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Contents

1 Introduction

Within the e-SOTER project, the e-SOTER database was developed. This database contains soil and terrain data (soter data). The goal of WP5 is to provide applications of the e-SOTER database. This is done with 2 main aims, namely 1) to demonstrate how the e-SOTER database can be used to evaluate threats to soils mentioned in the EU Soil Thematic Strategy, and 2) to investigate whether the use of the e-SOTER database compared with existing databases results in better predictions of soil threats. This implies investigating whether use of the e-SOTER database will improve evaluation of threats to soil quality and performance compared with using data from previous soil maps and databases. Two soil threats identified by the EU Soil Thematic Strategy were selected for the example applications of the e-SOTER database: soil erosion and subsoil compaction. Appropriate models were selected that can simulate the sensitivity to these threats at the relevant scales. These models were run with e-SOTER data and data from existing soil maps and databases. This was done for 3 so-called windows, namely a window in Western Europe (covering parts of France and UK), a window in Central Europe (covering most of the Czech Republic and parts of Germany, Austria, Slovak Republic and Hungary) and a window covering most of Morocco.

The objective of the first task (T5.1) was the identification of the most important threat to soil quality and performance in each window area. In the second task (T5.2), data for the models were collected. The third task (T5.3) compared threats assessed based on e-SOTER and on pre-existing data sources considering both spatial patterns and statistical trends. The fourth task (T5.4) according to the Description of Work was envisaged to make a comparison between existing data on threats and the results obtained from the 1:1 million and 1:250000-scale windows by running models for the most important threats determined in T5.1. However, since the e-SOTER database for the 1:250000 scale windows was not available in time, the task was cancelled in agreement with the project coordinator, and therefore is not described in this report.

The target variables selected for the soil threats included expressions of soil sensitivity, and therefore direct observations or other primary data sources of these variables were not available. As an alternative reference for comparison of the applications of the e-SOTER database versus legacy databases, expert elicitation was used. This report describes the work that was conducted in all tasks of WP5.

2 Task 5.1 – Identification of soil threats

2.1 Introduction

The aims of this task were:

- To determine for each of the windows (Figure 3-1) in which WP5 is working which the most important threats to soils are.
- To determine how these threats could be evaluated using the e-SOTER database
- To determine which data are needed for such an evaluation

2.2 Methodology

The research teams represented in WP5 identified the major threats in each window, and described methods suitable to evaluate these threats using a standardized format. This format included the following items:

- an accepted scientific definition of the soil threat,
- the method used to interpret this soil threat (e.g. a process model, decision tree, knowledge matrix)
- the scale of application
- the type and dimension or classification of the target variable describing the soil threat
- specifications of the input data: variable or parameter, data source, variable name in de legacy data, and dimension or classification of the input variables
- data for evaluation: type and source
- references

2.3 Results

The importance of soil threats in the study windows as identified by the research teams is given in Table 2-1.

Table 2-1 Importance of soil threats in study windows.

Rank order	Morocco	Western Europe	Central Europe
1	Water erosion	Water erosion	Water erosion
2	Loss organic matter	Compaction	Compaction
3	Landslides		Loss organic matter
4	Desertification		

Soil erosion by water was identified as the most important threat in all study windows. Loss of organic matter and soil compaction were identified to be important in two of the three windows. Landslides are only important in the northern part of the Moroccan window, and desertification is currently not one of the soil threats listed by the EU Soil Thematic Strategy.

Four models were selected to evaluate soil erosion by water and soil compaction. These models were described according to the format developed (see Appendix I). Several characteristics of the models are described in Table 2-2.

Methods to describe the loss of organic matter exist (e.g. ROTHAM-C, MINIP), but these methods require detailed data on soils, climate and land use at different moments in time, and therefore were considered too complex to demonstrate the improvement of the e-SOTER database compared with existing soil databases. For such a comparison it is an advantage if the methods are relatively simple and the results depend to a large extend on the soil data; this because to evaluate the effect of using different databases requires that all other model input is kept constant.

Table 2-2 Soil threats, models and output variables in Priority-1 applications of e-SOTER.

Soil threat	Model	Output	Units	Type of output variable	Classification
Soil erosion by water	MESALES[1]	Sensitivity to soil erosion	None	Categorical	5 ordinal classes (very low…very high)
Soil compaction	Jones[2]	Inherent susceptibility of subsoil compaction	None	Categorical	5 ordinal classes (low-moderate-medium/high-high-very high
Soil erosion by water	BGR 1[3]	Potential soil erosion	$t \cdot ha^{-1} \cdot y^{-1}$	Continuous	6 classes on a ratio scale (0-1, 1-5, 5-10, 10-20, 20-50, >50)
Soil erosion by water	BGR 2[4]	Sensitivity to soil erosion	none	Categorical	6 ordinal classes (0-not sensitive – 5-very high erosion sensitivity)

[1] Le Bissonnais, Y., C. Montier, M. Jamagne, J. Daroussin, D. King. 2001. Mapping erosion risk for cultivated soil in France. Catena 46 (2002) 207-220.
[2] Jones, R.J.A., G.Spoor, A.J.Thomasson 2003. Vulnerability of subsoils in Europe to compaction: a preliminary analysis. Soil & Tillage Research 73, 131-143.
[3] Eberhardt, E., 2009a. e-SOTER methods for threats – Potential soil loss by water erosion. BGR document, unpublished. BGR, Hannover
[4] Eberhardt, E., 2009b. e-SOTER methods for threats – Soil sensitivity to water erosion. BGR document, unpublished. BGR, Hannover.

3 Task 5.2 - Data collection for model applications

The goal of WP5 was to demonstrate the improvement of the e-SOTER database compared with existing databases, using models for soil threats as ‘proxies’ to evaluate the performance of the databases. The model applications in the windows selected for the e-SOTER project are illustrated in Figure 3-1.

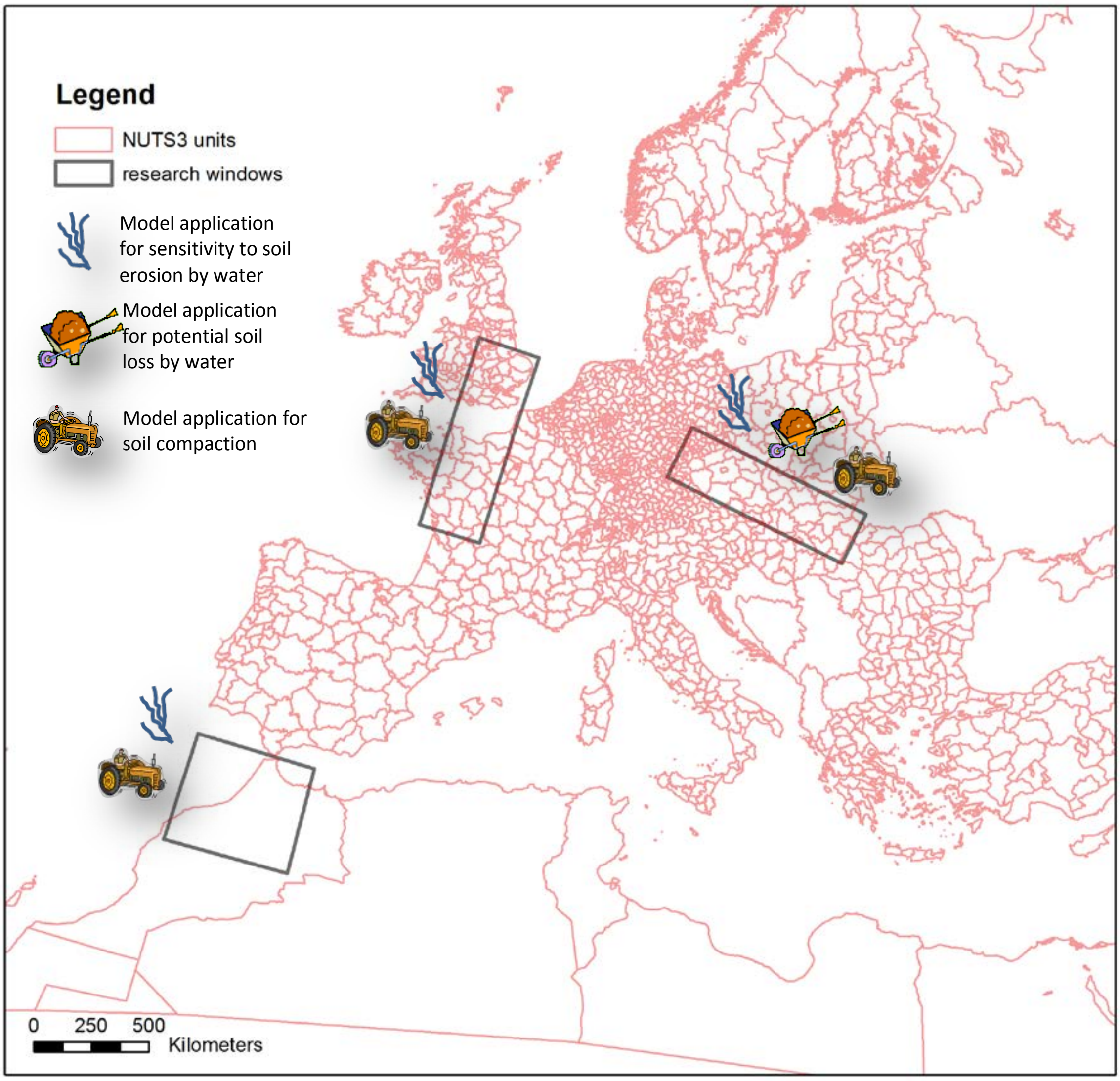


Figure 3-1 Locations of research windows and model applications in each window.

The existing soil database for the WEU and CEU windows used was the European Soil Database (ESDB), version 2.0. For the Moroccan window the Harmonized World Soil Database (HWSD) version 1.1 was used (FAO/IIASA/ISRIC/ISSCAS/JRC, 2009) to estimate sensitivity to compaction, and the Digital Soil Map of the World (FAO, 2007) to estimate sensitivity to soil erosion. Data on terrain characteristics were only used in the models on water erosion, but these data were retrieved from external sources to the soil legacy and e-SOTER databases (i.e. HYDRO1K[5] and SRTM90 (Jarvis et al., 2008) DEMs). Land use data (GLC2000) were

[5] USGS HYDRO1k Elevation Derivative database. USGS EROS data centre. http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30/hydro

used in the estimation of sensitivity to soil erosion. All data that are external to the soil databases was kept constant between applications with legacy data and applications with e-SOTER. Therefore the comparison of model applications using the e-SOTER database and pre-existing databases in Task 5.3 (chapter 4) will only consider data on soils.

The models used to simulate soil threats are differently parameterised using the legacy and the e-SOTER databases (Table 3-1 to 3-3). The databases also differ with regard to spatial configuration and source data from soil profiles used (Table 3-4). Detailed information on the input and output data of the models and the algorithms used can be found in the description of the models in Appendix 1, and in the reports of the model applications in Appendix 2-4.

Table 3-1 Differences in variables from ESDB and e-SOTER used in the MESALES model to simulate soil threats.

Data theme	Model variable	Variable in ESDB	Variable in e-SOTER <table name>
Terrain	Slope angle	Not a variable in the database; slope classes calculated in the model from HYDRO1K.	Not a variable in the database; slope classes calculated in the model from HYDRO1k
	Landform	Not used	Not used in calculation, but e-SOTER units are partly based on landform information derived from corrected SRTM DEM
Land Use	Land use	Not a variable in the database; derived from GLC2000[6]	GLC2000
Crusting	Soil type, parent material and surface texture	Soil name (FAO-Unesco 1985 classification): SN1, SN2, SN3	Soil name: WRBC (World Reference Base – classification) <Profile>
		Parent material: PM11, PM12, PM13 (Codes for dominant parent material of the STU)	Parent material: LITH (Parent material at the (exact) location of the soil profile) <Profile>
		Surface texture: TEXT1 (Dominant surface textural class of the STU)	Surface texture: TCTS (Textural class of the topsoil (CEC 1985)) <SoilComponent> If empty: SDTO (Weight% of particles 2.0 - 0.05 mm (total sand) in fine earth fraction), STPC (Weight% of particles < 0.002 mm (silt) in fine earth fraction) and CLPC (Weight% of particles < 0.002 mm (clay) in fine earth fraction) <RepresentativeHorizonValues>
		TEXT2 (Secondary surface textural class of the STU)	Same procedure but for Soil Component 2
Erodibility	Soil type, parent material and surface texture	Same as above	Same as above

6 Source: http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

Table 3-2 Differences in variables from ESDB and e-SOTER used in the Jones model to simulate soil threats.

Model variable	Variable in ESDB	Variable in e-SOTER <table name>
Subsoil texture	TEXT-SUB-DOM: Dominant sub-surface textural class of the STU ---------------- 0 No information 9 No mineral texture (Peat soils) 1 Coarse (18% < clay and > 65% sand) 2 Medium (18% < clay < 35% and >= 15% sand, or 18% < clay and 15% < sand < 65%) 3 Medium fine (< 35% clay and < 15% sand) 4 Fine (35% < clay < 60%) 5 Very fine (clay > 60 %)	Subsoil texture classes[7] to derive for the subsoil by query from CLPC (Weight% of particles < 0.002 mm (clay) in fine earth fraction) and SDTO (Weight% of particles 2.0 - 0.05 mm (total sand) in fine earth fraction) <RepresentativeHorizonValues> Subsoil to be defined. 3 options: 1. Based on depth of textural change. Since there is no variable in the new e-SOTER database indicating the depth of textural change, this option is cancelled 2. Soil below the A# horizons 3. Soil below a fixed depth, say 30 cm
Subsoil Packing Density (PD_SUB)	Derived from SGDBE input attributes: STR_SUB - Subsoil structure class TD - Subsoil textural class SN - FAO soil name (FAO-85, FAO-90) WRB soil name Calculated using PTR08 Rule, revised in SINFO Legend: Low <1.4 Medium 1.4 – 1.75 High > 1.75	Not available in the e-SOTER database. Can be calculated from Bulk Density (t*m-3) (corresponding variable BULK in kg*dm-3) (note the different dimensions) and Clay content (corresponding variable CLPC in weight %): PD = Bulk Density + 0.009*Clay Content

[7] As required by the Jones model, and also used to classify the subsoil texture for the legacy database (TEXT-SUB-DOM in ESDB v2.0):
1: coarse (<18% Clay, > 65% Sand)
2: medium (<35% Clay, > 15% sand; if more than 18% Clay > 65% Sand)
3: medium fine (< 35% Clay, < 15% Sand)
4: fine (30 – 60 % Clay)
5: very fine (> 60% Clay)
9: organic (no mineral texture)

Table 3-3 Differences in variables from ESDB and e-SOTER used in the BGR models to simulate soil threats.

Model variable	Variable in ESDB	Variable in e-SOTER <table name>
Soil factor KB	Surface texture: TEXT1 (Dominant surface textural class of the STU) ---------------- 0 No information 9 No mineral texture (Peat soils) 1 Coarse (<18% clay and > 65% sand) 2 Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%) 3 Medium fine (< 35% clay and < 15% sand) 4 Fine (35% < clay < 60%) 5 Very fine (clay > 60 %)	Surface texture: TCTS (Textural class of the topsoil (CEC 1985)) <SoilComponent> ---------------- - No information 0 No mineral texture (Peat soils) 1 Coarse (<18% clay and > 65% sand) 2 Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%) 3 Medium fine (< 35% clay and < 15% sand) 4 Fine (35% < clay < 60%) 5 Very fine (clay > 60 %)
Stone factor Ks	VS (Volume of stones) 00 = 0 % stones 10 = 10 % stones 15 = 15 % stones 20 = 20 % stones	CFRAG (Classes of volume% of rock and/or coarse fragments in the soil matrix (FAO, 1990)) <RepresentativeHorizonvalues>
Slope factor S	Not a variable in the database; calculated from SRTM 90 elevation model (Jarvis et al., 2008)	Not a variable in the database; calculated from SRTM 90 elevation model (Jarvis et al., 2008)
Precipitation factor R	Not a variable in the database; calculated from the world climate data set of Heijmans et al. (2005)	Not a variable in the database; calculated from the world climate data set of Heijmans et al. (2005)

Model variable	Variable in ESDB	Variable in e-SOTER <table name>
Surface soil texture	Surface texture: TEXT1 (Dominant surface textural class of the STU) ---------------- 0 No information 9 No mineral texture (Peat soils) 1 Coarse (<18% clay and > 65% sand) 2 Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%) 3 Medium fine (< 35% clay and < 15% sand) 4 Fine (35% < clay < 60%) 5 Very fine (clay > 60 %)	Surface texture: TCTS (Textural class of the topsoil (CEC 1985)) <SoilComponent> ---------------- - No information 0 No mineral texture (Peat soils) 1 Coarse (<18% clay and > 65% sand) 2 Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%) 3 Medium fine (< 35% clay and < 15% sand) 4 Fine (35% < clay < 60%) 5 Very fine (clay > 60 %)
Slope inclination	Not a variable in the database; calculated from SRTM 90 elevation model (Jarvis et al., 2008). ---------------- Slope class (%) <=1 1-5 5-9 9-18 18-36 >36	Not a variable in the database; calculated from SRTM 90 elevation model (Jarvis et al., 2008). ---------------- Slope class (%) <=1 1-5 5-9 9-18 18-36 >36

Table 3-4 Differences between the ESDB and e-SOTER databases.

Data theme	Applying to models	ESDB	e-Soter
Spatial configuration	All models	Soil Mapping Units (SMU) with a sub-division in Soil Terrain Units (STU) Delineation of SMUs based on expert judgment, national and regional soil maps	Soil and terrain units (Soter Units) (SUID) with a sub-division in Soil Components (SCID) and Terrain Components (TCID) Delineation of Soter Units as produced in WP1, 2 and 3.
Source soil profile data	All models	soil profile data from the Soil Profile Analytical Database of Europe	Additional soil profile data from UK, FR, CZ, DE and other countries as documented in WP2

4 Task 5.3 - Comparison of soil threat assessments using e-SOTER versus pre-existing databases

4.1 Introduction

The e-SOTER database was developed with the aim to improve and supplement soil and terrain data for use in environmental assessments. One of the objectives of WP5 was to investigate if using the e-SOTER database will improve the evaluation of soil threats compared to using data from previous databases. Four models were selected for the evaluation of soil threats. In this set-up, the models function as 'proxies' to evaluate the databases used to parameterise the models.

The difference between evaluations of soil threats using both databases can only be assessed in terms of the performance of both databases by comparing the model results obtained with the databases against independent observations of the soil threats concerned. However, independent observations on the target variables expressing the soil threats ('potential soil erosion', 'sensitivity to soil erosion' and 'inherent susceptibility of subsoil to compaction') are not available, since these variables cannot be measured or assessed directly. Therefore expert elicitation was used as independent reference data for evaluating the performance of the e-SOTER database versus legacy data in models simulating the soil threats. The procedure is illustrated in Figure 4-1.

