can be determined, as well as its associated Mualem-Van Genuchten parameters. It should be noted that in the STONE 2.0 schematisation 456 soil profiles have been defined. This greater number of soil profiles is due to the inclusion of additional soil characteristics, for example CEC and P-binding capacity. These properties are not relevant in the description of pesticide behaviour in soils.

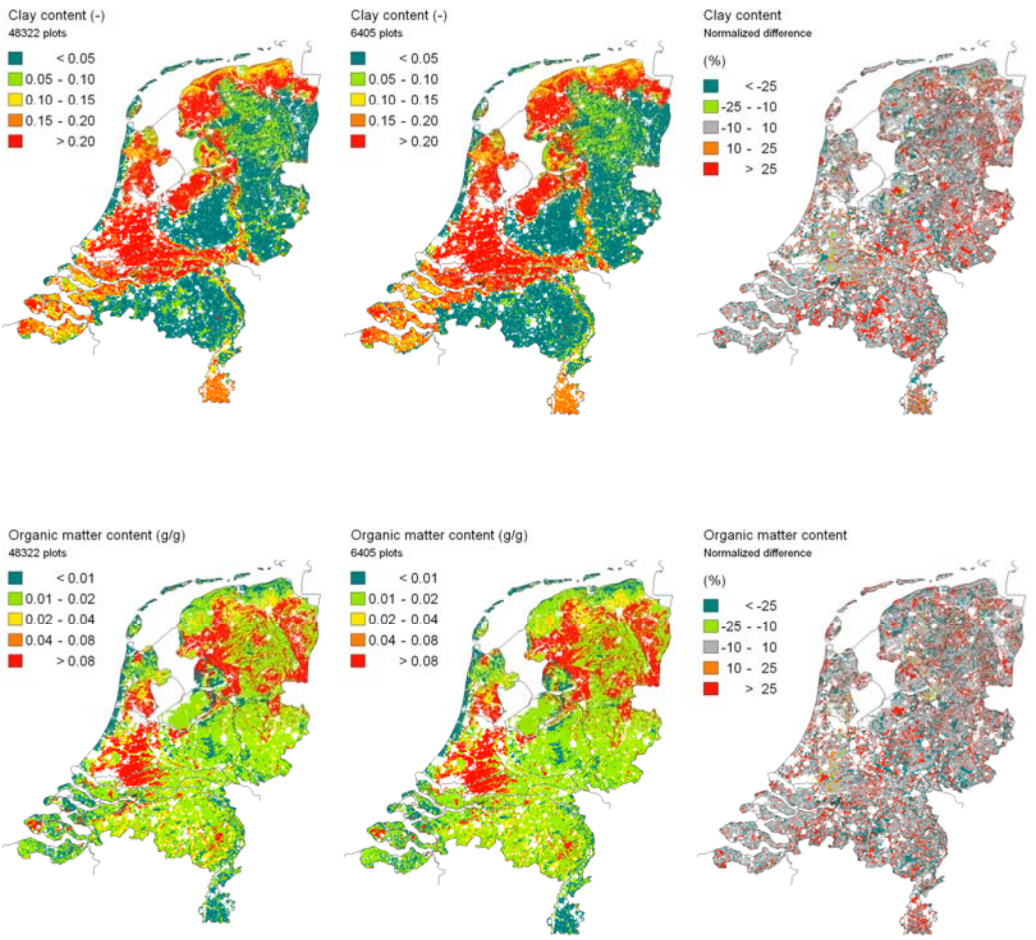

Figure 2.2. Clay content and organic matter content of layer 0 - 120 cm according to the map with STONE-plots (6405 units) and according to the new soil physical-chemical map (48 423 units).

Figure 2.2 shows maps of the clay content and organic matter content of the upper 120 cm of the soil profile as derived from the original map with STONE-plots and as derived from the new soil physical-chemical map. At first glance, both for clay content and organic matter content differences between the two maps are small. However, a closer look shows that there are considerable differences, up to 25% (right panel in Figure 2.2).

2.4 Procedure of model calculations

For the assessment of the effect of the detailed soil physical-chemical map on the predicted spatial 90 percentile leaching concentration, four pesticides were selected. The properties of these pesticides are given in Table 2.1. Pesticides NLA, NLB and NLD are described in FOCUS (2000). Pesticide NLE shows pH-dependent sorption behaviour, and is described in Tiktak et al. (2003). The pesticides were annually applied to the soil surface in spring (26 May). Assessments were made for both the detailed schematisation, and the original STONE schematisation.

A beta version of GeoPEARL_3.3.3 was used to calculate the spatial 90th percentile of the leaching concentrations for both schematisations. For the detailed soil schematisation, a schematisation.sol file was prepared, containing the description of the 330 soil profiles. In addition, a new .plo file was constructed containing the soil profile number for all plots in the detailed schematisation. As the leaching concentrations were calculated for the entire agricultural area, ploughing was not considered.

Table 2.1 Overview of the most important properties of the pesticides considered in this study.

Property[1]	NLA	NLB	NLD	NLE
M (g mol^{-1})	300	300	300	200
$P_{v,s}$ (Pa)	0	0.0001	0.0001	0
S_w (mg L^{-1})	90	90	90	50
$K_{om,ac,eq}$ (L kg^{-1})	60	10	35	500
$K_{om,ba,eq}$ (L kg^{-1})	60	10	35	25
$K_{om,ne}$ (L kg^{-1})	-	-	-	-
pKa	-	-	-	4.5
$DT_{50,ref}$ (d)	60 (20 °C)	20 (20 °C)	20 (15 °C)	50 (20 °C)
k_d (d^{-1})	0	0	0	0

1) M is the molar mass, $P_{v,s}$ is the saturated vapour pressure, S_w is the solubility in water, $K_{om,ac,eq}$ is the coefficient of equilibrium sorption on organic matter under acidic conditions, $K_{om,ba,eq}$ is the coefficient of equilibrium sorption on organic matter under basic conditions, $K_{om,ne}$ is the coefficient of sorption to the non-equilibrium domain, pKa is the negative logarithm of the dissociation constant, $DT_{50,ref}$ is the half-live under reference conditions, and k_d is the rate constant for non-equilibrium sorption.

For each pesticide, GeoPEARL was run for the entire agricultural area, so the median leaching concentration at 1 m depth was calculated for all 48324 plots. From these concentrations, GeoPEARL calculated the spatial 90 percentile of the leaching concentration at a depth of 1 m.

2.5 Results of GeoPEARL calculations

Comparison of results shows a minor effect of accounting for spatial variation of soil input variables within STONE plots on the nationwide cumulative frequency distribution of the predicted median annual leaching concentration for all pesticides (Figure 2.3).

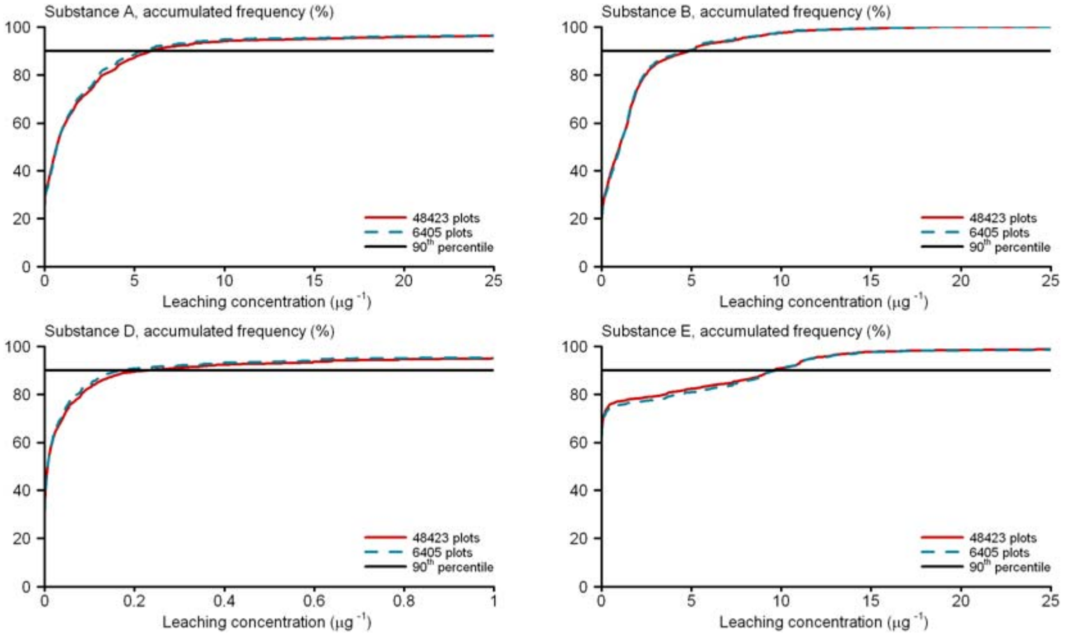

Figure 2.3. Spatial cumulative frequency distribution of the median annual leaching concentration of four pesticides (see table 3.1 for pesticide properties) calculated with the STONE schematisation (6405 plots) and the detailed soil physical-chemical map (48423 plots).

Also, the spatial 90th percentile leaching concentration was hardly affected by the spatial aggregation of soil type within larger spatial units.

Results for PEC50 were also compared on a pixel by pixel basis (grid cell size 250x250 m^2). These are shown in Figure 2.4. A first comparison of the spatial patterns does not show large differences. However, when evaluating the normalised differences between the two schematisations, meaningful differences are found (right panel of Figure 2.4). The normalised difference, *ND*, is calculated as follows:

$$ND = 100 \frac{c_{L,Det} - c_{L,Stone}}{c_{L,Det}} \tag{2.1}$$

In which:

$c_{L,Det}$ = PEC50 (μg/L) calculated using the detailed schematisation
$c_{L,Stone}$ = PEC50 (μg/L) calculated using the STONE schematisation

A frequency distribution of the normalised difference shows that 30-40% of the pixels show differences greater than 25% (Table 2.2).

Table 2.2 Frequency distribution of the normalised difference between the maps presented in Figure 2.2.

ND[1]	NLA	NLB	NLD	NLE
< -25 %	16	15	20	16
-25 - -10 %	2	3	0	1
-10 - +10 %	62	63	60	67
+10 - + 25 %	3	4	0	1
> + 25 %	17	15	20	15

1) calculated according to equation 2.1.

2.6 Conclusions

The current GeoPEARL schematisation appears to be sufficient for predicting pesticide leaching on the national scale. Local scale predictions are, however, meaningfully affected by spatial aggregation of soil input parameters. This conclusion is in line with earlier conclusions regarding the STONE hydrology (Van Bakel et al., 2002), who advised not to use the STONE schematisation for spatial scales smaller than 25 km^2.

Acknowledging that there is an increasing need for local-scale model predictions, based on national datasets, Alterra, Deltares and PBL have started the development of the Netherlands Hydrological Instrument (NHI). This new hydrological model will have a larger spatial resolution than the current STONE schematisation. The extended soil schematisation developed in this project can be used as input to the development of this new model.

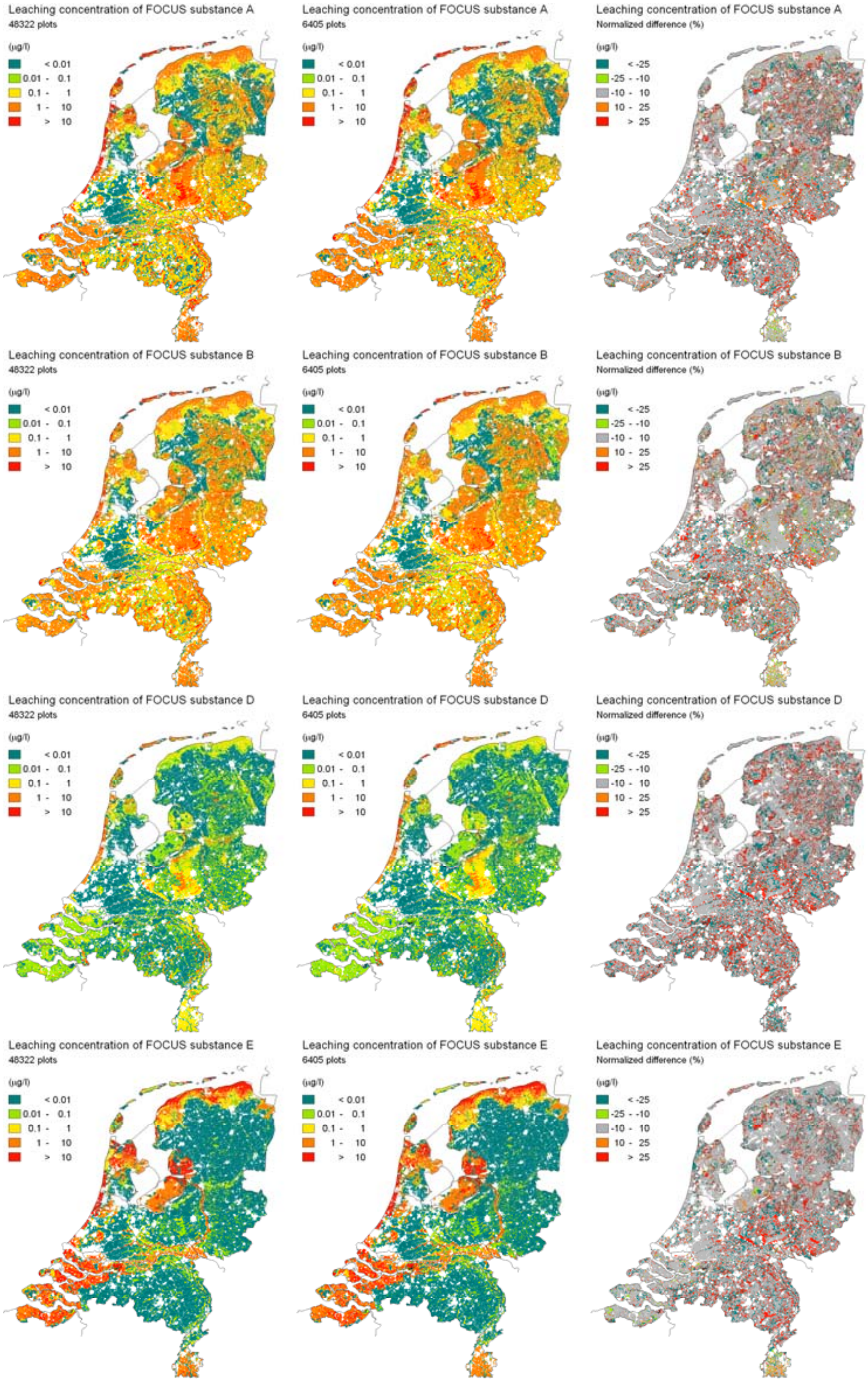

Figure 2.4. Predicted median value of the annual average leaching concentration of four example pesticides at 1-m depth. An annual pesticide dosage of 1 kg ha^{-1} was used. Left: detailed schematisation, middle: original STONE schematisation, right: normalised difference (%).

3 Uncertainty and sensitivity analysis of GeoPEARL

A complete analysis of the uncertainty in the leaching concentrations calculated with GeoPEARL would have to deal with uncertainties in all input data, i.e. soil, weather, drainage, bottom boundary conditions, land use and pesticide properties. This would be complex and very time consuming. In this study, the uncertainty analysis for GeoPEARL was therefore limited to soil properties and the two most important pesticide properties, i.e. the coefficient for sorption on organic matter and the half-life in soil (see Chapter 1 for justification). The set-up of this analysis results in the quantification of the uncertainty in the median annual average leaching concentration at point locations (PEC50) and the associated 90th percentile of the spatial frequency distribution for the entire agricultural area (SP90), as caused by uncertainty of pesticide properties and soil characteristics. Moreover, the contribution of individual uncertain inputs to the total uncertainty in PEC50 and SP90 (i.e. stochastic sensitivity analysis) is quantified.

Sensitivity analysis is the study of how variation in the output of a model can be apportioned to different sources of variation, and of how the given model depends upon the information fed into it. Uncertainty analysis quantifies the overall uncertainty associated with the response as a result of uncertainties in the model input (Saltelli et. al., 2000). These inputs may comprise model parameters, exogenous variables, initial conditions and so on. In this research a stochastic sensitivity analysis was performed, since the input variables taken into account are treated as stochastic variables due to their uncertainty. Instead of the effect of distinct individual inputs, it is possible to analyse the uncertainty contribution of distinct groups of inputs.

In the sensitivity and uncertainty analysis of GeoPEARL the following steps were specified:

1. Determine which input variables are taken into account in the analysis;
2. Assign probability distributions (or ranges of variation) to each input factor;
3. Generate an input matrix with simulated values of the uncertain inputs through an appropriate design;
4. Run the model for this input matrix and decide which of the model outputs are investigated;
5. Analyse the model output by looking at its distribution, confidence interval etc. (uncertainty analysis);
6. Assess the influence or relative importance of each uncertain input factor on the model outputs (sensitivity analysis).

The first two steps are described in Sections 3.1 and 3.2. It was decided to take eight soil properties and two pesticide properties into account. The probability distribution of these inputs are discussed and given in Sections 3.1 and 3.2.

The type of design chosen to generate the input matrix also influences the way in which the output can be analysed. The chosen design is described and discussed in Section 3.5.

The model outputs of interest are the PEC50 and the spatial P90 (SP90). The PEC50 is defined as the median over twenty years of the annual average of the Predicted Environmental Concentration in μg/L. In a normal GEOPEARL application, the PEC50 is calculated for 6 405 plots (see Section 2.1). Due to computational constraints, the PEC50 is calculated for 258 locations forming a square grid. The 90-percentile of the spatial distribution of the PEC50 over the agricultural area within the Netherlands is referred to as the SP90. It is estimated by the 90-percentile of the PEC50 at the 258 nodes of the square grid.

The preparation of the input data for GeoPEARL, the checks on the input data and the set-up of the execution of the runs are described in Sections 3.6 and 3.7

The aim of uncertainty analysis is to quantify the overall uncertainty of the model output as a result of the uncertainties in the model input (step 5 above). Quantiles such as the median, 5% and 95% percentiles, and the interquartile range (width of the 25-75% interval) are useful measures to quantify the uncertainty of the model output. These and graphical illustrations, such as box plots and histograms, of the model output and the results of the analysis are given and discussed in Chapter 4.

3.1 Identification and stochastic simulation of uncertain soil properties

The uncertainty and sensitivity analysis applied in this research makes use of the Monte Carlo method. This means that a large number of draws from the probability distributions of the uncertain inputs to the GeoPEARL model are made for a finite number of locations (in this case the nodes of a square grid) within the Netherlands. At these locations, the model is run for all draws, thus allowing an analysis of how uncertainties in the inputs propagate to the GeoPEARL output. The uncertainty analysis itself is explained above, but at this stage it is important to note that in order to do the analysis, it is necessary to generate draws or realisations from the probability distributions of the uncertain inputs. This chapter explains how this was done for the uncertain soil and pesticide properties.

The following basic soil properties and inputs to GeoPEARL are considered uncertain in this work:

1. clay content (kg kg^{-1})
2. silt content (kg kg^{-1})
3. sand content (kg kg^{-1})
4. organic matter content (kg kg^{-1})
5. median particle size of sand fraction (M50) (μm)

These basic properties were chosen because GeoPEARL is considered sensitive to these properties and because at the national scale, where these properties must be derived from the 1 : 50 000 Dutch soil map, uncertainties can be substantial. Note that the properties vary with depth as well as with geographic location. The variation in depth is modelled by assuming constant values within the soil horizons of the soil profile at any location. Soil profile descriptions of the Dutch 1 : 50 000 soil map typically contain between three and seven soil horizons. Thus, for each sampling location realisations of the uncertain basic soil properties are generated for all horizons. In addition to the basic soil properties, the thickness of the soil horizons is considered uncertain as well:

6. soil horizon thickness (m)

GeoPEARL also requires soil hydraulic properties. These properties often show strong spatial variation within mapping units of the 1 : 50 000 soil map and are therefore also included in the uncertainty analysis:

7. water retention characteristic $\theta(h)$ (cm^3 cm^{-3})
8. hydraulic conductivity $K(h)$ (cm d^{-1})

These eight soil properties and characteristics are the only uncertain soil properties and characteristics taken into account in this study. Clay content, silt content, M50 and organic matter content determine the water retention characteristic and hydraulic conductivity (through so-called physical building blocks of the Staring series, see section 3.1.1). Organic matter content is used in GeoPEARL to calculate the Freundlich coefficient (for adsorption). Clay content, sand content and organic matter content are needed for calculation of the heat transfer in soil.

Three steps are needed to make draws from the probability distributions of the uncertain soil properties. First, a statistical model that characterises the uncertainty by means of probability distribution functions (pdfs) must be defined (section 3.1.1). Next, the parameters of these pdfs must be quantified for the locations and horizons used in the uncertainty analysis (section 3.1.2). Third, simulated values must be generated for all locations and horizons by drawing realisations from the pdfs (section 3.1.3).

3.1.1 Probability distributions for uncertain soil properties

In the previous section eight uncertain soil properties were identified. Uncertainty about a soil property means that its true value is unknown for any given location and horizon. Although the true value may be unknown, in many cases there will be some idea about the distribution of values that it is likely to take. For example, it may be known with sufficient confidence that the chances are equal that the soil property is greater or smaller than a given 'representative' value (i.e., it is centred around a known mean value), or it may be known that in only five out of one hundred cases the absolute difference between the true and representative value is greater than a given number (i.e., a confidence interval). Such knowledge may be based on validation data, expert judgement or, under certain assumptions, be derived from the spatial variability of the soil property and the method that was used to create the soil map. In this work, uncertainty quantification in basic soil properties is based on findings from a previous project (De Vries, 1999), whereas uncertainty in soil hydraulic properties are based on the variability in curves fitted to soil samples from the Staring series database. This will be discussed in more detail in section 3.1.2.

Uncertainty as described above can be conveniently described with probability theory. For a numerical soil property at a single location and horizon, the unknown (because of uncertainty) value is represented by a random variable. A random variable has no fixed value but has many (often infinite) possible values, each with a certain probability of occurrence (i.e., probability distribution). Let the soil property be denoted by Z then its cumulative pdf F at some location s and horizon h is defined as:

$$F(z) = P[Z(\mathbf{s},h) \leq z] \tag{3.1}$$

where P represents probability. Important parameters of $Z(\mathbf{s},h)$ are its mean $\mu(\mathbf{s},h)$, which represents the expected or average value of $Z(\mathbf{s},h)$, and its standard deviation $\sigma(\mathbf{s},h)$, which characterises the variation or spread of $Z(\mathbf{s},h)$ around its mean value. Clearly, the standard deviation $\sigma(\mathbf{s},h)$ is a measure for the uncertainty in the soil property. To fully characterise $Z(\mathbf{s},h)$ it is further necessary to define the shape of F. Common shapes are the normal, lognormal, exponential and uniform distribution.

Uncertain soil properties are spatially distributed and vary with depth as well. The (marginal) pdf defined in Eq. (3.1.) must therefore be specified for each location and horizon. Neither the mean $\mu(\mathbf{s},h)$ nor the standard deviation $\sigma(\mathbf{s},h)$ need be constant in space and depth but will typically vary with **s** and h. In addition, spatially distributed uncertain soil properties will usually be spatially dependent, both laterally as well as vertically. For example, when at some location the clay content is greater than expected, then it is likely that the clay content at neighbouring locations is also greater than expected. Similarly, if soil organic matter at a horizon happens to be smaller than the representative value, then there is an increased chance that soil organic matter at horizons above and/or below it are also smaller than their representative value.

In this study, the locations for which calculations are done lie on a coarse square grid with a grid mesh of 9.5 km (see Section 3.3). This results in a total of locations almost equal to the number considered to be adequate for his analysis, i.e. 250. The distances between locations are sufficiently large that spatial correlation in soil properties may safely be ignored. In addition, it was also decided to ignore correlation between soil properties from different horizons at the same location. This greatly facilitates the subsequent analysis, although a critical analysis of the validity of this decision and its consequences for the results of the uncertainty analysis would be sensible.

Soil properties can also be cross-correlated. For instance, clay, silt and sand are negatively correlated because their sum must always equal 100 per cent. Part of the correlation between soil properties is explained by the fact that soil properties and their associated probability distributions depend on soil type, but the deviations from the map unit representative values may also be cross-correlated. For example, if at some location soil organic matter is greater than what would normally be expected for the soil type at the location, then perhaps clay content at the location should be smaller than usual. However, these within-unit cross-correlations were judged small and have therefore been ignored, except for soil texture. For soil texture, sand content was simply defined as 100 – clay – silt, thus creating negative correlations between sand and clay and between sand and silt. Cross-correlation between clay and silt is discussed below.

The remaining part of this section presents the approach used to derive the probability distribution function Eq. (3.1) for the basic and physical soil properties.

The Dutch 1 : 50 000 soil map predicts the soil type at each location in the Netherlands. Since the soil map is assumed error-free, it follows that the soil type at the location is perfectly known. The legend to the soil map presents a representative soil profile which specifies the basic soil properties for all horizons distinguished. In this way the mean or representative values of all basic soil properties for any location and depth in the Netherlands are derived.

In a previous study, de Vries (1999) determined for all soil types the spatial variation of basic soil properties per horizon. These properties were clay, loam, organic matter, median particle size (M50) and horizon thickness. Spatial variation was reported by quantifying for each combination of soil type and horizon the absolute minimum and maximum value for the soil property, the lower and upper limits of 'frequently observed values', and the 'modal or representative value'. The lower and upper limits of the 'frequently observed values' are assumed to refer to the 10 and 90 percentiles (q_{10} and q_{90}) of the distribution, thus implying that in 80 per cent of the cases the true value is in the range of the 'frequently observed values'. In addition, the 'modal or representative value' is interpreted as the median value (q_{50}) of the distribution.

The uncertainty about the soil properties is caused by the spatial variation of these properties within soil mapping units. Lack of knowledge about where the highs and lows within mapping units occur means that the mean or representative value is used as the best guess for all locations in the mapping unit, implying that the error or deviation from that value is dictated by the degree of spatial variation. Thus, the probability distribution associated with the soil property at an arbitrary location within the mapping unit is equal to the spatial distribution of the soil property within the unit. All that is available about the spatial distribution are the minimum, the q_{10}, the q_{50}, the q_{90} and the maximum. In order to derive the probability distribution, a parametric form must therefore be assumed and the pdf parameters derived from the available information.

In this work, all uncertain basic soil properties and the soil horizon thickness are described with a (truncated) lognormal distribution, because most of the uncertain variables are positively skewed and are not properly represented by a symmetric probability distribution. The parameters of the probability distribution were chosen such that the median of the soil property equalled the 'modal value' q_{50} and that the probability of a value greater than q_{10} or smaller than q_{90} equalled 0.80. This was done as follows. Let Y be the log-transformed soil property. Since Y is normally distributed it is fully characterised by its mean μ_Y and standard deviation σ_Y. To ensure that the median of the uncertain soil property equals q_{50} the mean of Y is taken as:

$$\mu_Y = \log(q_{50}) \tag{3.2}$$

Next σ_Y must be chosen such that P[organic matter content < q_{10} or organic matter content > q_{90}] = 0.20. In other words:

$$\begin{aligned}
&\mathrm{P}(\text{soil property} < q_{10} \text{ or soil property} > q_{90}) = \\
&= \mathrm{P}(\text{soil property} < q_{10}) + \mathrm{P}(\text{soil property} > q_{90}) = \\
&= \mathrm{P}(Y < \log(q_{10})) + \mathrm{P}(Y > \log(q_{90})) = \\
&= \mathrm{P}\left(\frac{Y-\mu_Y}{\sigma_Y} < \frac{\log(q_{10})-\mu_Y}{\sigma_Y}\right) + \mathrm{P}\left(\frac{Y-\mu_Y}{\sigma_Y} > \frac{\log(q_{90})-\mu_Y}{\sigma_Y}\right) = \\
&= \mathrm{F}\left(\frac{\log(q_{10})-\log(q_{50})}{\sigma_Y}\right) + 1 - \mathrm{F}\left(\frac{\log(q_{90})-\log(q_{50})}{\sigma_Y}\right) = 0.20
\end{aligned}$$

where F is the cumulative standard-normal distribution. Thus, using the bisection method (Kreyszig, 2006), σ_Y was chosen such that:

$$\mathrm{F}\left(\frac{\log(q_{90})-\log(q_{50})}{\sigma_Y}\right) - \mathrm{F}\left(\frac{\log(q_{10})-\log(q_{50})}{\sigma_Y}\right) = 0.80 \tag{3.3}$$

Note that this ensures that the probability of values falling in the $q_{10} - q_{90}$ range of 'frequently observed values' equals 0.80, but does not guarantee that the probability of values smaller than q_{10} (or greater than q_{90}) equals 0.10. It is only the summed probability that must be equal to 0.20. To also impose these individual constraints would require a pdf structure with an extra parameter (three instead of two). Obvious candidates for that are not available.

Figures 3.1 to 3.3 present frequency distributions of the organic matter content in the top layer of six example locations. These are also the locations for which in section 4.1.2 a location-specific uncertainty analysis will be performed. It is clear that the frequency distributions are not symmetric and positively skewed (except for location 208). Therefore it makes sense to represent organic matter content with a lognormal distribution.

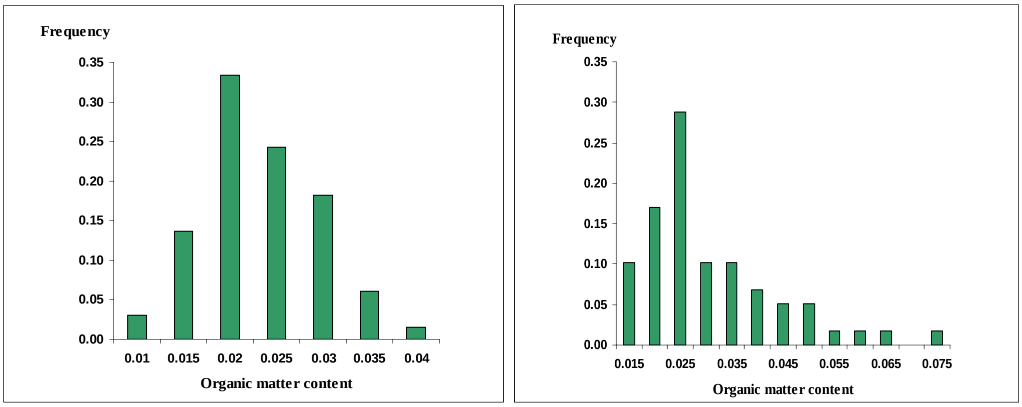

Figure 3.1 Frequency distribution of organic matter content in the top horizon for location 12 (left) and location 103 (right).