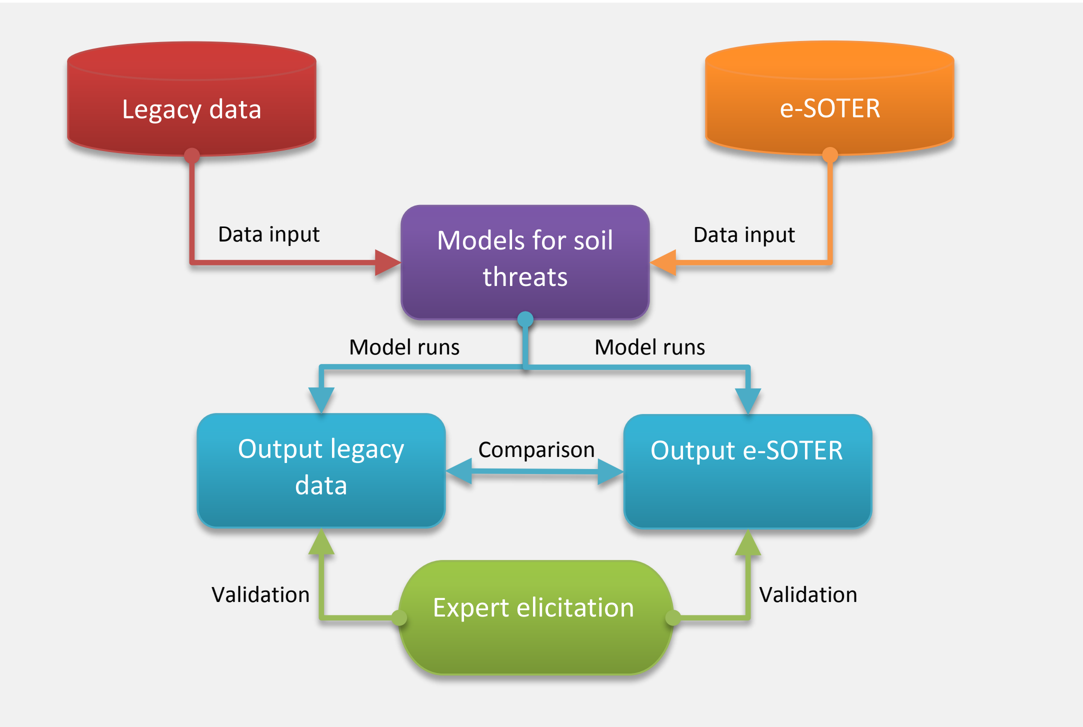


Figure 4-1 Procedure to evaluate the performance of the e-SOTER base employed in WP5.

Input data for the models were collected from the legacy and e-SOTER databases, as described under Task 5.2. The models were run for the research windows. The model outputs were compared between the two databases, and validated against expert elicitation for each model application and database. For the assessment of the performance of the e-SOTER database versus the legacy databases the following research questions were formulated:

1. What are the differences between model outputs for the soil threats obtained using the e-SOTER database and legacy databases?
2. To which differences in input variables are the differences in model outputs related?
3. What are the differences between model outputs for the soil threats obtained using respectively the e-SOTER and legacy databases on the one hand, and expert elicitation on the soil threats on the other hand?

4.2 Methods

The methods used for the application of the selected models are described in Appendix 2-4. This section describes the methods used to process and compare the model outputs between the e-SOTER and legacy databases, and to process the expert elicitation results for comparison with the model outputs.

4.2.1 Processing and comparing model outputs

To facilitate the analyses below, all model outputs have been converted to raster maps first with, for each window, the same map projection, the same spatial extent, and the same spatial resolution (*i.e.*, 1 by 1 km^2).

The outputs of the BGR1-model were available as potential soil loss by water erosion (in metric tons per hectare per year). These outputs are continuous and have been classified to the same classes as have been used during the expert elicitation (*i.e.*, 0-1, 1-5, 5-10, 10-20, 20-50, >50 tons per hectare per year).

4.2.2 Expert elicitation

Expert elicitation is a multi-disciplinary process that can inform decision making by characterizing uncertainty and filling data gaps where traditional scientific research is not feasible or data are not yet available (EPA, 2009). Most studies on expert elicitation formalize and quantify expert judgments of an uncertainty quantity as the probability of different events, relationships, or parameters (following EPA, 2009, quoting SRI, 1978; Morgan and Henrion, 1990), and consequently the available methods are tailored to probability statements. Probability is defined here as a statement of an observer's judgment that the event will occur (Morgan and Henrion, 1990), or to express his degree of belief in their judgment of the target variable value, and the credible interval within which it should fall in his opinion (Aspinall, 2008). Probabilities can be encoded as discrete probabilities (for categorical target variables), or as points on the cumulative distribution function (CDF) or probability density function (PDF) of continuous variables (usually the 5%, 50% and 95% percentiles) (Cooke, 1991) (fixed probability methods; Morgan and Henrion, 1990). For continuous variables it is also possible to encode the probability so that the quantity lies in a specified range of values (fixed value methods, Morgan and Henrion, 1990; Aspinall, 2008). In the last method, the range of the target variable is divided into equal intervals. The expert judges either the probabilities that the value lies in each interval (approximating the PDF), or that the quantity is less than a selection of given values (approximating the CDF).

Applying these methods to the current purpose of using expert elicitation, i.e. to judge the reliability of model outputs for soil threats, would imply asking from experts to judge the values of the target variable (e.g. potential soil loss, in t/ha/y) in a NUTS3 unit at their 5%, 50% and 95% percentiles (according to the fixed probability methods), or to indicate the probability that the value of, in this example, potential soil loss in a NUTS3 unit would fall within certain predefined intervals (according to the fixed value methods). In both cases the expert would be asked to judge probabilities of the average value of the target variables in NUTS3 units. We consider this a difficult task for any expert on soil threats, firstly, because the landscape features informing on the soil threats may vary considerably within NUTS3 units (e.g. the land use or terrain slope angle), and secondly, because not many scientists are familiar with the thought exercise of thinking in probabilities of target variable values, instead of values directly. For these reasons, in this study we developed a method to formalize and quantify expert judgments for the soil threats as the spatial distributions of the target variables reflecting the soil threats soil erosion and soil compaction. This requires a different way of eliciting expert judgments, i.e. not in terms of the probability of occurrence of the target variable expressed as the spatial mean of a specific area, but instead in terms of its spatial distribution within the area. Unfortunately, little literature was found on this way of eliciting expert judgments, and therefore a new methodology was developed, which is explained below. Software was developed to make the application of the method easier.

In the method, experts are asked to indicate the spatial distribution of the target variables ‘sensitivity to soil erosion’, ‘potential soil loss’ and ‘inherent susceptibility of subsoil compaction’ in a set of randomly selected NUTS3 units in the three windows. For each combination of window and soil threat, 3 specific experts in the field of soil erosion and/or compaction, and with regional knowledge of the window, were invited to respond. The number of experts chosen was the minimum according to a study using expert elicitation to estimate the capacity of larger portions of land to provide goods and services in Europe by Kienast et al. (2009).

The experts were asked to indicate the spatial distribution of the target variables by quantifying the areal coverage (in % of the unit) of each value class of the target variable (see Table 2-2 for the classification of values). The elicitation was done using a pie chart, in which the experts could adjust the areal coverage, while maintaining the sum of the coverage to 100% of each unit (Figure 4-2).
In order to inform the expert judgments, a set of auxiliary maps was provided showing information on relevant inputs (land use, parent material, climate, terrain) (Figure 4-2). Input data from the ESDB were deliberately not provided to the experts, in order to avoid bias to the advantage of the ESDB legacy data in the final application of expert judgments to judge the performance of the ESDB versus e-SOTER database.

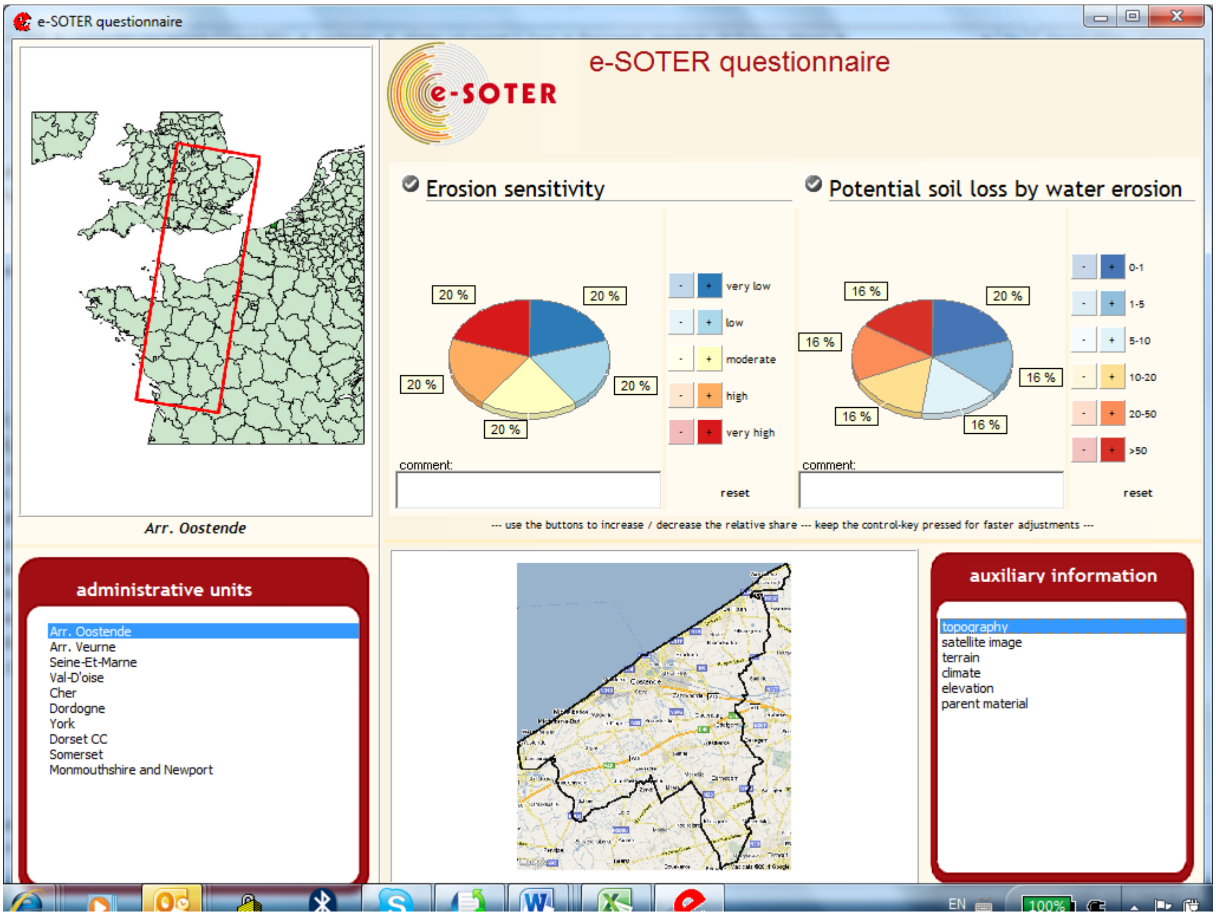


Figure 4-2 Main screen of the software developed for the expert elicitation on soil threats.

Experts were selected based on their knowledge of the soil threat and familiarity with the areas included in the research windows. Some of the experts had field knowledge in parts of the windows only, either from field studies or database or model studies. Experts were asked to indicate their confidence in their own assessments as poor, intermediate or excellent, based on their field knowledge.

For the expert elicitation, sets of 15 NUTS3-units in each window were randomly selected for the WE and CE windows. In the Moroccan window, only 8 NUTS3-units were available, and therefore the expert judgments on these units were taken as final elicitation results. In order to train the experts ('calibration'), they were asked to provide assessments for 10 NUTS3-units from a zone surrounding the windows (Figure 4-3). Inside the research windows, 15 NUTS3 units were randomly selected for the expert elicitation, except for the Moroccan window, where the 8 units were selected for elicitation as described above.

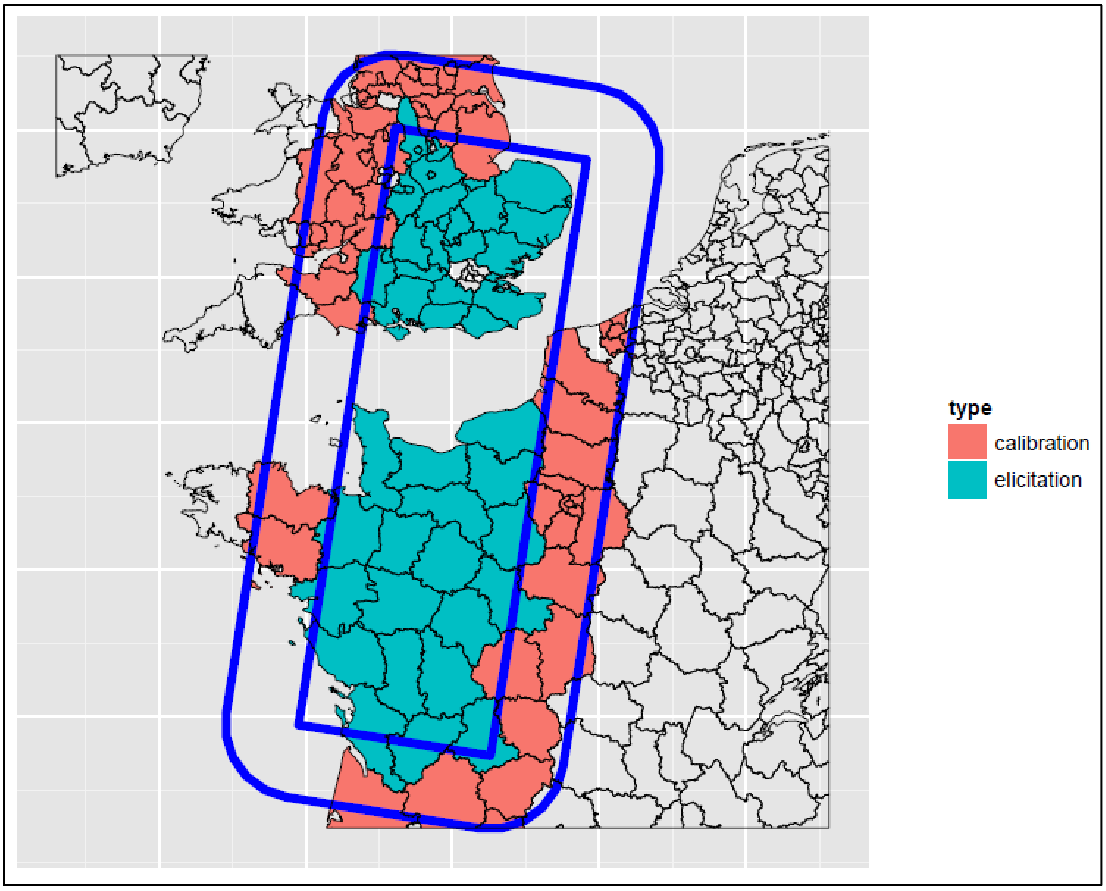


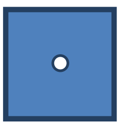
Figure 4-3 Zones for selection of NUTS3-units for calibration of experts (red) and final expert elicitation (blue).

4.2.3 Selection of support

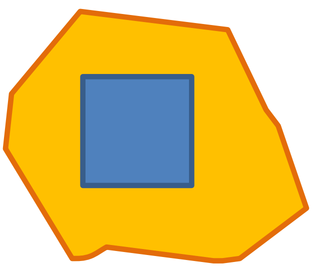
For the evaluation tasks in WP5, a choice had to be made of the support to which the model output and expert elicitation would refer. Three options were available:

1. *Area of a pixel (either 1*1 km2 or 250*250 m2)*

2. *Centre point of the pixel*



3. *Polygon containing the pixel*



Both the ESDB and e-SOTER provide soil data for polygons (SMUs). Several Soil Typological Units (STUs) can exist within 1 SMU. The values in the STUs are constructed based on idealized soil profile data reflecting the mean soil conditions over the STU. In addition, the location of an STU within a SMU is unknown, and therefore a relationship of the soil characteristic to a point location in space is impossible. In addition, other inputs for the models like land use data (e.g. Corine Land Cover) and terrain data (slope gradient) are available for pixels, and the support of the original data is unknown.

Therefore the most obvious support for evaluating model outputs is the pixel (option 1). However, it is not easy for an expert to assess the degree of a soil threat for a 1*1 km^2 pixel as would be required for the evaluation at the 1:1 M scale. Area-specific experts on soil threats in a region are expected to be familiar with administrative and physiographic units in the area of interest. An EU-wide division of administrative units is available in the NUTS system (Figure 4-4).

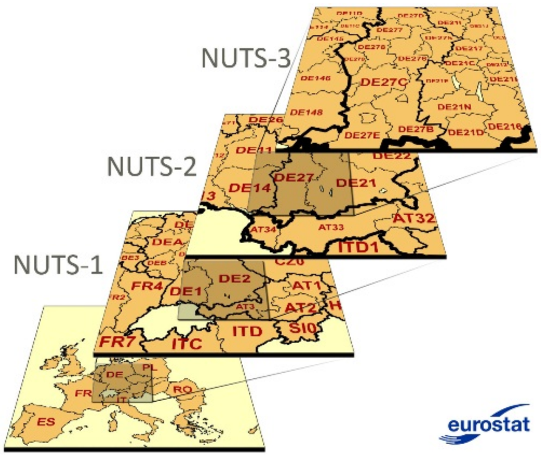


Figure 4-4 Division of the EU in NUTS-units at different levels. Source: Eurostat, 2010.

Therefore, NUTS-units are proposed as the support to elicit the experts on soil threats in the West- and Central European windows. Units at level 3 (NUTS-3) are chosen in order to maximize the number of expert judgments per window. The NUTS-units included in the windows and pilot areas of interest at NUTS3 level are shown in Figure 4-5. The map of JRC-AGRI4CAST has been used here, which includes an administrative division of the Northern African countries.

It should be realized that if the expert judgment is at NUTS-3 level, the results of the comparison of the expert judgment and the model result for the objectives of WP5 will also refer to NUTS-3 units, not to pixels.

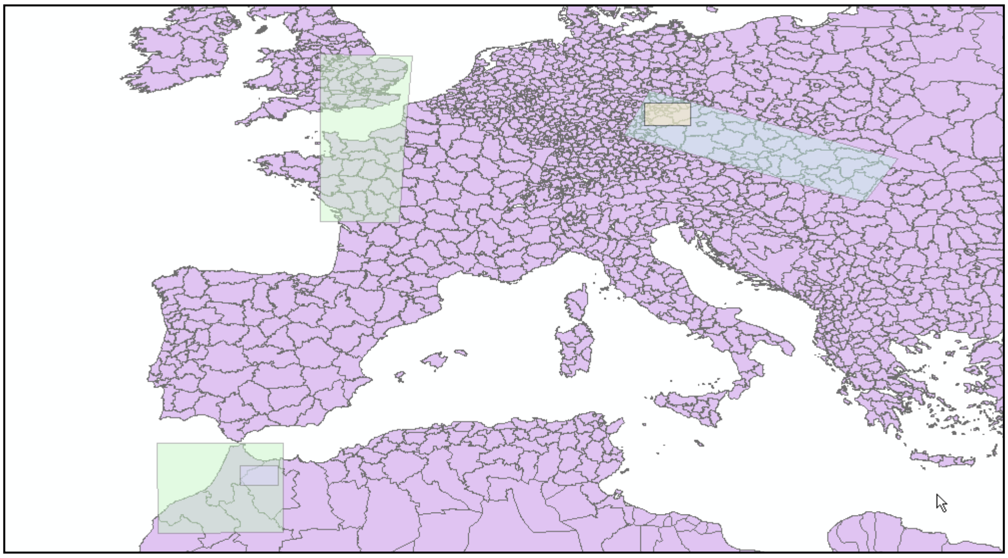


Figure 4-5 NUTS-3 units included in the West-European and Central European windows and German/Czech pilot area and in the Moroccan window and pilot area. Source: JRC-AGRI4CAST (with permission).

4.2.4 Comparing model results and expert elicitations

To quantify the (lack of) agreement between experts, and experts and model outputs, measures like Cohen's kappa statistic are often applied. Although this kind of statistics can provide useful information, Cohen's kappa also has its limitations. First, Cohen's kappa is usually applied to counts, and not to spatial distributions. Second, Cohen's kappa and related statistics may lead to counter-intuitive results (see Gwet, 2008, p.32-33) and should therefore be used with caution. Therefore, Cohen's kappa was not be used in this report[8], but rather another statistic that was better suitable for the specific requirements in this study was needed.

For these reasons, we will use a different statistic referred to as *D*, that is defined as the maximum difference between the cumulative probabilities of the (discrete) spatial distributions of model outputs and/or expert assessments. The larger *D*, the more distinct the spatial distributions. Statistic *D* varies from 0 (distributions are identical) to 100 (distributions are totally different). A notional example of how *D* is determined is given in Figure 4-6.

[8] Except in Appendix 2

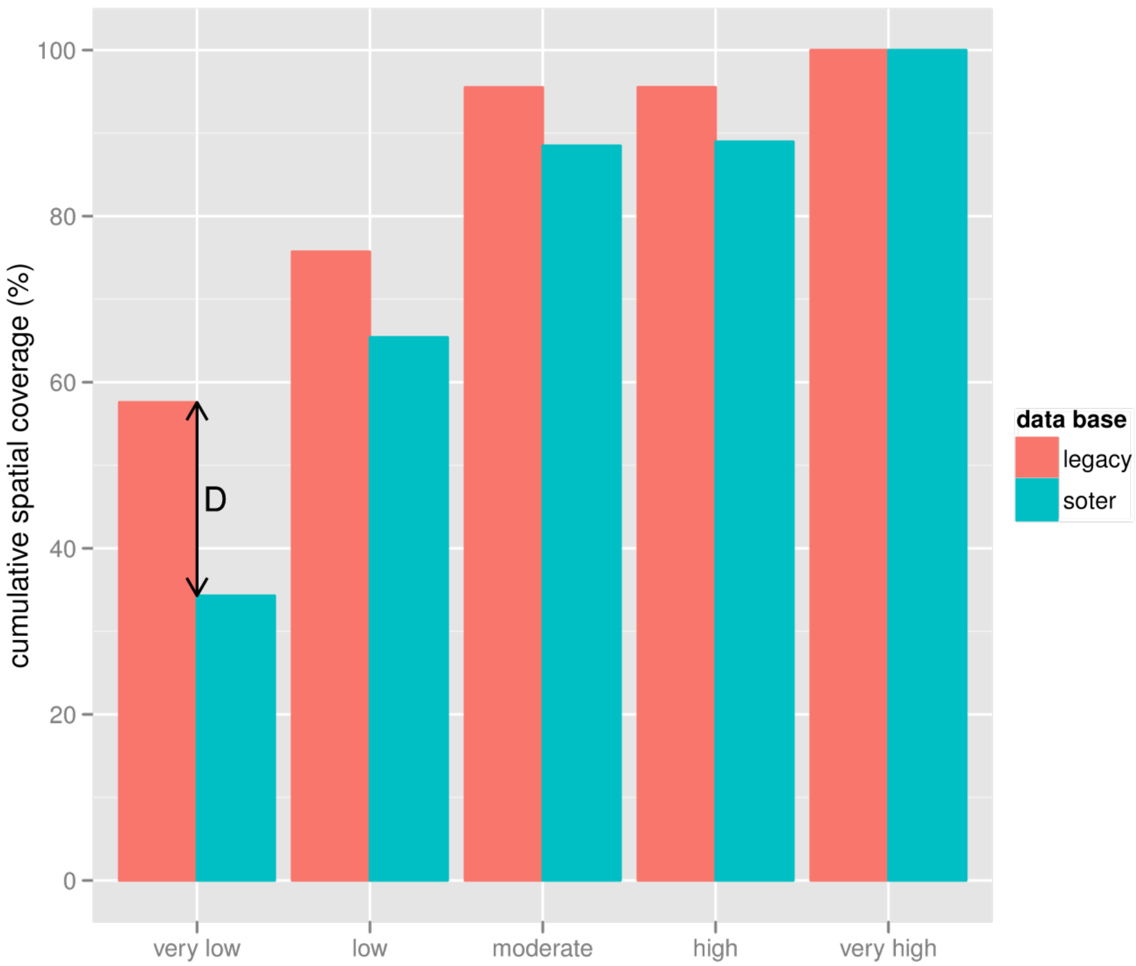


Figure 4-6 Notional example of how *D* is determined (see extent of the arrow).

5 Results

5.1 Model results

Examples of model results for combinations of a model application and window are presented below, ensuring that for each model application and for each window model results are shown, but without showing all combinations of model application and window. The results of all model applications and windows are available in the separate model application reports in Appendices 2, 3 and 4.

5.1.1 BGR model application on potential soil loss and soil sensitivity for the Central European window

Figure 5-1 shows the potential soil loss simulated with the BGR1 model for soil erosion for the CEU window, using the legacy and the e-SOTER databases. The model output for the application using the e-SOTER database is missing for a large part if the window due to missing information on coarse fragments in the e-SOTER database for the e-SOTER units in this part of the window. The information on coarse fragments is required to calculate the stone factor K_S as an input variable to the model (see table 3-3 and Appendix 1).

In the largest part of the area covered by input data from both databases, the model simulates similar potential soil loss using both databases. But in some areas in the south-eastern part of the window, the model simulates higher potential soil loss between 100 and 400 t/ha/y using the e-SOTER database, than when the legacy database is used. Two input variables differ between the model applications for both databases: the soil factor K_B (Figure 5-4) and the stone factor K_S (Figure 5-3). From a visual comparison of the difference between the potential soil loss estimates and the differences between these two model input variables, it appears that the difference in model output is related to a difference in the soil factor K_B in these areas, with values of 0.5 according to the e-SOTER database, corresponding to a medium soil texture, versus values of 0.3 according to the legacy database, corresponding to medium to fine soil texture (see also Figure 5-5). The higher value of the soil factor in the model application with the e-SOTER database results in higher values of the potential soil loss compared to the model application with the legacy data.

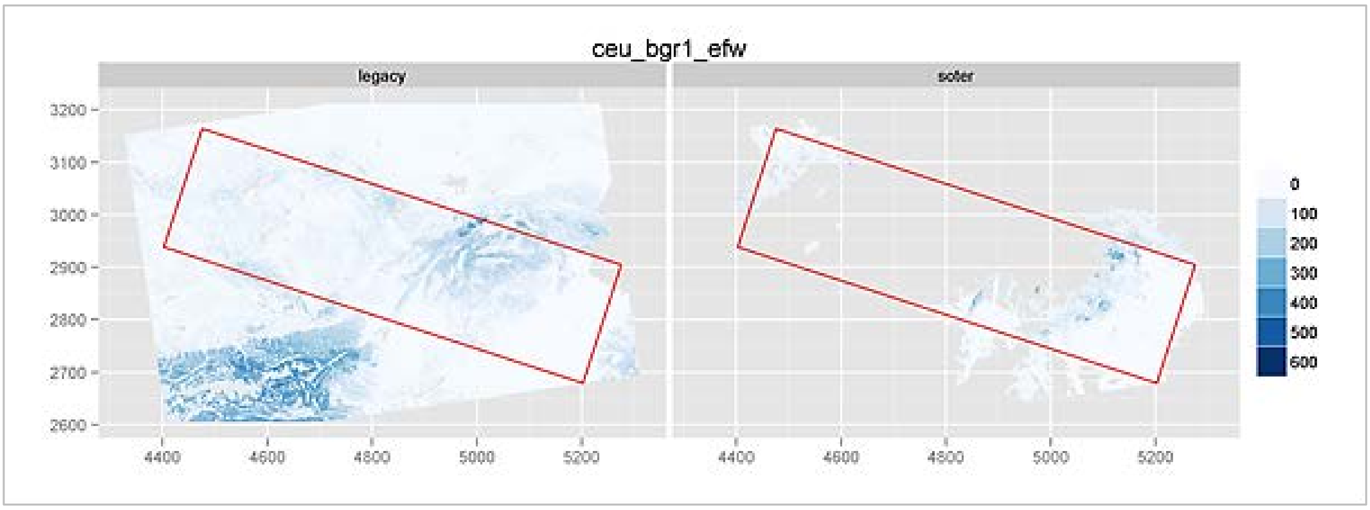


Figure 5-1 Potential soil loss simulated with the BGR model for potential soil erosion (BGR1) using the legacy database (left) and the e-SOTER database (right).

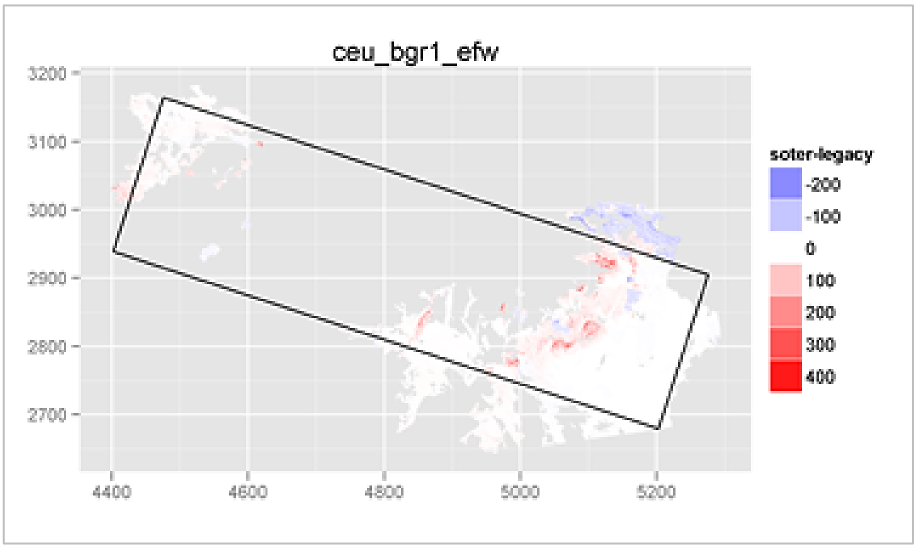


Figure 5-2 Difference in potential soil loss simulated with the BGR model for potential soil erosion (BGR1) using the legacy database and the e-SOTER database (difference calculated as output for e-SOTER minus output for legacy database).

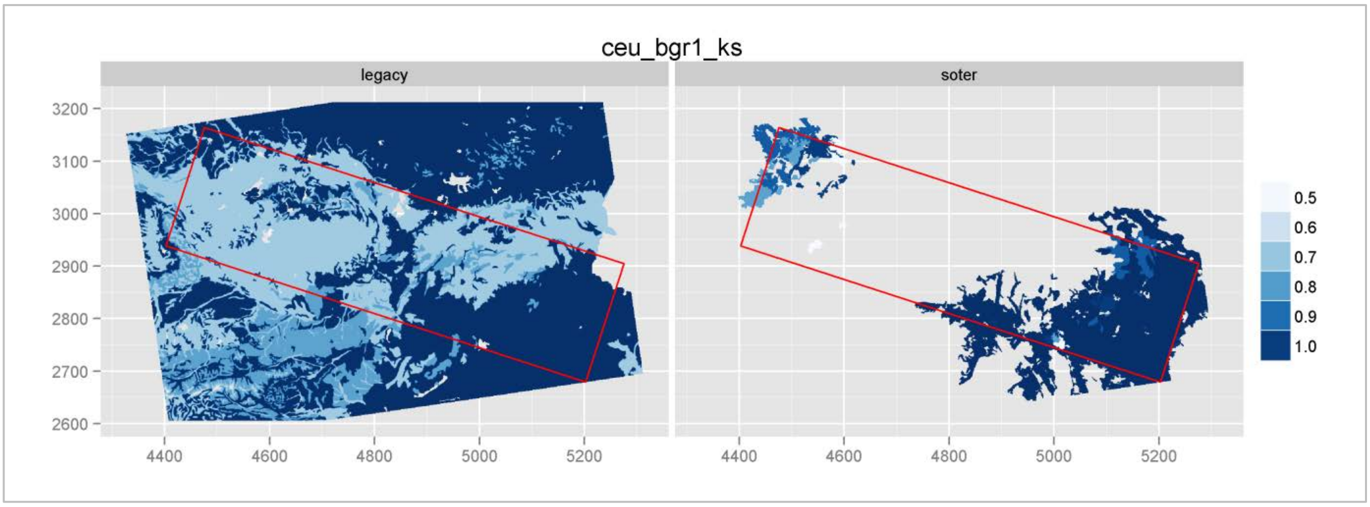


Figure 5-3 Values of the stone factor K_S based on the legacy database (left) and the e-SOTER database (right).

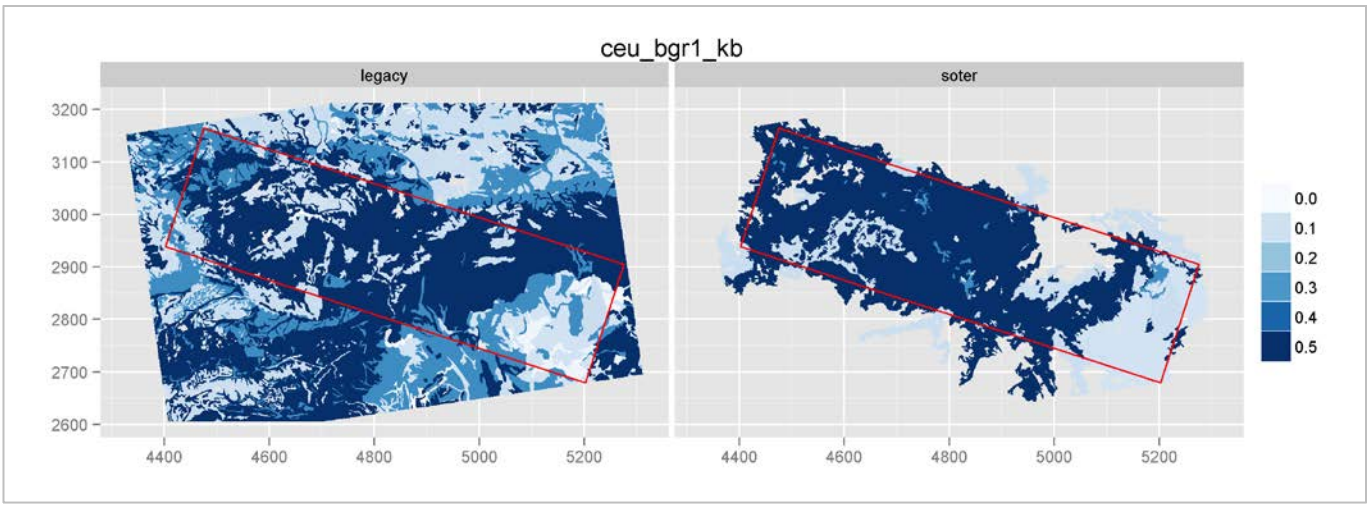


Figure 5-4 Values of the soil factor K_B based on the legacy database (left) and the e-SOTER database (right).

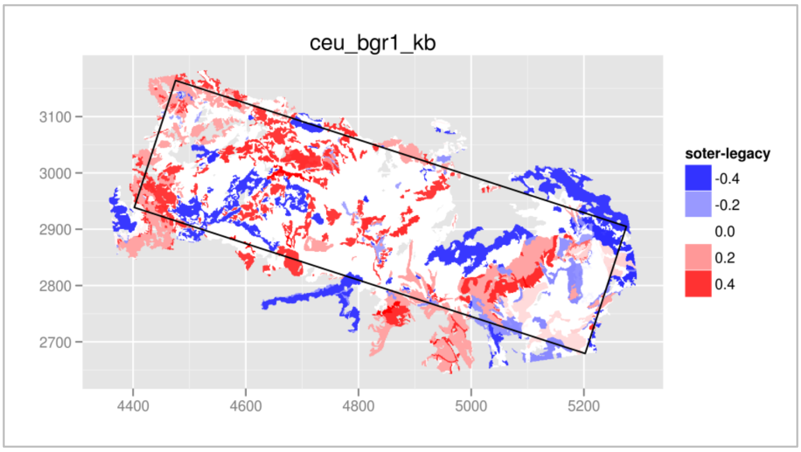


Figure 5-5 Difference in the value of the soil factor K_B between the e-SOTER and legacy databases.

The soil sensitivity to water erosion simulated by the BGR2 model using both databases shows higher sensitivity classes in the same areas in the southeastern part as in the applications with the BGR1 model (see the ellipse in Figure 5-6. However, there are also areas where the legacy database yields higher sensitivity to water erosion (Figure 5-6, Figure 5-7). Since the soil texture class is the only input variable that differs between the model applications for the two databases, the difference must be attributed to difference in soil texture classes. Similar to the BGR1 model application, the general soil texture in areas with higher soil erosion sensitivity in the BGR2 model application using the e-SOTER database is medium (class 2), compared to medium to fine in the model application using the legacy database (class 3) (Figure 5-8). In areas with higher sensitivity according to the model application using the legacy database, the general soil texture is mostly medium in the legacy database, but coarse in the e-SOTER database. This is conform the expectation that medium-textured soil is more sensitive to soil erosion than coarse-textured soil.

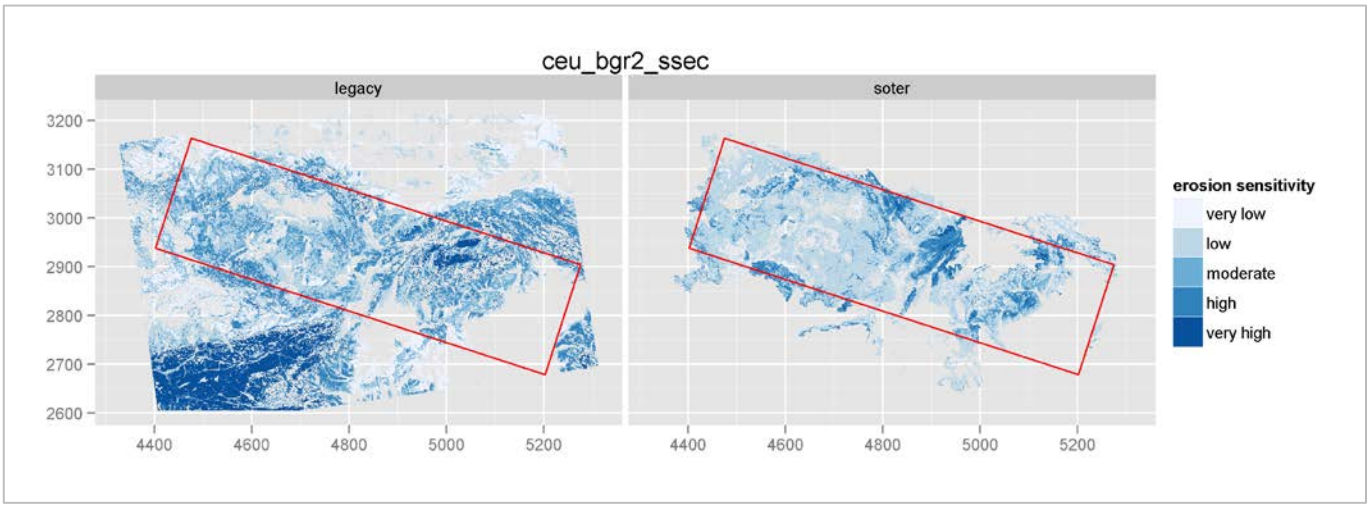


Figure 5-6 Soil sensitivity to water erosion simulated with the BGR2 model using the legacy database (left) and the e-SOTER database (right).