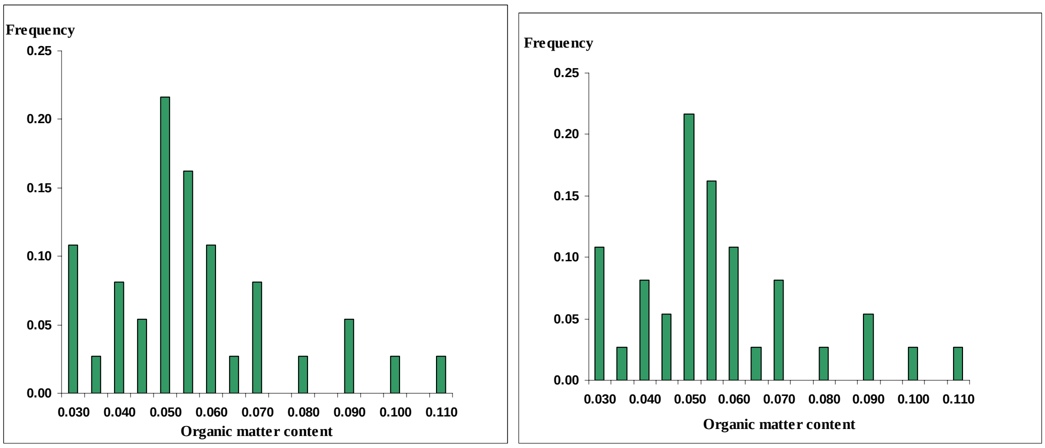

Figure 3.2 Frequency distribution of organic matter content in the top horizon for location 53 (left) and location 174 (right).

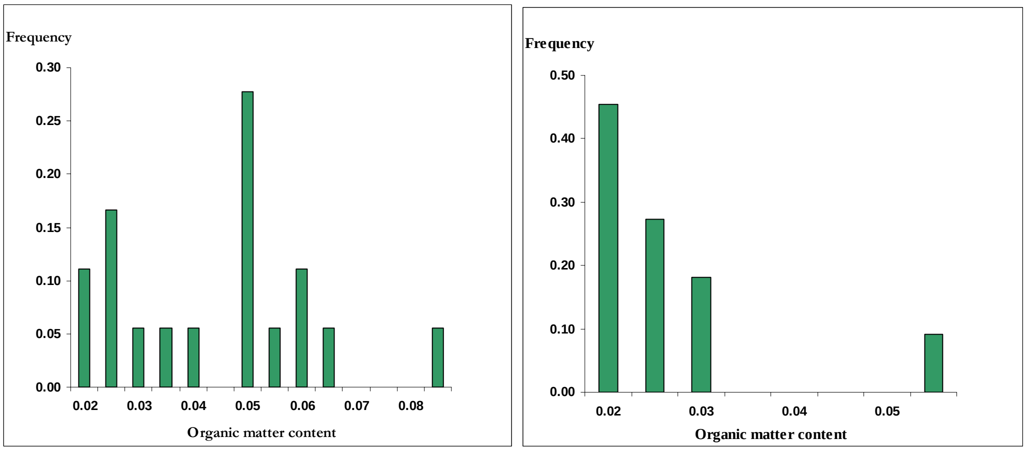

Figure 3.3 Spatial frequency distribution of organic matter content in the top horizon for location 208 (left) and location 257 (right).

The resulting lognormal distribution was truncated at the specified minimum and maximum, meaning that values smaller than the minimum and greater than the maximum were assigned a zero probability density. In practice, the truncation is achieved by discarding simulated values that are smaller than the minimum or greater than the maximum (see Section 3.1.3). The truncation effectively assigns larger probability density values to all remaining values. This is because the sum of the probabilities over all possible values must equal one by definition. As a result of this, the 10- and 90-quantiles of the truncated distribution with parameters obtained with Equations (3.2) and (3.3) are no longer entirely correct. This is because part of the tails of the distribution is removed and the associated probability mass is spread over all remaining values, including values in between q_{10} and q_{90}, meaning that less than 20 per cent of the distribution will have a value smaller than q_{10} or greater than q_{90}. Although in principle it is possible to correct for this bias by iterative search of adjusted parameters μ_Y and σ_Y, this would involve tedious computations and might in addition lead to an unwanted shift of the median. It was therefore decided to refrain from the correction. Note also that the lognormal distribution has zero as its minimum value, implying that imposing a minimum of zero has no truncation effect.

Since soil horizon thickness is uncertain, the sum of the soil horizon thicknesses is uncertain as well and need not to be equal to the standard fixed profile depth of 1.20 m. This problem was solved by assuming that the thickness of the bottom horizon equals 1.20 m minus the cumulative thickness of all horizons above. In the exceptional case where this would yield a negative thickness for the bottom horizon, it was assigned a zero value and the horizon just above it was corrected to match the 1.20 m depth criterion.

As mentioned above, sand, clay and silt will be negatively correlated because they must always sum to 100 per cent. To this end, sand was computed by subtracting the simulated values for silt and clay from the total value of 100 per cent. This did not lead to negative values for sand. Another problem was that the study of de Vries (1999) presents statistics of clay and loam, whereas in this study simulations for clay, silt and sand are required. Loam is the sum of clay and silt. Silt can therefore be computed by subtracting clay from loam, but to simulate clay and loam their correlation must be known. Here it was assumed that loam and clay are uncorrelated within the same mapping unit. This does not appear to be very realistic and may be relaxed in future work. Once the assumption is made, loam and clay can be independently simulated and silt can be computed by subtracting the simulated clay from the simulated loam. Negative values for silt were avoided by discarding cases where the simulated loam was smaller than the simulated clay.

Soil physical properties refer to parameters that characterise the water retention and hydraulic conductivity characteristics of the soil. These characteristics are essential input in models that calculate storage and transport of water in the unsaturated zone of the soil and thus influence pesticide leaching. In the Netherlands, these characteristics are stored in the Staring series.

The Staring series is a database containing measured data of the water retention ($\theta(h)$) and hydraulic conductivity ($K(h)$) characteristics of soils. The series present measured data of 36 different building blocks (18 for top- and subsoil, respectively). The Staring series was initially published in 1987 (Wösten et al., 1987) and updated in

1994 (Wösten et al., 1994) and 2001 (Wösten et al., 1994). The number of samples in the database increased from 237 in 1987, 620 in 1994 to 832 in 2001. For each sample, the hydraulic characteristics of the soil are represented by Mualem-van Genuchten equations (Van Genuchten et al., 1991):

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1 + |\alpha h|^n)^{1-1/n}} \tag{3.4}$$

$$K(h) = K_s \frac{((1 + |\alpha h|^n)^{1-1/n} - |\alpha h|^{n-1})^2}{(1 + |\alpha h|^n)^{(1-1/n)(l+2)}} \tag{3.5}$$

Where:
K(h) is hydraulic conductivity (cm d^{-1}), *h* is soil water pressure head (cm), θ is volumetric water content (cm^3 cm^{-3}), θ_s is the saturated water content (cm^3 cm^{-3}), θ_r is the residual water content in the very dry range (cm^3 cm^{-3}) and α (cm^{-1}), *n* and *l* (-) are shape parameters.

The parameters in Eqs. (3.4) and (3.5) are obtained by numerical optimisation (Stolte et al., 2007). Curves are fitted through measurements of $\theta(h)$ and $K(h)$ and parameters are chosen such that the curve best matches the measurements. The fit procedure was done using the RETC program code (Van Genuchten et al., 1991). The RETC code is capable of simultaneously fitting both the unsaturated hydraulic conductivity curve and the water retention curve on one specific dataset. With this, the interaction between these characteristics is taken into account. As a result the measured hydraulic characteristics became available via optimised model parameters (i.e. θ_r, θ_s, K_{sat}, α, l and n).

Curves were fitted for each of the 832 samples in the database. Each of the 36 building blocks has multiple associated curves. Some have over 100 curves, others fewer than 10. The curves per building block were treated as a random sample from all curves that populate the building block. Thus, the differences between curves of a building block represent the uncertainty about them. However, this was not the only source of uncertainty in soil physical parameters, because the building blocks themselves were uncertain as well. As was pointed out in Chapter 2, the building block at any location and horizon is determined by entering a scheme that uniquely derives the building block from parent material, texture, organic matter and M50. Some of these inputs are uncertain and consequently so is the building block.

The probability distribution of soil physical parameters is therefore partly derived from the probability distribution of the building blocks, which in turn depends on those of the basic soil properties, and partly from the random sample of curves corresponding with each building block. It is not easy to derive the exact pdfs for each of the soil physical parameters because of the complicated way in which it is defined, but in fact there is no need to know it explicitly. All that is needed is a way to sample from the pdfs. This is much easier, because all that needs to be done is enter the scheme with the simulated basic soil properties, derive the building block, and next randomly select a curve from the set of curves associated with it. This is explained in more detail in section 3.1.2. Note that because fitted curves are sampled rather than individual soil physical parameters, it is ensured that unrealistic combinations of soil physical parameters do not occur.

3.1.2 Parameter values for probability distributions of uncertain soil properties

As explained in Section 3.1.1, parameters of the truncated lognormal distributions of the basic soil properties were derived from the 10, 50 and 90 quantiles using Eqns. (3.2) and (3.3). Truncation was done by rejecting values greater than the maximum or smaller than the minimum. Quantiles and minima and maxima were derived from profile observations taken from each of the 330 soil types distinguished in the Dutch 1 : 50 000 soil map (de Vries, 1999). As an illustration, Table 3.1 presents the quantiles, minimum and maximum of thickness, clay content and organic matter for the horizons of the six example locations. The soil type and geographic location are also given. Recall that these are also the locations for which in chapter 4.1.2 a location-specific uncertainty analysis will be performed.

Table 3.1 confirms that the median is often smaller than the mid-point between the 10- and 90-quantiles, indicating positively skewed distributions. As expected, organic matter content generally decreases with depth. Note also that the spread is fairly small for the horizon thicknesses and relatively large for organic matter. In many cases the minimum is close to or even equal to the 10-quantile. Similarly, in many cases the maximum is equal or only marginally larger than the 90-quantile. Thus, truncation will definitely occur. Comparison of locations shows that locations 53, 174 and 208 have small clay contents, whereas location 104 has the largest clay content. Annex 3 provides fitted parameters for the organic matter distributions for all locations and layers. The annex confirms that truncation is substantial for some cases, because the fitted 90-quantile is larger than the maximum or the 10-quantile is smaller than the minimum.

Table 3.2 characterises all 36 building blocks and presents the number of soil samples per building block for which Mualem-VanGenuchten curves were fitted. Note that the number of samples strongly varies between building blocks. Many blocks have in between 10 and 30 samples, but some have many more and some have only a few. Note also that Table 3.2 presents two numbers per building block. The first number (before screening) refers to the number of samples for which curves were fitted. These curves were critically examined and some did not pass the test described below. The second number (after screening) refers to the number of samples that passed the test.

Table 3.1. Parameters of probability distributions of soil thickness, clay content and organic matter for six selected locations.

Location, geographical coordinates and soil type	horizon	Thickness (m)					Clay (%)					Organic matter (%)				
		min	q_{10}	q_{50}	q_{90}	max	min	q_{10}	q_{50}	q_{90}	max	min	q_{10}	q_{50}	q_{90}	max
012	1	0.18	0.20	0.25	0.30	0.32	17	18	22	25	26	0.9	1.0	2.0	4.0	4.2
X: 166 625	2	0.15	0.20	0.25	0.30	0.35	17	18	22	25	26	0.4	0.5	1.2	2.0	2.1
Y: 586 625	3	0.60	0.65	0.70	0.75	0.80	7	8	14	18	19	0.1	0.2	0.6	2.0	2.1
Mn25A																
053	1	0.18	0.20	0.25	0.30	0.32	1	2	3	4	5	1.5	2.0	5.4	7.0	7.5
X: 271 125	2	0.05	0.10	0.15	0.20	0.25	1	2	3	4	5	0.5	0.8	2.2	5.0	5.5
Y: 558 125	3	0.10	0.15	0.20	0.25	0.30	1	2	3	4	5	0.2	0.4	1.0	2.0	2.5
Hn21	4	0.50	0.55	0.60	0.65	0.70	1	2	3	4	5	0.1	0.2	0.3	1.0	1.5
103	1	0.18	0.20	0.25	0.30	0.32	24	25	30	35	37	0.9	1.0	2.5	4.0	4.2
X: 166 625	2	0.05	0.10	0.15	0.20	0.25	24	25	30	35	37	0.4	0.5	1.2	3.0	3.2
Y: 501 125	3	0.30	0.35	0.40	0.45	0.50	11	12	28	40	42	0.4	0.5	0.8	3.0	3.2
Mn35A	4	0.30	0.35	0.40	0.45	0.50	7	8	15	40	42	0.4	0.5	0.7	3.0	3.2
174	1	0.18	0.20	0.25	0.30	0.32	1	2	3	4	5	1.5	2.0	5.4	7.0	7.5
X: 233 125	2	0.05	0.10	0.15	0.20	0.25	1	2	3	4	5	0.5	0.8	2.2	5.0	5.5
Y: 444 125	3	0.10	0.15	0.20	0.25	0.30	1	2	3	4	5	0.2	0.4	1.0	2.0	2.5
Hn21	4	0.50	0.55	0.60	0.65	0.70	1	2	3	4	5	0.1	0.2	0.3	1.0	1.5
208	1	0.18	0.20	0.25	0.30	0.32	17	18	30	35	37	1.9	2.0	5.0	8.0	8.4
X: 195 125	2	0.20	0.25	0.30	0.35	0.40	17	18	34	40	42	0.4	0.5	1.1	3.0	3.2
Y: 406 125	3	0.55	0.60	0.65	0.70	0.75	24	25	43	60	63	0.4	0.5	0.6	3.0	3.2
Rn94C																
257	1	0.18	0.20	0.25	0.30	0.32	8	10	13	20	23	0.5	1.0	2.4	4.0	4.5
X: 185 625	2	0.05	0.10	0.15	0.20	0.25	8	10	13	20	23	0.2	0.5	0.8	2.0	2.5
Y: 311 125	3	0.10	0.15	0.20	0.25	0.30	10	13	15	20	23	0.1	0.2	0.5	1.0	1.4
BLd6	4	0.20	0.25	0.30	0.35	0.40	12	15	20	25	27	0.1	0.2	0.3	1.0	1.4
	5	0.20	0.25	0.30	0.35	0.40	12	13	15	23	27	0.1	0.2	0.3	1.0	1.4

Table 3.2. Description of 36 building blocks and number of samples per building block analysed on soil hydraulic properties, before and after screening.

Code	top- or subsoil	Description	Nr samples before screening	Nr samples retained after screening
B01	top	Loam-poor fine sand	32	32
B02	top	Slightly loamy fine sand	27	27
B03	top	Very loamy fine sand	14	14
B04	top	Extremely loamy fine sand	9	9
B05	top	Coarse sand	26	26
B06	top	Glacial till	8	7
B07	top	Sandy loam	6	6
B08	top	Slightly sandy loam	43	34
B09	top	Sandy clay loam	29	28
B10	top	Clay loam	12	7
B11	top	Heavy clay	13	2
B12	top	Very heavy clay	9	2
B13	top	Loam	10	10
B14	top	Silty loam	67	55
B15	top	Peaty sand	15	15
B16	top	Sandy peat and peat	20	18
B17	top	Peaty clay	25	17
B18	top	Clayey peat	20	13
O01	sub	Loam-poor fine sand	109	109
O02	sub	Slightly loamy fine sand	14	14
O03	sub	Very loamy fine sand	23	23
O04	sub	Extremely loamy fine sand	9	9
O05	sub	Coarse sand	17	17
O06	sub	Glacial till	15	13
O07	sub	Alluvial loam	15	12
O08	sub	Sandy loam	14	14
O09	sub	Slightly sandy loam	30	28
O10	sub	Sandy clay loam	25	19
O11	sub	Clay loam	11	7
O12	sub	Heavy clay	25	14
O13	sub	Very heavy clay	19	3
O14	sub	Loam	9	9
O15	sub	Silty loam	53	48
O16	sub	Oligotrophic peat	16	15
O17	sub	Eutrophic peat	36	36
O18	sub	Weathered peat	7	5
Total			832	717

Recent analyses with SWAP (version 2.0.9) have shown that problems arise with some combinations of Mualem-van Genuchten parameters. Vanderborght et al. (2005) show that numerical problems occur when hydrology in soil profiles with soil and clay horizons are simulated with curves that have a very small value for the parameter n. In such cases SWAP (version 2.0.9) runs very slowly, may produce erroneous results or may even crash. Small values of the l and K_s parameters also give rise to problems. After careful screening it was therefore decided to remove all curves for which the parameter n was smaller than 1.1 (73 cases), or where the parameter l was smaller than -5.0 (40 cases) or where K_s was smaller than 0.01 (2 cases). In this way, extreme curves that did not fit in the corresponding building block were eliminated and the total number of 832 samples was reduced to 717. Two examples of Mualem-van Genuchten curves that did not pass the screening tests are given in Figure 3.4.

The heterogeneity of the soil physical characteristics within a building block is also shown in Figure 3.4, where the distribution of Mualem-VanGenuchten curves of all individual samples of the B18 and O07 building blocks are presented. Other building blocks have similar results. It is clear from the large differences between the curves that soil hydraulic properties can markedly differ within building blocks.

It is not only the variability within building blocks that determines the uncertainty about soil hydraulic properties. There is also uncertainty about which building block corresponds with each location and horizon. The building block is determined by entering the decision tree presented in Chapter 2 (see also Appendix 1). The way through the decision tree is partly determined by the basic soil properties of the location and horizon. Since these are uncertain, so is the building block. Table 3.3 gives the probability associated with the three most likely building blocks for all horizons of the six example locations. Note that the probability of the most likely building block varies between 0.31 and 1.00. Thus, uncertainty about basic soil properties causes a substantial uncertainty about what the building block at a location and horizon could be. However, alternative building blocks are typically 'nearby' building blocks that have similar behaviour, implying that the effect on soil physical properties may still be small. Note also that for all locations except location 257, uncertainty increases with increasing depth.

Table 3.3. Three most probable building blocks with associated probability for all horizons of the six selected locations.

location	horizon	First building block		Second building block		Third building block	
		Code	*probability*	*code*	*probability*	*code*	*probability*
12	1	B09	0.92	B10	0.05	B08	0.03
	2	O10	0.88	O11	0.08	O09	0.04
	3	O09	0.61	O08	0.31	O10	0.06
53	1	B02	0.85	B01	0.15		
	2	O02	0.54	O01	0.46		
	3	O02	0.57	O01	0.43		
	4	O01	0.59	O02	0.38	O03	0.02
103	1	B10	0.91	B11	0.05	B09	0.04
	2	O11	0.87	O12	0.08	O10	0.05
	3	O11	0.37	O10	0.30	O12	0.17
	4	O09	0.31	O10	0.25	O08	0.24
174	1	B02	0.82	B01	0.18		
	2	O02	0.52	O01	0.48		
	3	O02	0.57	O01	0.43		
	4	O01	0.58	O02	0.40		
208	1	B10	0.74	B09	0.17	B11	0.09
	2	O11	0.55	O12	0.39	O10	0.07
	3	O12	0.47	O11	0.29	O13	0.23
257	1	B14	0.94	B13	0.06		
	2	O15	0.94	O14	0.06		
	3	O15	1.00				
	4	O15	1.00				
	5	O15	0.95	O14	0.05		

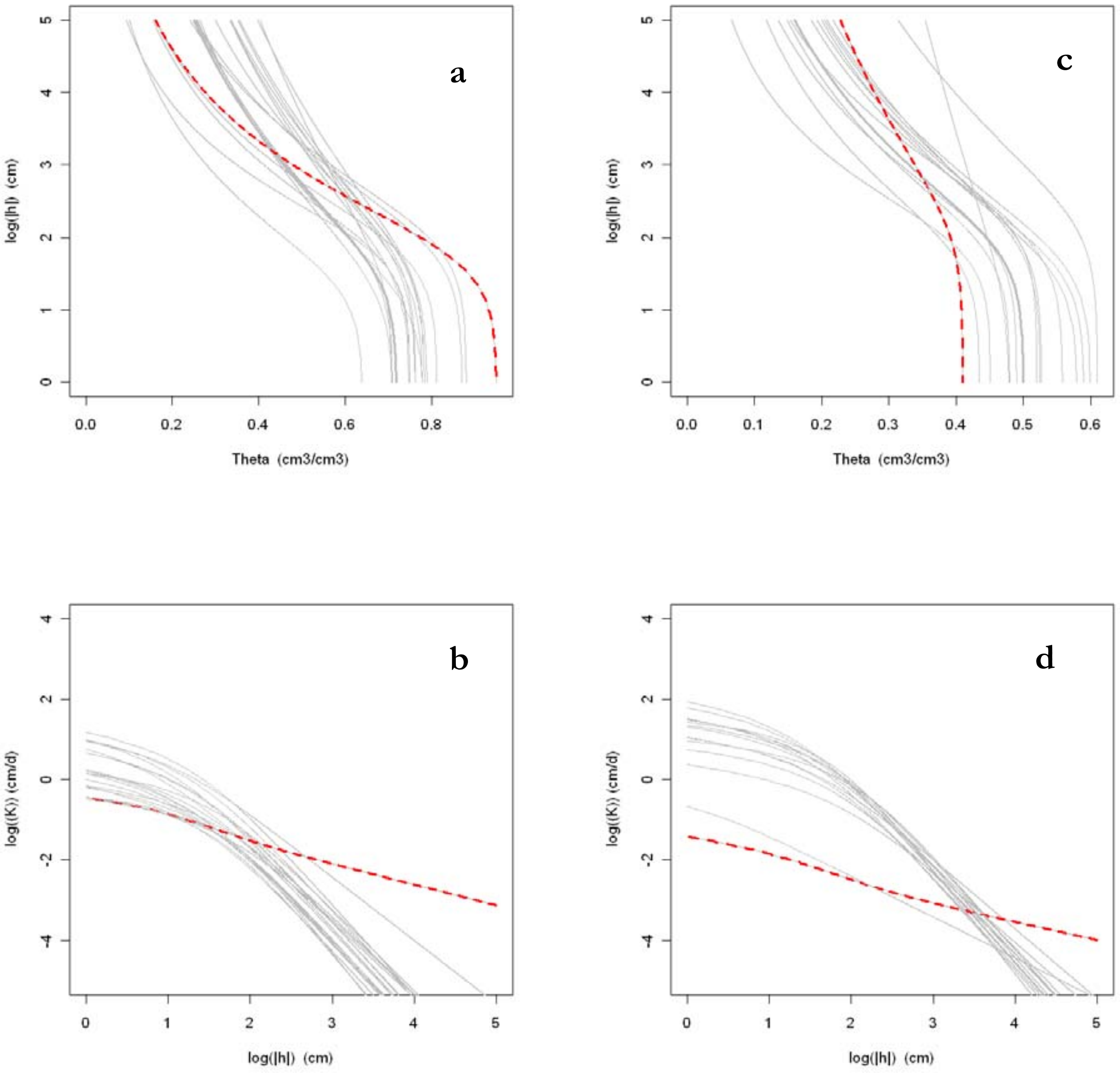

Figure 3.4. Curves h(θ), and K(h) for two example building blocks B18 (left, a and b) and O07 (right, c and d). Solid grey lines are all curves that passed the screening, dashed red lines are example curves that did not pass the test.

3.1.3 Stochastic simulation of uncertain soil properties

The previous sections have explained how uncertainty in soil properties can be represented by probability distributions and how the parameters of these distributions were derived. This section discusses how samples can be generated from these distributions. Random samples are needed for the Monte Carlo uncertainty analysis discussed in the next chapter.

Random sampling from pdfs is also referred to as stochastic simulation and can be done with computers by using so-called pseudo-random number generators. Using appropriate algorithms, the computer mimics a chance experiment such as the throwing of a die or the tossing of a coin. In this work the *normrnd* and *randperm* functions of the Matlab programming environment were used. These functions allow sampling from the normal and discrete uniform distributions. The first was needed for the basic soil properties, the second for randomly selecting a Mualem-Van Genuchten curve from the set belonging to a building block. The basic soil properties were simulated by taking the antilog of normally distributed simulations, thus yielding simulations from the lognormal distribution. Truncation was achieved simply by discarding simulated values that were greater than the maximum or smaller than the minimum. Stochastic simulation with computers is fast. Thousands of simulations and many more can be generated in a few seconds. This is important because Monte Carlo uncertainty analyses require many simulations to get stable results. The results presented in this work are based on over 12 million simulated random numbers.

In summary, the following steps were used to simulate the basic and hydraulic soil properties at a location where the uncertainty propagation analysis with GeoPEARL was run.

1. determine the dominant soil map unit at the location;
2. determine the number of soil horizons in the representative soil profile description for the soil map unit;
3. take the first soil horizon (from the top);
4. draw a value from the (truncated lognormal) probability distribution associated with the soil horizon thickness;
5. repeat steps 3 and 4 for the basic soil properties loam content, clay content, organic matter content and M50;
6. calculate silt by subtracting clay from loam and compute sand by subtracting loam from 100 per cent;
7. redo sampling for realisations that have unacceptable values (i.e., values that are smaller than the minimum or greater than the maximum);
8. determine the soil building block on the basis of the simulated basic soil properties, the position of the soil horizon (top or bottom) and the dominant soil map unit at the location;
9. draw one sample from the group of soil samples of this building block, and determine the Mualem-VanGenuchten parameters of this sample;
10. repeat steps 4 to 9 as many times as required by the Monte Carlo uncertainty analysis (in our case 1000 times, see Section 3.5);
11. repeat steps 4 to 10 for all remaining soil horizons.

As an example, Figure 3.5 shows the histograms of 1000 simulated values for horizon thickness, clay content and organic matter for the first horizon of location 12 and second horizon of location 208. Note that the simulated values are all within the minima and maxima as given in Table 3.2. Note also that the truncation effect is clearly visible for the clay content, where the histograms do not tail off but are cut off abruptly. Simulated organic matter contents are positively skewed (in agreement with the observations, see Figures 3.1 to 3.3), whereas the clay contents are slightly negatively skewed.

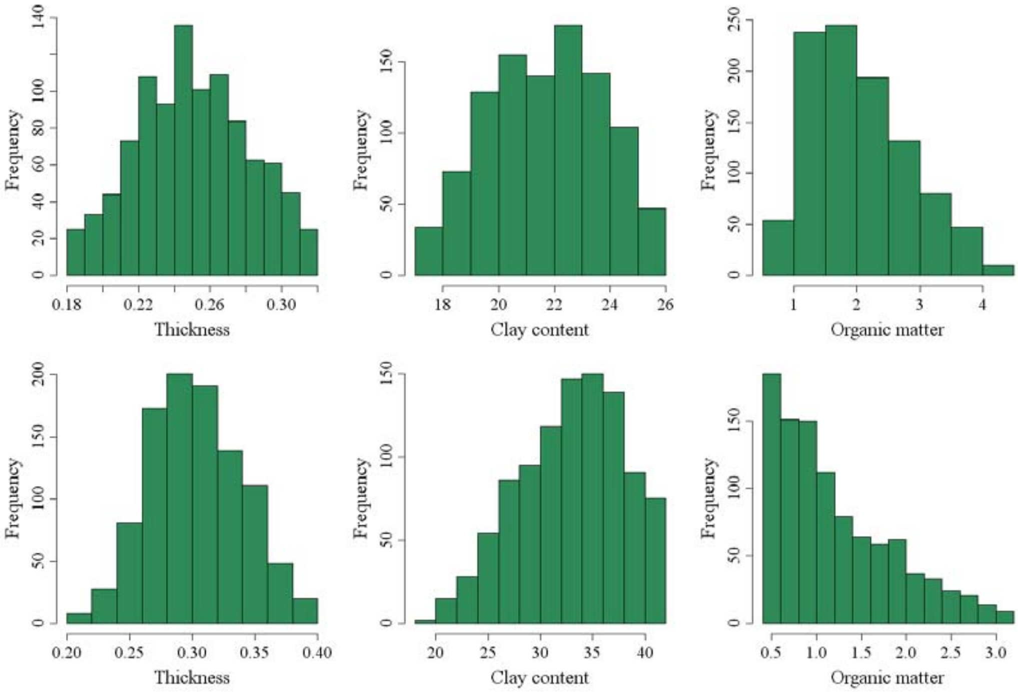

Figure 3.5 Histograms of 1000 simulated realisations of thickness (left), clay content (centre) and organic matter content (right) of the first horizon of location 12 (top) and the second horizon of location 208 (bottom).

3.2 Identification and stochastic simulation of uncertain pesticide properties

In this study, two pesticide properties are considered uncertain, the half-life of the pesticide under reference conditions (days) and the sorption coefficient of the pesticide (L kg^{-1}). Both properties are pesticide-dependent and may also vary with location. In principle they may even vary with depth, but this will not be considered here, except the effect of depth in soil on the rate coefficient of transformation that GeoPEARL takes into account. The uncertainty propagation from pesticide properties will be evaluated for three representative pesticides.

The half-life of a pesticide in soil differs between soil types. Allen and Walker (1987) and Walker and Thompson (1977) studied the effect of soil properties on the rate of degradation of various pesticide in 18 soils, with a clay percentage greater than 15%. The pesticides studied were metamitron, metazachlor, simazine, linuron and propyzamide. The average coefficient of variation was measured for simazin and the highest was measured for metazachlor. Figure 3.6 shows that the coefficient of variation was on average about 25%.

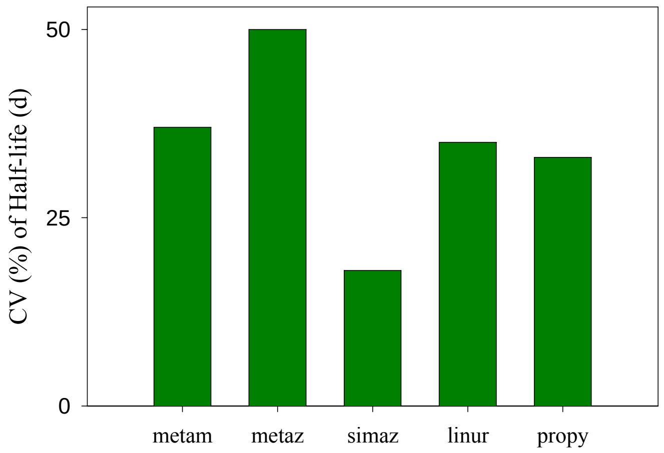

Figure 3.6: The coefficient of variation (CV) for the half-life for 5 pesticides, averaged over 18 UK soils (metamitron, metazachlor, simazine, linuron and propyzamide) as derived from Allen and Walker (1987) and Walker and Thompson (1977).

Allen and Walker (1987) and Walker and Thompson (1977) also studied the effect of soil properties on the sorption coefficient on organic matter. The lowest coefficient of variation was measured for linuron, whereas the highest was measured for metamitron (see Figure 3.7). On average the coefficient of variation was about 25%.

As little is known on the relationship between half-life and sorption coefficient on the one hand and soil properties on the other, the coefficient of variation was assumed to be 25% for both pesticide properties.