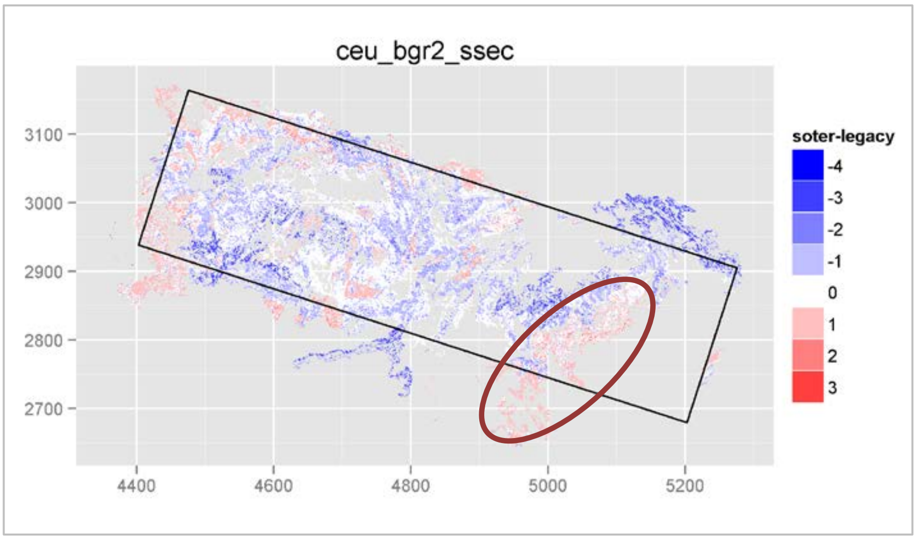


Figure 5-7 Difference in soil sensitivity to water erosion simulated with the BGR2) using the legacy database and the e-SOTER database (difference calculated as output for e-SOTER minus output for legacy database in terms of numbers of classes). Red ellipse indicates area referred to in the text.

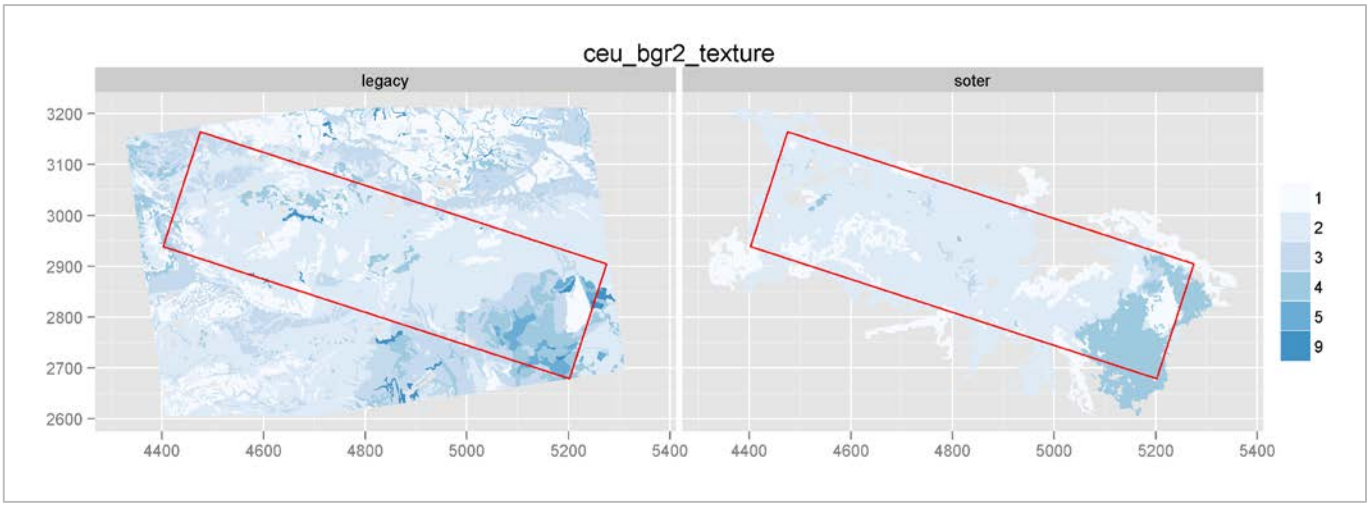


Figure 5-8 Soil texture classes in the CEU window in the legacy database (left) and the e-SOTER database (right). 1: Coarse (<18% clay and > 65% sand), 2: Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%), 3: Medium fine (< 35% clay and < 15% sand), 4: Fine (35% < clay < 60%), 5: Very fine (clay > 60 %), 9 (legacy; 0 in e-SOTER): No mineral texture (Peat soils).

For the comparison of model results to expert elicitation results, which were collected for NUTS3 units, the model output was aggregated to NUTS3 units in terms of the spatial distribution of model output classes in % of the area of the NUTS3 units (see Figure 5-9 and Figure 5-10 for an explanation). Figure 5-12 displays the spatial distribution of the potential soil loss classes in the BGR1 model in the NUTS3 units selected for the expert elicitation, in % coverage of the NUTS3 unit. The location of the NUTS3-units is given in Figure 5-11. The spatial distributions of the potential soil loss classes in the model application using the legacy databases are indicated by red bars, those of the model application using the e-SOTER database by the blue bars. For the NUTS3 units with red bars only, the model input from the e-SOTER database was incomplete due to missing information on either the soil texture or the coarse fragments in the topsoil. The figure shows examples of NUTS3 units with similar spatial distributions of the potential soil loss classes (e.g. CZ032, HU323, DED18). Unit DE24B is an example of a unit with larger areas covered by high potential soil loss (>20 t/h/y) in the model application with the e-SOTER database than in the application with the legacy database. Unit SK022 is an example of the opposite situation.

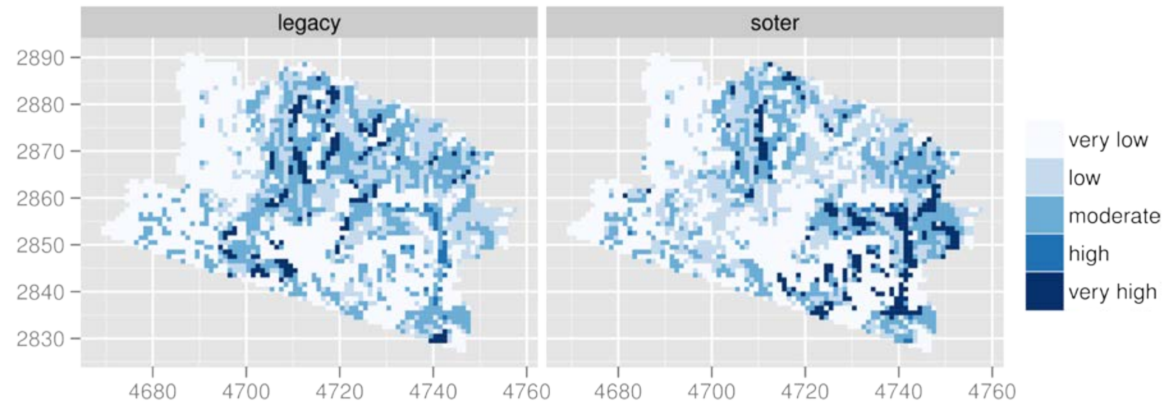


Figure 5-9 Hypothetical spatial distribution of model output in a hypothetical area. Corresponding aggregated spatial distribution of model output classes in % of the area of the NUTS3 units in the figure below.

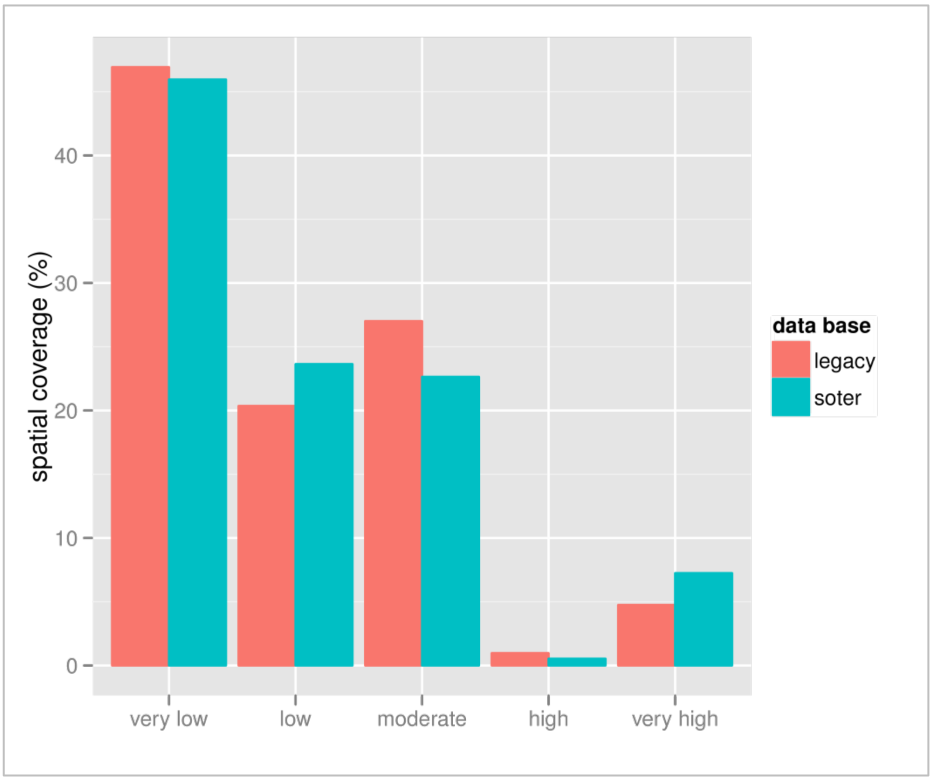


Figure 5-10 Aggregated cumulative spatial distribution of model output classes in % of the hypothetical area in the previous figure.

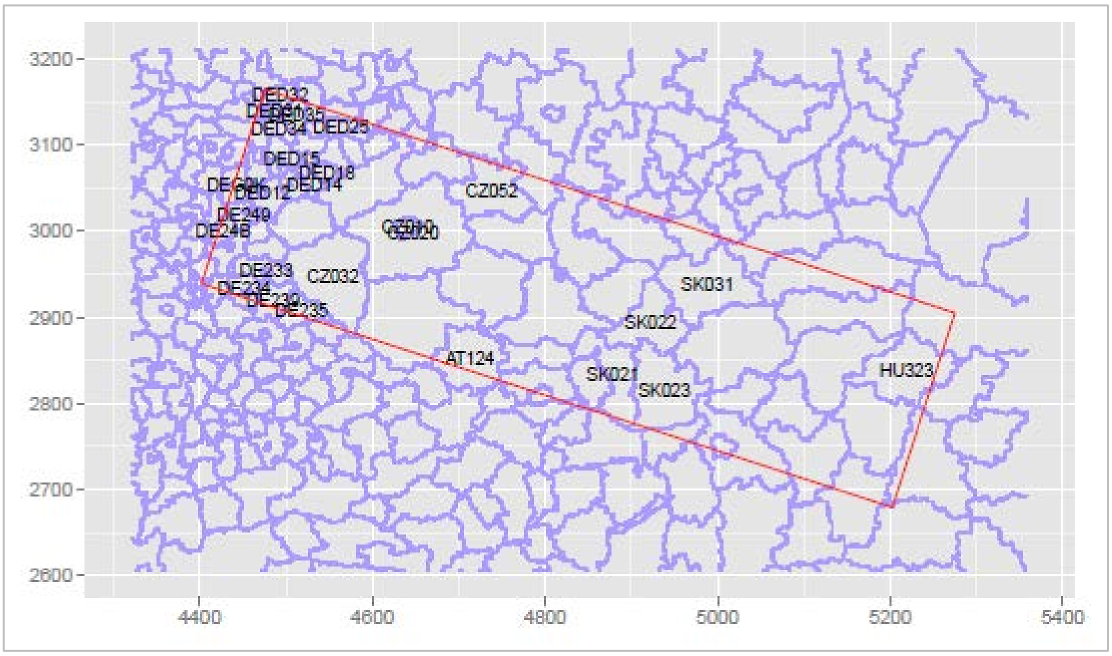


Figure 5-11 Location of NUTS3-units in the Central-European window.

When comparing the model outputs in the maps (Figure 5-1 till -7) to the model outputs in the bar charts it should be noted that the maps display the model output at the level of 1*1 km pixels, whereas the bar charts display the output as spatial distributions of the model output classes over NUTS3 units. Furthermore, the selected NUTS3 reflect only a sample of the CEU and WEU windows, since the number of selected units is small compared to the total number of units in the windows.

Figure 5-12 Spatial distributions of potential soil loss classes in selected NUTS3 units (in % coverage of the unit), simulated with the BGR1 model using the legacy database (red bars) and the e-SOTER database (blue bars).

5.1.2 MESALES model application for sensitivity to soil erosion for the West-European window

The sensitivity to soil erosion in the West-European window according to the MESALES model using the legacy and e-SOTER databases is given in Figure 5-13. The model application using the e-SOTER database does not yield outputs for most of the French part of the window, because the e-SOTER database did not provide soil profile information for these Soter units.

In the north-western part of the window, the sensitivity to soil erosion is higher (moderate to high) for the application with the e-SOTER database than with the application using the legacy database (very low to low), the difference being 2 to 4 classes (Figure 5-14). This is also reflected in the spatial distributions of the erosion sensitivity classes in the NUTS3-units selected in this area (e.g. UKG13, UKG31, UKG33; see Figure 5-16, and Figure 5-18 for the location of these units). The e-SOTER database reports lower or equal values of the erodibility in this area (Figure 5-15), and therefore the higher erosion sensitivity must be explained by the higher sensitivity to crusting (Figure 5-15).

In the French part of the window, the lower sensitivity to crusting and the higher erodibility in the model application using the e-SOTER database seems to cancel out, as a result of which the sensitivity to soil erosion does not differ much between the two database applications in this part of the window. This shows that whereas differences in the soil databases used in the model may exist, this does not necessarily show in different model outputs for the soil threat.

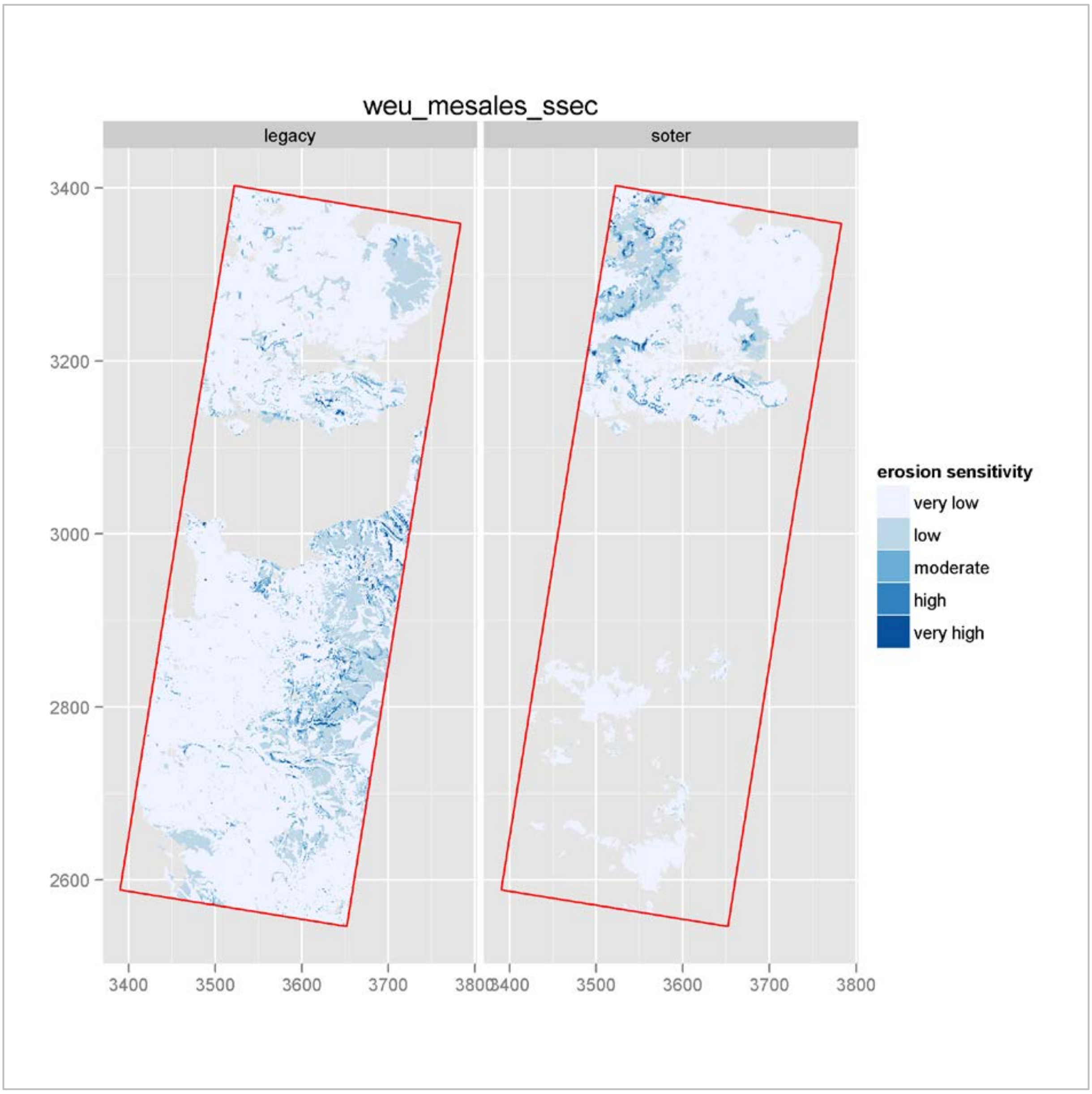


Figure 5-13 Sensitivity to soil erosion simulated with the MESALES model for the West-European window (weu) using the legacy database (left) and the e-SOTER database (right).