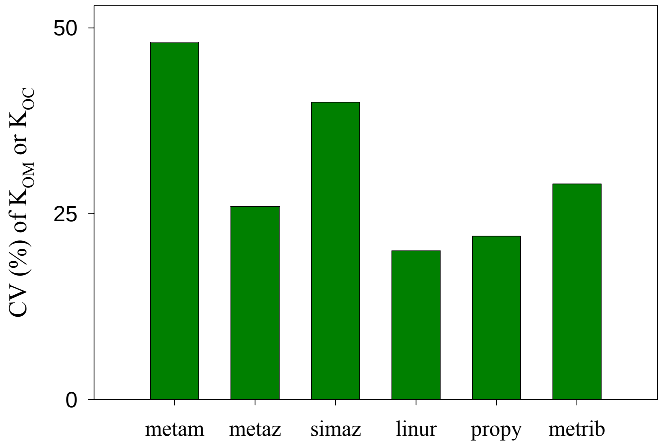

Figure 3.7: The coefficient of variation (CV) for the sorption coefficient for 6 pesticides in 18 UK soils (metamitron, metazachlor, simazine, linuron, propyzamide and metribuzin) as derived from Allen and Walker (1987) and Walker and Thompson (1977).

In the present study, three example pesticides were taken from FOCUS (2000), i.e. pesticides A, B and D. These example pesticides cover a range of values for DT_{50} and K_{om}. DT_{50} and K_{om} were drawn for each location (grid node) separately, by sampling from a single (not location-specific) lognormal distribution. The choice for a lognormal distribution was justified by analysis of data present in the Dutch pesticide registration dossier. This implies that it is assumed that DT_{50} and K_{om} are independent of soil type and soil properties. Moreover it is also assumed that DT_{50} and K_{om} at different locations are independent. The mean values and the standard deviation for the properties of the example pesticides are listed in Table 3.4.

Table 3.4: Mean values and standard deviation (sd) for the properties of the selected pesticides.

Pesticide	Property			
	Kom (L kg^{-1})		DT_{50} (d)	
	Mean	sd	Mean	Sd
A	60	15	60	15
B	20	2.5	20	5
D	35	8.75	20	5

The procedure used to draw from the probability distributions of the pesticide properties is the same as that reported in Section 3.1 for the uncertain soil properties.

3.3 Required data on soil properties and locations

Using all 6 405 STONE-plots to assess the effect of uncertain soil properties would not be feasible, as the required computing time would be very high. Therefore, a smaller sample of locations was selected by placing a north-south east-west oriented square grid with a grid distance of 9 500 m randomly over the Netherlands. This led to a sample of 258 locations (Figure 3.8). In Section 3.6, checks are reported to justify that this number of locations is large enough to provide a sufficiently accurate estimate of the entire population (i.e. all agricultural land in the Netherlands).

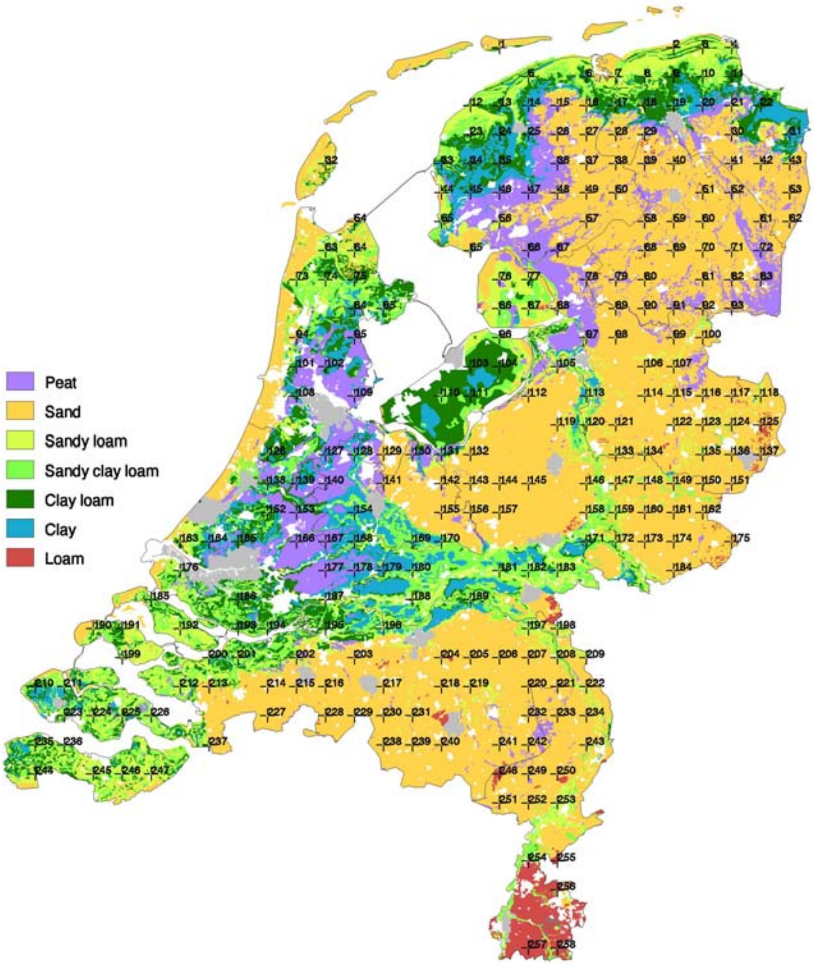

Figure 3.8. Randomly placed square grid sample used in the uncertainty analysis

Six specified point-locations were selected for a more detailed sensitivity and uncertainty analysis. These six point-locations were chosen so that the ensemble of the six locations represents most of the arable land-use in the Netherlands, but the choice is rather arbitrary. Locations 012 and 103 represent fertile arable soils in the Northern part of the Netherlands and the polder area, respectively. Potatoes, sugar beets and wheat are the major crops grown here. Note that organic matter content is low in these soils. Location 053 is in an area of reclaimed peat soils. Due to intensive arable land-use over the past three centuries, organic matter content has decreased considerably. Location 174 and 208 are both in the sandy part of the Netherlands. Main land-use is maize and grassland. The final location, location 257 is in the loess region. The wind-deposited loamy soils are fertile, but have extremely low organic matter contents, making them vulnerable to pesticide leaching. The area, soil type and some soil characteristics of each location are given in Table 3.5. For more information, see Tables 3.1 and 3.3 (Section 3.1.2).

Table 3.5: Location number, region and soil type and some soil characteristics at the six locations

Location number	Region within the Netherlands	Soil type	OM Layer 1 (kg/kg)	OM Layer 2 (kg/kg)	Clay Layer 1 (kg/kg)	Clay Layer 2 (kg/kg)	Sand Layer 1 (kg/kg)	Sand Layer 2 (kg/kg)
012	Friesland	Silty loam	0.021	0.012	0.22	0.22	0.36	0.36
053	Veenkoloniën	Sand	0.051	0.022	0.03	0.03	0.88	0.89
103	Flevopolder	Clay	0.024	0.013	0.30	0.30	0.27	0.27
174	Achterhoek	Sand	0.052	0.023	0.03	0.03	0.88	0.90
208	Oost Brabant	Sand	0.048	0.013	0.29	0.33	0.27	0.15
257	Zuid Limburg	Loam	0.023	0.009	0.13	0.13	0.08	0.08

3.4 Sensitivity analysis

Sensitivity analysis is the study of how variation in the output of a model can be apportioned to different sources of variation in the input and this variance can be seen as the specification of the uncertainty. The variance of the model output y (=f(x)) is induced by the distribution D of model inputs x = (x_1 …x_k) and will be called VTOT. It is of interest to know how much the output variance would decrease if specific information about the input would become available, in addition to the information contained in input distribution D. Let S denote a subset of the x's, for instance a group of parameters corresponding to a particular sub-model. The uncertainty contribution of S can then be expressed in two ways. Firstly, the top marginal variance, TMV_S, is the variance reduction that would occur in case one would get perfect new information about the inputs S. Secondly, the bottom marginal variance, BMV_S, is the variance that will remain as long as one gets no new information about S. Stated differently, TMV_S is the variance accounted for by S, whereas BMV_S is the variance not accounted for by inputs other than those in S (Jansen, 1994). Usually, TMV and BMV are expressed as a fraction or percentage of VTOT. The concepts of top and bottom marginal variances have been introduced in uncertainty and sensitivity analysis by various authors, under various names. The relative top marginal variance (TMV_S/VTOT) for an independent group S of inputs (S can also consist of a single input) is also called the correlation ratio or the first order sensitivity index. The top marginal variance for (groups of) soil and pesticide properties are calculated (see also Section 3.2) and presented in Chapter 4.

In a regression-based sensitivity analysis the relationship between the model output (y) and the model inputs x_1…x_k is approximated by a regression relation. By means of regression, the contributions to the variance of the model output from individual or pooled model inputs is calculated. In a linear analysis the relationship between the model output (y) in model inputs is based on a linear function. The top marginal variance of a model input is calculated as the percentage of variance accounted for when that input is the only one fitted. The calculation is successful if the percentage of variance accounted for by all inputs considered is close to 100. If model output (y) cannot be approximated by a linear function of the x's, it can be useful to try a more general additive function, i.e. splines. Analogous to linear analysis, spline sensitivity analysis is based on comparison of the variances accounted for by different least squares approximation of model output f(x).

In the sensitivity analysis of the PEC50 of a specified location, it is possible to use a regression-based approach. For this location, the probability distributions of the eight soil parameters are known for all soil horizons, and in the simulation a number of draws are taken from these distributions. The results, for instance for the clay content in the first soil horizon, are model outputs (PEC50) for a range of clay contents in the first soil horizon. The relationship between the clay content in the first soil horizon and the PEC50 can be investigated by a linear or spline regression, resulting in the top marginal variance for clay content in the first soil horizon. The same holds for the other soil and pesticide properties. In case of an ordinary random sample, bootstrap methods can be used to constitute a (1-2α) bootstrap confidence interval (Efron and Tibshirani, 1993) for the top marginal variance.

The sensitivity analysis of SP90 is much more complex. The SP90 is computed from the PEC50 for all 258 nodes of the square grid. This implies that the SP90 is not only determined by the random draws of the probability distributions at a given location, but by the probability distributions at all 258 nodes of the square grid. So, for the SP90 it is impossible to analyse the sensitivity by a regression-based method. The alternative is a regression-free approach.

In a regression-free sensitivity analysis the inputs are first divided into independent groups (Jansen et al., 2005). For two independent groups, S and T the model output can be written as $y=f(S,T)$. The bottom marginal variance and the top marginal variance of S and T can be estimated from a sample of the following structure :

$$\begin{array}{lll}
f(S_{11},T_{11}) & f(S_{21},T_{11}) & f(S_{11},T_{21}) \\
f(S_{12},T_{12}) & f(S_{22},T_{12}) & f(S_{12},T_{22}) \\
f(S_{13}, T_{13}) & f(S_{23}, T_{13}) & f(S_{13},T_{23}) \\
\ldots\ldots & \quad\ldots\ldots & \quad\ldots\ldots \\
f(S_{1N},T_{1N}) & f(S_{2N},T_{1N}) & f(S_{1N,}T_{2N})
\end{array}$$

So, the sample consists of 3N draws (and model runs). Denote the three columns above by y_1, y_2 and y_3. The input parameters S_{ij} and T_{ij} are independent realisations of S and T but T_{ij} is the same in de first two columns resulting in y_1 and y_2. The top marginal variance (TMV) of T and the bottom marginal variance (BMV) of S may be estimated by :

$$\mathrm{T\hat{M}V}(T) = \mathrm{Cov}(y_1, y_2) \tag{3.6}$$

$$\mathrm{B\hat{M}V}(S) = \tfrac{1}{2}\mathrm{Var}(y_1 - y_2) \tag{3.7}$$

The two are complementary and add up to the total variance. The calculation of the top marginal variance of S is based on the runs where S_{ij} remained the same, i.e. modeloutput y_1 and y_3 :

$$\mathrm{T\hat{M}V}(S) = \mathrm{Cov}(y_1, y_3) \tag{3.8}$$

$$\mathrm{B\hat{M}V}(T) = \tfrac{1}{2}\mathrm{Var}(y_1 - y_3) \tag{3.9}$$

These two are also complementary and add up to the total variance. The top marginal variance can also be expressed as a percentage of the total variance.

In a regression-free sensitivity analysis only the model outputs are needed to calculate the top marginal variance, and the model inputs (random draws of probability distributions) are not needed. In Section 3.5 the groups of input variables, and the design of the input-matrix, necessary for the regression-free sensitivity analysis, are described.

The main disadvantage of a regression-free sensitivity analysis is that only part of the runs are taken into account by calculating the top marginal variance of an input parameter (or group of input parameters). This does not seem very efficient, since the information of all other runs is not used. This will also mean that to obtain a comparable accuracy as in a regression-based method more runs are needed. On the other hand, no relation between the input parameters and model output is needed. So for the SP90, this is a good option to perform a sensitivity analysis.

3.5 Design of the input-matrix in a regression-free sensitivity analysis

In a regression-free approach it is necessary to define independent input groups, where a group can also be one variable. In this study, four groups of independent input-variables were defined:

1. organic matter content
2. texture and VanGenuchten-parameters (clay, silt and sand content, median particle size of sand fraction, soil horizon thickness, water retention characteristic and hydraulic conductivity)
3. half-life of the pesticide (DT_{50})
4. sorption coefficient of the pesticide (K_{om})

Unfortunately, a large number of soil properties ended up in one group. This is due to the fact that these properties could not be assumed to be (and drawn) independently (see Section 3.1.1). The organic matter content was assumed independent from the other groups, although this is not formally correct.

Restricted by computing time limitations, the total number of Monte Carlo runs at each location was set at 1000. Since there are four groups, the set-up of the input-matrix consisted of five groups of 200 draws. The first group of 200 input values are random draws from all defined distributions. The second group of 200 input values have the same organic matter content (om) as input as the first group of 200 values but are different for all other variables (i.e. texture and Van Genuchten (TVG), DT_{50} and K_{om}). The third group of 200 input values have the same texture and VanGenuchten parameter values as the first group of 200 values but are different for all other variables. The fourth group of 200 input values have the same DT_{50} values as the first group of 200 values and the fifth group of 200 input values have the same K_{om} value as the first group of 200 values. This set-up was realized by taking 1000 random draws for all the input parameters and overwriting the second group of 200 values for organic matter with the first 200 values, and so on.

In matrix notation, the design of the input-matrix can be given as :

$$\begin{pmatrix} om_1 & TVG_1 & DT50_1 & Kom_1 \\ om_2 & TVG_2 & DT50_2 & Kom_2 \\ ... & ... & ... & ... \\ om_{200} & TVG_{200} & DT50_{200} & Kom_{200} \\ om_1 & TVG_{201} & DT50_{201} & Kom_{201} \\ om_2 & TVG_{202} & DT50_{202} & Kom_{202} \\ ... & ... & ... & ... \\ om_{200} & TVG_{400} & DT50_{400} & Kom_{400} \\ om_{401} & TVG_1 & DT50_{401} & Kom_{401} \\ om_{402} & TVG_2 & DT50_{402} & Kom_{402} \\ ... & ... & ... & ... \\ om_{600} & TVG_{200} & DT50_{600} & Kom_{600} \\ om_{601} & TVG_{601} & DT50_1 & Kom_{601} \\ om_{602} & TVG_{602} & DT50_2 & Kom_{602} \\ ... & ... & ... & ... \\ om_{800} & TVG_{800} & DT50_{200} & Kom_{800} \\ om_{801} & TVG_{801} & DT50_{801} & Kom_1 \\ om_{802} & TVG_{802} & DT50_{802} & Kom_2 \\ ... & ... & ... & ... \\ om_{1000} & TVG_{1000} & DT50_{1000} & Kom_{200} \end{pmatrix}$$

It should be noted that om, DT_{50} and K_{om} are single values, whereas the matrix element TVG represents the sampling of the texture and VanGenuchten parameters for all horizons.

Comparing the output from the first 200 runs with the second 200 runs gives an impression of the effect of uncertainty in organic matter on output uncertainty. If organic matter is very important then this results in a strong correlation between the two outputs. The top marginal variance in this regression-free approach is calculated as the covariance between these two parts of outputs in relation to the total variance of the output (Section 3.4). Comparing the first 200 runs with the third 200 runs gives an impression of the effect of uncertainty in texture and VanGenuchten-parameters on the model output uncertainty and by comparing the first 200 runs with the fourth and fifth 200 runs the effect of DT_{50} and K_{om} can be established. The top marginal variance (in relation to the total variance) is calculated for each group and presented in Chapter 4.

3.6 Checks on GeoPEARL input

To verify that the 258 grid locations are a satisfactory approximation of the entire agricultural area in the Netherlands, first a table was prepared containing all soil profiles occurring within each STONE plot (total of 6 405 plots) as well as the relative area for their occurrence within this plot. Next, for each of the 258 locations, the STONE plot was identified in which this location fell. Then the dominant soil profile for these STONE plots was looked up in the table mentioned above. These profiles were used to derive probability distributions (see Section 3.1.1) and a cumulative frequency distribution for the simulated median organic matter content in the top 1.20 m was constructed. This distribution was compared with the cumulative frequency distribution of the organic matter content in the STONE plots associated with the 258 selected locations. The results of the comparison are presented in Figure 3.9. The two cumulative frequency distributions correspond very well. In addition, the cumulative frequency distribution of the organic matter content in all 6 405 STONE plots was made. This distribution also coincided with the distributions shown in Figure 3.9.

For five random chosen locations the distribution of the simulated values for texture were compared with the given distribution in Table 3.1. Also the distribution of DT_{50} and K_{om} for the three pesticides were checked for these locations. No big differences were found. For a few of the random draws of these locations, it was established that the VanGenuchten-parameters were sampled from the right building block, given the values of texture.

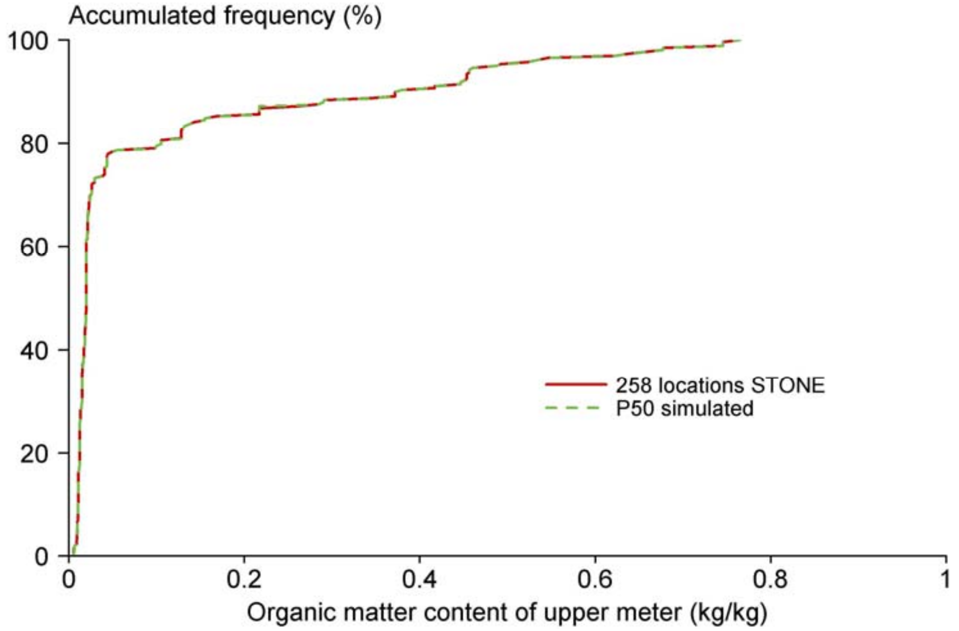

Figure 3.9. Frequency distribution of the organic matter content in the top 1 m of the dominant soil profiles of the STONE plots associated with the locations (solid line) and for the frequency distribution of the median organic matter content in the simulated probability distributions of the 258 locations (dotted line).

3.7 GeoPEARL simulations

Monte Carlo runs were carried out for three pesticides at 258 locations as given in Figure 3.8, using a research version of GeoPEARL_3.3.3. Adaptation of GeoPEARL was necessary, because in the standard GeoPEARL version, only one value of the pesticide properties is used for all plots. In this study, however, the values of the half-life and the coefficient of sorption on organic matter are different for all Monte Carlo runs. To run GeoPEARL efficiently, the schematisation.plo file was extended to contain six extra columns listing the values of DT_{50} and K_{om} of the three pesticides for each Monte Carlo run. For each location, the set of input files was prepared using an awk script. Checks were done to verify that all input files were prepared correctly.

The runs for each location were submitted to a computer grid consisting of approximately 250 CPU's. As the input data for a Monte Carlo run contained the pesticide data for all three pesticides, the hydrological model SWAP had only to be run once. Normally, SWAP has to be run for each pesticide separately, so the procedure developed for the Monte Carlo analysis made the execution of the runs much faster.

The 90th percentile of the leaching concentrations were calculated for the entire agricultural area. The result of the Monte Carlo simulations is a matrix of 258 columns by 1000 rows with the PEC50 (X) for each combination of location and run as element :

Run number	Location					
	1	2	3	4	258	SP90 (spatial)
1	(X	X	X	X	X)	*
2	(X	X	X	X	X)	*
3	(				)	
.	(				)	
.	(				)	
	(				)	
.	(				)	
1000	(X	X	X	X	X)	*
median-PEC50	Z	Z	Z	Z	Z	
25%-quantile	Z	Z	Z	Z	Z	
75%-quantile	Z	Z	Z	Z	Z	
Deterministic run	D	D	D	D	D	SP90

For each location, the median PEC50 over the 1000 runs and the 25%-percentile and 75%-percentile can be determined (Z). For each location also the PEC50 of the deterministic run is known (D). In Section 4.1 the deterministic run is compared to this median PEC50 to check whether these are comparable (as would be expected). Six columns (i.e. locations) of this matrix are investigated further by conducting uncertainty and sensitivity analyses for these locations separately. In Section 4.2, the 90th percentile of the leaching concentration over all locations (the spatial P90 or SP90), is computed and analysed. These P90s are also compared to the SP90 of the deterministic run.

4 Results of the uncertainty and sensitivity analysis of GeoPEARL

4.1 PEC50 at point locations

In Section 4.1.1, the median of the 1000 Monte Carlo simulations of the PEC50 for pesticide D at the 258 locations are presented. In Section 4.1.2, the results of the uncertainty analysis for the six selected locations are presented, and the results of the sensitivity analysis for these locations are presented in Sections 4.1.3 and 4.1.4. In Section 4.1.3 the sensitivity of the PEC50 is quantified using a regression-free approach, whereas in Section 4.1.4 the sensitivity obtained with the spline regression is quantified.

4.1.1 PEC50 at all locations

The median value of the PEC50 of pesticide D at each of the 258 locations is shown in Figure 4.1 The left panel of the figure shows results of the Monte Carlo runs only. In the right panel the results at the grid nodes are plotted as obtained with a 'deterministic' GeoPEARL run, using the 6 405 STONE plots. In this figure, locations will only be visible if the Monte Carlo simulation differs from the deterministic run. This is the case in a limited number of locations only. It can therefore be concluded that the spatial pattern of PEC50 obtained with Monte Carlo simulations is similar to the spatial pattern obtained with a deterministic run of GeoPEARL.

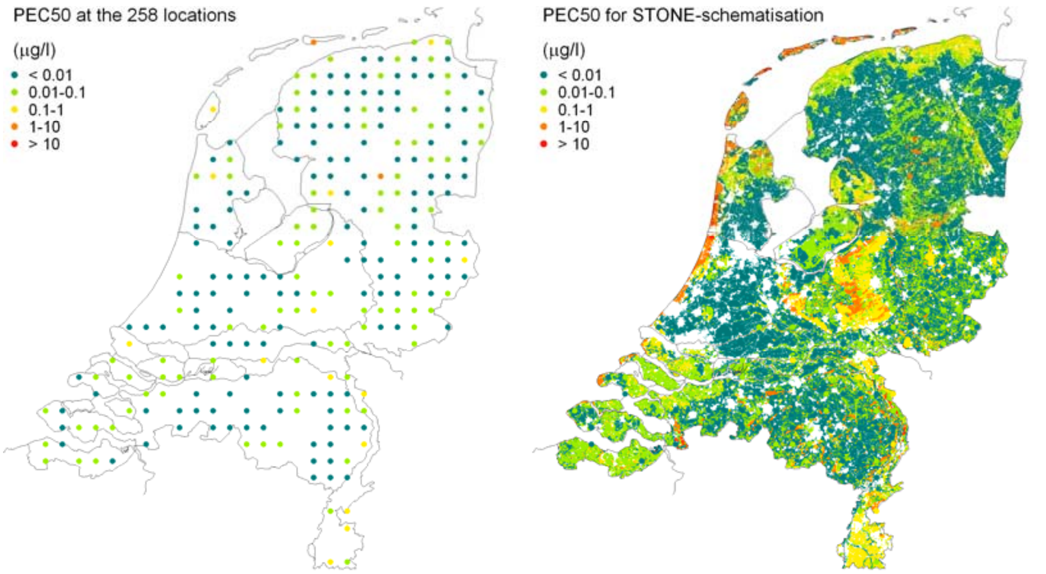

Figure 4.1 Median value of 1000 Monte Carlo predictions of PEC50 for pesticide D at 258 locations (left). In the right hand panel the results at the grid nodes are plotted on the map obtained with a deterministic GeoPEARL run.

The spatial pattern in Figure 4.1 corresponds to a large extent to the spatial pattern in the organic matter content map of the Netherlands (Figure 2.2), which is in agreement with earlier findings (e.g. Tiktak et al., 1996, 2002; Leterme et al., 2007). So, both in the deterministic and in the Monte Carlo simulations, leaching is highest in soils with small organic matter contents and lowest in soils with large organic matter contents (particularly peat soils).

Figure 4.2 shows the spatial cumulative frequency distributions of the PEC50 for pesticide D obtained with the deterministic run and with the Monte Carlo simulations. The figure shows that the cumulative frequency distribution of the median values of the Monte Carlo simulations nicely matches the frequency distribution of the deterministic run. Apparently, the 258 locations are a good representation of the leaching concentration in the Netherlands. The figure also shows the interquartile range, i.e. the area bounded by the 25th and the 75th percentile of the Monte Carlo run for the point-locations. The uncertainty at point-locations is considerable. For instance, the lower and upper bound of the 50 per cent prediction interval of the SP90 are 0.02 and 0.38 μg L^{-1}, respectively.

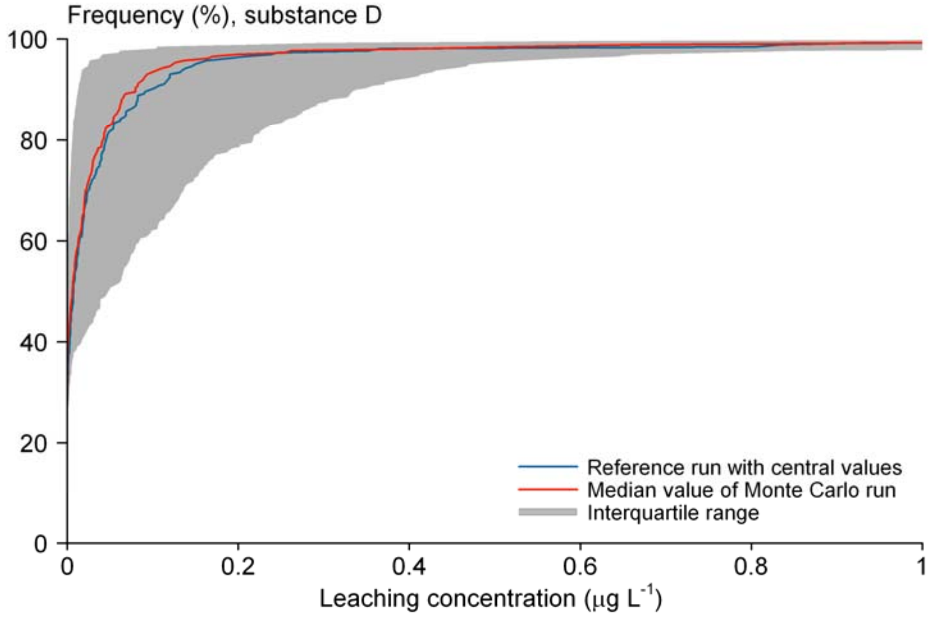

Figure 4.2. Spatial cumulative frequency distribution of the PEC50 for pesticide D. The figure shows results from the deterministic GeoPEARL run, and the median value of the Monte Carlo runs.

4.1.2 Uncertainty analysis at the six locations

In this section, results of the uncertainty analysis are presented for the six locations described in Section 3.3. The model output analysed is the PEC50, as before. In uncertainty analysis, the aim is to quantify the overall uncertainty of the model output as a result of uncertainties in the model input. The median (P50), 5th percentile (P5) and 95th percentile (P95) and the interquartile range (P75-P25) are useful measures to quantify the uncertainty of the model output. They are given for each location and each pesticide in Table 4.1.

Table 4.1. The P50, P5 and P95 of the PEC50, and the percentage of runs with a PEC50 value larger than 0.1 µg/L, based on 1000 simulation runs, for the six locations.

Pesticide A

Location	*P50*	*P5*	*P95*	*Interquartile range (P75-P25)*	*Percentage PEC50 > 0.1*
012	4.71	0.26	21.4	7.87	97.7
053	1.11	0.015	8.85	2.76	86.0
103	2.37	0.083	13.7	4.92	93.9
174	1.62	0.035	11.5	3.42	90.2
208	0.037	2.3E-5	1.62	0.22	35.2
257	4.64	0.223	21.6	7.55	97.2

Pesticide B

Location	*P50 Quantile*	*P5 quantile*	*P95 quantile*	*Interquartile range (P75-P25)*	*Percentage PEC50 > 0.1*
012	1.67	0.18	7.41	2.60	97.3
053	2.07	0.16	8.90	3.02	97.0
103	1.19	0.09	6.31	2.10	94.8
174	1.94	0.21	7.95	3.11	97.9
208	0.052	2.6E-4	1.24	0.22	38.3
257	1.55	0.14	7.25	2.38	96.1

Pesticide D

Location	*P50 Quantile*	*P5 quantile*	*P95 quantile*	*Interquartile range (P75-P25)*	*Percentage PEC50 > 0.1*
012	0.092	4.8E-4	1.82	0.38	49.0
053	0.016	1.3E-5	0.69	0.11	26.0
103	0.036	1.1E-4	0.84	0.16	32.3
174	0.018	2.2E-5	0.96	0.12	27.6
208	4.4E-5	6.4E-11	0.03	0.0012	2.0
257	0.111	2.3E-4	1.75	0.38	52.1

Table 4.1 shows that the median of PEC50 for pesticide D is much smaller than for the other two pesticides. For pesticide D the number of runs that exceeds the regulatory limit of 0.1 µg/L is also much smaller. The interquartile range increases with an increasing PEC50 for all pesticides and locations.

The water balance affects pesticide leaching. Table 4.2 shows the average water balance (mm/year) for the six locations. Results are shown for the deterministic run only. The table shows the importance of lateral drainage in Dutch conditions, which is due to the strong interaction between the groundwater system and the local surface water system. At location 103, situated in a polder area, lateral drainage even adds up to 75% of annual rainfall. Note that groundwater leaching is significantly lower at location 208 than at the other five locations. Location 208 has a continuous upward seepage flux at bottom of the soil profile. Location 53 has an upward seepage flux in spring and a leaching flux in autumn. The average downward water flux of location 053 and 208 is the same: -15 mm.year^{-1}

Table 4.2: Average of the water balance over a 20 years simulation period (mm year^{-1}) for the six locations. Last column specifies number of runs for which SWAP has no solution.

Location number	Prc	LeaSol	LeaGrw	SolAct	TrpAct	EvpInt	RunOff	Dra	Missing runs
012	818	-2	442	170	177	22	13	437	2
053	814	-15	296	84	345	92	0	311	56
103	815	-188	388	170	170	22	40	601	0
174	808	290	435	166	180	22	0	152	64
208	782	-15	199	91	328	92	47	239	0
257	817	373	363	180	180	22	26	34	5

Prc = precipitation, LeaSol = Leaching from the soil profile, LeaGtrw = Leaching into the groundwater (positive value means downward), SolAct = Actual evaporation from the soil surface, TrpAct = actual transpiration, EvpInt = evaporation of intercepted water, RunOff = surface runoff, Dra = lateral drainage

Combined inspection of Table 3.5 and Table 4.1 reveals that the leaching concentrations of pesticide A and pesticide D decrease with increasing organic matter content. This correlation is not found for pesticide B. This is to be expected from the pesticide properties: in contrast to pesticide A and D, pesticide B has a low sorption coefficient (K_{om}). Location 208 shows a smaller PEC50 than all other locations. This is due to the dynamics of the vertical downward water flux at location 208 (Table 4.2). Location 208 has a continuous upward seepage flux, whereas the comparable location 053 has a strong downward flux in autumn when the concentration of substance in soil is high and leaching of substances will occur causing an increase in the level of concentration. This confirms the importance of the water balance for pesticide leaching.

In calculating the quantiles, the missing values (crashed PEARL-runs for single plots) are not taken into account. So, for instance for location 053 it was assumed that only (1000-56=) 944 runs were performed. This is reasonable under the assumption that the missing values mimic the distribution of the output. If the runs that crashed did so because of extreme high or low PEC50-values, the given quantiles are under- or overestimated.

Figure 4.3 shows the uncertainty of the model output (PEC50) for pesticide D as a box-and-whisker plot for each location. Boxplots are used to display the distribution of data. The box spans the interquartile range of the values of the PEC50, so that the middle 50% of the data lie within the box, with a horizontal line indicating the median. Whiskers extend beyond the ends of the box as far as the minimum and maximum. The Y-axis in Figure 4.3 is scaled on a ^{10}log-scale to give a better view of the data.

The box plots are a graphical representation of the information in Table 4.1. The box plots show that there are no large differences between the locations concerning the maxima for pesticide D. Figure 4.3 also shows that location 208 differs from the other locations. Furthermore, it can be seen that on a log transformed scale the model output PEC50 is more or less normally distributed. (the median is in the middle of the box). Note that the regulatory limit is 0.1 μg/L.

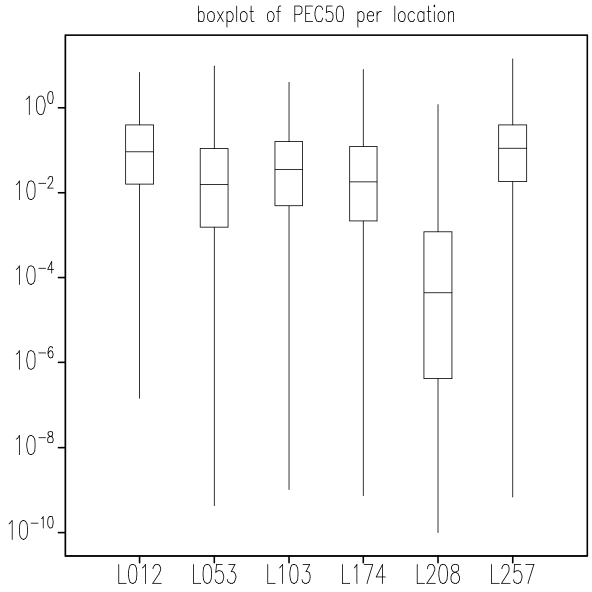

Figure 4.3 Boxplot of the 1000 simulated PEC50-values for pesticide D for the six locations.

4.1.3 Sensitivity analysis for the six locations : regression-free

The results for pesticide D using the regression-free approach are given in Table 4.3. In Table 4.4 the 90% bootstrap percentile confidence interval for each top marginal variance is given. The TMV is computed from untransformed values of PEC50. It will be shown that these TMV's are strongly determined by a few Monte Carlo runs. For this reason, TMVs from transformed PEC50-values were also computed.

Table 4.3. Top marginal variance (percentage) of OM, texture and VanGenuchten (TVG), DT_{50} en K_{om} for each location based on the PEC50, Pesticide D.

Location	*Organic matter*	*TVG*	*DT_{50}*	*K_{om}*
012	2.5	21.7	53.1	33.5
053	0	5.9	20.3	14.3
103	1.2	4.8	34.2	6.5
174	0	2.5	17.8	6.3
208	0	13.6	0	0.1
257	0	6.0	33.4	0.6

Table 4.4. 90% Bootstrap percentile confidence interval for TMV of organic matter, TVG, DT_{50} and Kom, Pesticide D.

Location	*Organic matter*		*TVG*		*DT_{50}*		*Kom*	
	Lower	*upper*	*Lower*	*upper*	*Lower*	*upper*	*Lower*	*upper*
012	-5.9	12.4	-4.1	42.9	36.9	64.6	14.9	49.5
053	-9.6	0	-5.3	20.7	10.0	33.6	0.8	55.8
103	-7.7	11.5	-6.1	19.4	12.5	51.4	-2.5	18.5
174	-9.7	5.0	-9.8	12.8	12.9	25.6	-8.3	22.5
208	-2.8	2.7	-0.5	35.4	-2.3	2.2	-1.2	4.3
257	-7.2	15.1	-5.6	10.9	29.2	54.8	-3.5	18.8

The top marginal variance of DT_{50} at location 012 is 53%. This means that the variance in PEC50 would reduce with 53% if the DT_{50} is known exactly. It also means that the bottom marginal variance of organic matter, texture and Van Genuchten and K_{om} is 47%. So, 47% of the variance in the model output will remain as long as these variables remain uncertain (with their given distributions).

Table 4.3 shows that the uncertainty in DT_{50} is the main cause for the uncertainty in the PEC50, except for location 208. The uncertainty in K_{om} has some influence and the influence of texture and VanGenuchten (*TVG*) parameters depends very much on the location. The uncertainty of organic matter does not result in uncertainty in the model output. Since the top marginal variance in a regression-free sensitivity analysis is based on a covariance and a covariance can be negative, it is possible that the calculation of the top marginal variance results in a negative value. The top marginal variance in this case is zero, since no variation in the model output is explained by this input parameter.

Judging from the top marginal variances, a large part of the variation in the model output remains unexplained (except for location 012). The total top marginal variance is 40% for location 053 which leaves 60% unexplained. The bootstrap confidence intervals are wide. This is due to the fact that only two times 200 runs can be used for calculating the top marginal variance.

The results, based on the 1000 GeoPEARL-runs for each location, can be divided in five groups. The first 200 runs are random draws from the defined distributions. The second 200 runs have the same OM values (as input) as the first 200 runs but are different for all other variables (i.e. TVG, DT_{50} and K_{om}). Comparing the output from the first 200 runs with the second 200 runs gives an impression of the effect of organic matter on the output. If organic matter is very important then this results in a strong correlation between the two outputs. The top marginal variance of organic matter in this regression-free approach is calculated as the covariance between these two parts of outputs in relation to the total variance of the output. This can also be shown in a graph as is done in Figure 4.4.

The third 200 runs have the same texture and Van Genuchten parameter values as the first 200 runs but are different for all other variables. Thus, comparison of the first 200 runs with the third 200 runs gives an impression of the effect of texture and Van Genuchten on the model output (PEC50). The fourth 200 runs have the same

DT_{50} values as the first 200 runs and the fifth 200 runs have the same K_{om} value as the first 200 runs. In Figure 4.4 the model output of the first 200 runs is compared with respectively the second, third, fourth and fifth 200 runs for location 012.

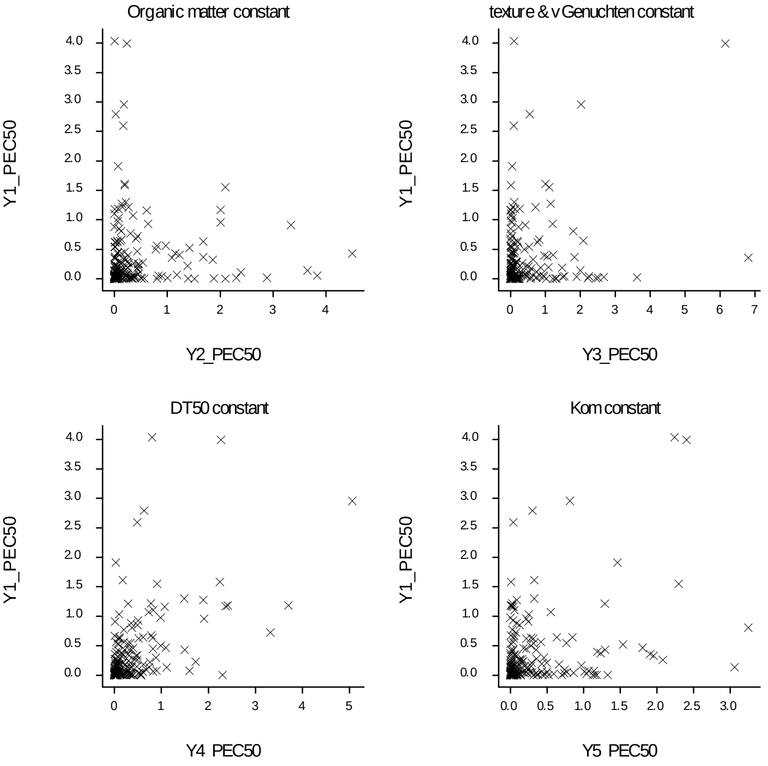

Figure 4.4. Scatter plot of PEC50 of pesticide D for location 012 comparing the output of the first 200 runs with the second, third, fourth and fifth 200 runs.

As can be seen in the graphs for many runs the calculated PEC50 is a very small value. By calculating the top marginal variance on these data only few runs play an important role, i.e. the runs with a high PEC50 value. For example, the top marginal variance of 53% for DT_{50} for location 012 is mainly based on 20 runs out of the 1000. The range of interest for the PEC50 are the values between 0.0001 and 10.0. By transforming the data and calculating the top marginal variance after transformation, it is possible to look at the effect of the input variables with emphasis on this range. A suitable transformation is ^{10}log(PEC50 + 1E-5). This results in a scale from -4 to 1 on the range of interest and by adding 1E-5 the very small values become -5 after transformation.

Figure 4.5 shows the scatter plots for the log transformed PEC50 of pesticide D for location 012. This figure shows that after transformation the model output covers the range of interest more gradually. So in calculating the top marginal variance after transformation the output of all runs participate. Further, Figure 4.5 gives an impression of the correlation between the runs when everything was changed except the variable that remains constant

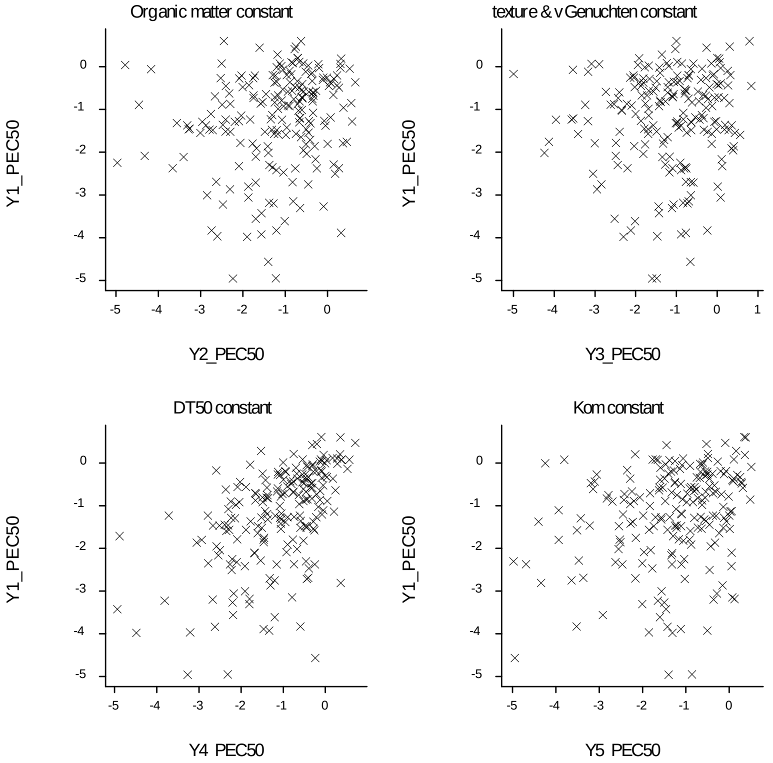

Figure 4.5 Scatter plot of the log transformed PEC50 of pesticide D, for location 012, comparing the output of the first 200 runs with the second, third, fourth and fifth 200 runs.

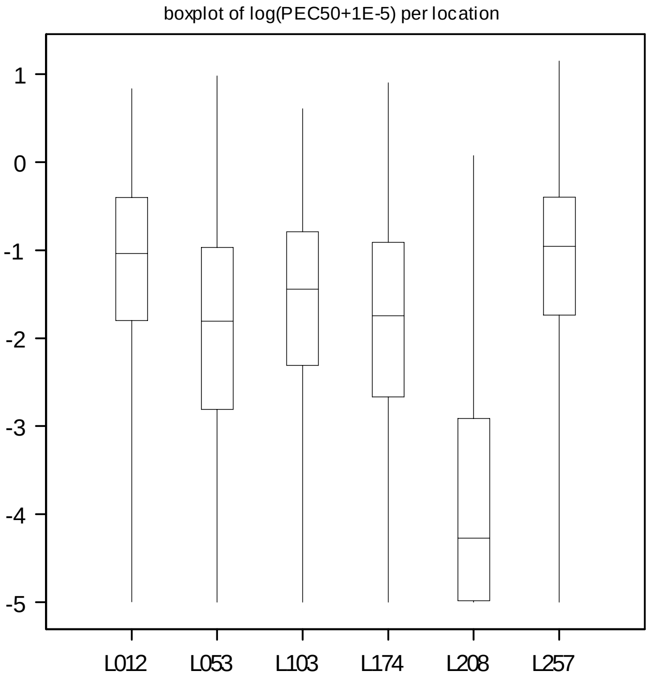

Figure 4.6 Boxplot of the 1000 simulated log-transformed PEC50-values of pesticide D for the six locations.

Figure 4.6 shows the boxplot for the log transformed PEC50 of pesticide D for all six locations. The regulatory limit of 0.1 μg/L corresponds to -1.0 on the log transformed scale (^{10}log(0.1+1E-5)=-1.0). The boxplots in Figure 4.6 are comparable with the boxplots in Figure 4.3 with the difference that the smallest value now is -5.

Table 4.5.a. Top marginal variance (percentage) of OM, TVG, DT_{50} en Kom for each location based on the transformed PEC50 of pesticide D: log10 (PEC50 + 1E-5).

Location	*Organic matter*	*TVG*	*DT_{50}*	*K_{om}*
012	19.2	7.1	51.9	25.6
053	0	9.7	36.9	32.9
103	12.3	1.1	53.3	15.0
174	0.6	0	57.3	27.5
208	19.7	25.5	28.6	25.0
257	10.0	10.0	52.8	25.5

Table 4.5.b. Lower and upper bound of 90% Bootstrap percentile confidence interval for TMV of organic matter, TVG, DT_{50} and Kom. Pesticide D

Location	*Organic matter*		*TVG*		*DT_{50}*		*K_{om}*	
	Lower	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
012	8.6	30.7	0	17.3	42.6	60.3	14.1	39.4
053	0	0	0	23.3	24.2	45.7	19.7	45.8
103	0	24.4	0	12.5	46.5	61.6	2.9	26.4
174	0	12.4	0	10.0	47.9	66.1	15.0	40.3
208	9.2	28.4	15.9	37.3	18.3	38.9	12.8	34.7
257	0	21.5	0	26.3	41.8	62.4	15.4	36.1

Table 4.6.a. Top marginal variance (percentage) of OM, TVG, DT_{50} en Kom for each location based on the transformed PEC50 of pesticide A: log10 (PEC50 + 1E-5).

Location	*Organic matter*	*TVG*	*DT_{50}*	*Kom*
012	20.6	0	57.6	22.5
053	14.9	11.0	45.8	23.4
103	23.0	4.5	42.1	23.6
174	13.1	0.6	42.6	35.8
208	16.6	25.7	26.0	13.6
257	20.9	13.0	41.6	17.7

Table 4.6.b. Lower and upper bound of 90% Bootstrap percentile confidence interval for TMV of organic matter, TVG, DT_{50} and Kom. Pesticide A

Location	*Organic matter*		*TVG*		*DT_{50}*		*Kom*	
	Lower	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
012	9.3	30.8	0	8.3	47.2	66.5	13.0	34.3
053	2.6	27.9	0	23.8	37.9	53.7	9.1	34.3
103	13.6	37.0	0	7.5	29.1	55.9	11.6	35.0
174	2.9	27.3	0	15.2	30.2	52.8	24.6	49.2
208	4.1	26.7	13.6	37.4	12.0	37.4	4.3	24.5
257	9.6	32.1	0.7	23.9	31.3	51.8	8.0	27.8

Table 4.7.a Top marginal variance (percentage) of OM, TVG, DT50 en Kom for each location based on the transformed PEC50 of pesticide B: log10 (PEC50 + 1E-5).

Location	*Organic matter*	*TVG*	DT_{50}	K_{om}
012	0.6	15.7	82.1	5.5
053	3.7	0	75.4	10.3
103	4.4	0	71.9	6.6
174	0.3	2.7	76.4	6.3
208	6.0	37.4	50.5	7.2
257	4.3	17.2	71.7	5.5

Table 4.7.b. Lower and upper bound of 90% Bootstrap percentile confidence interval for TMV of organic matter, TVG, DT50 and Kom. Pesticide B

Location	*Organic matter*		*TVG*		DT_{50}		K_{om}	
	Lower	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
012	0	9.6	5.4	26.1	77.0	85.5	0	15.1
053	0	18.3	0	6.7	67.9	80.9	0	20.9
103	0	16.6	9	9.1	65.6	76.5	0	15.4
174	0	12.7	0	15.9	70.1	81.4	0	18.0
208	0	19.1	28.8	46.5	40.7	59.0	0	20.2
257	0	13.2	3.4	31.5	63.8	80.2	0	15.5

In Table 4.5.a the top marginal variances based on the transformed model output are given for the six locations for pesticide D. In Table 4.5.b. the 90% bootstrap percentile confidence interval is given for each top marginal variance. The top marginal variances based on the log transformed scale are also calculated for pesticides A and B. The results for each location and the bootstrap-intervals are given in Tables 4.6 and 4.7.

In Table 4.5.a the top marginal variance of DT_{50} at location 012 is 52%. This means that the variance in PEC50 would reduce with 52% if the DT_{50} is known exactly. It also means that the bottom marginal variance of organic matter, TVG and K_{om} is 48%. So, 48% of the variance in the model output will remain as long as these variables remain uncertain (with their given distributions). The top marginal variance for organic matter is 10% for location 257. The means that the bottom marginal variance for TVG, DT_{50} and K_{om} is 90% and therefore that 90% of the variance in the model output will remain as long as no new information about these variables becomes available.

Table 4.5.shows that the uncertainty in DT_{50} is the main cause for the uncertainty in the PEC50 for all locations. The uncertainty in K_{om} also has substantial influence, but the influence of organic matter content and of texture and Van Genuchten parameters differs strongly between the locations. These results are comparable to the results of the untransformed PEC50.

The difference between Tables 4.5 and 4.3 is that for all locations the total top marginal variance is much larger with the transformed data. The total top marginal variance over the four input groups now adds up to 80% for location 053, and for the other locations it is even higher. For location 012 it is even higher than 100%. The bootstrap confidence intervals remain wide.

The results in Table 4.6 for pesticide A show that again the uncertainty in DT_{50} is the main cause for the uncertainty in the PEC50. The top marginal variances for DT_{50}, K_{om} and Texture and Van Genuchten are comparable to pesticide D. The top marginal variance for organic matter content is for four of the six locations much larger for pesticide A compared to D. This was expected, because pesticide A has the highest (nominal) sorption coefficient. The total top marginal variance is (with exception of 208) at least 92%. So, for pesticide A no interaction between the input parameters is to be expected.

Pesticide B is a weakly sorbing pesticide, so no relationship with organic matter content is expected. This is confirmed in Table 4.7, where it is shown that the uncertainty of organic matter content does not result in uncertainty of the model output. Table 4.7 also shows that the contribution of K_{om} to the uncertainty in PEC50 is smaller than for pesticide A and D. This is also a result of the small (nominal) value of the K_{om}. For pesticide B, the major source of uncertainty in the PEC50 results from uncertainty in the DT_{50}. The top marginal variance for DT_{50} is in the range of 51 to 82% and therefore much larger compared to pesticide D and A. The effect of texture and VanGenuchten parameters again depends on the location and ranges between 0 and 37%. Since the top marginal variance for DT_{50} is high, also the total top marginal variance is at least 83%.

4.1.4 Sensitivity analysis for the six locations by spline regression

The sensitivity of the PEC50 for uncertainty in groups of model input parameters can also be analysed by a regression-based method (see Section 3.4). Theoretically, to use the 1000 Monte Carlo runs generated for the regression-free analysis, only the first 200 runs that are sampled independently can be used to calculate the top marginal variance by means of a spline regression. On the other hand, it would be inefficient not to use all 1000 runs while the main parts are sampled independently. So, all 1000 runs were used to calculate the top marginal variance. The results of the analyses for the six locations and the three pesticides are given in Table 4.8. The analyses are again based on the log transformed PEC50. The adjusted R^2 is the percentage variance accounted for when all input-parameters are fitted into the regression model. The splines are based on two degrees of freedom for all input-parameters (GenStat Committee, 2007)

The results of the regression-based sensitivity analysis are very similar to the results obtained with the regression-free approach. The top marginal variances for DT_{50} and K_{om} are more or less the same for all locations and pesticides and definitely within the confidence limits. For organic matter content the sum of the top marginal variances of the two horizons are a few percent smaller for pesticides A and B, all locations. For pesticide D the differences between the locations for organic matter found with the regression-free approach were not mimicked in the regression-approach.

Table 4.8.a Top marginal variance (percentage) of 12 inputs at six locations, based on spline regression with 2 df on the transformed PEC50 (log10 of (PEC50 + 1E-5)), 1000 runs. Percentage variance accounted for (R^2adjusted) of the spine regression with all input variables in the model. Pesticide D

Input	*012*	*053*	*103*	*174*	*208*	*257*
DT_{50}	56.7	44.1	50.6	50.7	36.6	46.9
K_{om}	18.9	33.6	21.3	31.3	21.0	18.6
OM horizon 1	4.4	6.9	5.9	4.7	4.3	11.8
OM horizon 2	2.0	3.0	3.0	3.4	5.3	1.7
Clay horizon 1	0.2	0.0	0.3	0.0	0.0	0.1
Clay horizon 2	0.0	0.2	0.0	0.0	1.4	0.0
Sand horizon1	0.3	0.0	0.1	0.0	0.0	0.0
Sand horizon2	0.0	0.5	0.2	0.0	0.2	0.0
ThetaSat	0.0	0.5	0.2	0.0	0.1	0.7
Alpha dry	0.0	0.0	0.5	0.0	0.9	1.0
n	0.0	0.2	0.0	0.0	0.3	0.9
L	0.0	0.1	0.2	0.2	2.1	0.0
R^2adjusted	82.2	88.0	83.5	88.7	67.3	80.6

Table 4.8.b. Top marginal variance (percentage) of different inputs for each location based on spline regression with 2 df on the transformed PEC50 (log10 of (PEC50 + 1E-5)), 1000 runs. Percentage variance accounted for (R^2adjusted) of the spine regression with all variables in the model. Pesticide A

Input	*012*	*053*	*103*	*174*	*208*	*257*
DT_{50}	47.4	41.8	43.8	39.1	28.0	37.6
K_{om}	23.3	33.9	26.3	34.2	24.3	16.5
OM horizon 1	8.0	5.8	7.7	6.1	4.9	15.2
OM horizon 2	3.3	2.7	3.9	5.5	6.9	1.7
Clay horizon 1	0.0	0.0	0.1	0.5	0.1	0.0
Clay horizon 2	0.0	0.0	0.3	0.0	0.9	0.0
Sand horizon1	0.0	0.4	0.0	0.3	0.3	0.0
Sand horizon2	0.3	0.4	0.1	0.0	0.0	0.4
ThetaSat	0.4	0.0	0.0	0.0	0.1	1.4
Alpha dry	0.0	0.0	0.7	0.0	0.4	1.2
n	0.4	0.0	0.0	0.0	0.4	0.1
L	0.0	0.0	0.7	0.0	2.3	0.0
R2adjusted	80.0	87.3	79.9	86.5	70.6	75.3

Table 4.8.c Top marginal variance (percentage) of different inputs for each location based on spline regression with 2 df on the transformed PEC50 (log10 of (PEC50 + 1E-5)), 1000 runs. Percentage variance accounted for (R^2adjusted) of the spline regression with all variables in the model. Pesticide B

Input	*012*	*053*	*103*	*174*	*208*	*257*
DT_{50}	79.6	71.7	71.8	75.5	50.4	73.3
K_{om}	3.9	10.7	10.0	9.6	8.7	5.8
OM horizon 1	1.9	1.8	1.5	2.3	1.3	5.0
OM horizon 2	0.0	0.3	0.2	0.2	4.6	0.2
Clay horizon 1	0.0	0.0	0.3	0.0	0.0	0.0
Clay horizon 2	0.0	0.0	0.0	0.0	0.7	0.0
Sand horizon1	0.2	0.0	0.0	0.0	0.0	0.0
Sand horizon2	0.0	0.1	0.2	0.0	0.0	0.0
ThetaSat	0.0	0.6	0.4	0.0	0.4	0.8
Alpha dry	0.3	0.8	0.5	1.4	1.7	0.9
n	0.0	0.0	0.0	0.4	0.2	0.1
L	0.0	0.3	0.8	0.3	2.8	0.0
R^2adjusted	86.2	89.9	84.7	91.2	67.8	83.4

The top marginal variances were very small for the sum of the texture and Van Genuchten parameters for all locations and pesticides. For location 208 the top marginal variance of texture and Van Genuchten parameters was substantial, which was not found with the spline regression. In this regression not all TVG parameters and all horizons were taken into account.

Overall, the conclusions regarding the sensitivity analyses were the same in the regression-based and regression-free approach.

4.2 Results for 90th percentile of spatial cumulative frequency distribution of PEC50

For each Monte Carlo run (1000 runs) the PEC50 is calculated for 258 locations, resulting in a matrix of 258 columns by 1000 rows with PEC50 (see Section 3.8). In Section 4.1 the results of only six columns of this matrix were analysed. For each simulation run the 90th percentile of the PEC50 over the 258 locations (SP90) can be computed. The population of 1000 SP90 values obtained in this way expresses the uncertainty about the true SP90. The uncertainty and sensitivity of the SP90 for the groups of model input parameters are described in this section.

For each Monte Carlo run a few locations can be missing due to crashed PEARL-runs. The maximum number of missing locations for a simulation run is 16 for all pesticides. The number of missing locations varies over the runs but is equal for the three pesticides. The P90 of each simulation run is based on the locations with a PEC50-value. Since the number of missing locations is small, its effect on the SP90 is expected to be small.

4.2.1 Uncertainty analysis of the SP90

The 50 (median), 5 and 95 percentiles and the interquartile range (P75-P25) of the uncertain SP90 are given in Table 4.9 for the three pesticides D, A en B. Figure 4.7 depicts the uncertainty of the SP90 as a boxplot.

Table 4.9. The 50, 5 and 95 percentiles of the SP90, based on 1000 simulation runs, and the percentage of runs with a SP90 value bigger than 0.1 .

Pesticide	*50 percentile*	*5 percentile*	*95 percentile*	*interquartile range (P75-P25)*	*Percentage SP90 > 0.1*
D	0.37	0.24	0.59	0.14	100
A	7.12	5.56	8.95	1.46	100
B	4.18	3.42	5.10	0.68	100

Table 4.9 and Figure 4.7 show large differences between the pesticides in their median SP90, as well as in the range of values. The larger the median the larger the range of values. For all three pesticides the number of Monte Carlo runs with SP90 > 0.1 µg/L (the regulatory limit) is 100%.

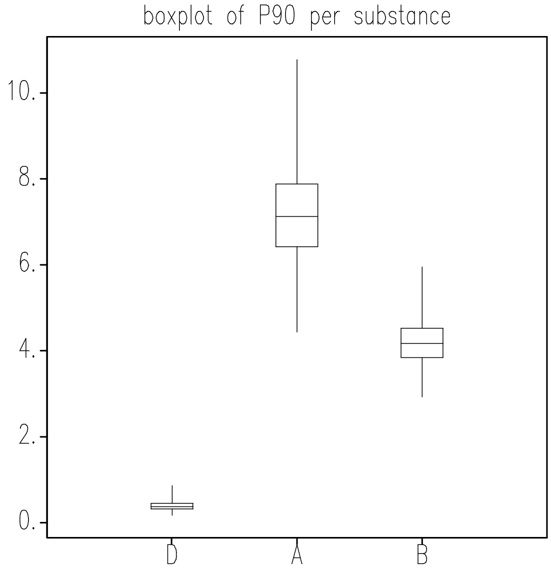

Figure 4.7 Boxplot of the 1000 simulated SP90 values of the leaching concentrations (µg L^{-1}), Pesticide D, A and B.

Figure 4.8 shows the spatial cumulative frequency distribution of the PEC50, estimated from the 258 locations, for both the Monte Carlo simulations and the deterministic run. Both the median value of the Monte Carlo simulations and the 80%-prediction interval are depicted. For all three pesticides, the spatial cumulative frequency distribution of the PEC50 obtained with Monte Carlo simulation shows stronger spatial variation than in the deterministic simulations, as shown by the more gentle slope of the frequency distributions of the Monte Carlo approach. This is a consequence of assuming the model input uncertain at individual locations. This has particularly consequences for the SP90 (the 90th percentile of the spatial cumulative frequency distribution), which is shifted towards larger values. This is shown in Figure 4.9.