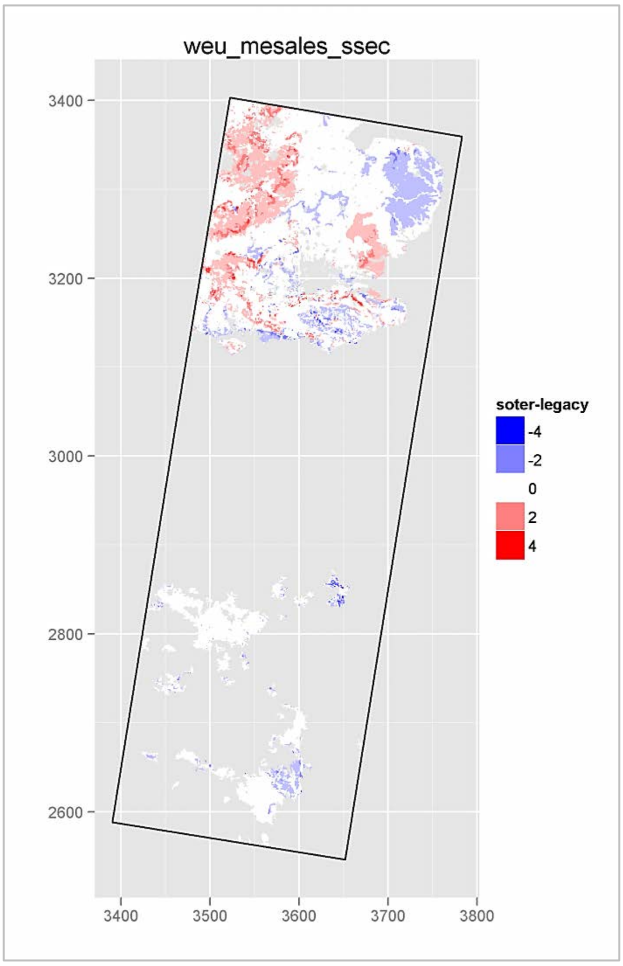


Figure 5-14 Difference in erosion sensitivity simulated with the MESALES model in the legacy database and the e-SOTER database (difference calculated as output for e-SOTER minus output for legacy database in terms of numbers of classes).

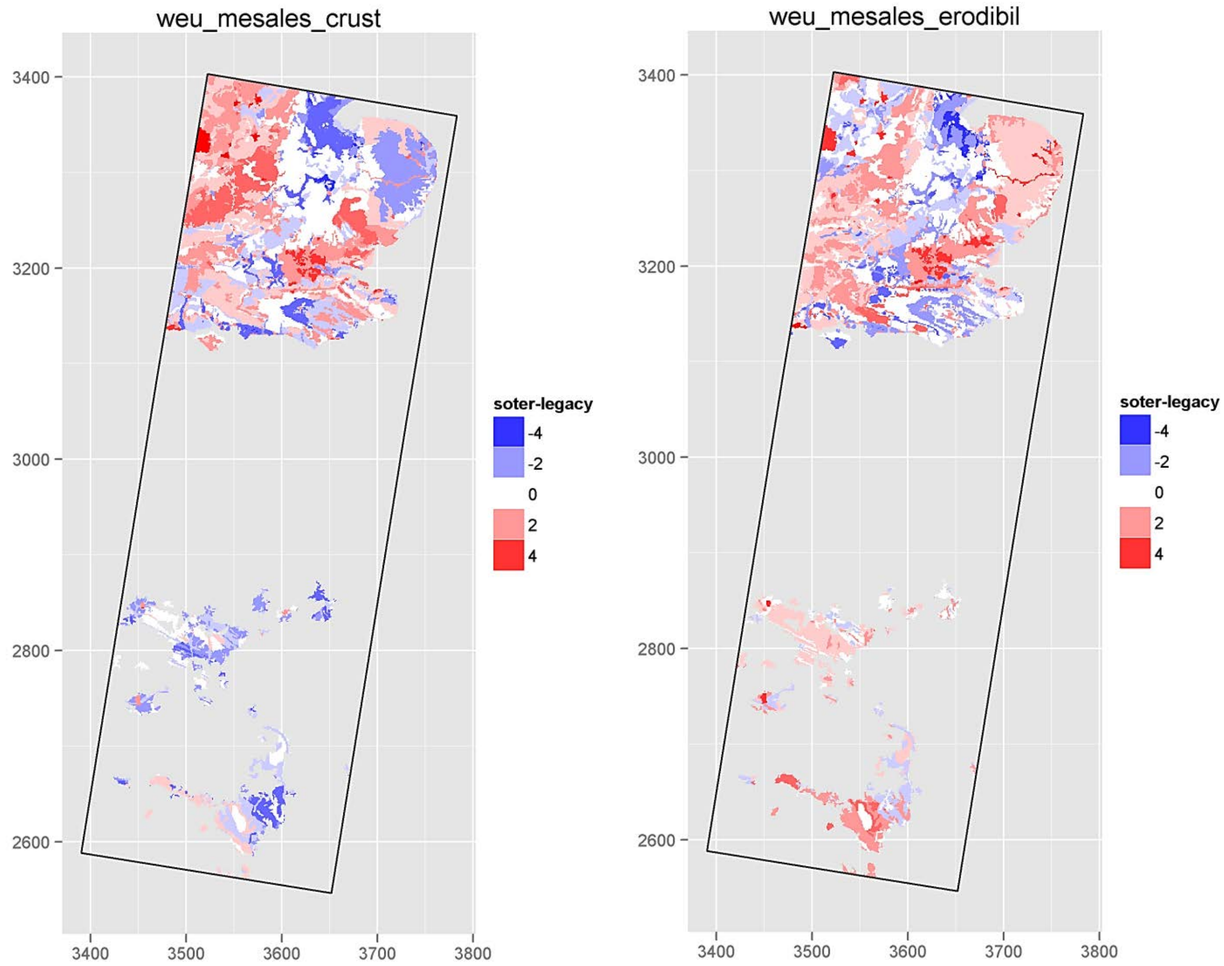


Figure 5-15 Difference in sensitivity to crusting (left) and erodibility (right) in the MESALES model application between the e-SOTER and legacy databases for the West-European window. Difference calculated as model variable in application using the e-SOTER database minus the model variable in the legacy database, in terms of numbers of classes.

Figure 5-16 shows the spatial distributions of the erosion sensitivity classes in the NUTS3-units selected for expert elicitation. The spatial distributions confirm the predominance of the low to very low erosion sensitivity classes in the part of the window situated in the UK, and the higher erosion sensitivity resulting from the application of the model to the e-SOTER database, except for NUTS3-units UKH13 and UKH14, which have almost 100% of their area in the lowest erosion sensitivity class according to the model application using the e-SOTER database, compared to resp. 55% and 60% according to the model application using the legacy database (Figure 5-16).

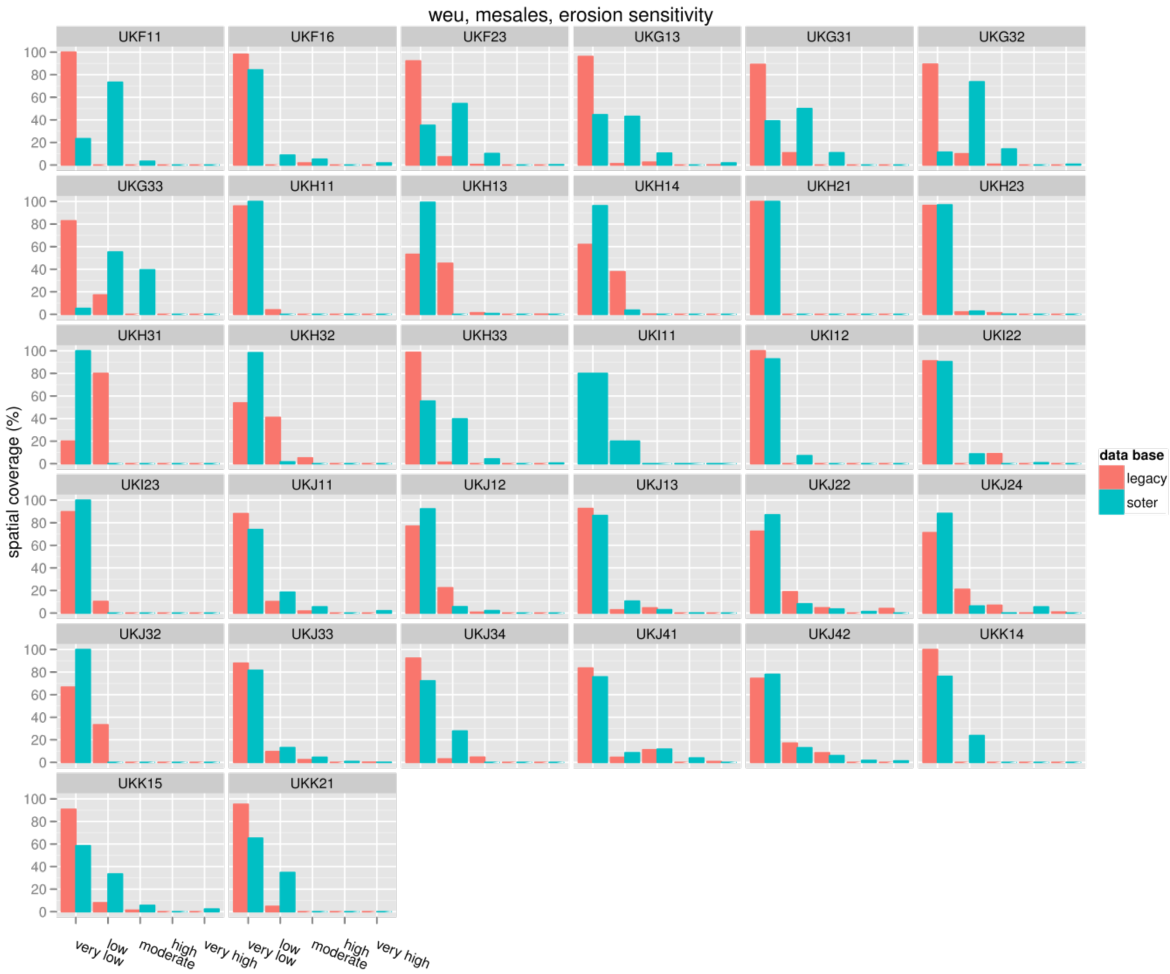


Figure 5-16 Spatial distributions of erosion sensitivity classes in selected NUTS3 units (in % coverage of the unit) in the West-European window, simulated with the MESALES model using the legacy database (red bars) and the e-SOTER database (blue bars).

The cumulative spatial distributions of the erosion sensitivity classes in the NUTS3-units selected for expert elicitation (Figure 5-14) confirm that the largest differences in the coverage of erosion sensitivity classes between the model applications using the legacy and e-SOTER databases occurs for the very low and low erosion sensitivity classes. This is also related to the fact that these classes cover the largest areas in the NUTS3-units.

Figure 5-17 Cumulative spatial distributions of erosion sensitivity classes in selected NUTS3 units (in % coverage of the unit) in the West-European window, simulated with the MESALES model using the legacy database (red bars) and the e-SOTER database (blue bars).

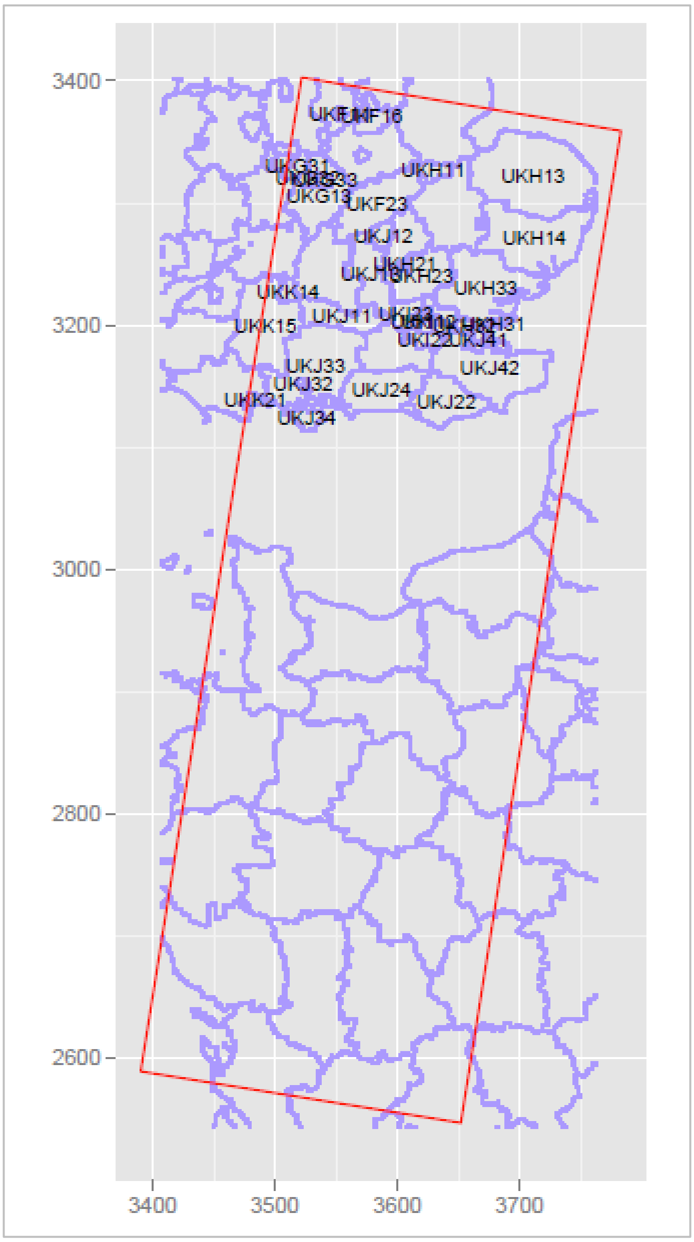


Figure 5-18 NUTS3-units selected for expert elicitation in the West-European window.

5.1.3 Jones model application for susceptibility to soil compaction for the Moroccan window

Figure 5-19 shows the susceptibility to soil compaction in the Moroccan window simulated with the Jones model using the legacy and e-SOTER databases. The model results obtained with the e-SOTER database cover only small parts of the windows, because information on the model input variables (bulk density and subsoil texture) was available for Soter units covering only small portions of the window. The results show that in some parts of the window, the e-SOTER database yields a higher susceptibility to subsoil compaction (red areas in Figure 5-20), and in other parts the legacy database gives higher susceptibility (blue areas in Figure 5-20). The areas with high to very high susceptibility to soil compaction simulated with the e-SOTER database compared to the moderate susceptibility simulated with the legacy database result from the difference between the subsoil texture in both databases. The subsoil texture is documented in the e-SOTER database with very low clay contents (2-4%) and high sand contents (70-90%), whereas the legacy database reports a fine subsoil texture in these areas (30-60% clay) (Figure 5-21). Also, in this area the packing density has lower values in the e-SOTER database (Figure 5-22).

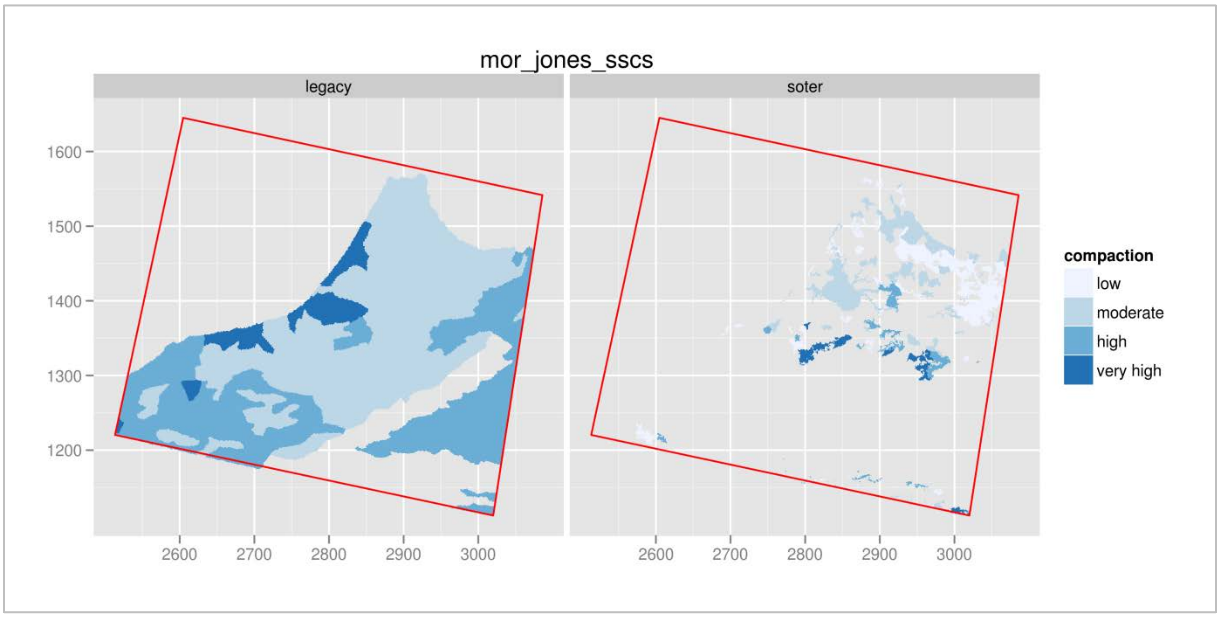


Figure 5-19 Inherent susceptibility to subsoil compaction simulated with the Jones model for the Moroccan window (mor) using the legacy database (left) and the e-SOTER database (right).

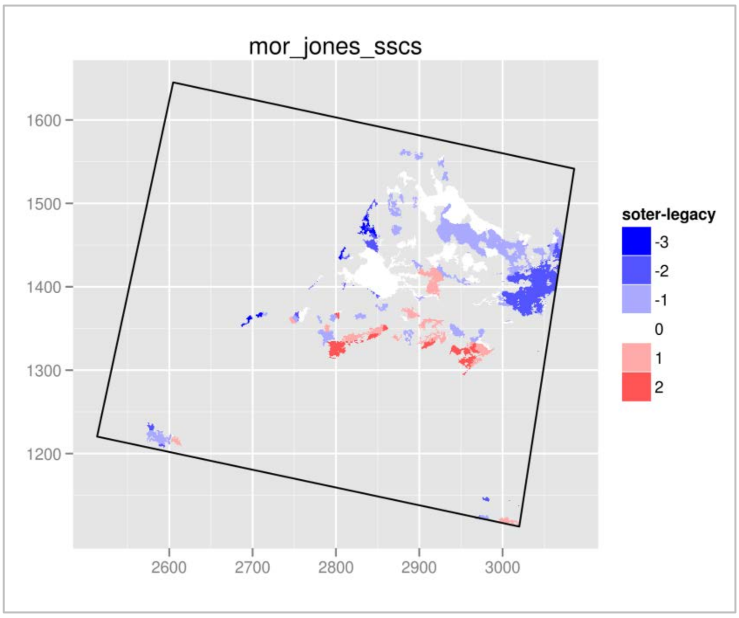


Figure 5-20 Difference in susceptibility to subsoil compaction simulated with the Jones model between the legacy database and the e-SOTER database (difference calculated as output for e-SOTER minus output for legacy database in terms of numbers of classes).