In Figure 4.9 the cumulative probability distribution of SP90 for pesticides A, B and D are shown for the Monte Carlo runs and the deterministic run. For all three pesticides, the SP90 calculated from the Monte Carlo runs is much larger than that for the deterministic run. So when taking the uncertainty in the input parameters into account, in particular the half-life of the pesticide, the SP90 increases substantially.

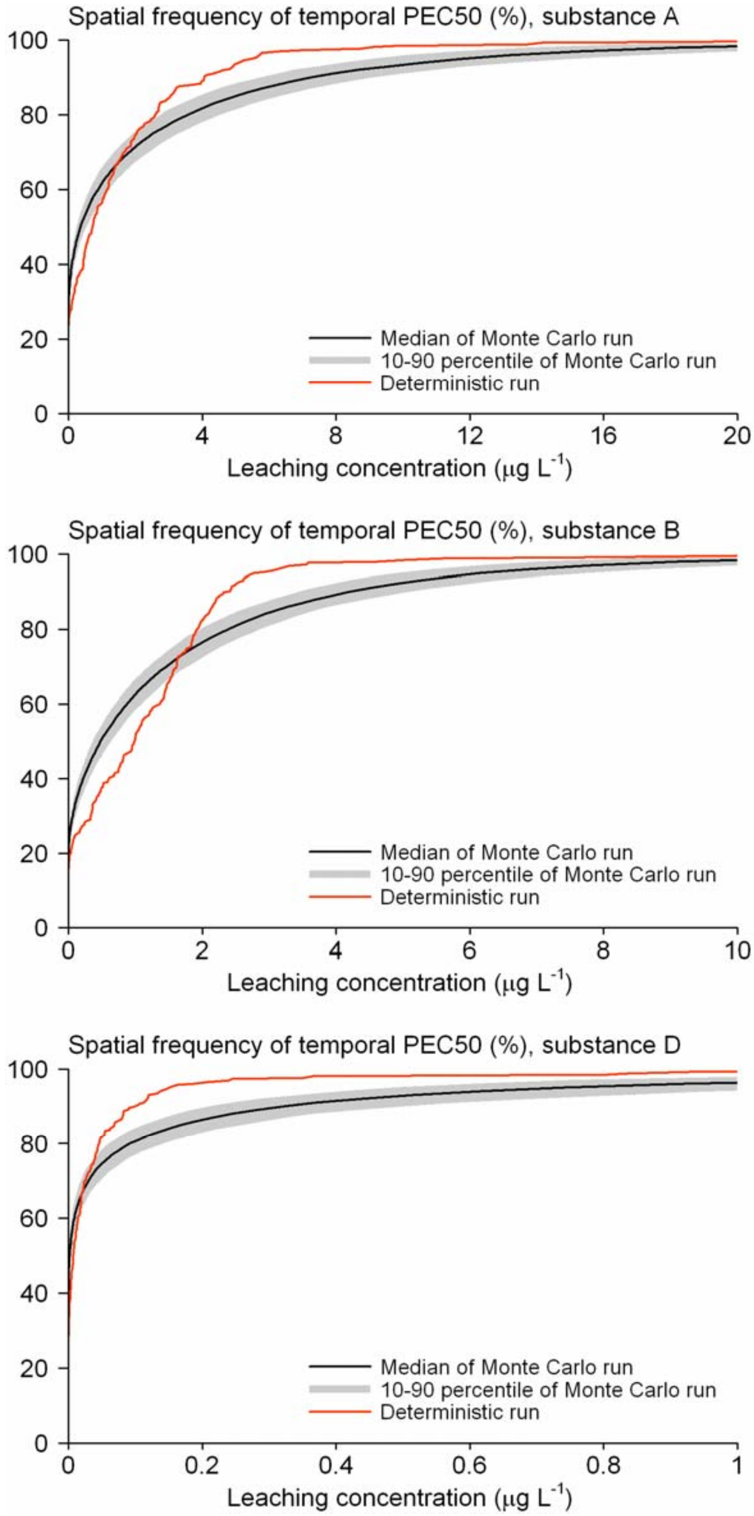

Figure 4.8. Spatial cumulative frequency distribution of the PEC50 for pesticides A, B and D estimated from the 258 locations. The figure shows both the median value of the Monte Carlo run, the 80%-prediction interval, and the spatial cumulative frequency distribution obtained with the deterministic run

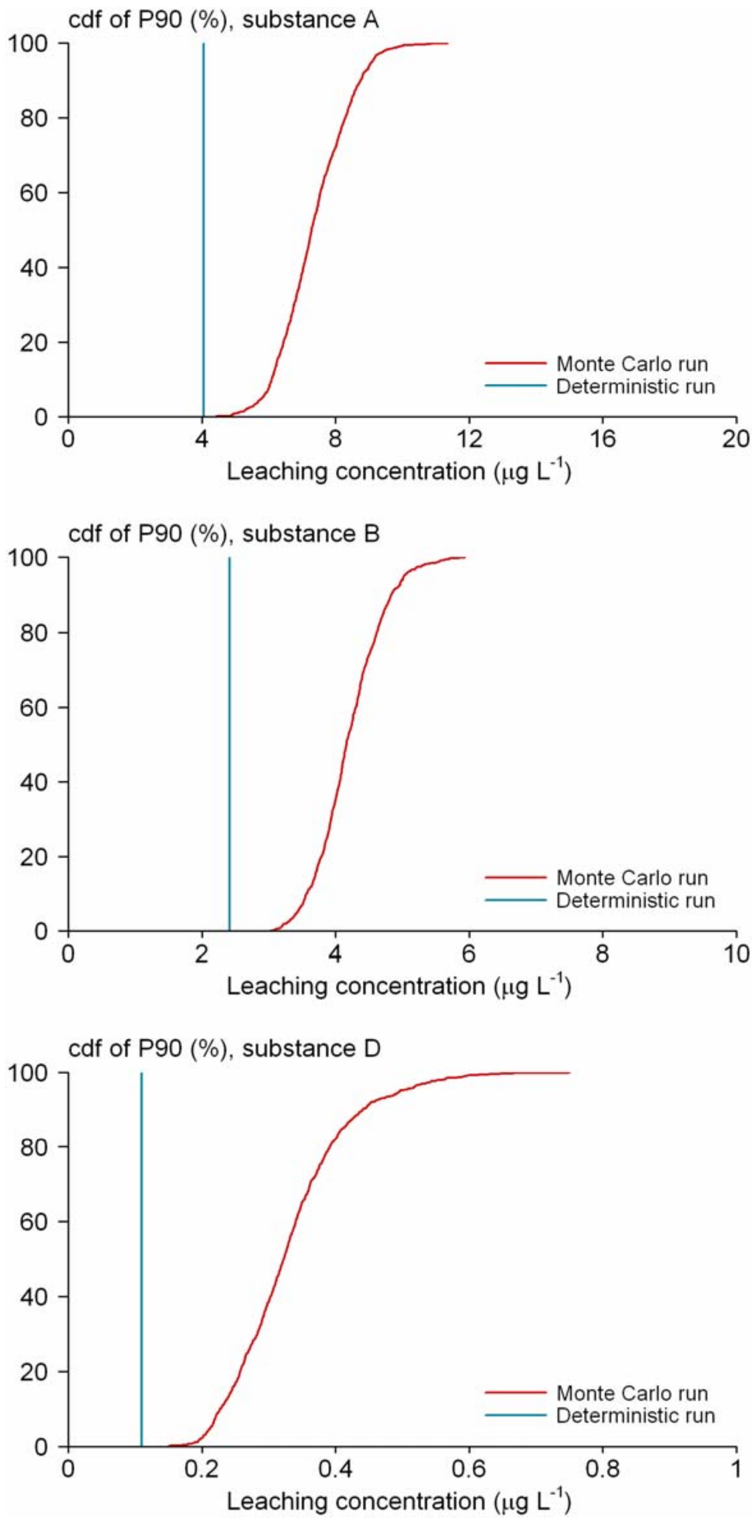

Figure 4.9 Cumulative probability distribution of the spatial P90 for pesticides A, B and D. Both results of the Monte Carlo simulation and the deterministic run are given. Note the different scale of PEC50 for pesticide D

4.2.2 Sensitivity analysis of the SP90

The sensitivity of the 90th percentile of SP90 was analysed by a regression-free approach. Analysis of the sensitivity of this target quantity by a regression approach, as done for the PEC50 at locations, is unsuitable as it requires besides the model output the model input parameters (see Section 3.4). In Figure 4.10 the results of the 1000 simulation runs are shown for the four groups (for explanation see Section 3.5).

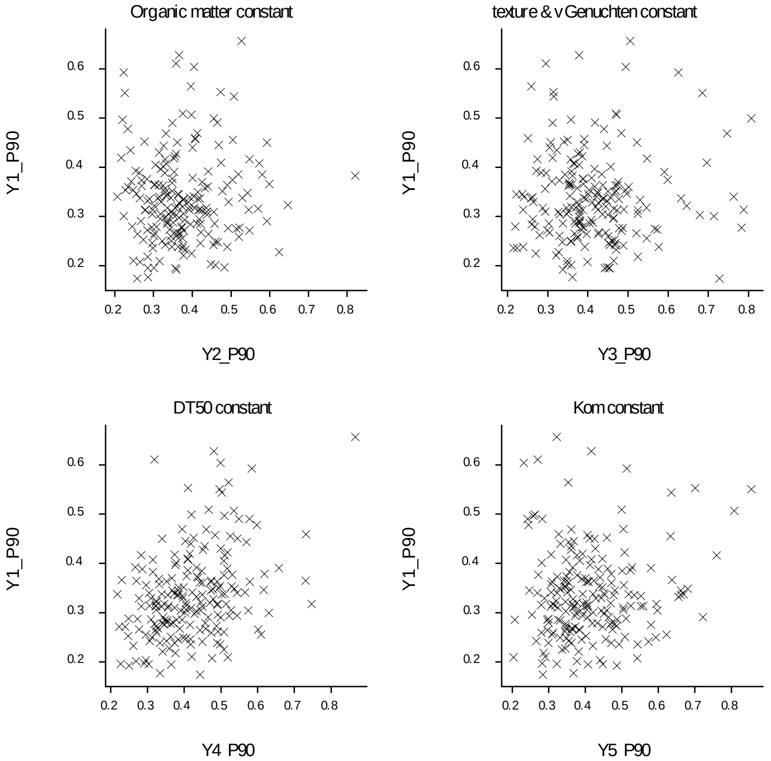

Figure 4.10. Scatter plot of the model output (SP90) comparing the output of the first 200 runs with the second, third, fourth and fifth 200 runs.

Given the scale of the SP90, transformation is not necessary. The top marginal variance was calculated for the four groups of input variables. The results for pesticide D, A and B are given in Table 4.10 with the 90% bootstrap percentile confidence interval for each top marginal variance.

Table 4.10.Top marginal variance (percentage) of OM, TVG, DT_{50} en K_{om} for the P90 and the lower and upper bound of their 90% bootstrap percentile confidence interval.

Pesticide A

P90	*Organic matter*	*TVG*	*DT_{50}*	*K_{om}*
Top Marginal Variance	7.4	2.8	31.9	5.3
Lower	0	0	22.0	-3.5
Upper	17.4	13.9	42.4	17.6

Pesticide B

P90	*Organic matter*	*TVG*	*DT_{50}*	*K_{om}*
Top Marginal Variance	7.6	0.0	50.3	7.1
Lower	-3.7	-14.2	39.4	-5.2
Upper	17.8	11.8	60.3	16.3

Pesticide D

P90	*Organic matter*	*TVG*	*DT_{50}*	*K_{om}*
Top Marginal Variance	4.6	3.7	37.3	9.7
Lower	-6.6	-10.8	26.2	-5.6
Upper	15.0	13.3	48.3	19.7

The top marginal variance for DT_{50} for pesticide D is 37%. This means that the variance in P90 would reduce by 37% if the DT_{50} for this pesticide were known exactly. It also means that the bottom marginal variance for organic matter, TVG and K_{om} is 63%. Hence, 63% of the variance in P90 will remain as long as these variables remain uncertain (with their given distributions). Since the bottom and top marginal variance in a regression-free approach add to 100%, all variance is accounted for. On the other hand, if the sum of the top marginal variances also add to a substantial amount (say 90%) this would indicate that the effect of the input groups on the model output is independent and additive. The top marginal variances for organic matter, TVG and K_{om} are small, resulting in a total top marginal variance of 55%. This leaves 45% of the variance in the P90 unexplained and suggests that interaction between input-parameters can be important.

For pesticides A and B the results are very comparable to the results of pesticide D. DT_{50} remains the main source of uncertainty in P90 with a top marginal variance of 32% for pesticide A and 50% for pesticide B. The total top marginal variance is 47% and 65% for pesticide A and B, respectively.

5 Discussion

This chapter addresses the research issues described in Chapter 1:

- quantification of the error resulting from the use of a simplified spatial schematisation, consisting of 6 405 unique combinations (Section 5.1);
- quantification of the uncertainty about the median annual average leaching concentration at point locations (Section 5.2) and about the associated spatial 90th percentile for the entire Dutch agricultural area, as caused by uncertainty of pesticide properties and soil characteristics (Section 5.3);
- assessment of the contribution of individual uncertain input parameters to the total uncertainty in PEC50 and SP90 (Section 5.4);
- effect of other uncertainties on the spatial 90th percentile of the leaching concentration (Section 5.5);
- proposal of a strategy to reduce the uncertainty of the current GeoPEARL simulations (Section 5.6).

5.1 Quantification of the error resulting from the use of simplified physical-chemical soil map

The current schematisation of GeoPEARL consists of 6 405 unique combinations of soil type, weather district and groundwater depth group. GeoPEARL results obtained with this schematisation were compared with GeoPEARL results obtained with a higher spatial resolution. The comparison showed for all three pesticides considered that the nationwide spatial frequency distribution of the predicted leaching concentration and the spatial 90th percentile leaching concentration (SP90) was hardly affected by spatial aggregation of soil type within larger spatial units.

The absence of an effect of the use of the detailed soil schematisation seems to be in contradiction with results obtained by Vanclooster et al. (2003) and Piñeros Garcet et al. (2003). They found that elimination of subdominant soil types of the 1 : 1 000 000 European soil map resulted in the elimination of leaching hotspots. As a consequence, the frequency distribution of the leaching concentration was steeper, and the SP90 was smaller. Therefore, for an accurate prediction of SP90, it was concluded that it is important to retain the leaching hotspots in the spatial schematisation. In this study, however, hotspots are not eliminated (although their locations changed).

Tiktak et al. (2004) created a coarser spatial schematisation by merging unique combinations with the same relative leaching vulnerability, thus substantially reducing the number of 6 405 combinations (‘zonation’). Their results show that the spatial frequency distribution of the leaching concentration and the SP90 could be accurately predicted with as few as 250 unique combinations. In our study, 258 point locations were selected from the STONE schematisation by placing a square grid over the Netherlands. Also in this case, the SP90-value and the spatial frequency distributions were both predicted accurately.

For adequate prediction of the spatial frequency distribution and the SP90, it is not necessary to use a detailed spatial soil schematisation. Hence, for model predictions at the national scale, the current GeoPEARL schematisation, or even a coarser schematisation with approximately 250 point locations, is sufficient. Results also show, however, that for smaller areas the SP90 substantially differs between the two soil schematisations. Therefore, for smaller areas (less than a few hundred km^2), it is advised to use the detailed schematisation. The Netherlands Hydrological Instrument (NHI), which is currently being developed by Alterra, Deltares and PBL, could also benefit from the improved physical-chemical soil map.

5.2 Effect of uncertainty of pesticide properties and soil characteristics on the median annual average leaching concentrations at locations

Stochastic simulations at six point locations showed that uncertainty about PEC50 at point locations is large, also at the 0.1 μg/L level. For example, the width of the interquartile range is approximately 150% of the median PEC50 in the case of pesticide A and B and 500% in the case of pesticide D (which has a median leaching concentration around 0.1 μg/L).

The spatial pattern of the median value of the predicted PEC50 in the Monte Carlo simulations corresponded well with the spatial pattern predicted in an ordinary deterministic GeoPEARL run. Further analysis revealed that both in the stochastic simulation and in the deterministic simulation, there is a strong correlation between PEC50 and organic matter. DT_{50} and K_{om} have a strong influence on the PEC 50 as well and contribute more to the uncertainty in PEC50, but these variables are spatially invariant (i.e. constant). Soil organic matter is the most important spatially distributed input variable, and this explains that the spatial pattern of PEC50 is largely determined by the spatial pattern of soil organic matter. It should be noted that for PEC50, on several locations, uncertainty in soil texture was found to be an important source of uncertainty. Further study is needed to explain this.

The conclusions regarding the stochastic sensitivity analyses for PEC50 are in general the same in the regression-based and regression-free approach. Leterme et al. (2007) derived the same conclusion when applying GeoPEARL to the Dyle catchment in Belgium. The disadvantage of a regression-free approach is that – due to computational restrictions – the number of independent groups is limited. For a more detailed analysis of uncertainties in all relevant input parameters, a regression-based approach is therefore required. A regression-based approach, however, cannot be applied to aggregated parameters such as the spatial P90.

5.3 Effect of uncertainty of pesticide properties and soil characteristics on the spatial 90th percentile of the leaching concentrations

The uncertainty about the spatial P90 – which is the regulatory endpoint in Dutch pesticide registration – is smaller than the uncertainty about PEC50 at point locations. The width of the interquartile range is computed to be 15% of the median spatial P90 for pesticides A and B and approximately 40% in the case of pesticide D.

For the spatial 90th percentile of the leaching concentration (SP90), the most important source of uncertainty on the model output is the pesticide degradation half-life (DT_{50}). The contribution of K_{om} and organic matter is also substantial. The sensitivity for texture and the soil physical characteristics is small and practically zero for substance B.

From a regulatory point of view, by far the most important implication of this study is the shift of the SP90-value towards greater values when uncertainty of pesticide and soil properties are considered. For example, the spatial P90 of substance D increased from 0.1 μg/L to approximately 0.4 μg/L when uncertainty in soil and pesticide properties was considered. The reason is that when uncertainty in soil and pesticide properties is taken into account, the spatial variation in PEC50 values is increased. Each Monte Carlo run samples from the probability distribution of the uncertain properties at each of the 258 locations. Different values are drawn at different locations within a run, thus increasing the spread of the spatial distribution of PEC50. Since SP90 is defined as the 90th percentile of this distribution, an increase of the spread will result in a shift away from the mean, towards greater values (likewise, a shift to a smaller value will occur for percentiles below the median). The important implication for regulation is that the SP90 is systematically underestimated when uncertainty is ignored. However, the 90th percentile was chosen bearing in mind that due to uncertainty it is important to be on the safe side. When uncertainty is included in the analysis, it may be sensible to use a less extreme percentile for regulatory evaluation, such as the 80th percentile of this distribution. This would compensate for the systematic shift, perhaps even undo it or overcompensate for the effect.

It should be noted that the shift of SP90-values found in this study is completely in line with results from earlier studies examining the effect of spatial variability of pesticides by stochastic simulation. Jury and Gruber (1989) and Van der Zee and Boesten (1991) applied an analytical model to leaching at the field scale and concluded that stochastic simulations are likely to generate more extreme events that are not captured within an ‘average’ deterministic simulation. Leterme et al. (2007) applied the GeoPEARL model to the catchment scale and also found a shift of the leaching concentration towards larger values.

5.4 Assessment of the contribution of individual uncertain input parameters to the total uncertainty in PEC50 and SP90

Uncertainty in the pesticide degradation half-life (DT_{50}) is the main cause of uncertainty in the median leaching concentration over time. The contributions of the sorption coefficient (K_{om}) and organic matter to the total uncertainty in PEC50 were smaller, but meaningful. The contribution of uncertainty in texture and soil physical properties to the total uncertainty is generally small and varies with location. These findings confirm earlier (stochastic) sensitivity analyses by Boesten (1991), Tiktak et al. (1994) and Dubus et al. (2003).

The analysis further showed that sensitivity of PEC50 is pesticide dependent. For example, the contribution of organic matter and the sorption coefficient to the total uncertainty is small for the weakly sorbing pesticide (B) and large for the moderately sorbing pesticides (A and D).

Uncertainty in PEC50 at individual locations is much larger than in the SP90. This is because errors level out when they are spatially averaged (see also section 5.3). In fact, it is not surprising that the spatial P90 can be estimated more accurately than the PEC50 at point locations: the data used by GeoPEARL are derived from a nationwide database that is meant to be used on a national scale. When these data are used to make predictions of the PEC50 at point locations then one is bound to obtain poor results, simply because the information in the database may be a very poor estimate of the true state of the location. However, the database does provide a fair description of the country as a whole, and thus the spatial aggregate of the PEC50 over the entire country (i.e., the SP90) can be estimated much more accurately.

In the uncertainty analysis it was assumed that there was no spatial autocorrelation in the uncertainty of the soil and pesticide properties. This was justified by the large spacing of the grid. However, if an assessment is needed on the effect of uncertainty in the properties on a regional scale, smaller grid spacings will be required, so that spatial autocorrelation can no longer be ignored. Accounting for spatial autocorrelation will likely lead to an increase of the uncertainty of the SP90 (compared to neglecting autocorrelation) because the effect of levelling out of errors becomes smaller. Note that apart from lateral spatial correlation, vertical spatial correlation (i.e., between soil layers) may also need to be included to improve the methodology. As yet, little to no attention has been paid to this complex issue. Cross-correlation between uncertain inputs was also ignored, except for the soil texture variables. This was partly because some of the uncertain inputs are truly independent or their correlation is negligibly small, but partly also because little information was available to estimate the correlations. If cross-correlations would have been included, it would likely have caused an increase of the PEC50 and SP90 uncertainty, although this is somewhat speculative because the result of complex interactions in GeoPEARL is difficult to predict.

All quantitative uncertain variables included in this study were assumed to be lognormally distributed. Truncation was applied where minima and maxima were known. The choice for the lognormal distribution was inspired by the fact that many of the variables were known to be positively skewed, implying that the normal distribution would not satisfy. The lognormal distribution can accommodate highly skewed distributions as well as distributions that are near-symmetric and is therefore flexible. Parameter estimation and stochastic simulation are also straightforward, which further adds to the attractivity of the lognormal distribution. However, alternative distributions such as the beta-distribution for DT_{50} and the normal distribution for K_{om} have also been used in the past (e.g. Dubus et al., 2003). With little experimental data available, it is difficult to decide which parametric form is best. Sensitivity of the results to the choice of distribution may therefore be sensible. Beulke et al. (2006) argued that user subjectivity in Monte Carlo analyses (truncation, type and parameterisation of the distributions, correlation between parameters) is an important source of bias in uncertainty analyses.

5.5 Effect of other uncertainties on the spatial 90th percentile of the leaching concentration

This study assumed that the Dutch 1 : 50 000 soil map was free of errors. However, it is well known that soil map units are to a higher or lesser degree impure, with impurities that are typically 30 per cent or greater (Marsman and De Gruijter, 1986; Brus et al., 1992; Visschers et al., 2007). To keep things simple at first instance, uncertainty about the soil map was ignored, which means that the contribution of the uncertainty about the basic soil properties to the total uncertainty about the pesticide leaching is underestimated. In order to include the effect of uncertainty in soil type, it is necessary to characterise it using a probabilistic model, similar to what was done in this study for the quantitative soil and pesticide properties. However, the difficulty is that soil type is a categorical variable. Although approaches to statistical modelling of uncertain spatially distributed categorical variables exist (Brus and Heuvelink, 2007), these approaches should be developed further for their ability to quantify the effect of soil map purity on model output.

The analysis reported here is limited to the propagation of input errors. Another major source of error is caused by the generalised way in which processes are represented by the model (the model error, also referred to as conceptual error (Loague and Corwin, 1996). One way to get insight into the model error is to simulate field leaching data. Previous studies have shown that a perfect fit to experimental field leaching data has rarily been achieved, particularly if the model is not calibrated (Van den Bosch and Boesten, 1994; Tiktak et al., 1998; Vanclooster et al., 2003). GeoPEARL operates at the national scale, so comparison with nationwide groundwater monitoring datasets would be preferable. So far, only a few such studies have been carried out (e.g. Tiktak et al., 2005), and results were only qualitative. The current working group 'Validation of the Decision Tree Leaching' makes monitoring data available for a series of relevant pesticides, so that GeoPEARL can be confronted with nationwide monitoring data in the near future. These data can, in combination with the findings reported here, provide a good basis for further debate on the target percentile. It should be noted, however, that the choice of the target spatial percentile is a political choice (i.e. risk management). The only role of scientists is to feed decision makers with appropriate information (Van der Sluijs et al., 2003).

In this study only the uncertainty propagation of soil and pesticide parameters was studied. These variables were chosen *a-priori*, based on results from earlier studies. There is, however, also uncertainty in other input data, such as the bottom boundary condition, the dispersion length, land use data and drainage data. It would be of interest to study the effect of these uncertainties on the spatial 90 percentile of leaching concentrations. In this way an overall view would be obtained of the effect of all uncertainties. This would be useful to identify the weakest parts of the GeoPEARL model chain and to prioritize further improvements.

As GeoPEARL requires a lot of computation time, it is recommended to check whether part of the analyses could be done with a simpler model. A prerequisite is that the simple model captures the most important processes and shows the same behaviour as the complex model. A metamodel – a statistical representation of the complex model – may be suitable for this purpose. An example is the metamodel described by Tiktak et al. (2006).

5.6 Proposal of a strategy to reduce the uncertainty of the current GeoPEARL simulations

The degradation half-life is by far the most important source of uncertainty of both the PEC50 at individual locations and the spatial P90. Strategies to reduce the overall uncertainty should therefore first be directed towards obtaining better estimates of the degradation half-life and its dependence on soil type. This would require measurements on this parameter in different soil types under prevailing field conditions, as well as a method to quantify the effect of relevant soil parameters on the degradation half-life. It is generally accepted that variability of the degradation half-life is caused to a large extent by properties that affect the microbial population (Walker and Brown, 1983). Description of pesticide degradation could benefit from experimental research into the interaction of soil properties, microbial activity and pesticides.

The soil data for the uncertainty analysis in this study were obtained from the Dutch Soil Information System (BIS). There are almost 250 000 additional soil analyses available in the TAGA-archives (Ehlert et al., 2002), which are currently being digitized. As many of the analyses include geo-referenced organic matter observations, combination of TAGA-data with BIS gives the opportunity to improve the description of variability of organic matter (and thus reduce the uncertainty of the predicted leaching concentration). The storage of TAGA-data into BIS probably also enhances the study of correlation structures within and between soil mapping units and the analysis of its effect on uncertainty of the predicted leaching concentration.

In this study, the spatial distribution of the soil organic matter content was completely determined by that of soil type, causing a strong resemblance between the PEC50 spatial pattern and that of the 1 : 50 000 soil map. In reality, the spatial distribution of soil organic matter content differs from that of soil type because soil organic matter content varies within soil mapping units and is correlated across unit boundaries. Geostatistical approaches such as regression kriging (Brus and Heuvelink, 2007) may be used to combine soil map information and soil organic matter content point observations to produce more accurate maps of soil organic matter content, thus yielding an improved spatial pattern of PEC50.

6 Conclusions and recommendations

6.1 Conclusions

Use of simplified spatial schematisation in GeoPEARL
For model predictions at the national scale, the current GeoPEARL schematisation is sufficient. For smaller areas, the SP90 substantially differs between the simplified and detailed soil schematisations.

Uncertainties in PEC50 and SP90 caused by uncertainty in soil and pesticide characteristics
The uncertainty propagation from soil and pesticide properties to PEC50 is large. The width of the interquartile range is approximately 150% of the median PEC50 for pesticides A and B and 500% for pesticide D. The national database that is used by GeoPEARL is not suited to make predictions at point locations.

The uncertainty about the spatial P90 – the regulatory endpoint in Dutch pesticide registration – as caused by uncertainty in soil and pesticide properties is smaller than the uncertainty about PEC50 at point locations but it is still comparatively large. The width of the interquartile range is 15% of the median spatial P90 for pesticides A and B and approximately 40% for pesticide D.

The spatial pattern of pesticide leaching (PEC50) is determined to a large extent by the soil organic matter map. Errors on this map contribute to the uncertainty in the median leaching concentrations.

When uncertainty of pesticide and soil properties is considered, the spatial P90 is shifted towards higher values.

The degradation half-life is by far the most important source of uncertainty of both the PEC50 at individual locations and the spatial P90. The contributions of the sorption coefficient (K_{om}) and organic matter to the total uncertainty in PEC50 are smaller, but substantial. The contribution of uncertainty in texture and soil physical properties to the total uncertainty is generally small and varies with location.

The contribution of uncertainties in model inputs to uncertainties in PEC50 was found to be pesticide dependent. The contribution of organic matter and the sorption coefficient to the total uncertainty was computed to be small for the weakly sorbing pesticide and large for the moderately sorbing pesticides.

6.2 Recommendations

Use of detailed spatial schematisation in GeoPEARL
The course spatial schematisation used in current GeoPEARL studies is adequate for nationwide studies and need not be refined. For the assessment of leaching of pesticides to groundwater in comparatively small areas (up to about a few hundred km^2), it is recommended to use the detailed soil schematisation.

The improved physical-chemical soil map could be important input for models operating at a more detailed spatial scale, such as the new Netherlands Hydrological Instrument (NHI). This instrument is currently being developed by Alterra, Deltares and PBL.

Uncertainties in PEC50 and SP90 and possible options to reduce these uncertainties
The PEC50 for a pesticide at point locations calculated with GeoPEARL using the current national soil database is very uncertain and can therefore not be used for evaluating measures at a local scale.

The large shift of the mean of the SP90 towards larger values when taking uncertainty into account must be carefully assessed.

Strategies to reduce the overall uncertainty should be directed towards obtaining better estimates of the degradation half-life and its dependence on soil type. This would require measurements of this parameter in different soil types under prevailing field conditions, as well as a method to quantify the effect of relevant soil parameters on the degradation half-life.

The soil organic matter map can be improved by including the soil data in the TAGA-archives. This will result in a more accurate soil organic matter map and will yield improved spatial patterns of PEC50.

The assessment of the uncertainty in soil properties on leaching concentrations could be improved by inclusion of the vertical spatial correlation, i.e. between soil layers. Before this can be done, statistical models and software that describe this correlation need to be improved.

For an overall assessment of the effect of uncertainties in the model input on the target output, uncertainty in other input data, such as the bottom boundary condition, the dispersion length, land use data and drainage data should be investigated. From an overall view on the effect of all sources of uncertainty, the weakest parts of the GeoPEARL model chain can be identified and a prioritization can be presented for further improvement of the model.

To get more insight into the model error, comparison with nationwide groundwater monitoring datasets is necessary. The current working group 'Validation of the Decision Tree Leaching' makes monitoring data available for a series of relevant pesticides and these data can be used to assess the performance of GeoPEARL.

As GeoPEARL requires a lot of computation time, it is recommended to check whether part of the analyses could be done with a simpler model.

The results of this report provide a good basis for further debate on the target percentile. It should be noted, however, that the choice of the target spatial percentile is a political choice (i.e. risk management). The role of scientists consists of supplying the decision makers with appropriate information.

Acknowledgements

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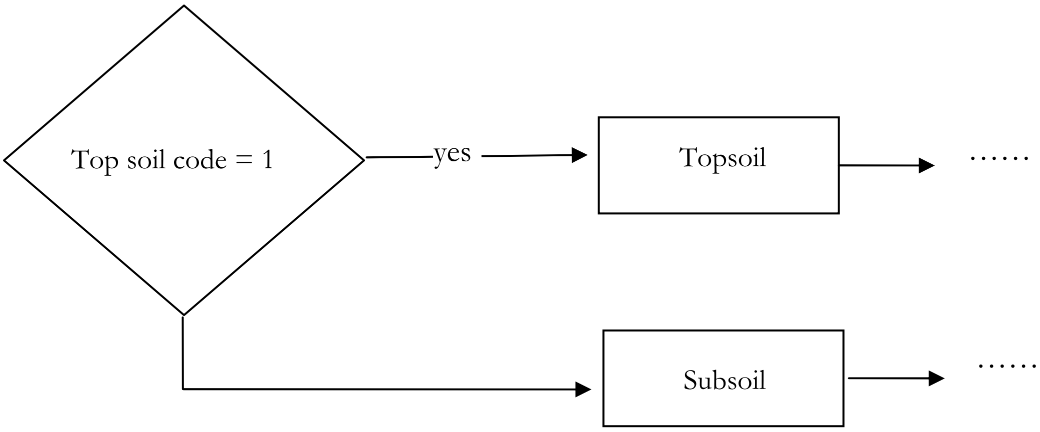
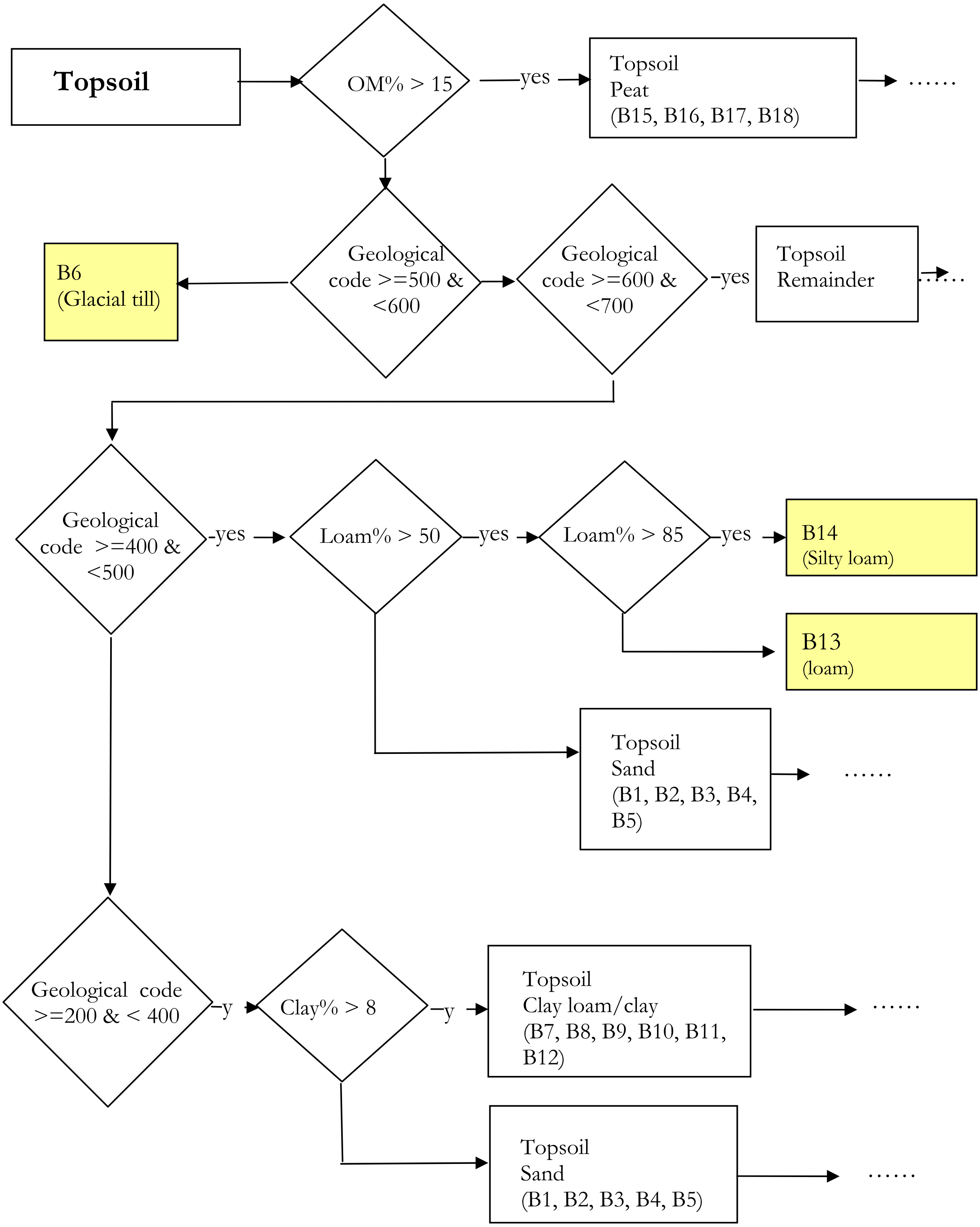
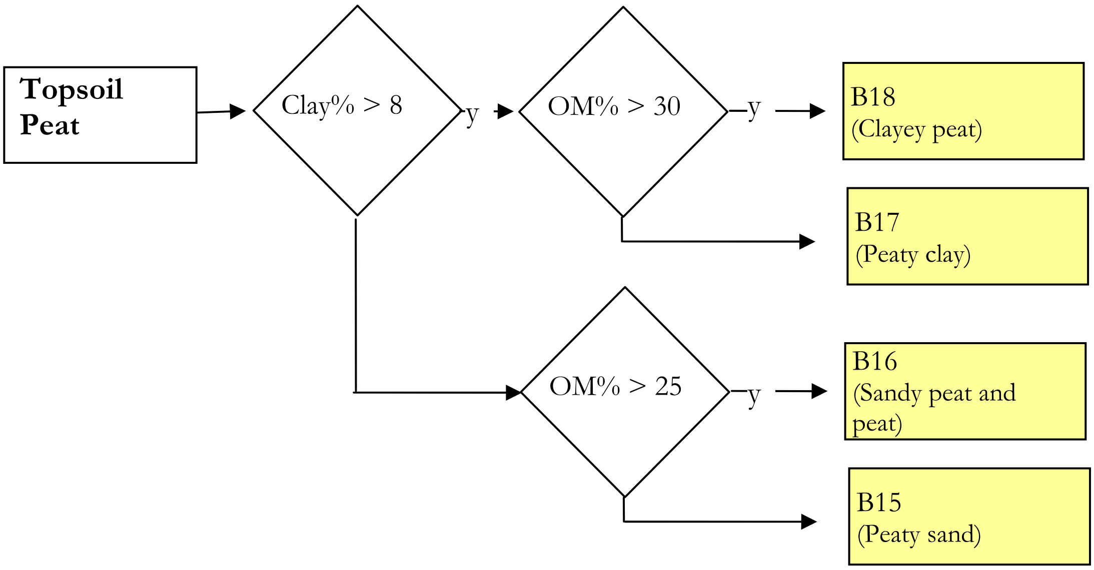
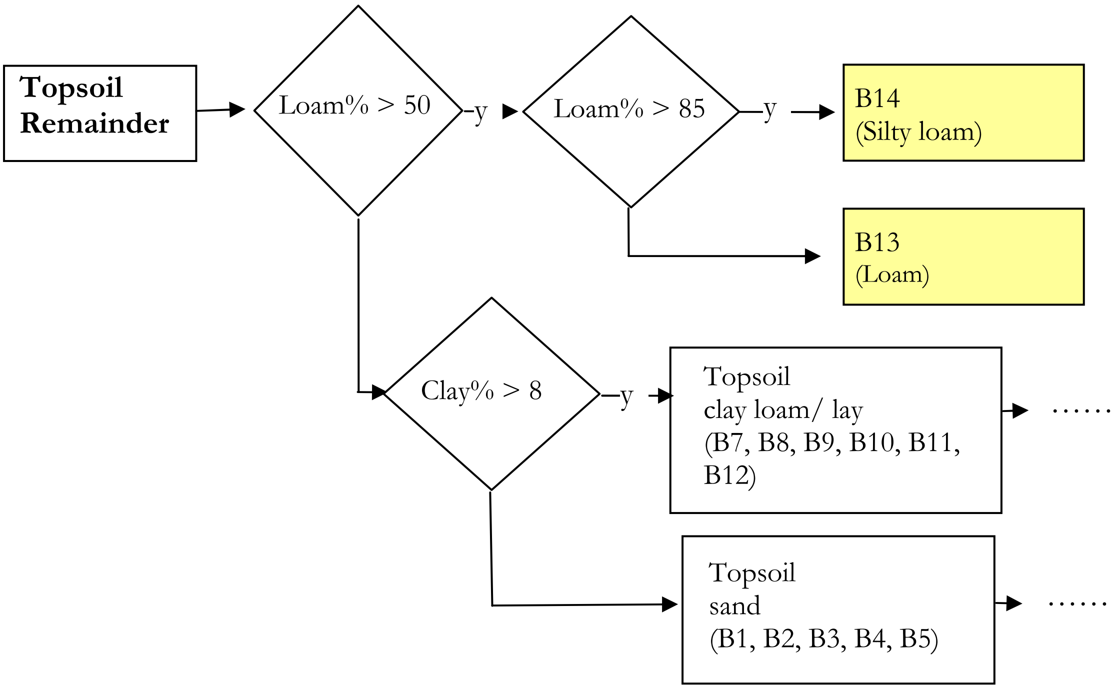
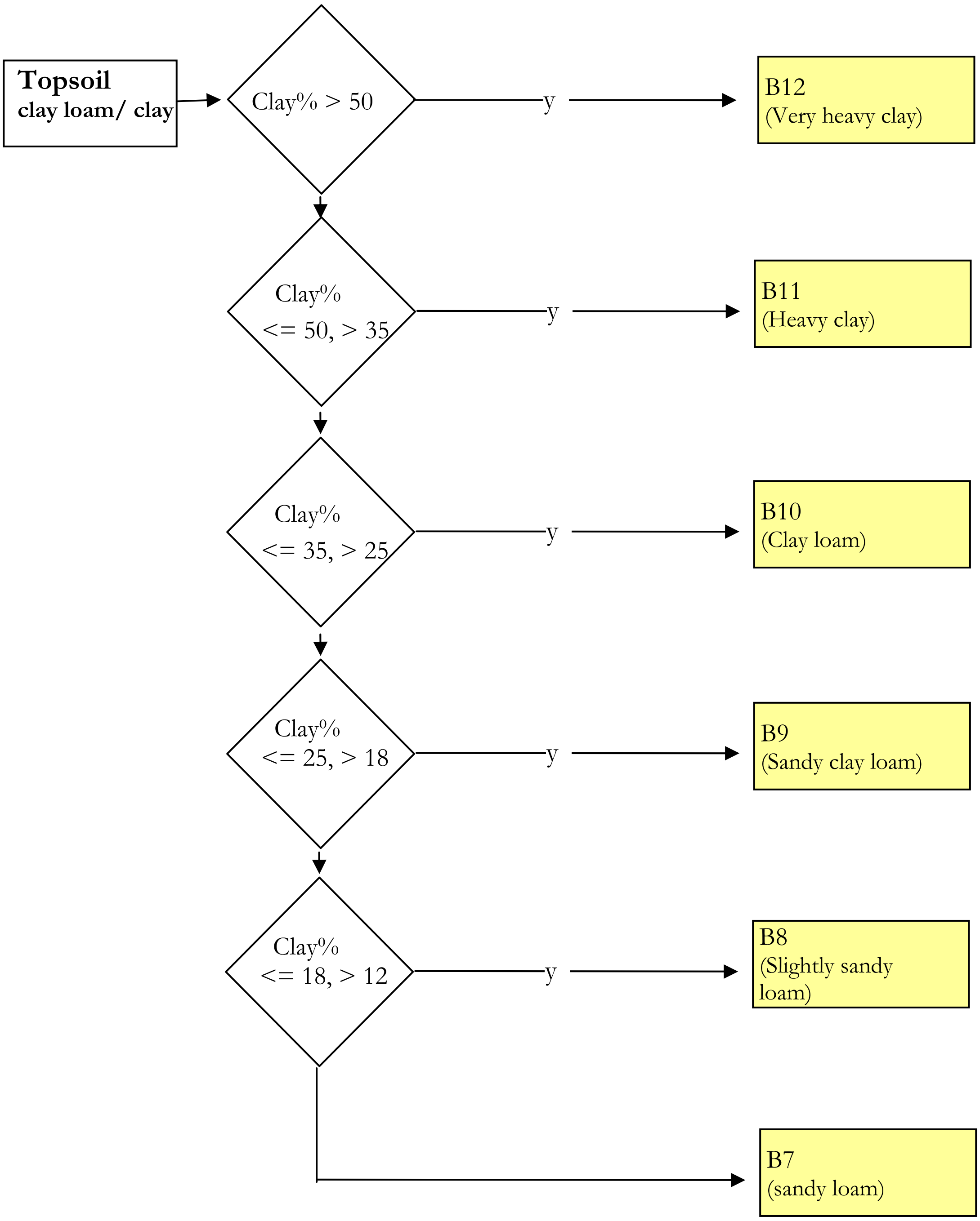
Appendix 1 Classification tree Staring series building blocks

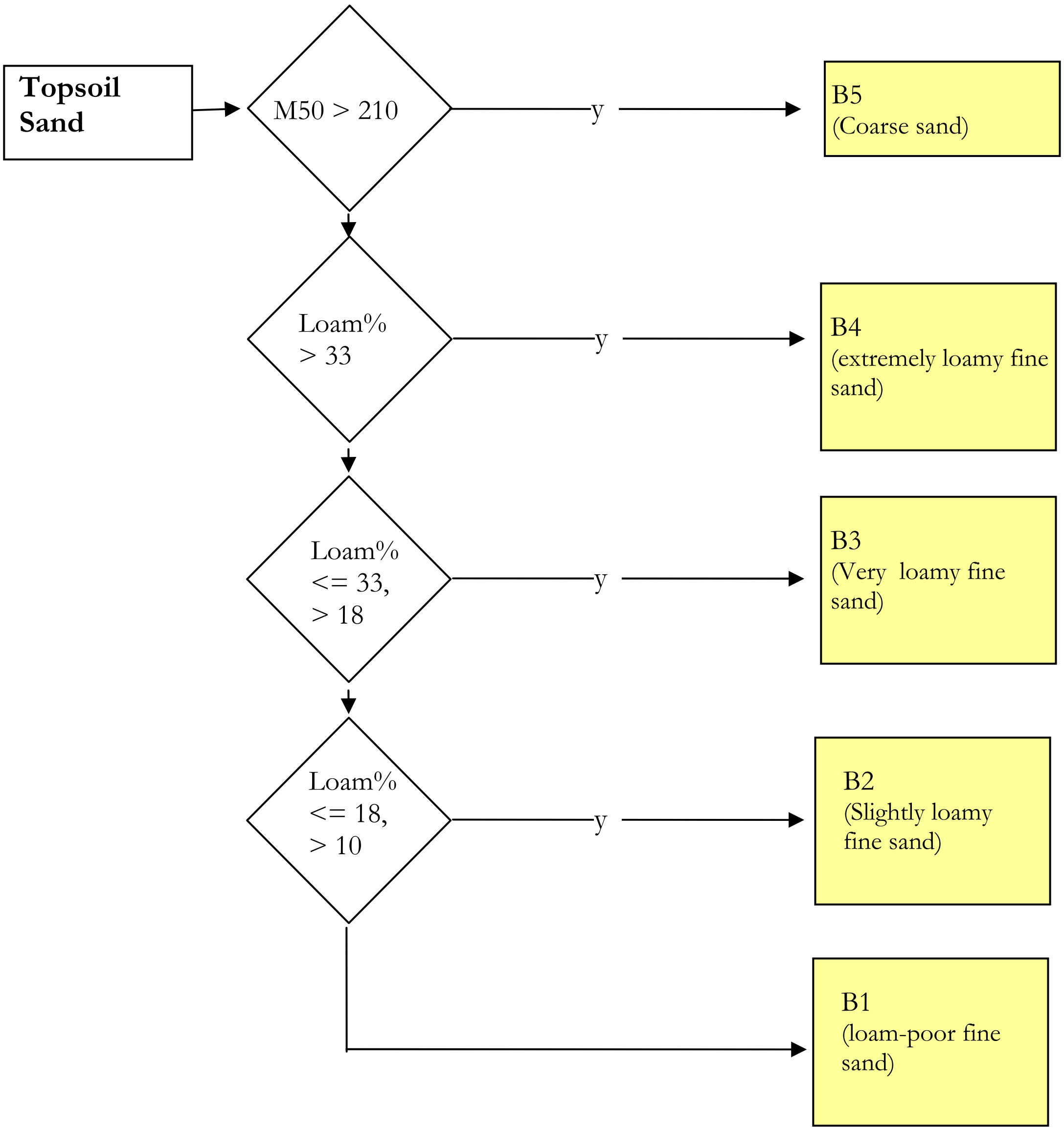


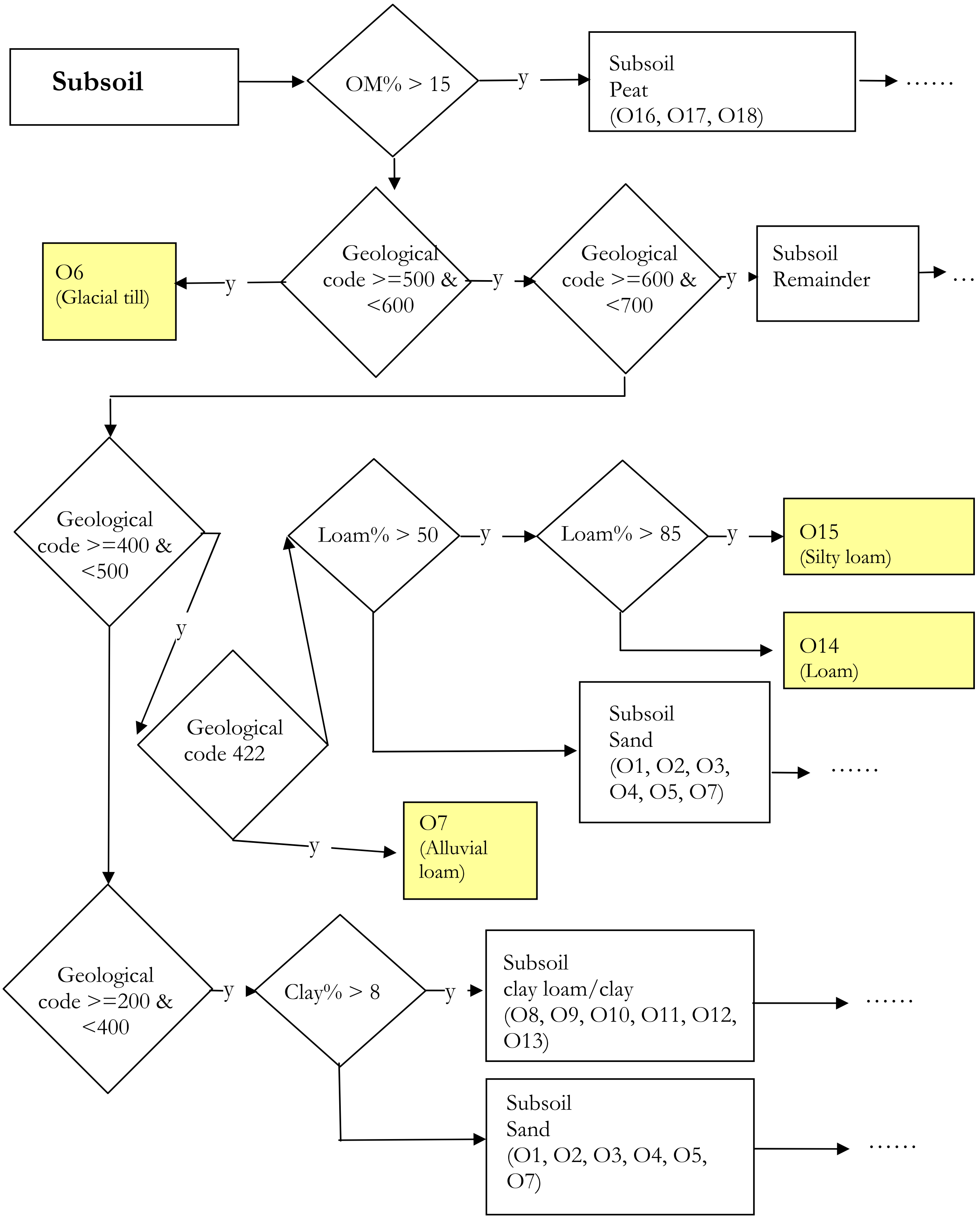

Topsoil
OM% > 15
yes
Topsoil
Peat
(B15, B16, B17, B18)
……
B6
(Glacial till)
Geological code >=500 & <600
Geological code >=600 & <700
yes
Topsoil
Remainder
……
Geological code >=400 & <500
yes
Loam% > 50
yes
Loam% > 85
yes
B14
(Silty loam)
B13
(loam)
Topsoil
Sand
(B1, B2, B3, B4, B5)
……
Geological code >=200 & < 400
y
Clay% > 8
y
Topsoil
Clay loam/clay
(B7, B8, B9, B10, B11, B12)
……
Topsoil
Sand
(B1, B2, B3, B4, B5)
……

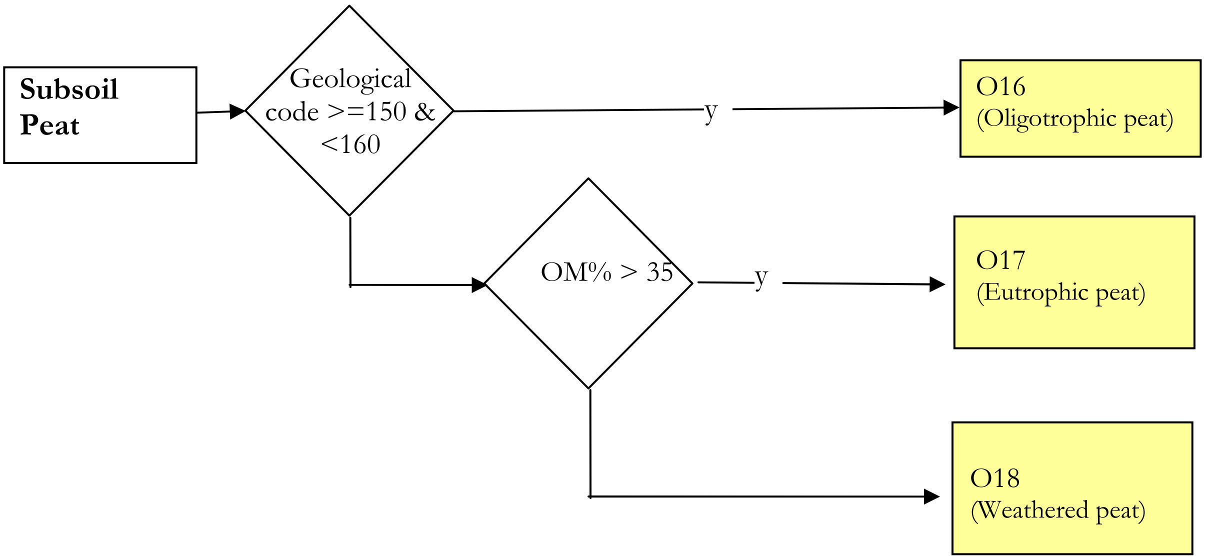

Topsoil Peat
Clay% > 8
y
OM% > 30
y
B18 (Clayey peat)
B17 (Peaty clay)
OM% > 25
y
B16 (Sandy peat and peat)
B15 (Peaty sand)

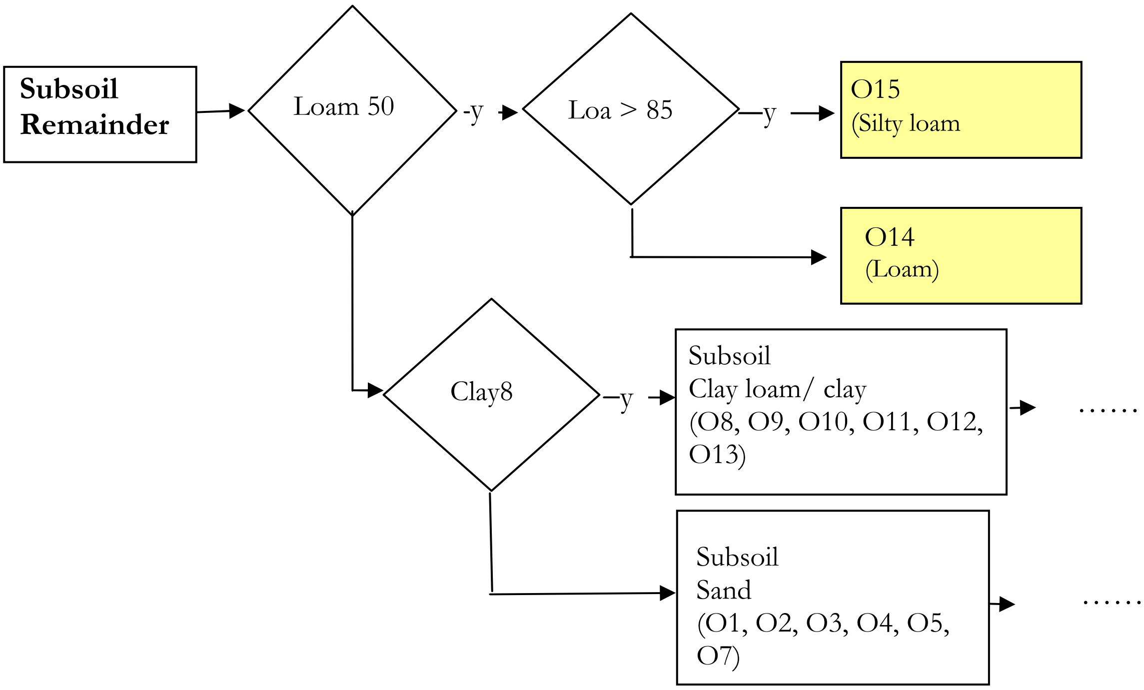

Topsoil Remainder
Loam% > 50
y
Loam% > 85
y
B14 (Silty loam)
B13 (Loam)
Clay% > 8
y
Topsoil clay loam/ lay (B7, B8, B9, B10, B11, B12)
……
Topsoil sand (B1, B2, B3, B4, B5)
……

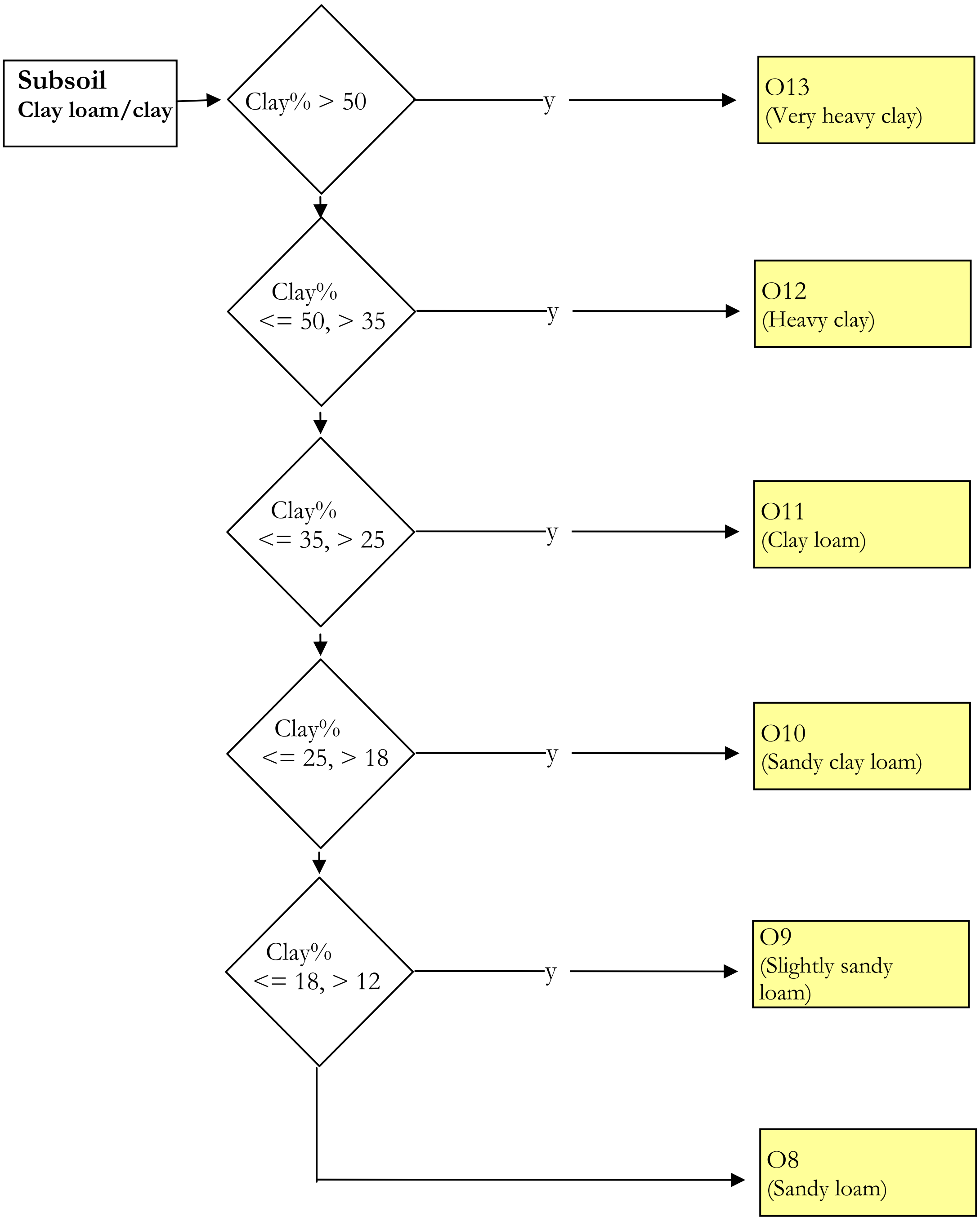

Topsoil
clay loam/ clay
Clay% > 50
y
B12
(Very heavy clay)
Clay%
<= 50, > 35
y
B11
(Heavy clay)
Clay%
<= 35, > 25
y
B10
(Clay loam)
Clay%
<= 25, > 18
y
B9
(Sandy clay loam)
Clay%
<= 18, > 12
y
B8
(Slightly sandy loam)
B7
(sandy loam)