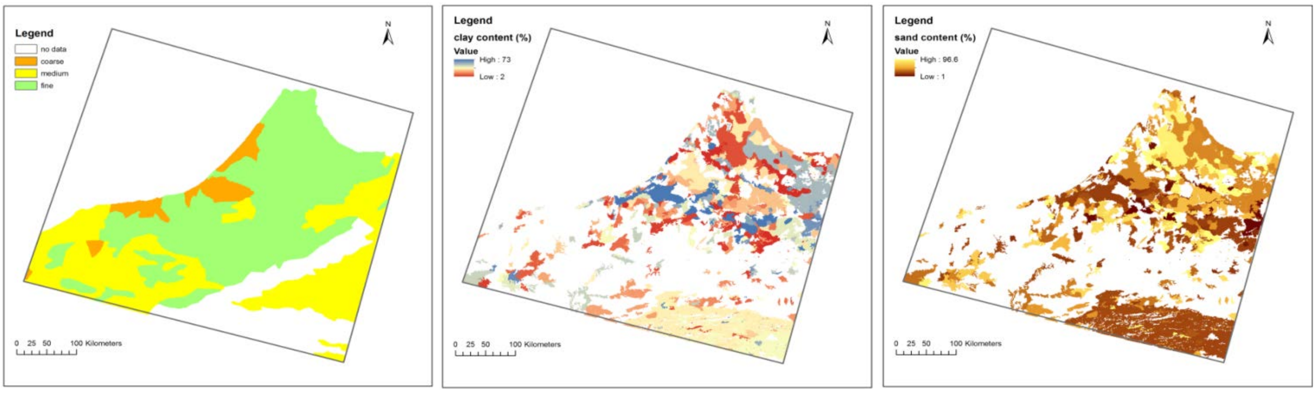


Figure 5-21 General subsoil texture in the Moroccan window according to the HWSD (left), clay content in the subsoil according to the e-SOTER database (middle) and sand content (right).

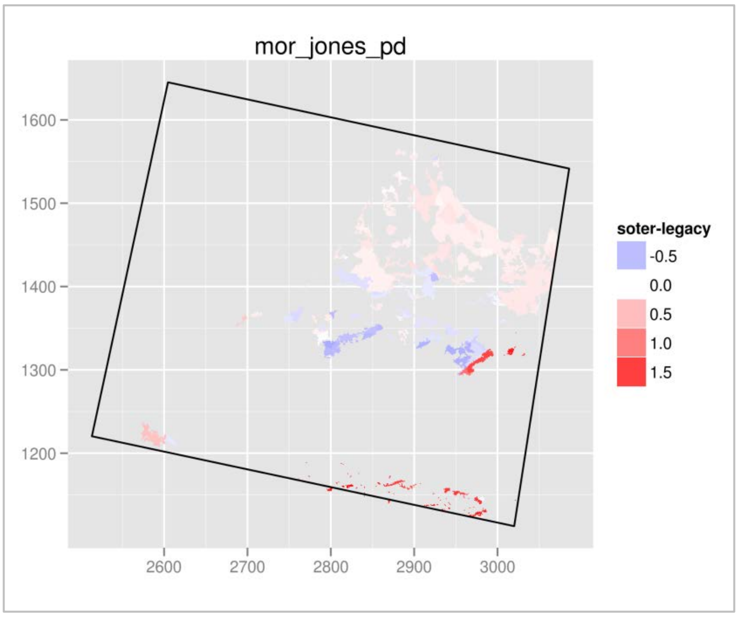


Figure 5-22 Difference in packing density in the Jones model application between the e-SOTER and legacy databases for the West-European window (in $t*m^{-3}$). Difference calculated as model variable in application using the e-SOTER database minus the model variable in the legacy database.

The spatial distributions of classes of susceptibility to subsoil compaction in the administrative units for the model applications with the legacy and e-SOTER databases are shown in Figure 5-23. The numbers refer to the administrative units in Figure 5-24. It should be noticed that the coverage in the spatial distributions refers to the areas covered by model outputs from the model applications using either database, and that 100% refers to the total area covered by model outputs, not to the total area of the administrative unit. The spatial distribution of unit 13655 reflects the areas with high to very high susceptibility to soil compaction simulated with the e-SOTER database compared to the moderate susceptibility simulated with the legacy database described above.

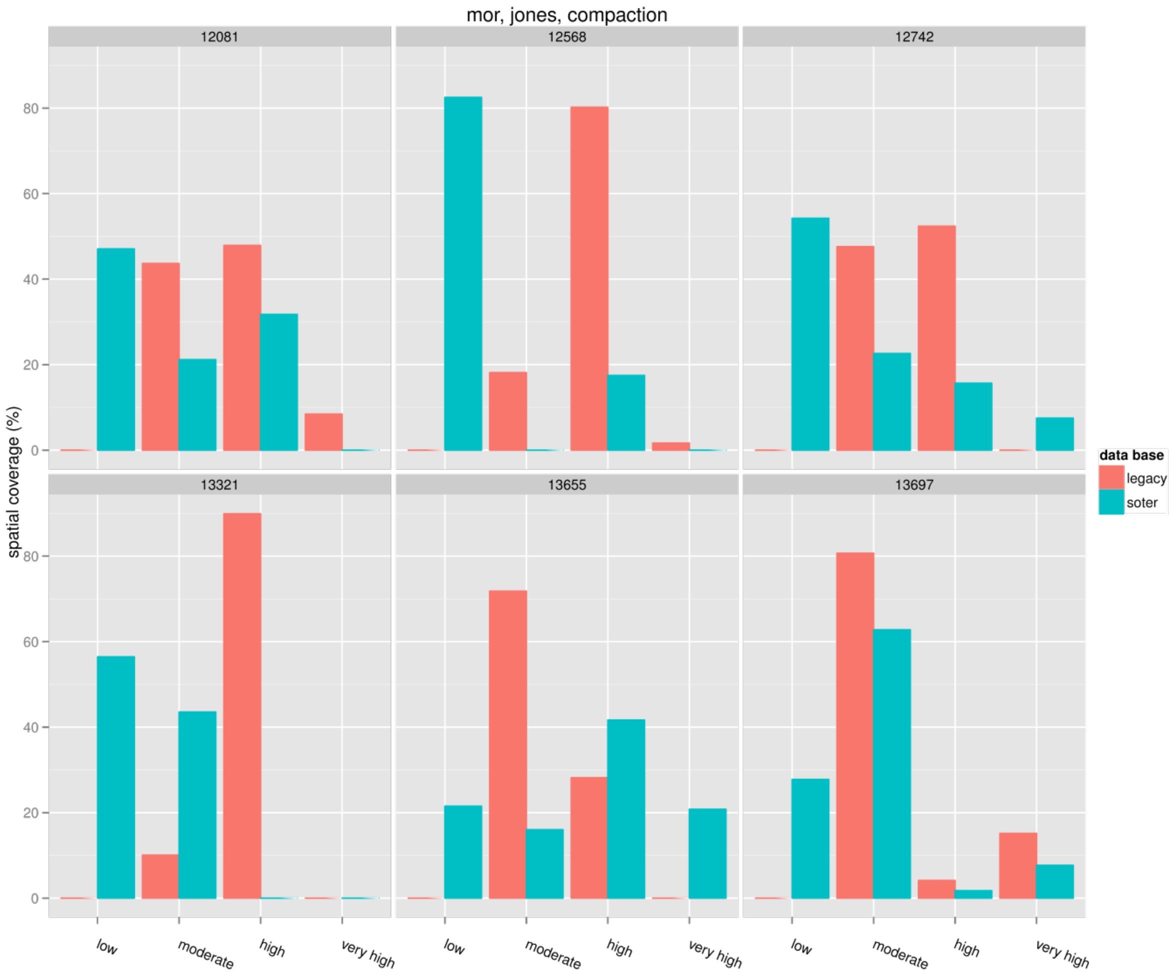


Figure 5-23 Spatial distributions of susceptibility to subsoil compaction classes in selected administrative units (in % coverage of the unit) in the Moroccan window, simulated with the Jones model using the legacy database (red bars) and the e-SOTER database (blue bars).

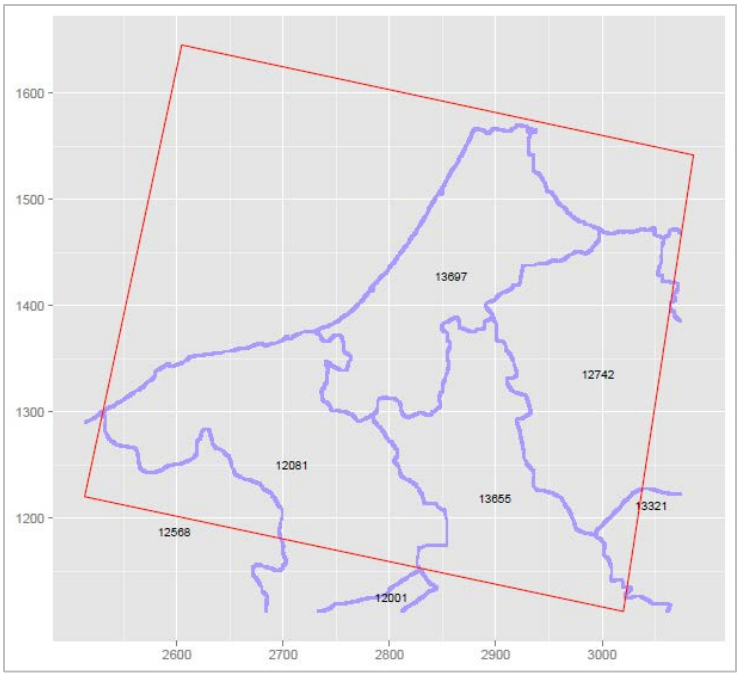


Figure 5-24 Administrative units in the Moroccan window.

5.2 Expert results

The available responses from the expert elicitation over target variables and windows in terms of numbers of administrative units assessed is displayed in Figure 5-25. It shows that for all target variables responses were obtained for each window, either in the calibration or in the elicitation round. In the following description of results the experts have been assigned letters A-L to allow a discussion of results obtained from different experts without revealing their identity.

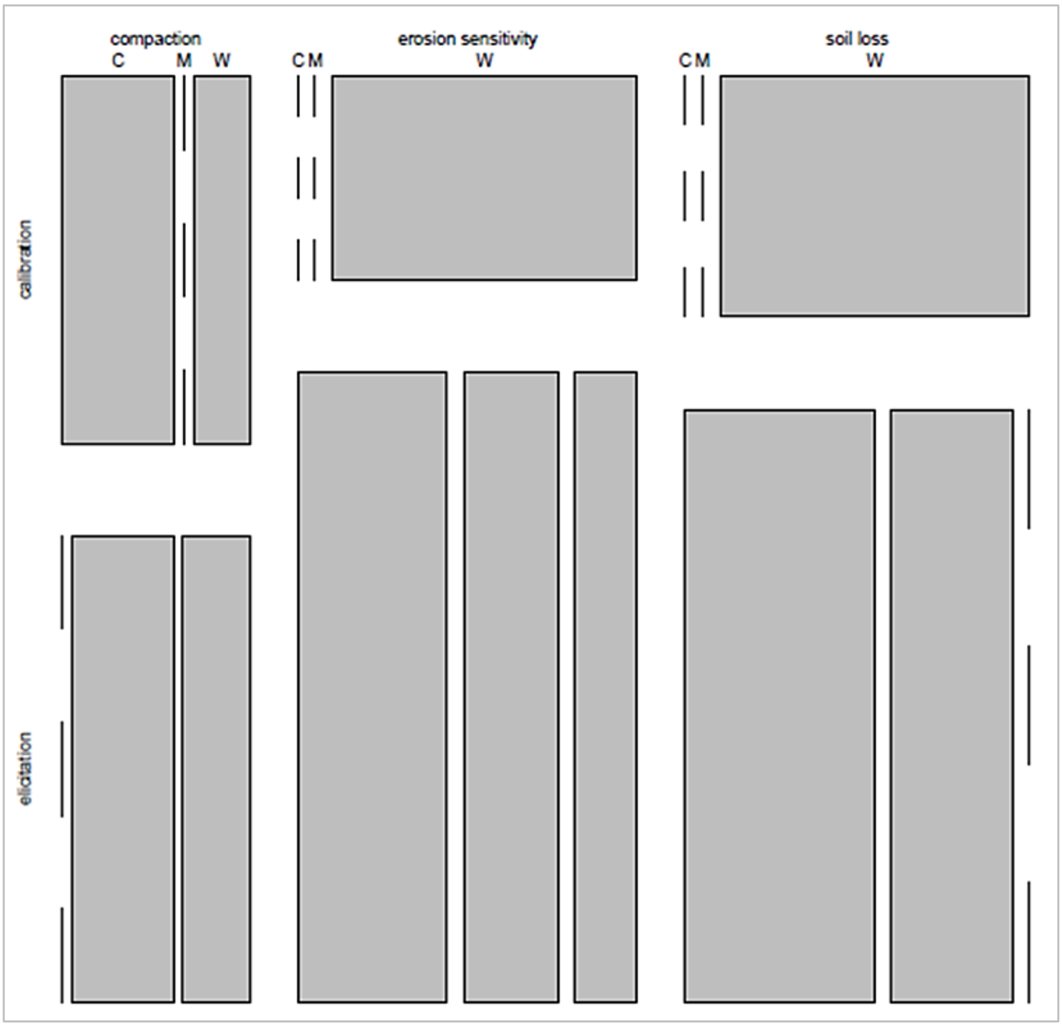


Figure 5-25 'Mosaic plot' showing by the area of the blocks the availability of expert elicitation results over target variables and windows (C: Central European window; M: Moroccan window, W: West European window). Vertical bars indicate absence of data for the combination of window and target variable concerned.

5.2.1 Maximum cumulative difference in spatial distributions of target variables according to expert elicitations (*D*)

The cumulative spatial distributions of the target variables as assessed by the experts were compared in order to analyse their degree of agreement or disagreement on the target variables. This is information is required if the expert judgment is to be used as a 'true' reference for the target variables in the comparison of the model outputs for these target variables obtained using the legacy and e-SOTER databases. If the experts agree to a large extent on the spatial distributions of the target variables, the difference between the model output obtained using either database and the expert judgment is a more reliable measure to assess if the e-SOTER database improves model simulations of soil threats than when the experts disagree to a large extent. In other words, the combined expert judgments provide a more reliable 'decision maker' if the agreement between experts is larger (Clemen and Winkler, 1999).

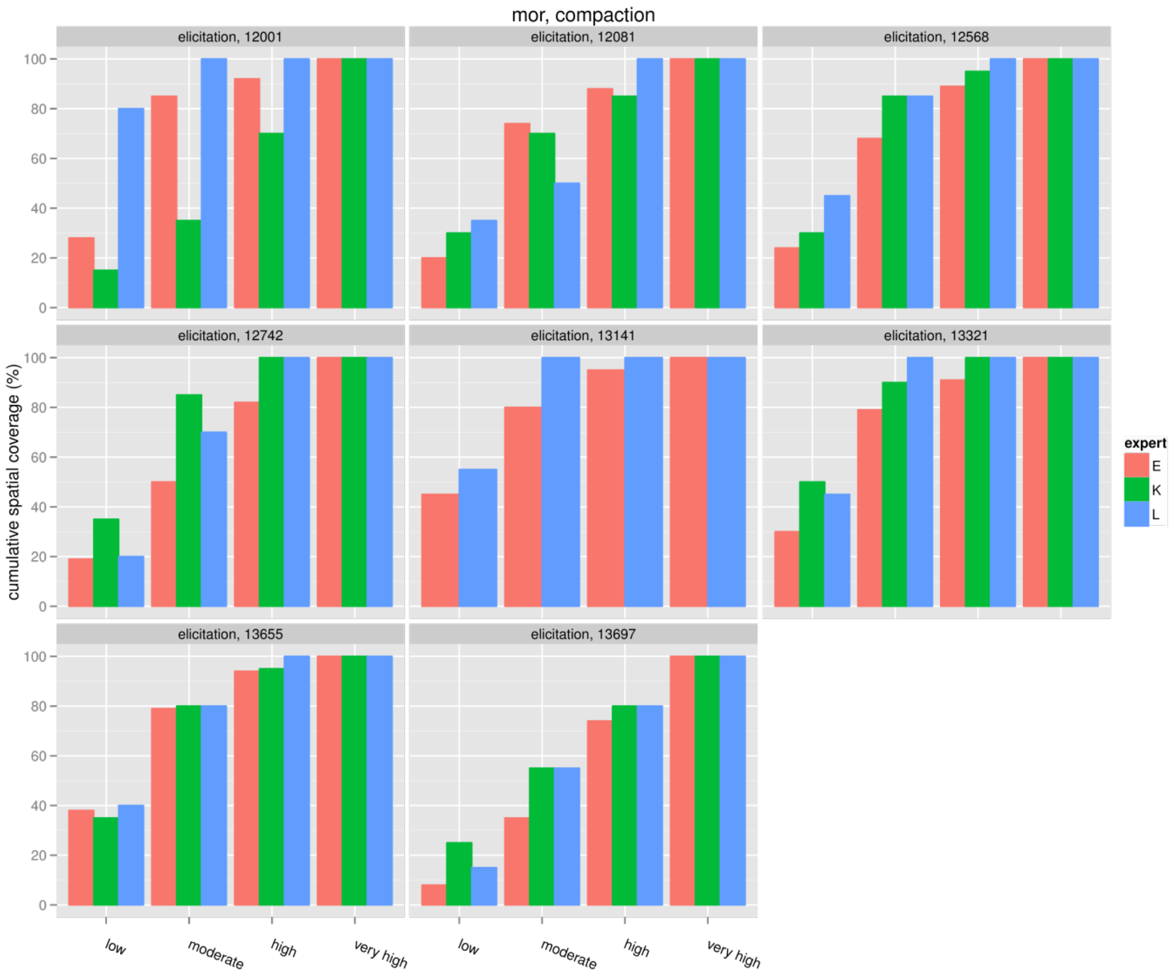


Figure 5-26 Cumulative spatial distributions of the susceptibility to soil compaction in the Moroccan window according to experts.

Figure 5-26 shows the cumulative spatial distributions of the susceptibility to soil compaction in the Moroccan window according to three experts. There is a large agreement of the experts on the spatial coverage of susceptibility to subsoil compaction classes in most units, except for unit 12001, where expert L assesses 80% of the unit to have a low susceptibility to subsoil compaction, whereas expert E thinks only 25% of the unit is in this class, and expert K thinks that the larger part of the unit (65%) has a high to very high susceptibility to subsoil compaction.

Figure 5-27 shows the maximum cumulative difference in spatial distributions of the three target variables (*D*) assessed by experts for the CEU window (in % of the coverage of the NUTS3-units in the window). *D* is represented for pairs of experts (F versus J, G versus H). The width of the shapes expresses the density of data points along the ordinate for each target variable. The areas of each shape represent a unit surface, and should not be compared. The figure shows that the deviation of expert responses between each other has the largest variation for susceptibility to subsoil compaction (between roughly 10 and 70%), and also reaches the largest value for this target variable. For the erosion sensitivity and potential soil loss *D* varies between roughly 5 and 35%. The areas of the NUTS3-units do not seem to influence the result very much, except for the potential soil loss, where the expert judgments seem to differ less for larger NUTS3-units.

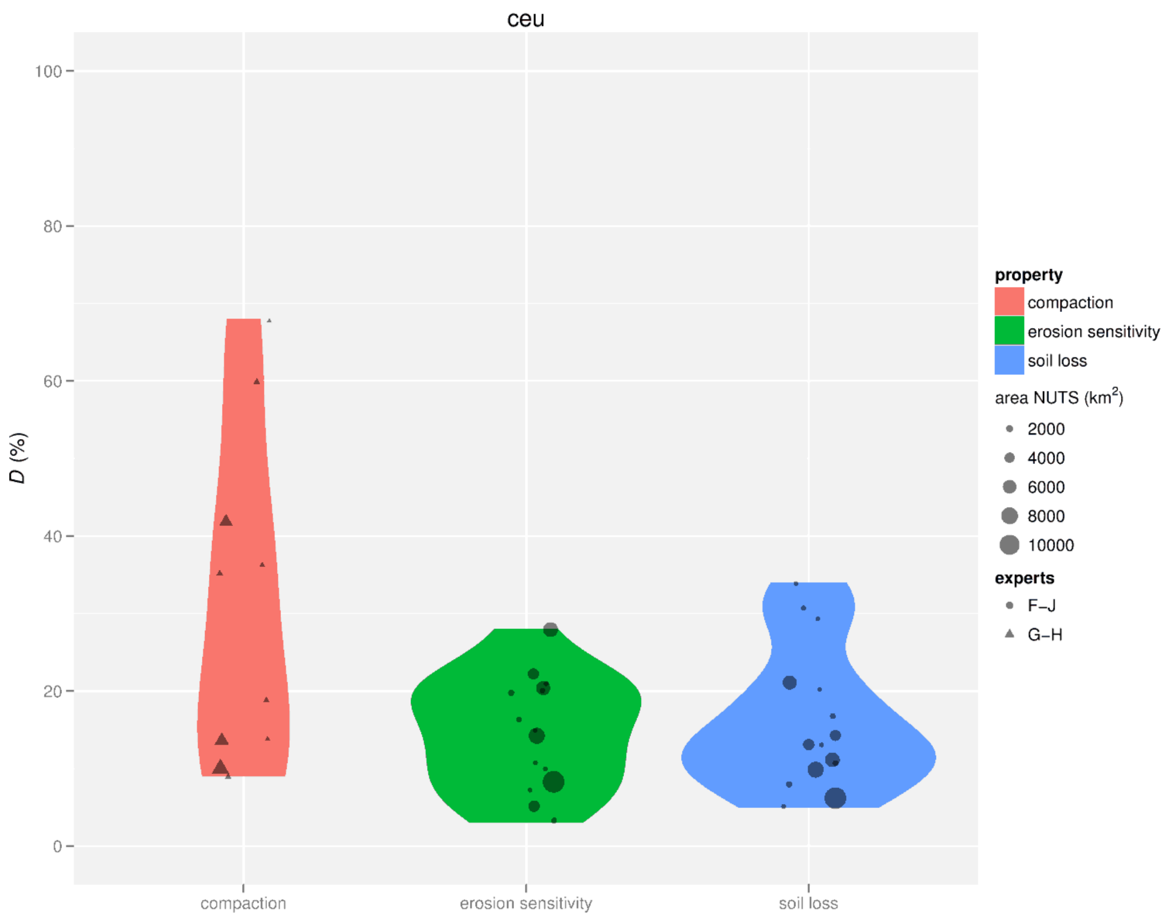


Figure 5-27 'Violin plot' of maximum cumulative difference in spatial distributions of target variables (*D*) assessed by experts for the CEU window. Colors distinguish target variables, symbol types distinguish experts, and each individual symbol representing a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

For the West-European window the maximum cumulative difference in the spatial distributions as assessed by the experts is much higher for all three target variables, and also has a much larger variation (Figure 5-28). D varies from 5 to 85% for the erosion sensitivity and from 10 to 90% for potential soil loss, and is mostly above 50% of the administrative units for susceptibility to soil compaction. For erosion sensitivity and potential soil loss, the assessments by experts c and m differ less than between experts b and m and b and c. The area of the NUTS3-units does not influence the maximum cumulative difference in spatial distributions of the target variables between the experts.

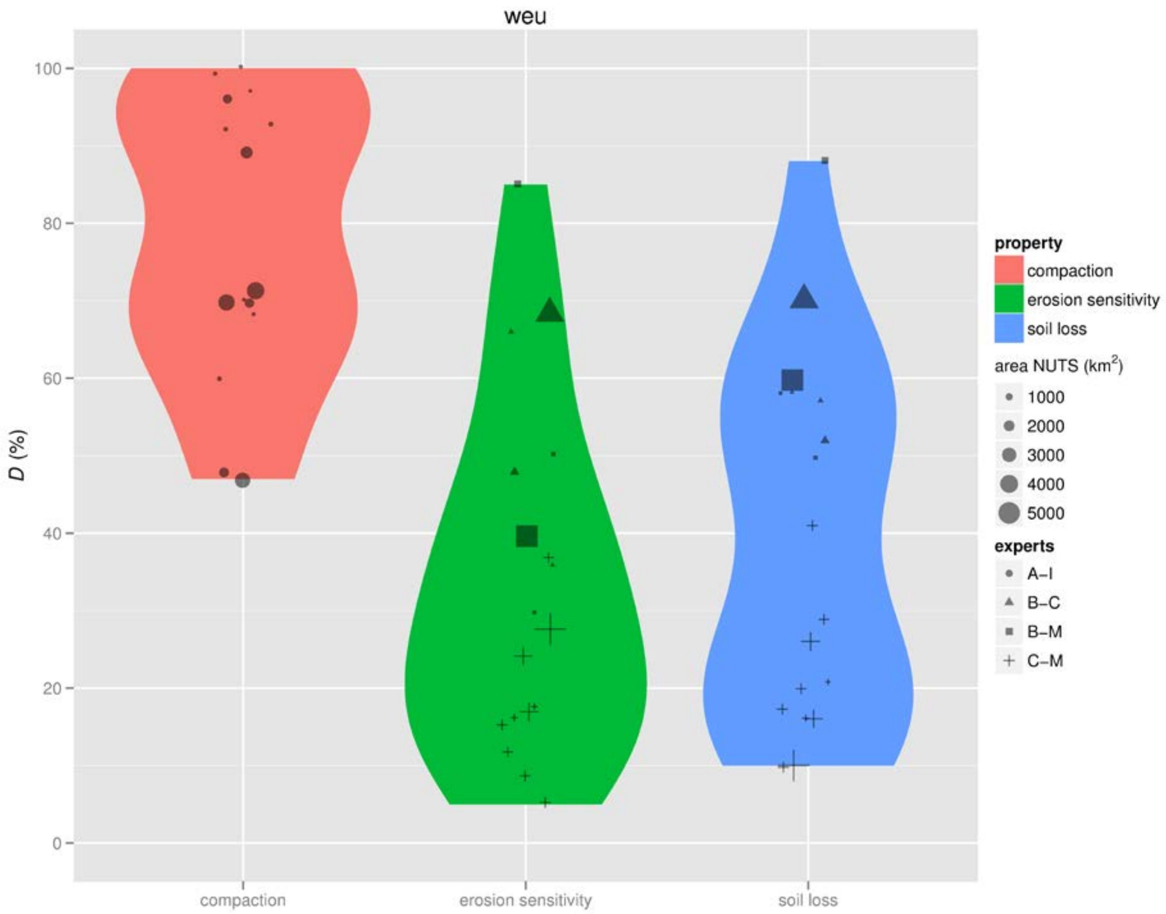


Figure 5-28 'Violin plot' of maximum cumulative difference in spatial distributions of target variables (*D*) assessed by experts for the WEU window. Colours distinguish target variables, symbol types distinguish experts, and each individual symbol representing a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

For the Moroccan window, the maximum cumulative difference in the spatial distributions assessed by the experts has similar ranges for the three target variables, with values of *D* roughly between 5 and 40% of the area of the administrative units, except for the susceptibility to soil compaction, where differences amount to 65% of the units.

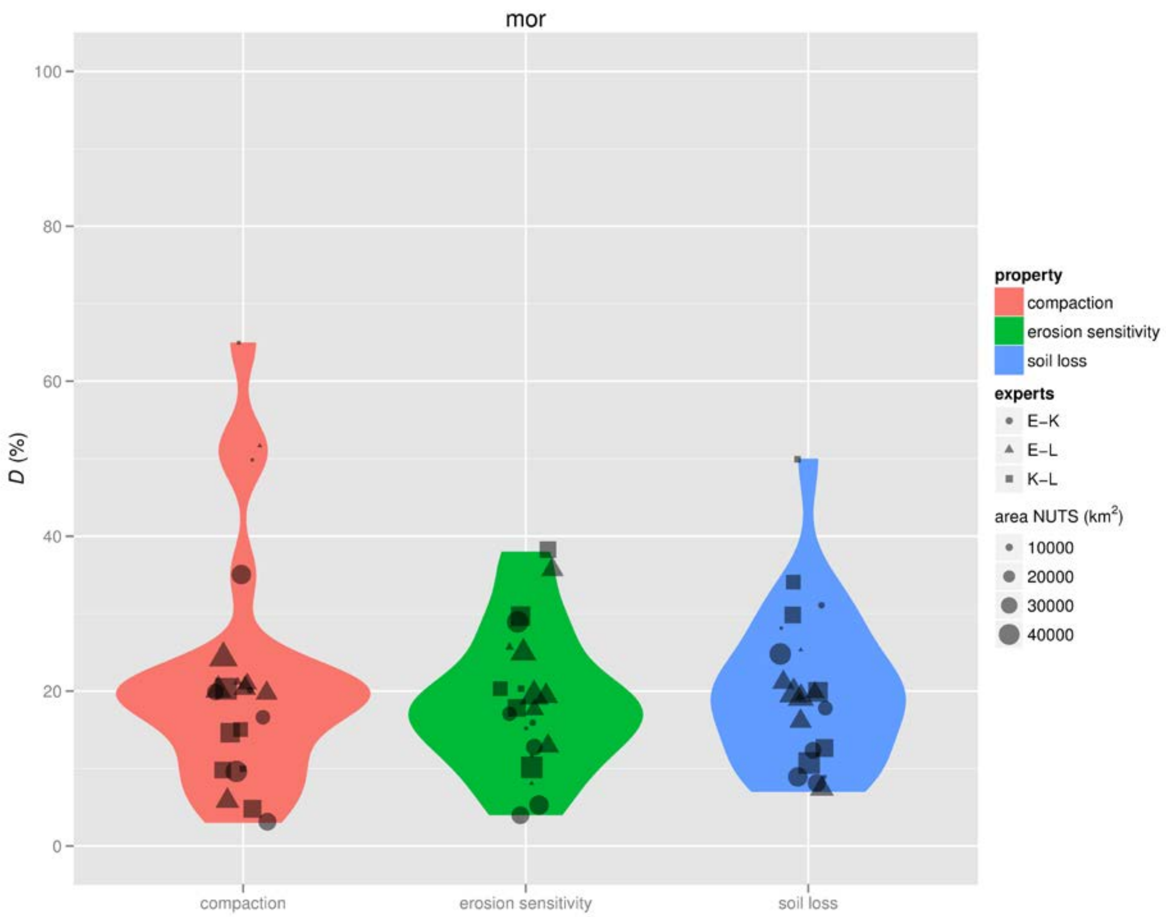


Figure 5-29 'Violin plot' of maximum cumulative difference in spatial distributions of target variables (*D*) assessed by experts for the Moroccan window. Colours distinguish target variables, symbol types distinguish experts, and each individual symbol representing a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

5.2.2 Informedness of experts

Eight out of the 12 experts provided a self-assessment on their informedness on the NUTS3 units in the windows. For 43 % of NUTS3-units, experts indicated to be only poorly informed, but for 36% they claimed to be well informed (Figure 5-30). As data on informedness were not complete, it could, in the analysis, only be taken into account to a certain extent (section 5.4).

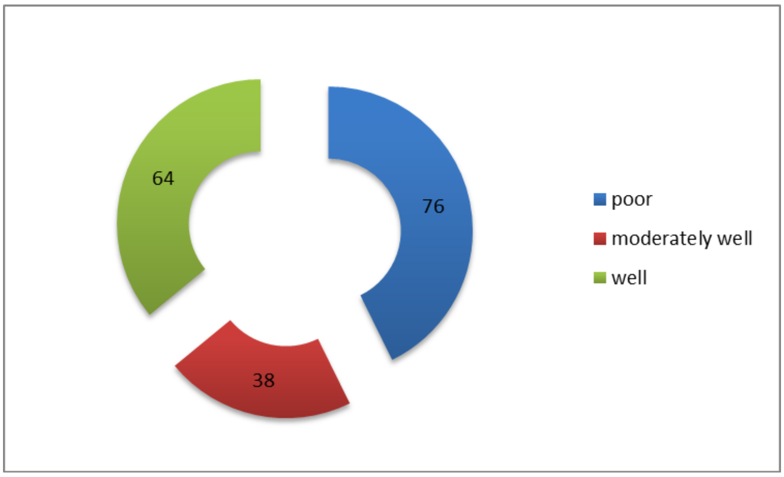


Figure 5-30 Informedness of experts on NUTS3-units, based on a self assessment.

5.2.3 Information sources of experts

All experts used their process knowledge of the soil threats, since they were selected as experts on soil erosion and soil compaction. Eight experts provided information on which information they used in addition to the maps provided in the interface for the questionnaire. Overall, the experts mentioned three information sources for their expert judgments: models (model results already available for the area concerned, or models by applying simple model rules in their mind during the assessment), external data and field knowledge. Six experts used field knowledge for their assessment, four used model results or models, and three used external data. Some experts used two of the three information sources, none used all three.

The model results used were obtained using the same models as in this study: the MESALES and Jones models for respectively sensitivity to soil erosion and susceptibility to compaction. As external data Google Earth and national soil maps were used by two experts. Many experts commented on the absence of information on the spatial coverage of map units in the auxiliary maps provided in the interface. This information was omitted on purpose in order to stimulate the expert to use other sources of information, preferably his/her field knowledge, instead of simply copying the coverage of map units from auxiliary attributes (like the parent material) to areal coverages of estimated model output classes. One expert made eye-ball estimates of the coverage of map units on the national soil map for the UK window, and verified these with the areas calculated in a GIS. The detailed report is given in Appendix 5.

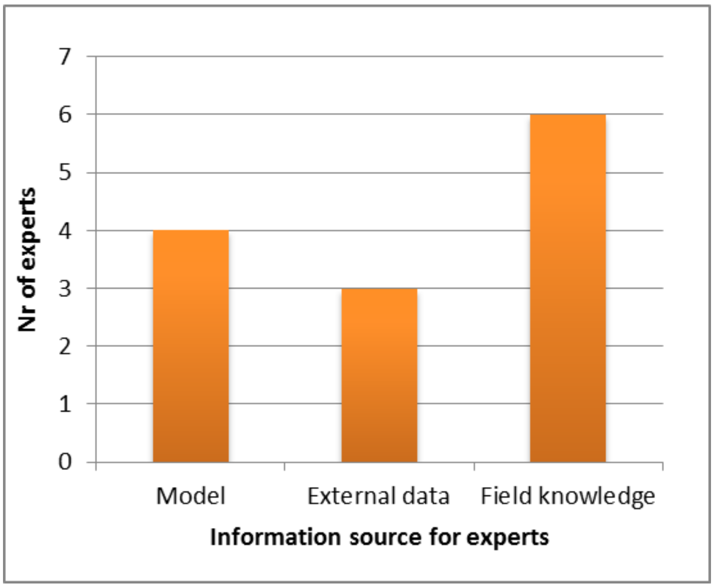


Figure 5-31 Information sources used by experts in the expert elicitation.

5.3 Comparison of model and expert results

In this research, the expert judgments of the target variables were used as a proxy for 'true' reference data on the target variables. The maximum difference in the cumulative spatial distributions of model outputs versus expert results (*D*) then indicates the deviation of the model output with regard to the 'true' reference data of the target variables. This deviation is used to assess if the model output is improved by using the e-SOTER database instead of the legacy databases. If model outputs obtained using the e-SOTER database have smaller values of *D* compared to the model results obtained with legacy data, the e-SOTER database can be claimed to improve the simulation of the target variable by the model in the window concerned. If however the value of *D* is larger than in the model application using the legacy database, the e-SOTER database does not improve the simulation of the target variable for the model and window concerned.

Figure 5-32, Figure 5-33 and Figure 5-34 show the value of *D* between the expert judgment and model output for all three target variables in the three windows. For each target variable, density function is given of the deviations with regard to the model output obtained using the legacy database and the e-SOTER base. The first impression from the figures is that *D* has large values, up till 100% for erosion sensitivity and susceptibility to subsoil compaction in the CEU and WEU windows. This implies that expert judgments on the spatial distributions of the target variables differ greatly from the model outputs. For example, the experts agreed on erosion sensitivity in CEU fairly well (D between 5 and 35%, Figure 5-24), but the comparison between expert judgement and model results now shows D-values of about 7 to 100% for erosion sensitivity in this window, both for legacy and for e-SOTER data (Figure 5-29). The large differences between expert judgment and model result may be explained by several reasons:

1. The experts were provided with less detailed spatial information on the land properties relevant to the soil threat, whereas the models were fed with this information at the level of 1 km^2 pixels. Note, however, that although the maps had 1 km pixels, this does not mean that the actual information was also available at that scale. Level of detail of data is for the soil related input dependent on the polygon size in the soil map (or the e-SOTER unit size in e-SOTER). Hence, this reason is more applicable to data that indeed differed from 1 pixel to the next, such as slope angle.

2. The experts estimated the coverage of the classes of the target variables visually ('eye-ball estimates'), whereas the coverage of classes was exactly determined in the analysis software.

3. The experts used process knowledge, external information and field knowledge, that was not available to or incorporated in the model applications.

4. The experts were insufficiently informed on the areas selected for the questionnaire. This seems to be confirmed by the finding that the majority of the expert assessments was poorly or moderately well informed.

For the West-European window, *D* has a larger variation and reaches higher values for susceptibility to soil compaction than for erosion sensitivity. This may be explained by either a larger disagreement between the experts, or a larger difference between the outputs of the model applications using the e-SOTER and the legacy databases. Based on the clustering of values corresponding to assessments of expert I for lower values of *D* (triangles), and assessments by expert A (dots) in the upper part, the first explanation seems most plausible. Such larger disagreement might indicate that susceptibility to compaction is more difficult to estimate than susceptibility to erosion.

The second observation on the plots is that *D* is not clearly smaller for the model applications using the e-SOTER database; in most cases the plots for legacy data and e-SOTER are fairly similar. This implies that the e-SOTER database cannot be concluded to yield more reliable simulations of the target variables than the legacy databases.

The third observation on the plots is that *D* shows almost no differentiation according to individual experts or NUTS3-units. This is demonstrated by the occurrence of symbols representing experts and area sizes occurring through the full range of the density functions of *D* for each combination of target variable and window.

The significance of the observed differences in *D* between the legacy and eSOTER databases compared to expert judgment was statistically tested using a Mann-Whitney test. In the table below, the Mann-Whitney test has been carried out for each target variable (property) and window (if relevant). Note that statistical testing does not make sense for the Moroccan window, because in that case the entire population has been evaluated by the experts.

The (one-sided) alternative hypothesis can be formulated that the median of D for the legacy database is greater than the median of D for the eSoter database. From the table below, it can be concluded that there is no evidence in the data to reject the null hypothesis of no difference between the medians.