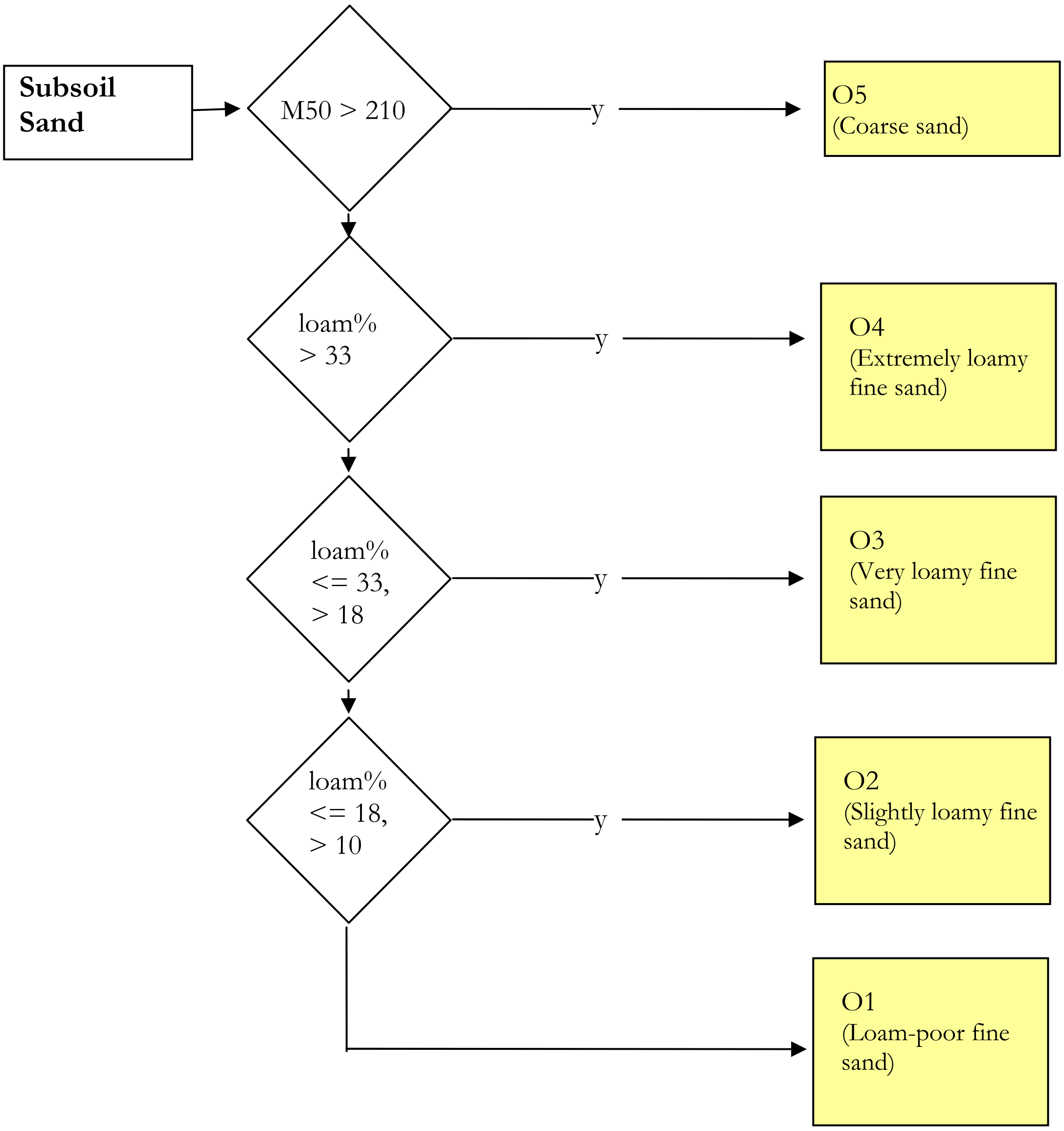

Topsoil
Sand
M50 > 210
y
B5
(Coarse sand)
Loam%
> 33
y
B4
(extremely loamy fine sand)
Loam%
<= 33,
> 18
y
B3
(Very loamy fine sand)
Loam%
<= 18,
> 10
y
B2
(Slightly loamy fine sand)
B1
(loam-poor fine sand)


Subsoil
OM% > 15
y
Subsoil
Peat
(O16, O17, O18)
……
O6
(Glacial till)
y
Geological code >=500 & <600
y
Geological code >=600 & <700
y
Subsoil
Remainder
…
Geological code >=400 & <500
y
Geological code 422
Loam% > 50
y
Loam% > 85
y
O15
(Silty loam)
O14
(Loam)
Subsoil
Sand
(O1, O2, O3, O4, O5, O7)
……
y
O7
(Alluvial loam)
Geological code >=200 & <400
y
Clay% > 8
y
Subsoil
clay loam/clay
(O8, O9, O10, O11, O12, O13)
……
Subsoil
Sand
(O1, O2, O3, O4, O5, O7)
……


Subsoil Peat
Geological code >=150 & <160
y
O16 (Oligotrophic peat)
OM% > 35
y
O17 (Eutrophic peat)
O18 (Weathered peat)


Subsoil Remainder
Loam 50
-y
Loa > 85
y
O15 (Silty loam
O14 (Loam)
Clay8
y
Subsoil Clay loam/ clay (O8, O9, O10, O11, O12, O13)
……
Subsoil Sand (O1, O2, O3, O4, O5, O7)
……


Subsoil
Clay loam/clay
Clay% > 50
y
O13
(Very heavy clay)
Clay%
<= 50, > 35
y
O12
(Heavy clay)
Clay%
<= 35, > 25
y
O11
(Clay loam)
Clay%
<= 25, > 18
y
O10
(Sandy clay loam)
Clay%
<= 18, > 12
y
O9
(Slightly sandy loam)
O8
(Sandy loam)


Subsoil Sand
M50 > 210
y
O5
(Coarse sand)
loam%
> 33
y
O4
(Extremely loamy fine sand)
loam%
<= 33,
> 18
y
O3
(Very loamy fine sand)
loam%
<= 18,
> 10
y
O2
(Slightly loamy fine sand)
O1
(Loam-poor fine sand)

Appendix 2 Example SOL file

```
*-------------------------------------------------------------------------------
*
* SOIL DATABASE FOR THE NETHERLANDS
* =================================
*
* File containing the soil database for the Netherlands.
* The first part of the file contains paramters that are assumed to be spatially
* constant. The second part of the file contains the spatially distributed
* parameters.
*
*-------------------------------------------------------------------------------
* Soil evaporation
Black      OptSolEvp                    Use the Black option for soil evaporation
0.005      PrcMinEvp          (m.d-1)   Minimum rainfall to reset Black model
0.35       CofRedEvp          (cm1/2)   Reduction parameter in Black equation
1.0        FacEvpSol          (-)       "Crop" factor for soil evaporation
*-------------------------------------------------------------------------------
* Dispersion length and relative diffusion coefficient
* GeoPEARL only supports the Millington Quirk option!
2.0               ExpDifLiqMilNom (-)         Exponent in nominator of equation [0.1|5]
0.67              ExpDifLiqMilDen (-)         Exponent in denominator of eqn    [0.1|2]
2.0               ExpDifGasMilNom (-)         Exponent in nominator of equation [0.1|5]
0.67              ExpDifGasMilDen (-)         Exponent in denominator of eqn    [0.1|2]
*-------------------------------------------------------------------------------
* Depth dependence of transformation
table FacZTra (-)
0.00  1.00
0.30  1.00
0.31  0.50
0.60  0.50
0.61  0.30
1.00  0.30
1.01  0.00
50.00 0.00
end_table
*-------------------------------------------------------------------------------
* Depth dependence of sorption
table FacZSor (-)
```

```
0.00  1.00
0.30  1.00
0.31  1.00
0.60  1.00
0.61  1.00
1.00  1.00
1.01  1.00
50.00 1.00
end_table
*--------------------------------------------------------------------------------
* Column 1  :  Soil profile number
* Column 2  :  Soil horizon number
* Column 3  :  Horizon thickness (m)
* Column 4  :  Number of numerical soil compartments
* Column 5  :  Sand fraction (kg.kg-1) as part of mineral soil
* Column 6  :  Silt fraction (kg.kg-1) as part of mineral soil
* Column 7  :  Clay fraction (kg.kg-1) as part of mineral soil
* Column 8  :  Organic matter content (kg.kg-1)
* Column 9  :  pH-KCl
* Column 10 :  Saturated soil water content (m3.m-3)
* Column 11 :  Residual water content (m3.m-3)
* Column 12 :  Parameter alpha (dry) (cm-1)
* Column 13 :  Parameter alpha (wet) (cm-1)
* Column 14 :  Parameter n (-)
* Column 15 :  Saturated hydraulic conductivity (m.d-1)
* Column 16 :  Physical saturated hydraulic conductivity (m.d-1)
* Column 17 :  Parameter L (-)
* Column 18 :  Dispersion length (m)
* Column 19 :  Sesqui-oxide content (mmol.kg-1)

table SoilProfiles
1       1       0.05    5      0.35    0.224  0.426   0.34   4.5     0.77   0   0.0197  0.0197 1.154   0.0667 0.0667  -1.845 0.05  286
1       2       0.1     4      0.35    0.224  0.426   0.344  4.5     0.77   0   0.0197  0.0197 1.154   0.0667 0.0667  -1.845 0.05  286
1       3       0.05    1      0.091   0.563  0.346   0.381  4.5     0.77   0   0.0197  0.0197 1.154   0.0667 0.0667  -1.845 0.05  286
1       4       0.05    1      0.2     0.4    0.4     0.707  3.9     0.77   0   0.0197  0.0197 1.154   0.0667 0.0667  -1.845 0.05  263
1       5       0.1     2      0.2     0.4    0.4     0.707  3.9     0.77   0   0.0197  0.0197 1.154   0.0667 0.0667  -1.845 0.05  263
1       6       0.15    3      0.2     0.4    0.4     0.764  3.5     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.05  287
1       7       0.1     2      0.13    0.65   0.22    0.764  3.5     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.05  287
1       8       0.15    3      0.13    0.65   0.22    0.763  3.3     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.05  2.2
1       9       1       10     0.868   0.086  0.046   0.589  3.7     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.05  1.9
1       10      0.25    3      0.868   0.086  0.046   0.589  3.7     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.25  1.9
1       11      11      22     0.868   0.086  0.046   0.589  3.7     0.86   0   0.0127  0.0127 1.274   0.0275 0.0275  -1.832 0.25  1.9
```

Appendix 3 Parameters of the fitted lognormal distributions for organic matter content

Parameters of the fitted lognormal distributions for organic matter content for all locations and horizons. The fit parameters are chosen such that the median (p50) is identical to that reported in de Vries (1999). Minima and maxima from de Vries (1999) are also presented.

loc	number of location in grid sample
lay	horizon number (1=top horizon)
log_mu	mean of log-transformed organic matter (fit parameter)
log_sd	standard deviation of log-transformed organic matter (fit parameter)
min	minimum of organic matter (de Vries 1999)
p10	10-quantile of organic matter probability distribution function (pdf, computed from fit parameters)
p50	median of organic matter pdf (computed from fit parameters)
p90	90-quantile of organic matter pdf (computed from fit parameters)
max	maximum of organic matter (de Vries 1999)

loc	lay	log_mu	log_sd	min	p10	p50	p90	max
1	1	1.253	0.782	0.90	1.29	3.50	9.53	8.40
1	2	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
1	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
2	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
2	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
2	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
3	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
3	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
3	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
4	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
4	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
4	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
5	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
5	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
5	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
6	1	2.079	0.261	3.80	5.73	8.00	11.17	10.50
6	2	1.386	0.541	1.90	2.00	4.00	7.99	8.40
6	3	1.030	0.393	1.90	1.69	2.80	4.63	8.40
6	4	0.095	0.161	0.90	0.90	1.10	1.35	5.30
6	5	0.095	0.161	0.90	0.90	1.10	1.35	5.30
7	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
7	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
7	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
8	1	1.792	0.551	1.90	2.96	6.00	12.15	10.50
8	2	0.693	0.541	0.90	1.00	2.00	4.00	4.20
8	3	0.000	0.668	0.40	0.43	1.00	2.35	3.20
8	4	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
8	5	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
9	1	2.197	0.551	2.90	4.45	9.00	18.22	15.80
9	2	1.386	0.541	1.90	2.00	4.00	7.99	8.40
9	3	0.095	0.691	0.40	0.45	1.10	2.66	3.20
9	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
10	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
10	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
10	3	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
10	4	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
11	1	2.079	0.261	3.80	5.73	8.00	11.17	10.50
11	2	1.386	0.541	1.90	2.00	4.00	7.99	8.40
11	3	1.030	0.393	1.90	1.69	2.80	4.63	8.40
11	4	0.095	0.161	0.90	0.90	1.10	1.35	5.30
11	5	0.095	0.161	0.90	0.90	1.10	1.35	5.30
12	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20

```
12   2  0.182  0.508  0.40  0.63  1.20   2.30  2.10
12   3 -0.511  0.897  0.10  0.19  0.60   1.89  2.10
13   1  0.916  0.491  0.90  1.33  2.50   4.69  4.20
13   2  0.182  0.699  0.40  0.49  1.20   2.94  3.20
13   3 -0.223  0.541  0.40  0.40  0.80   1.60  3.20
13   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
14   1  1.792  0.354  3.80  3.82  6.00   9.43 10.50
14   2  0.336  0.811  0.40  0.50  1.40   3.95  4.20
14   3 -0.511  0.217  0.40  0.45  0.60   0.79  2.10
15   1  3.219  0.444 15.00 14.16 25.00  44.13 60.00
15   2  4.094  0.316 30.00 40.02 60.00  89.96 95.00
15   3  1.099  0.897  0.50  0.95  3.00   9.45 15.00
15   4  1.609  0.765  0.50  1.88  5.00  13.31 12.00
15   5  0.000  0.765  0.30  0.38  1.00   2.66  6.00
15   6 -0.916  0.765  0.10  0.15  0.40   1.06  3.00
16   1  1.609  0.461  2.50  2.77  5.00   9.02 11.00
16   2  1.548  0.443  2.50  2.66  4.70   8.29 11.00
16   3  0.588  0.588  0.50  0.85  1.80   3.82  6.00
16   4 -0.357  0.396  0.10  0.42  0.70   1.16  1.50
16   5 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
17   1  0.693  0.541  0.90  1.00  2.00   4.00  4.20
17   2  0.182  0.508  0.40  0.63  1.20   2.30  2.10
17   3 -0.511  0.897  0.10  0.19  0.60   1.89  2.10
18   1  1.792  0.551  1.90  2.96  6.00  12.15 10.50
18   2  1.386  0.403  1.90  2.39  4.00   6.70  6.30
18   3  0.405  0.809  0.40  0.53  1.50   4.23  4.20
18   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
18   5  0.405  0.668  0.40  0.64  1.50   3.53  3.20
19   1  2.197  0.551  2.90  4.45  9.00  18.22 15.80
19   2  1.386  0.541  1.90  2.00  4.00   7.99  8.40
19   3  0.095  0.691  0.40  0.45  1.10   2.66  3.20
19   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
20   1  3.401  0.264 17.00 21.40 30.00  42.05 45.00
20   2  3.807  0.330 25.00 29.49 45.00  68.66 80.00
20   3  1.099  0.897  0.50  0.95  3.00   9.45 12.00
20   4  0.693  0.765  0.50  0.75  2.00   5.32 12.00
21   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
21   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
21   3  0.000  0.618  0.20  0.45  1.00   2.21  2.50
21   4 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
22   1  2.197  0.125  3.80  7.67  9.00  10.56 10.50
22   2  1.386  0.403  1.90  2.39  4.00   6.70  6.30
22   3  0.588  0.774  0.40  0.67  1.80   4.85  4.20
22   4  0.095  0.771  0.40  0.41  1.10   2.95  4.20
22   5  4.317  0.140 52.30 62.66 75.00  89.77 89.30
23   1  0.916  0.491  0.90  1.33  2.50   4.69  4.20
23   2  0.182  0.699  0.40  0.49  1.20   2.94  3.20
23   3 -0.223  0.541  0.40  0.40  0.80   1.60  3.20
23   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
24   1  2.197  0.305  4.80  6.09  9.00  13.30 12.60
24   2  1.609  0.382  2.90  3.07  5.00   8.15  8.40
24   3  0.693  0.618  0.90  0.91  2.00   4.41  5.30
24   4  0.095  0.161  0.90  0.90  1.10   1.35  5.30
24   5 -0.223  0.554  0.40  0.39  0.80   1.63  4.20
25   1  2.197  0.305  4.80  6.09  9.00  13.30 12.60
25   2  1.609  0.382  2.90  3.07  5.00   8.15  8.40
25   3  0.693  0.618  0.90  0.91  2.00   4.41  5.30
25   4  0.095  0.161  0.90  0.90  1.10   1.35  5.30
25   5 -0.511  0.897  0.10  0.19  0.60   1.89  2.10
26   1  1.609  0.461  2.50  2.77  5.00   9.02 11.00
26   2  1.548  0.443  2.50  2.66  4.70   8.29 11.00
26   3  0.588  0.588  0.50  0.85  1.80   3.82  6.00
26   4 -0.357  0.396  0.10  0.42  0.70   1.16  1.50
26   5 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
27   1  2.197  0.436  1.00  5.15  9.00  15.73 15.00
27   2  4.094  0.403 25.00 35.82 60.00 100.52 95.00
27   3  1.099  0.897  0.50  0.95  3.00   9.45 12.00
27   4  1.504  0.823  0.50  1.57  4.50  12.91 12.00
27   5  0.693  0.867  0.20  0.66  2.00   6.06  6.00
27   6 -1.204  0.482  0.10  0.16  0.30   0.56  3.00
28   1  1.609  0.461  2.50  2.77  5.00   9.02 11.00
28   2  1.548  0.443  2.50  2.66  4.70   8.29 11.00
28   3  0.588  0.588  0.50  0.85  1.80   3.82  6.00
28   4 -0.357  0.396  0.10  0.42  0.70   1.16  1.50
28   5 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
29   1  3.555  0.270 15.00 24.77 35.00  49.46 90.00
29   2  3.912  0.319 25.00 33.25 50.00  75.18 90.00
29   3  4.317  0.215 35.00 56.95 75.00  98.77 95.00
29   4  4.382  0.140 35.00 66.88 80.00  95.69 95.00
30   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
30   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
30   3  0.000  0.618  0.20  0.45  1.00   2.21  2.50
30   4 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
31   1  1.253  0.595  0.90  1.63  3.50   7.49  6.30
```

31	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
31	3	0.405	0.668	0.40	0.64	1.50	3.53	3.20
31	4	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
32	1	0.405	0.515	0.70	0.78	1.50	2.90	3.20
32	2	-0.916	0.618	0.10	0.18	0.40	0.88	1.10
32	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
32	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
33	1	2.197	0.305	4.80	6.09	9.00	13.30	12.60
33	2	1.609	0.382	2.90	3.07	5.00	8.15	8.40
33	3	0.693	0.618	0.90	0.91	2.00	4.41	5.30
33	4	0.095	0.161	0.90	0.90	1.10	1.35	5.30
33	5	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
34	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
34	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
34	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
34	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
35	1	2.197	0.305	4.80	6.09	9.00	13.30	12.60
35	2	1.609	0.382	2.90	3.07	5.00	8.15	8.40
35	3	0.693	0.618	0.90	0.91	2.00	4.41	5.30
35	4	0.095	0.161	0.90	0.90	1.10	1.35	5.30
35	5	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
36	1	3.689	0.403	15.00	23.88	40.00	67.01	70.00
36	2	4.248	0.150	35.00	57.74	70.00	84.86	95.00
36	3	4.443	0.068	35.00	77.92	85.00	92.72	99.00
36	4	-0.693	1.032	0.10	0.13	0.50	1.87	8.00
37	1	1.723	0.469	2.50	3.07	5.60	10.21	11.00
37	2	1.609	0.461	2.50	2.77	5.00	9.02	11.00
37	3	0.588	0.889	0.10	0.58	1.80	5.62	6.00
37	4	-0.916	0.618	0.10	0.18	0.40	0.88	1.50
37	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
38	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
38	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
38	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
38	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
38	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
39	1	3.555	0.270	15.00	24.77	35.00	49.46	60.00
39	2	4.317	0.149	20.00	62.00	75.00	90.73	95.00
39	3	4.382	0.075	20.00	72.64	80.00	88.10	95.00
39	4	-0.693	1.060	0.10	0.13	0.50	1.94	12.00
40	1	1.609	0.385	1.50	3.05	5.00	8.19	8.00
40	2	1.099	0.461	1.00	1.66	3.00	5.41	6.00
40	3	0.405	0.668	0.20	0.64	1.50	3.53	3.50
40	4	0.000	0.618	0.20	0.45	1.00	2.21	2.50
40	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
41	1	2.708	0.341	3.00	9.70	15.00	23.21	25.00
41	2	4.443	0.068	35.00	77.92	85.00	92.72	95.00
41	3	4.407	0.110	35.00	71.27	82.00	94.35	95.00
41	4	2.079	0.421	2.00	4.67	8.00	13.72	25.00
41	5	-0.916	0.822	0.10	0.14	0.40	1.15	8.00
42	1	2.565	0.469	4.00	7.13	13.00	23.70	25.00
42	2	4.443	0.130	45.00	71.96	85.00	100.40	99.00
42	3	4.500	0.064	45.00	82.90	90.00	97.71	99.00
42	4	1.386	0.867	0.50	1.32	4.00	12.13	15.00
42	5	1.609	0.765	0.50	1.88	5.00	13.31	12.00
42	6	0.000	0.765	0.10	0.38	1.00	2.66	6.00
42	7	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
43	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
43	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
43	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
43	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
44	1	1.792	0.551	1.90	2.96	6.00	12.15	10.50
44	2	0.693	0.541	0.90	1.00	2.00	4.00	4.20
44	3	0.000	0.668	0.40	0.43	1.00	2.35	3.20
44	4	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
44	5	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
45	1	2.485	0.508	4.80	6.26	12.00	23.00	21.00
45	2	1.946	0.421	1.90	4.08	7.00	12.00	10.50
45	3	1.099	0.551	0.90	1.48	3.00	6.07	5.30
45	4	3.807	0.264	28.50	32.10	45.00	63.08	63.00
45	5	4.443	0.068	57.00	77.92	85.00	92.72	94.50
46	1	2.996	0.264	8.00	14.27	20.00	28.04	45.00
46	2	2.303	0.403	2.00	5.97	10.00	16.75	20.00
46	3	4.317	0.157	40.00	61.36	75.00	91.68	99.00
46	4	4.500	0.064	40.00	82.90	90.00	97.71	99.00
47	1	3.555	0.274	15.00	24.65	35.00	49.70	90.00
47	2	4.382	0.140	25.00	66.88	80.00	95.69	99.00
47	3	4.443	0.130	25.00	71.96	85.00	100.40	99.00
48	1	3.219	0.444	15.00	14.16	25.00	44.13	55.00
48	2	3.912	0.319	20.00	33.25	50.00	75.18	80.00
48	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
48	4	-0.916	0.820	0.10	0.14	0.40	1.14	6.00
49	1	1.482	0.328	2.50	2.89	4.40	6.70	8.00
49	2	1.361	0.257	2.50	2.81	3.90	5.42	7.00
49	3	0.336	0.686	0.20	0.58	1.40	3.37	3.50

49	4	-0.511	0.461	0.10	0.33	0.60	1.08	1.50
49	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
50	1	3.555	0.270	15.00	24.77	35.00	49.46	90.00
50	2	3.912	0.319	25.00	33.25	50.00	75.18	90.00
50	3	4.317	0.215	35.00	56.95	75.00	98.77	95.00
50	4	4.382	0.140	35.00	66.88	80.00	95.69	95.00
51	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
51	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
51	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
51	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
52	1	3.555	0.270	15.00	24.77	35.00	49.46	60.00
52	2	4.317	0.149	20.00	62.00	75.00	90.73	95.00
52	3	4.382	0.075	20.00	72.64	80.00	88.10	95.00
52	4	-0.693	1.060	0.10	0.13	0.50	1.94	12.00
53	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
53	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
53	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
53	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
54	1	1.504	0.330	2.50	2.95	4.50	6.87	8.00
54	2	1.253	0.745	0.50	1.35	3.50	9.09	8.00
54	3	0.095	0.786	0.20	0.40	1.10	3.01	3.50
54	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
55	1	2.996	0.403	5.00	11.94	20.00	33.51	40.00
55	2	1.946	0.369	1.00	4.37	7.00	11.22	20.00
55	3	4.317	0.157	35.00	61.36	75.00	91.68	95.00
55	4	1.099	0.809	0.50	1.06	3.00	8.45	12.00
55	5	-0.916	0.803	0.10	0.14	0.40	1.12	5.00
56	1	2.485	0.508	3.00	6.26	12.00	23.00	25.00
56	2	2.079	0.421	3.00	4.67	8.00	13.72	20.00
56	3	1.099	0.471	1.00	1.64	3.00	5.48	12.00
56	4	4.174	0.246	18.00	47.45	65.00	89.04	90.00
56	5	2.303	0.541	2.00	5.00	10.00	19.98	25.00
56	6	1.386	0.668	1.00	1.70	4.00	9.41	15.00
56	7	-0.916	0.765	0.10	0.15	0.40	1.06	6.00
57	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
57	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
57	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
57	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
57	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
58	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
58	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
58	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
58	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
59	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
59	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
59	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
59	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
59	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
60	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
60	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
60	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
60	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
60	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
61	1	2.565	0.469	4.00	7.13	13.00	23.70	25.00
61	2	4.443	0.130	45.00	71.96	85.00	100.40	99.00
61	3	4.500	0.064	45.00	82.90	90.00	97.71	99.00
61	4	1.386	0.867	0.50	1.32	4.00	12.13	15.00
61	5	1.609	0.765	0.50	1.88	5.00	13.31	12.00
61	6	0.000	0.765	0.10	0.38	1.00	2.66	6.00
61	7	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
62	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
62	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
62	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
62	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
63	1	1.386	0.628	0.90	1.79	4.00	8.93	7.40
63	2	-0.105	0.530	0.40	0.46	0.90	1.77	2.10
63	3	4.094	0.175	47.50	47.93	60.00	75.11	84.00
63	4	0.693	0.867	0.40	0.66	2.00	6.06	5.30
63	5	0.693	0.867	0.40	0.66	2.00	6.06	5.30
64	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
64	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
64	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
65	1	2.303	0.403	4.80	5.97	10.00	16.75	15.80
65	2	1.099	0.551	0.90	1.48	3.00	6.07	5.30
65	3	0.182	0.854	0.40	0.40	1.20	3.58	5.30
65	4	3.807	0.264	28.50	32.10	45.00	63.08	63.00
65	5	4.443	0.068	57.00	77.92	85.00	92.72	94.50
66	1	3.091	0.257	15.00	15.84	22.00	30.56	50.00
66	2	2.708	0.403	5.00	8.95	15.00	25.13	50.00
66	3	2.996	0.403	5.00	11.94	20.00	33.51	80.00
66	4	4.382	0.098	50.00	70.59	80.00	90.66	99.00
66	5	4.500	0.064	50.00	82.96	90.00	97.64	99.00
67	1	3.497	0.301	15.00	22.44	33.00	48.53	90.00
67	2	4.174	0.088	25.00	58.07	65.00	72.75	99.00

67	3	4.489	0.078	25.00	80.59	89.00	98.28	99.00
68	1	2.197	0.436	1.00	5.15	9.00	15.73	15.00
68	2	4.094	0.403	25.00	35.82	60.00	100.52	95.00
68	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
68	4	1.504	0.823	0.50	1.57	4.50	12.91	12.00
68	5	0.693	0.867	0.20	0.66	2.00	6.06	6.00
68	6	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
69	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
69	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
69	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
69	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
70	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
70	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
70	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
70	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
71	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
71	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
71	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
71	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
71	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
72	1	2.565	0.469	4.00	7.13	13.00	23.70	25.00
72	2	4.443	0.130	45.00	71.96	85.00	100.40	99.00
72	3	4.500	0.064	45.00	82.90	90.00	97.71	99.00
72	4	1.386	0.867	0.50	1.32	4.00	12.13	15.00
72	5	1.609	0.765	0.50	1.88	5.00	13.31	12.00
72	6	0.000	0.765	0.10	0.38	1.00	2.66	6.00
72	7	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
73	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
73	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
73	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
74	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
74	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
74	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
75	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
75	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
75	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
75	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
76	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
76	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
76	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
76	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
77	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
77	2	0.000	0.668	0.40	0.43	1.00	2.35	3.20
77	3	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
77	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
78	1	2.079	0.602	2.00	3.70	8.00	17.29	18.00
78	2	4.248	0.225	25.00	52.51	70.00	93.31	90.00
78	3	4.317	0.149	25.00	62.00	75.00	90.73	90.00
78	4	0.000	1.256	0.10	0.20	1.00	4.99	8.00
79	1	1.253	0.421	0.90	2.04	3.50	6.00	5.30
79	2	-0.511	0.551	0.10	0.30	0.60	1.21	1.10
79	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
79	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
80	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
80	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
80	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
80	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
81	1	1.775	0.541	2.50	2.95	5.90	11.79	13.00
81	2	1.335	1.036	0.50	1.01	3.80	14.32	13.00
81	3	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
81	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
81	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
82	1	1.131	0.450	1.60	1.74	3.10	5.51	8.00
82	2	0.916	0.461	1.10	1.39	2.50	4.51	5.50
82	3	0.336	0.399	0.80	0.84	1.40	2.33	5.50
82	4	-0.105	0.725	0.10	0.36	0.90	2.28	2.30
82	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.30
83	1	2.708	0.341	3.00	9.70	15.00	23.21	25.00
83	2	4.533	0.062	35.00	85.88	93.00	100.71	99.00
83	3	1.609	0.265	2.00	3.56	5.00	7.02	25.00
83	4	2.079	0.602	1.00	3.70	8.00	17.29	20.00
83	5	-0.916	0.803	0.10	0.14	0.40	1.12	6.00
84	1	2.485	0.624	4.80	5.40	12.00	26.67	26.30
84	2	1.386	0.618	1.90	1.81	4.00	8.82	10.50
84	3	1.386	0.618	1.90	1.81	4.00	8.82	10.50
84	4	0.693	0.730	0.90	0.79	2.00	5.09	8.40
85	1	1.386	0.321	2.90	2.65	4.00	6.03	8.40
85	2	-0.357	1.203	0.10	0.15	0.70	3.27	5.30
85	3	-0.223	1.236	0.10	0.16	0.80	3.89	5.30
86	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
86	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
86	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
87	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
87	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10

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 87   3 -0.357  0.893  0.10  0.22  0.70   2.19  2.10
 88   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
 88   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
 88   3  0.000  0.618  0.20  0.45  1.00   2.21  2.50
 88   4 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
 89   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
 89   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
 89   3  0.000  0.618  0.20  0.45  1.00   2.21  2.50
 89   4 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
 90   1  1.649  0.467  2.90  2.86  5.20   9.45 10.50
 90   2  0.875  0.624  0.90  1.08  2.40   5.33  5.30
 90   3 -0.916  0.765  0.10  0.15  0.40   1.06  2.10
 90   4 -1.204  0.482  0.10  0.16  0.30   0.56  2.10
 91   1  2.565  0.469  4.00  7.13 13.00  23.70 25.00
 91   2  4.443  0.130 45.00 71.96 85.00 100.40 99.00
 91   3  4.500  0.064 45.00 82.90 90.00  97.71 99.00
 91   4  1.386  0.867  0.50  1.32  4.00  12.13 15.00
 91   5  1.609  0.765  0.50  1.88  5.00  13.31 12.00
 91   6  0.000  0.765  0.10  0.38  1.00   2.66  6.00
 91   7 -1.204  0.482  0.10  0.16  0.30   0.56  3.00
 92   1  1.609  0.461  2.50  2.77  5.00   9.02 11.00
 92   2  1.548  0.443  2.50  2.66  4.70   8.29 11.00
 92   3  0.588  0.588  0.50  0.85  1.80   3.82  6.00
 92   4 -0.357  0.396  0.10  0.42  0.70   1.16  1.50
 92   5 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
 93   1  1.609  0.699  1.00  2.04  5.00  12.23 14.00
 93   2  4.174  0.209 25.00 49.73 65.00  84.97 85.00
 93   3  0.000  1.256  0.10  0.20  1.00   4.99  6.00
 93   4 -1.204  0.482  0.10  0.16  0.30   0.56  6.00
 94   1  3.555  0.270 15.00 24.77 35.00  49.46 70.00
 94   2  4.248  0.159 20.00 57.13 70.00  85.76 90.00
 94   3  4.317  0.215 20.00 56.95 75.00  98.77 95.00
 94   4  2.996  0.618  5.00  9.07 20.00  44.11 60.00
 94   5  0.693  0.867  0.20  0.66  2.00   6.06 15.00
 95   1  3.497  0.301 15.00 22.44 33.00  48.53 90.00
 95   2  4.174  0.088 25.00 58.07 65.00  72.75 99.00
 95   3  4.489  0.078 25.00 80.59 89.00  98.28 99.00
 96   1  0.693  0.541  0.90  1.00  2.00   4.00  4.20
 96   2  0.182  0.508  0.40  0.63  1.20   2.30  2.10
 96   3 -0.511  0.897  0.10  0.19  0.60   1.89  2.10
 97   1  1.792  0.461  2.90  3.33  6.00  10.82 10.50
 97   2  0.182  0.217  0.90  0.91  1.20   1.58  5.30
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 97   3 -0.916  0.765  0.10  0.15  0.40   1.06  2.10
 97   4 -1.204  0.482  0.10  0.16  0.30   0.56  2.10
 98   1  1.482  0.328  2.50  2.89  4.40   6.70  8.00
 98   2  1.361  0.257  2.50  2.81  3.90   5.42  7.00
 98   3  0.336  0.686  0.20  0.58  1.40   3.37  3.50
 98   4 -0.511  0.461  0.10  0.33  0.60   1.08  1.50
 98   5 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
 99   1  2.565  0.469  4.00  7.13 13.00  23.70 25.00
 99   2  4.443  0.130 45.00 71.96 85.00 100.40 99.00
 99   3  4.500  0.064 45.00 82.90 90.00  97.71 99.00
 99   4  1.386  0.867  0.50  1.32  4.00  12.13 15.00
 99   5  1.609  0.765  0.50  1.88  5.00  13.31 12.00
 99   6  0.000  0.765  0.10  0.38  1.00   2.66  6.00
 99   7 -1.204  0.482  0.10  0.16  0.30   0.56  3.00
100   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
100   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
100   3  0.000  0.618  0.20  0.45  1.00   2.21  2.50
100   4 -1.204  0.471  0.10  0.16  0.30   0.55  1.50
101   1  2.079  0.261  3.80  5.73  8.00  11.17 10.50
101   2  1.386  0.403  1.90  2.39  4.00   6.70  6.30
101   3  0.336  0.811  0.40  0.50  1.40   3.95  4.20
101   4  4.007  0.248 33.30 40.03 55.00  75.57 73.50
101   5  0.693  0.478  0.40  1.08  2.00   3.69  3.20
101   6  0.693  0.478  0.40  1.08  2.00   3.69  3.20
102   1  3.497  0.301 15.00 22.44 33.00  48.53 90.00
102   2  4.174  0.088 25.00 58.07 65.00  72.75 99.00
102   3  4.489  0.078 25.00 80.59 89.00  98.28 99.00
103   1  0.916  0.491  0.90  1.33  2.50   4.69  4.20
103   2  0.182  0.699  0.40  0.49  1.20   2.94  3.20
103   3 -0.223  0.541  0.40  0.40  0.80   1.60  3.20
103   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
104   1  0.916  0.491  0.90  1.33  2.50   4.69  4.20
104   2  0.182  0.699  0.40  0.49  1.20   2.94  3.20
104   3 -0.223  0.541  0.40  0.40  0.80   1.60  3.20
104   4 -0.357  0.400  0.40  0.42  0.70   1.17  3.20
105   1  2.996  0.403  5.00 11.94 20.00  33.51 40.00
105   2  1.946  0.369  1.00  4.37  7.00  11.22 20.00
105   3  4.317  0.157 35.00 61.36 75.00  91.68 95.00
105   4  1.099  0.809  0.50  1.06  3.00   8.45 12.00
105   5 -0.916  0.803  0.10  0.14  0.40   1.12  5.00
106   1  1.686  0.308  1.50  3.64  5.40   8.00  7.50
106   2  0.788  0.709  0.50  0.89  2.20   5.45  5.50
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106	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
106	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
107	1	3.219	0.444	15.00	14.16	25.00	44.13	55.00
107	2	3.912	0.319	20.00	33.25	50.00	75.18	80.00
107	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
107	4	-0.916	0.820	0.10	0.14	0.40	1.14	6.00
108	1	1.792	0.551	1.90	2.96	6.00	12.15	10.50
108	2	1.099	0.452	1.90	1.68	3.00	5.35	8.40
108	3	0.470	0.524	0.90	0.82	1.60	3.13	5.30
108	4	0.470	0.524	0.90	0.82	1.60	3.13	5.30
108	5	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
109	1	1.253	0.595	0.90	1.63	3.50	7.49	6.30
109	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
109	3	0.405	0.668	0.40	0.64	1.50	3.53	3.20
109	4	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
110	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
110	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
110	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
110	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
111	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
111	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
111	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
111	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
112	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
112	2	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
112	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
113	1	1.792	0.341	1.90	3.88	6.00	9.28	8.40
113	2	1.099	0.264	1.90	2.14	3.00	4.21	4.20
113	3	0.693	0.478	0.40	1.08	2.00	3.69	3.20
113	4	0.588	0.575	0.40	0.86	1.80	3.76	3.20
114	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
114	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
114	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
114	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
115	1	3.219	0.444	15.00	14.16	25.00	44.13	55.00
115	2	3.912	0.319	20.00	33.25	50.00	75.18	80.00
115	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
115	4	-0.916	0.820	0.10	0.14	0.40	1.14	6.00
116	1	2.197	0.436	1.00	5.15	9.00	15.73	15.00
116	2	4.094	0.403	25.00	35.82	60.00	100.52	95.00
116	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
116	4	1.504	0.823	0.50	1.57	4.50	12.91	12.00
116	5	0.693	0.867	0.20	0.66	2.00	6.06	6.00
116	6	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
117	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
117	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
117	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
117	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
118	1	1.131	0.450	1.60	1.74	3.10	5.51	8.00
118	2	0.916	0.461	1.10	1.39	2.50	4.51	5.50
118	3	0.336	0.399	0.80	0.84	1.40	2.33	5.50
118	4	-0.105	0.725	0.10	0.36	0.90	2.28	2.30
118	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.30
119	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40
119	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
119	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
119	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
119	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
120	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
120	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
120	3	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
121	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
121	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
121	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
121	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
122	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
122	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
122	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
122	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
123	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
123	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
123	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
123	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
124	1	1.792	0.341	1.90	3.88	6.00	9.28	8.40
124	2	1.386	0.403	1.90	2.39	4.00	6.70	6.30
124	3	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
124	4	-0.693	0.867	0.10	0.16	0.50	1.52	2.10
125	1	1.386	0.403	1.90	2.39	4.00	6.70	6.30
125	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
125	3	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
126	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
126	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
126	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
126	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20

127	1	3.912	0.211	25.00	38.18	50.00	65.48	80.00
127	2	4.248	0.150	25.00	57.74	70.00	84.86	90.00
127	3	4.317	0.077	25.00	67.99	75.00	82.74	90.00
127	4	2.708	0.403	5.00	8.95	15.00	25.13	35.00
128	1	1.792	0.341	1.90	3.88	6.00	9.28	8.40
128	2	1.386	0.403	1.90	2.39	4.00	6.70	6.30
128	3	-0.105	0.663	0.40	0.39	0.90	2.10	4.20
128	4	0.588	0.575	0.40	0.86	1.80	3.76	3.20
128	5	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
129	1	1.609	0.491	1.50	2.67	5.00	9.37	9.00
129	2	0.875	0.691	0.50	0.99	2.40	5.81	5.50
129	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
129	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
129	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
130	1	2.996	0.264	8.00	14.27	20.00	28.04	45.00
130	2	1.946	0.369	2.00	4.37	7.00	11.22	20.00
130	3	4.094	0.264	30.00	42.80	60.00	84.11	90.00
130	4	4.382	0.132	30.00	67.59	80.00	94.69	95.00
131	1	2.485	0.508	4.80	6.26	12.00	23.00	21.00
131	2	1.946	0.421	1.90	4.08	7.00	12.00	10.50
131	3	1.099	0.551	0.90	1.48	3.00	6.07	5.30
131	4	3.807	0.264	28.50	32.10	45.00	63.08	63.00
131	5	4.443	0.068	57.00	77.92	85.00	92.72	94.50
132	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
132	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
132	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
132	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
133	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
133	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
133	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
133	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
134	1	2.079	0.515	3.80	4.14	8.00	15.46	15.80
134	2	0.693	0.618	0.90	0.91	2.00	4.41	5.30
134	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
134	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
135	1	1.609	0.319	2.90	3.33	5.00	7.52	7.40
135	2	1.504	0.330	2.90	2.95	4.50	6.87	7.40
135	3	1.194	0.472	1.90	1.80	3.30	6.04	7.40
135	4	0.470	0.898	0.40	0.51	1.60	5.05	5.30
135	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
136	1	1.609	0.319	2.90	3.33	5.00	7.52	7.40
136	2	1.504	0.330	2.90	2.95	4.50	6.87	7.40
136	3	1.194	0.472	1.90	1.80	3.30	6.04	7.40
136	4	0.470	0.898	0.40	0.51	1.60	5.05	5.30
136	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
137	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
137	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
137	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
137	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
138	1	2.708	0.443	4.80	8.51	15.00	26.43	23.10
138	2	2.485	0.508	4.80	6.26	12.00	23.00	21.00
138	3	2.079	0.452	2.90	4.48	8.00	14.27	12.60
138	4	1.099	0.897	0.90	0.95	3.00	9.45	10.50
138	5	4.007	0.215	38.00	41.78	55.00	72.41	73.50
139	1	3.219	0.412	15.00	14.75	25.00	42.37	50.00
139	2	2.833	0.110	15.00	14.77	17.00	19.56	50.00
139	3	2.996	0.299	15.00	13.65	20.00	29.31	90.00
139	4	3.912	0.270	25.00	35.38	50.00	70.66	90.00
139	5	4.248	0.159	25.00	57.13	70.00	85.76	90.00
140	1	3.219	0.412	15.00	14.75	25.00	42.37	50.00
140	2	2.833	0.110	15.00	14.77	17.00	19.56	50.00
140	3	2.996	0.299	15.00	13.65	20.00	29.31	90.00
140	4	3.912	0.270	25.00	35.38	50.00	70.66	90.00
140	5	4.248	0.159	25.00	57.13	70.00	85.76	90.00
141	1	2.197	0.436	1.00	5.15	9.00	15.73	15.00
141	2	4.094	0.403	25.00	35.82	60.00	100.52	95.00
141	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
141	4	1.504	0.823	0.50	1.57	4.50	12.91	12.00
141	5	0.693	0.867	0.20	0.66	2.00	6.06	6.00
141	6	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
142	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
142	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
142	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
142	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
143	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40
143	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
143	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
143	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
143	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
144	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
144	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
144	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
144	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
145	1	1.526	0.522	1.50	2.36	4.60	8.98	9.00

145	2	0.742	0.851	0.20	0.71	2.10	6.24	6.00
145	3	1.435	0.950	0.50	1.24	4.20	14.17	13.00
145	4	-0.223	0.739	0.10	0.31	0.80	2.06	2.50
145	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
145	6	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
146	1	1.792	0.551	1.90	2.96	6.00	12.15	10.50
146	2	1.099	0.452	1.90	1.68	3.00	5.35	8.40
146	3	0.470	0.524	0.90	0.82	1.60	3.13	5.30
146	4	0.470	0.524	0.90	0.82	1.60	3.13	5.30
146	5	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
147	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40
147	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
147	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
147	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
147	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
148	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
148	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
148	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
148	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
149	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
149	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
149	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
149	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
150	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
150	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
150	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
150	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
151	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
151	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
151	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
151	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
152	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
152	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
152	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
153	1	3.219	0.412	15.00	14.75	25.00	42.37	50.00
153	2	2.833	0.110	15.00	14.77	17.00	19.56	50.00
153	3	2.996	0.299	15.00	13.65	20.00	29.31	90.00
153	4	3.912	0.270	25.00	35.38	50.00	70.66	90.00
153	5	4.248	0.159	25.00	57.13	70.00	85.76	90.00
154	1	2.485	0.551	3.80	5.93	12.00	24.29	21.00
154	2	2.079	0.515	3.80	4.14	8.00	15.46	15.80
154	3	1.099	0.897	0.90	0.95	3.00	9.45	10.50
154	4	1.099	0.897	0.90	0.95	3.00	9.45	10.50
154	5	4.174	0.230	38.00	48.45	65.00	87.20	84.00
155	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
155	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
155	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
155	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
156	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
156	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
156	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
156	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
157	1	1.386	0.452	1.00	2.24	4.00	7.14	7.00
157	2	0.336	0.893	0.20	0.45	1.40	4.39	5.00
157	3	-0.357	0.576	0.10	0.33	0.70	1.46	2.50
157	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.50
158	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
158	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
158	3	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
159	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
159	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
159	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
159	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
160	1	1.792	0.461	2.90	3.33	6.00	10.82	10.50
160	2	0.182	0.217	0.90	0.91	1.20	1.58	5.30
160	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
160	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
161	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
161	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
161	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
161	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
162	1	1.740	0.577	1.50	2.72	5.70	11.94	11.00
162	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
162	3	-0.223	0.618	0.20	0.36	0.80	1.76	2.50
162	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
162	5	-1.204	0.354	0.10	0.19	0.30	0.47	1.00
163	1	1.386	0.321	2.90	2.65	4.00	6.03	8.40
163	2	-0.357	1.203	0.10	0.15	0.70	3.27	5.30
163	3	-0.223	1.236	0.10	0.16	0.80	3.89	5.30
164	1	2.197	0.551	2.90	4.45	9.00	18.22	15.80
164	2	1.386	0.541	1.90	2.00	4.00	7.99	8.40
164	3	0.095	0.691	0.40	0.45	1.10	2.66	3.20
164	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
165	1	1.792	0.354	3.80	3.82	6.00	9.43	10.50

165	2	1.386	0.261	1.90	2.86	4.00	5.58	5.30
165	3	0.405	0.668	0.40	0.64	1.50	3.53	3.20
165	4	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
166	1	3.555	0.225	15.00	26.23	35.00	46.70	50.00
166	2	3.219	0.332	15.00	16.34	25.00	38.26	50.00
166	3	3.912	0.270	25.00	35.38	50.00	70.66	90.00
166	4	4.248	0.159	25.00	57.13	70.00	85.76	90.00
167	1	3.332	0.082	15.00	25.21	28.00	31.10	55.00
167	2	2.708	0.403	5.00	8.95	15.00	25.13	40.00
167	3	2.708	0.403	5.00	8.95	15.00	25.13	40.00
167	4	3.912	0.270	25.00	35.38	50.00	70.66	85.00
167	5	4.248	0.159	25.00	57.13	70.00	85.76	85.00
168	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
168	2	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
168	3	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
168	4	-0.916	0.342	0.20	0.26	0.40	0.62	2.10
169	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
169	2	0.405	0.403	0.90	0.90	1.50	2.51	3.20
169	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
169	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
170	1	1.099	0.264	1.90	2.14	3.00	4.21	4.20
170	2	0.693	0.541	0.90	1.00	2.00	4.00	4.20
170	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
170	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
171	1	1.872	0.484	3.80	3.50	6.50	12.08	15.80
171	2	0.693	0.618	0.90	0.91	2.00	4.41	5.30
171	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
171	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
172	1	1.099	0.264	1.90	2.14	3.00	4.21	4.20
172	2	0.693	0.541	0.90	1.00	2.00	4.00	4.20
172	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
172	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
173	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
173	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
173	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
173	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
174	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
174	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
174	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
174	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
175	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
175	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
175	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
175	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
176	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
176	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
176	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
177	1	3.332	0.082	15.00	25.21	28.00	31.10	55.00
177	2	2.708	0.403	5.00	8.95	15.00	25.13	40.00
177	3	2.708	0.403	5.00	8.95	15.00	25.13	40.00
177	4	3.912	0.270	25.00	35.38	50.00	70.66	85.00
177	5	4.248	0.159	25.00	57.13	70.00	85.76	85.00
178	1	3.091	0.268	8.00	15.61	22.00	31.00	45.00
178	2	2.303	0.403	2.00	5.97	10.00	16.75	20.00
178	3	4.174	0.088	35.00	58.07	65.00	72.75	90.00
178	4	4.317	0.077	35.00	67.99	75.00	82.74	90.00
179	1	2.197	0.551	2.90	4.45	9.00	18.22	15.80
179	2	1.946	0.396	2.90	4.22	7.00	11.62	10.50
179	3	1.099	0.749	0.90	1.15	3.00	7.82	7.40
179	4	4.174	0.209	42.80	49.73	65.00	84.97	84.00
180	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
180	2	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
180	3	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
180	4	-0.916	0.342	0.20	0.26	0.40	0.62	2.10
181	1	1.099	0.264	1.90	2.14	3.00	4.21	4.20
181	2	0.693	0.541	0.90	1.00	2.00	4.00	4.20
181	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
181	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
182	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
182	2	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
182	3	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
182	4	-0.916	0.342	0.20	0.26	0.40	0.62	2.10
183	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
183	2	0.405	0.403	0.90	0.90	1.50	2.51	3.20
183	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
183	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
184	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
184	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
184	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
184	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
185	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
185	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
185	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
186	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20

186	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
186	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
186	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
187	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
187	2	-0.223	0.554	0.40	0.39	0.80	1.63	4.20
187	3	-0.511	0.693	0.20	0.25	0.60	1.46	2.10
187	4	-0.916	0.342	0.20	0.26	0.40	0.62	2.10
188	1	0.405	0.515	0.70	0.78	1.50	2.90	3.20
188	2	-0.916	0.618	0.10	0.18	0.40	0.88	1.10
188	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
189	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
189	2	0.405	0.403	0.90	0.90	1.50	2.51	3.20
189	3	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
189	4	-0.511	0.481	0.30	0.32	0.60	1.11	3.20
190	1	1.946	0.343	3.80	4.52	7.00	10.85	10.50
190	2	1.099	0.668	0.90	1.28	3.00	7.06	6.30
190	3	0.262	0.697	0.40	0.53	1.30	3.17	3.20
190	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
191	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
191	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
191	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
191	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
192	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
192	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
192	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
193	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
193	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
193	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
193	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
194	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
194	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
194	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
194	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
195	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
195	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
195	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
195	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
196	1	1.609	0.461	2.50	2.77	5.00	9.02	11.00
196	2	1.548	0.443	2.50	2.66	4.70	8.29	11.00
196	3	0.588	0.588	0.50	0.85	1.80	3.82	6.00
196	4	-0.357	0.396	0.10	0.42	0.70	1.16	1.50
196	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
197	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
197	2	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
197	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
197	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
198	1	0.916	0.217	0.90	1.89	2.50	3.30	3.20
198	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
198	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
198	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
199	1	2.079	0.261	3.80	5.73	8.00	11.17	10.50
199	2	1.386	0.403	1.90	2.39	4.00	6.70	6.30
199	3	0.405	0.897	0.40	0.48	1.50	4.73	5.30
199	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
199	5	0.405	0.668	0.40	0.64	1.50	3.53	3.20
200	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
200	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
200	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
201	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
201	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
201	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
202	1	2.303	0.216	4.80	7.58	10.00	13.19	12.60
202	2	1.386	0.730	0.90	1.57	4.00	10.18	8.40
202	3	1.386	0.730	0.90	1.57	4.00	10.18	8.40
202	4	1.386	0.730	0.90	1.57	4.00	10.18	8.40
203	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
203	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
203	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
203	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
204	1	1.705	0.470	2.90	3.01	5.50	10.03	10.50
204	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
204	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
204	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
204	5	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
205	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
205	2	0.916	0.618	0.90	1.13	2.50	5.51	5.30
205	3	-0.223	0.867	0.10	0.26	0.80	2.43	2.10
205	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
206	1	1.609	0.491	1.50	2.67	5.00	9.37	9.00
206	2	0.875	0.691	0.50	0.99	2.40	5.81	5.50
206	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
206	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
206	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
207	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40

207	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
207	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
207	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
207	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
208	1	1.609	0.491	1.90	2.67	5.00	9.37	8.40
208	2	0.095	0.691	0.40	0.45	1.10	2.66	3.20
208	3	-0.511	0.217	0.40	0.45	0.60	0.79	3.20
209	1	0.916	0.217	0.90	1.89	2.50	3.30	3.20
209	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
209	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
209	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
210	1	0.916	0.217	0.90	1.89	2.50	3.30	3.20
210	2	0.000	0.541	0.40	0.50	1.00	2.00	2.10
210	3	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
210	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
211	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
211	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
211	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
212	1	0.693	0.403	0.90	1.19	2.00	3.35	3.20
212	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
212	3	-0.357	0.893	0.10	0.22	0.70	2.19	2.10
213	1	3.219	0.444	15.00	14.16	25.00	44.13	60.00
213	2	4.094	0.316	30.00	40.02	60.00	89.96	95.00
213	3	1.099	0.897	0.50	0.95	3.00	9.45	15.00
213	4	1.609	0.765	0.50	1.88	5.00	13.31	12.00
213	5	0.000	0.765	0.30	0.38	1.00	2.66	6.00
213	6	-0.916	0.765	0.10	0.15	0.40	1.06	3.00
214	1	1.609	0.319	2.90	3.33	5.00	7.52	7.40
214	2	1.504	0.330	2.90	2.95	4.50	6.87	7.40
214	3	1.194	0.472	1.90	1.80	3.30	6.04	7.40
214	4	0.470	0.898	0.40	0.51	1.60	5.05	5.30
214	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
215	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40
215	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
215	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
215	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
215	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
216	1	1.792	0.354	3.50	3.82	6.00	9.43	11.00
216	2	1.705	0.269	3.50	3.90	5.50	7.76	9.00
216	3	1.569	0.775	1.50	1.78	4.80	12.94	16.00
216	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
217	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
217	2	0.916	0.618	0.90	1.13	2.50	5.51	5.30
217	3	-0.223	0.867	0.10	0.26	0.80	2.43	2.10
217	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
218	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
218	2	0.916	0.618	0.90	1.13	2.50	5.51	5.30
218	3	-0.223	0.867	0.10	0.26	0.80	2.43	2.10
218	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
219	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
219	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
219	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
219	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
220	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
220	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
220	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
220	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
221	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
221	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
221	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
221	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
222	1	1.649	0.349	1.00	3.33	5.20	8.12	8.00
222	2	1.163	0.683	0.50	1.33	3.20	7.67	6.50
222	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
223	1	2.485	0.508	4.80	6.26	12.00	23.00	21.00
223	2	1.946	0.421	1.90	4.08	7.00	12.00	10.50
223	3	1.099	0.551	0.90	1.48	3.00	6.07	5.30
223	4	3.807	0.264	28.50	32.10	45.00	63.08	63.00
223	5	4.443	0.068	57.00	77.92	85.00	92.72	94.50
224	1	0.916	0.217	0.90	1.89	2.50	3.30	3.20
224	2	0.000	0.541	0.40	0.50	1.00	2.00	2.10
224	3	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
224	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
225	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
225	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
225	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
226	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
226	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
226	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
226	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
227	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
227	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
227	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
227	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50

228	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
228	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
228	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
228	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
229	1	2.197	0.436	1.00	5.15	9.00	15.73	15.00
229	2	4.094	0.403	25.00	35.82	60.00	100.52	95.00
229	3	1.099	0.897	0.50	0.95	3.00	9.45	12.00
229	4	1.504	0.823	0.50	1.57	4.50	12.91	12.00
229	5	0.693	0.867	0.20	0.66	2.00	6.06	6.00
229	6	-1.204	0.482	0.10	0.16	0.30	0.56	3.00
230	1	1.569	0.327	2.90	3.16	4.80	7.30	7.40
230	2	1.569	0.327	2.90	3.16	4.80	7.30	7.40
230	3	1.361	0.487	1.90	2.09	3.90	7.27	7.40
230	4	0.531	0.895	0.40	0.54	1.70	5.35	5.30
230	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
231	1	1.609	0.319	2.90	3.33	5.00	7.52	7.40
231	2	1.504	0.330	2.90	2.95	4.50	6.87	7.40
231	3	1.194	0.472	1.90	1.80	3.30	6.04	7.40
231	4	0.470	0.898	0.40	0.51	1.60	5.05	5.30
231	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
232	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
232	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
232	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
232	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
233	1	1.504	0.330	2.50	2.95	4.50	6.87	8.00
233	2	1.253	0.745	0.50	1.35	3.50	9.09	8.00
233	3	0.095	0.786	0.20	0.40	1.10	3.01	3.50
233	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
234	1	1.504	0.330	2.50	2.95	4.50	6.87	8.00
234	2	1.253	0.745	0.50	1.35	3.50	9.09	8.00
234	3	0.095	0.786	0.20	0.40	1.10	3.01	3.50
234	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
235	1	0.693	0.541	0.90	1.00	2.00	4.00	4.20
235	2	0.182	0.508	0.40	0.63	1.20	2.30	2.10
235	3	-0.511	0.897	0.10	0.19	0.60	1.89	2.10
236	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
236	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
236	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
236	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
237	1	2.996	0.246	15.00	14.59	20.00	27.41	40.00
237	2	2.708	0.403	5.00	8.95	15.00	25.13	40.00
237	3	3.219	0.217	5.00	18.95	25.00	32.99	50.00
237	4	4.094	0.264	30.00	42.80	60.00	84.11	90.00
237	5	-0.693	1.076	0.10	0.13	0.50	1.98	20.00
238	1	1.609	0.491	1.50	2.67	5.00	9.37	9.00
238	2	0.875	0.691	0.50	0.99	2.40	5.81	5.50
238	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
238	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
238	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
239	1	1.609	0.491	1.50	2.67	5.00	9.37	9.00
239	2	0.875	0.691	0.50	0.99	2.40	5.81	5.50
239	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
239	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
239	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
240	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
240	2	0.916	0.618	0.90	1.13	2.50	5.51	5.30
240	3	-0.223	0.867	0.10	0.26	0.80	2.43	2.10
240	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
241	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
241	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
241	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
241	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
242	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
242	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
242	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
242	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
243	1	0.405	0.403	0.90	0.90	1.50	2.51	3.20
243	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
243	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
243	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
244	1	0.916	0.491	0.90	1.33	2.50	4.69	4.20
244	2	0.182	0.699	0.40	0.49	1.20	2.94	3.20
244	3	-0.223	0.541	0.40	0.40	0.80	1.60	3.20
244	4	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
245	1	0.531	0.428	0.90	0.98	1.70	2.94	3.20
245	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
245	3	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
245	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
246	1	0.531	0.428	0.90	0.98	1.70	2.94	3.20
246	2	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
246	3	-0.223	0.491	0.40	0.43	0.80	1.50	2.10
246	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
247	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
247	2	0.916	0.618	0.90	1.13	2.50	5.51	5.30

247	3	-0.223	0.867	0.10	0.26	0.80	2.43	2.10
247	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
248	1	1.099	0.551	0.90	1.48	3.00	6.07	5.30
248	2	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
248	3	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
249	1	1.504	0.330	2.50	2.95	4.50	6.87	8.00
249	2	1.253	0.745	0.50	1.35	3.50	9.09	8.00
249	3	0.095	0.786	0.20	0.40	1.10	3.01	3.50
249	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
250	1	1.705	0.364	2.90	3.45	5.50	8.77	8.40
250	2	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
250	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.10
251	1	1.649	0.467	2.90	2.86	5.20	9.45	10.50
251	2	0.875	0.624	0.90	1.08	2.40	5.33	5.30
251	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
251	4	-1.204	0.482	0.10	0.16	0.30	0.56	2.10
252	1	1.686	0.308	1.50	3.64	5.40	8.00	7.50
252	2	0.788	0.709	0.50	0.89	2.20	5.45	5.50
252	3	0.000	0.618	0.20	0.45	1.00	2.21	2.50
252	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.50
253	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
253	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
253	3	-0.357	0.400	0.40	0.42	0.70	1.17	3.20
254	1	1.099	0.341	0.90	1.94	3.00	4.64	4.20
254	2	0.405	0.668	0.40	0.64	1.50	3.53	3.20
254	3	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
254	4	-0.916	0.765	0.10	0.15	0.40	1.06	2.10
255	1	0.916	0.491	0.50	1.33	2.50	4.69	4.50
255	2	0.000	0.541	0.20	0.50	1.00	2.00	2.50
255	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
255	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
255	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
256	1	0.531	0.515	0.50	0.88	1.70	3.29	4.50
256	2	-0.357	0.400	0.20	0.42	0.70	1.17	3.50
256	3	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
256	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
257	1	0.875	0.508	0.50	1.25	2.40	4.60	4.50
257	2	-0.223	0.491	0.20	0.43	0.80	1.50	2.50
257	3	-0.693	0.618	0.10	0.23	0.50	1.10	1.40
257	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
257	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
258	1	0.875	0.508	0.50	1.25	2.40	4.60	4.50
258	2	-0.223	0.491	0.20	0.43	0.80	1.50	2.50
258	3	-0.693	0.618	0.10	0.23	0.50	1.10	1.40
258	4	-1.204	0.471	0.10	0.16	0.30	0.55	1.40
258	5	-1.204	0.471	0.10	0.16	0.30	0.55	1.40