Table 5-1 Mann-Whitney test results for differences between values of D obtained with the legacy and eSOTER databases for each combination of window and target variable (property).

	window	property	p
1	ceu	compaction	0.12
2	ceu	erosion sensitivity	0.96
3	ceu	soil loss	0.66
4	weu	compaction	0.62
5	weu	erosion sensitivity	0.47

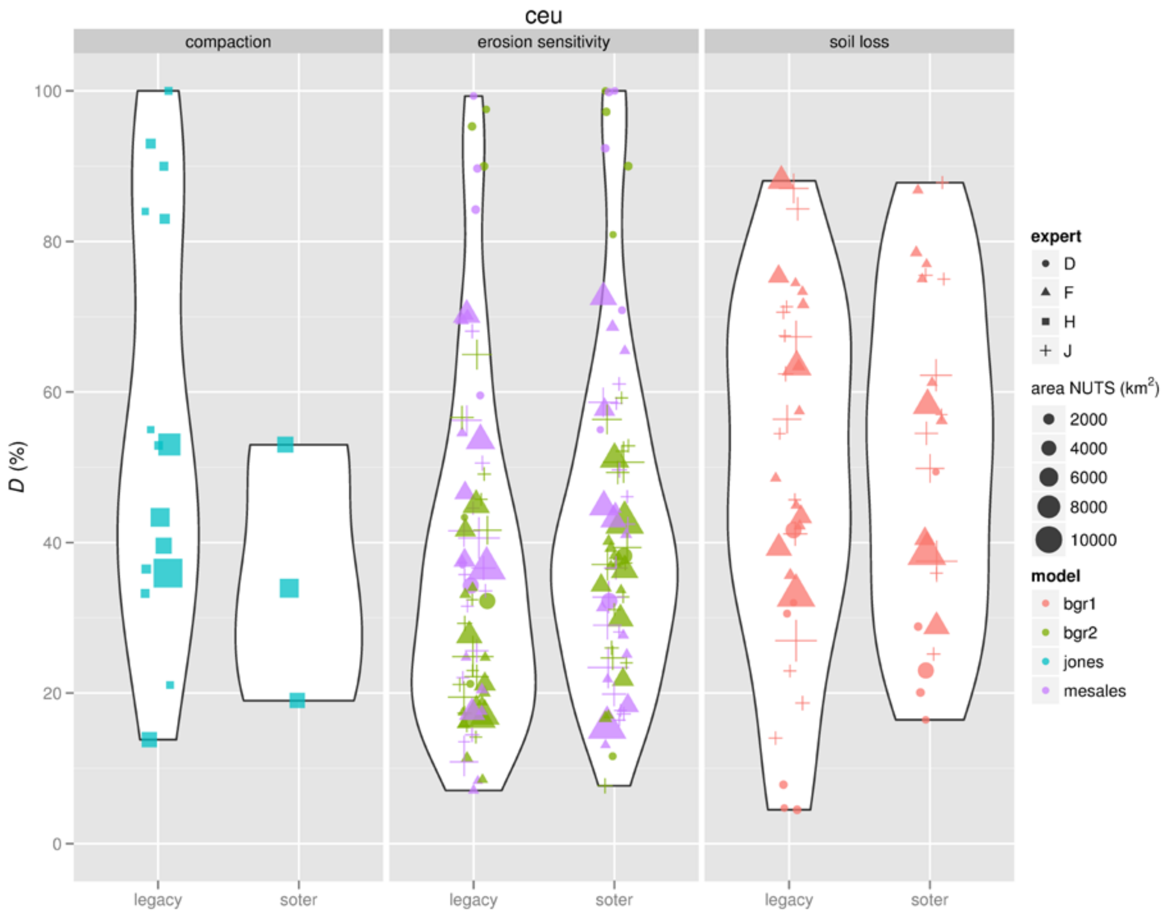


Figure 5-32 Maximum cumulative difference in spatial distributions of target variables assessed by experts for the CEU window, compared to the model outputs for the target variables using the legacy and e-SOTER databases (*D*). Colors distinguish models, symbol types distinguish experts, and each individual symbol represent a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

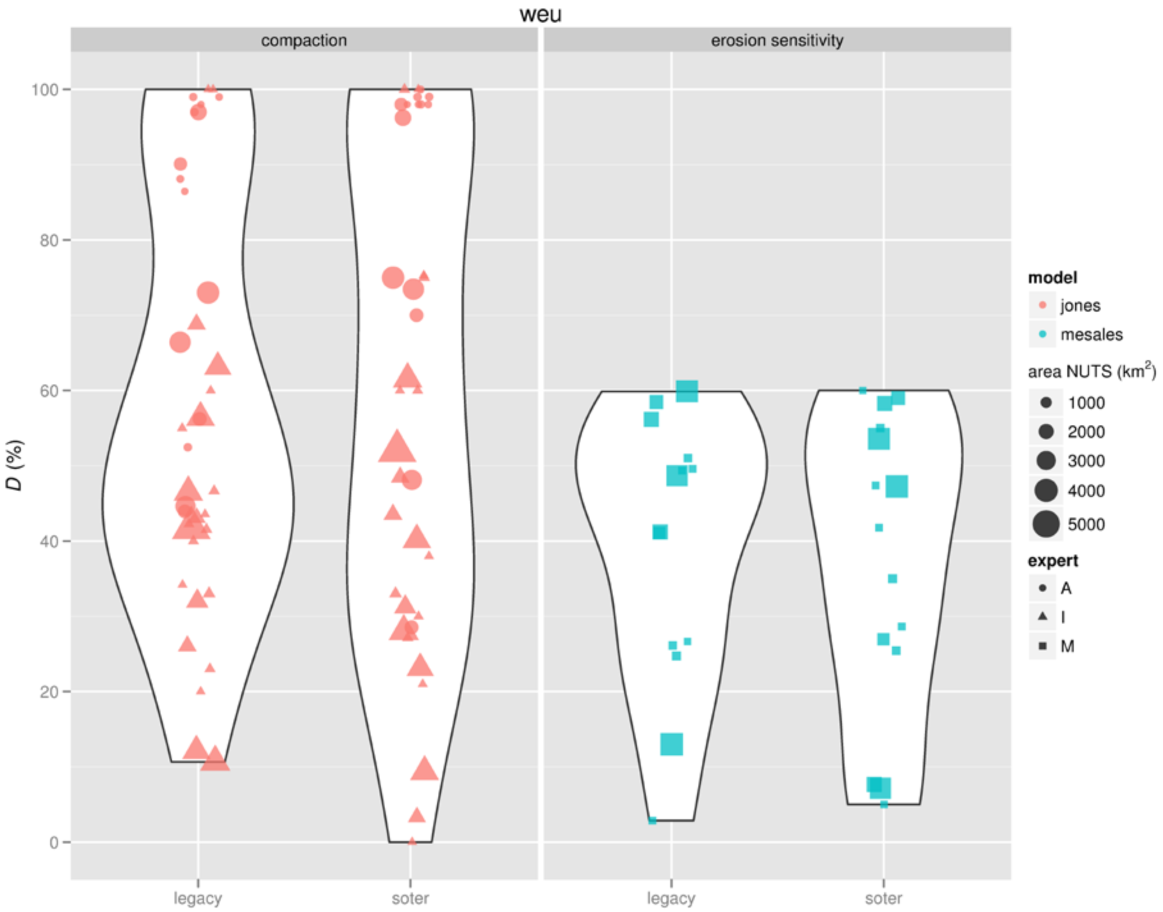


Figure 5-33 Maximum cumulative difference in spatial distributions of target variables (*D*) assessed by experts for the WEU window, compared to the model outputs for the target variables using the legacy and e-SOTER databases. Colors distinguish models, symbol types distinguish experts, and each individual symbol representing a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

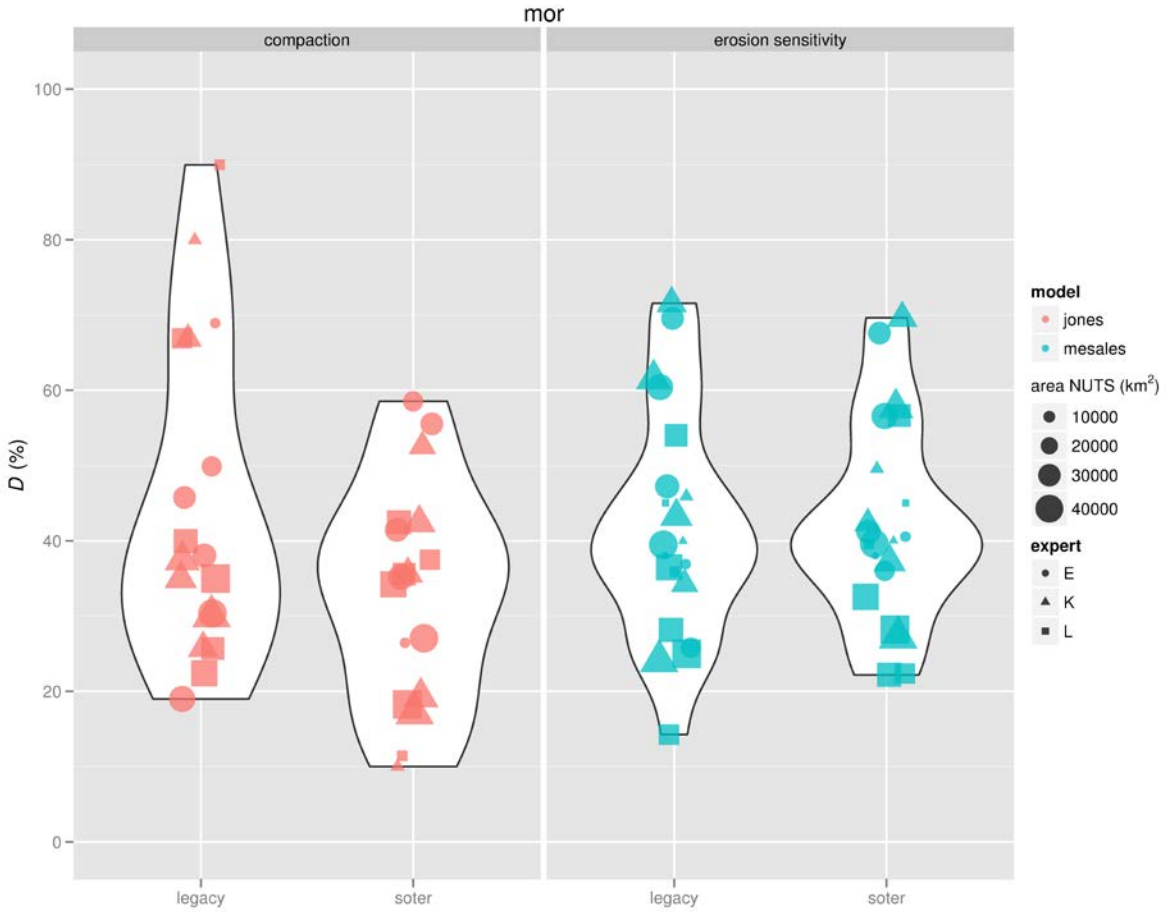


Figure 5-34 Maximum cumulative difference in spatial distributions of target variables (*D*) assessed by experts for the MOR window, compared to the model outputs for the target variables using the legacy and e-SOTER databases. Colors distinguish models, symbol types distinguish experts, and each individual symbol representing a NUTS3 unit. The size of the symbol indicates the area of the NUTS3 unit in km^2. The areas of the shapes express the frequency of occurrence of *D*, and represent a unit surface for each target variable.

5.4 Synthesis

Figure 5-35 presents the information in the previous figures in a slightly different way. It gives the difference between D_{soter} and D_{legacy} for each NUTS3-unit (administrative unit in the case of the Moroccan window). Hence, each dot represents a NUTS3-unit where model outputs are available based on both the e-SOTER and legacy databases. Because model outputs based on the e-SOTER database are not available for each NUTS3-unit, the number of dots in this figure is smaller than in the previous figures.

If model outputs based on the e-SOTER database are more in agreement with the expert assessments than model outputs based on the legacy databases, the dots will be below the red horizontal line. It seems that the dots are at both sides of this line, indicating that model outputs based on the e-SOTER database are not always better according to the experts than those based on legacy databases. This observation applies to assessments from experts irrespective of their informedness, meaning that the results do not change if only well informed experts are considered. Model outputs for the susceptibility to soil compaction show the largest differences in the use of the e-SOTER or the legacy database when compared to the expert assessments.

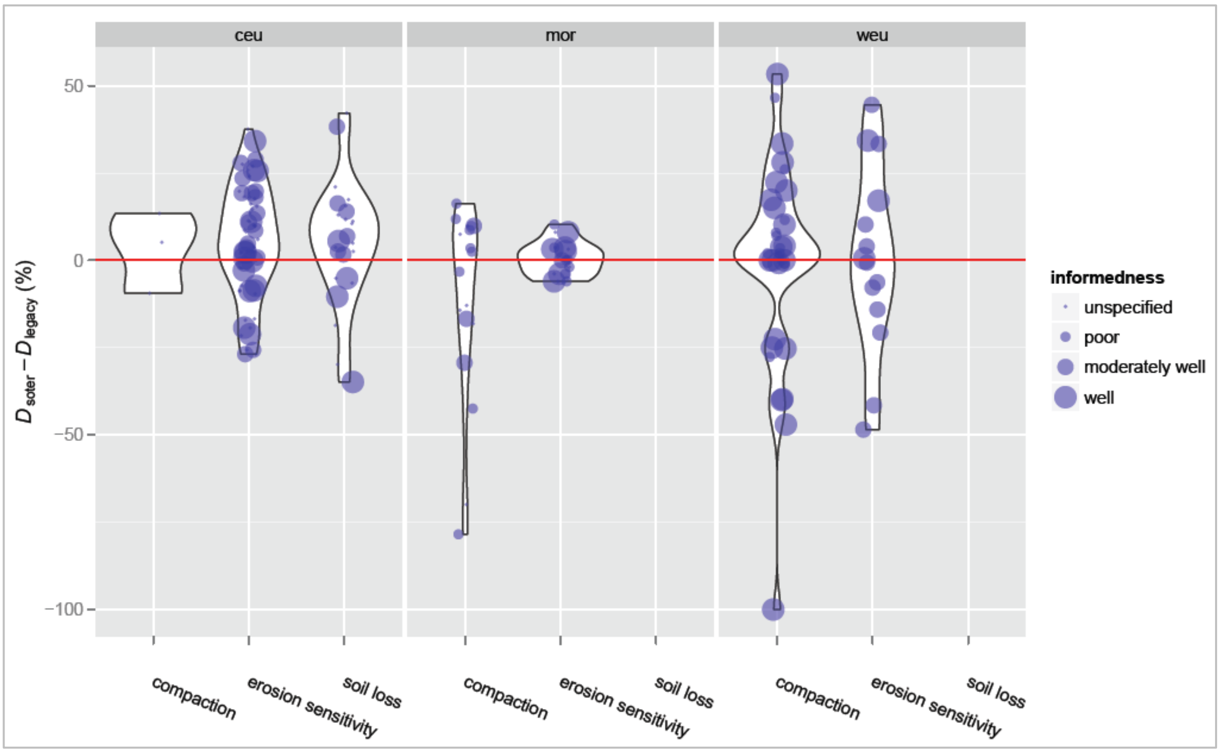


Figure 5-35 Difference between *D*soter and *D*legacy for each NUTS3-unit (blue dots). The size of each dot represents the informedness of the experts.

Figure 5-36 gives another way of looking at the results. It gives scatter plots of *D*soter versus *D*legacy for each window and model output. For points (NUTS3- or administrative units) on the red line, there are no differences between the spatial distributions of model outputs based on the e-SOTER database and those on the legacy database. Dots below the red line indicate that the e-SOTER database outperforms the legacy database and *vice versa* for dots above the red line. Again, it can be concluded that no database outperforms the other for all NUTS3- or administrative units. The degree of informedness of the experts does not show clear patterns.

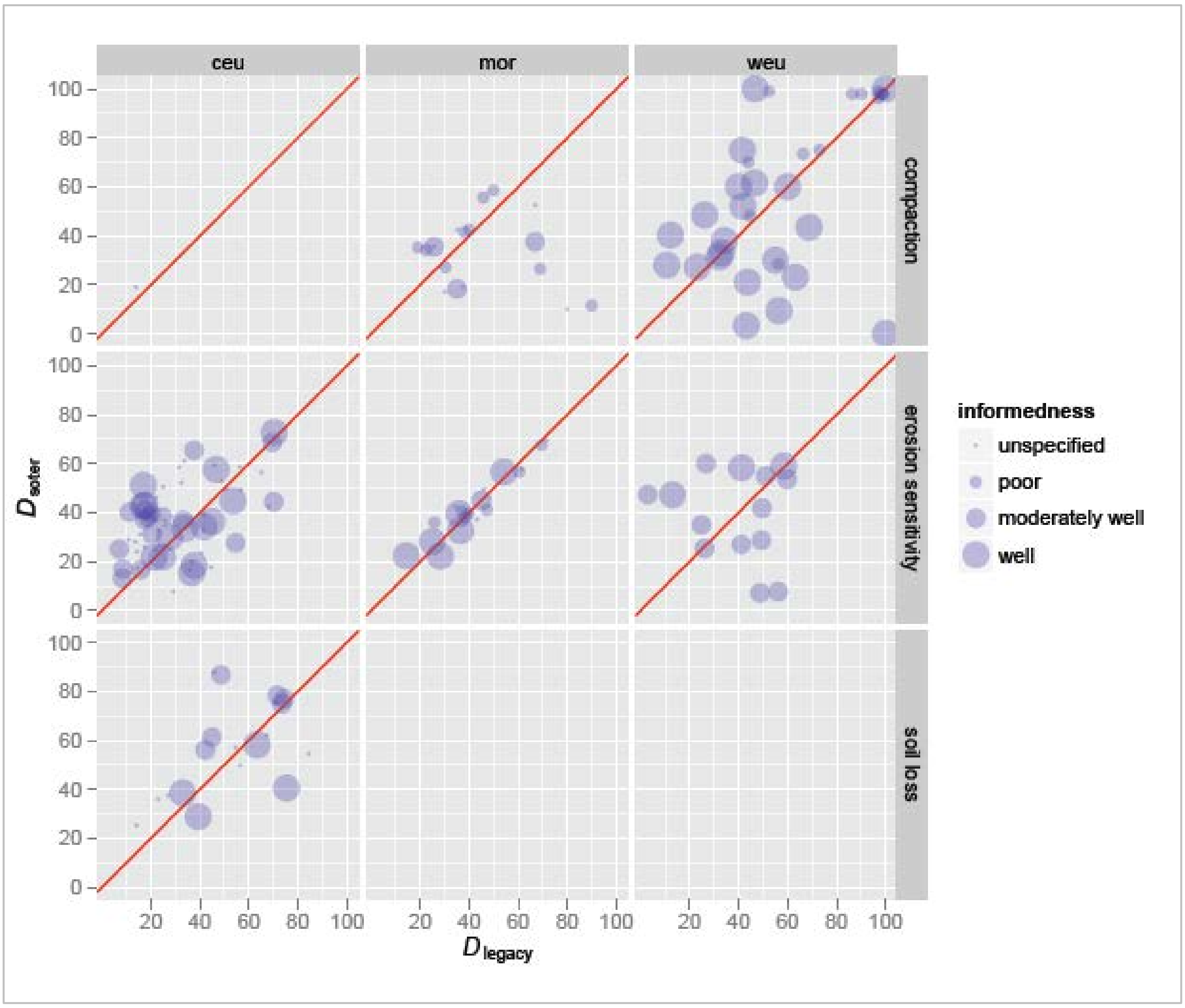


Figure 5-36 Scatter plots of *D*soter versus *D*legacy for each NUTS3-unit in the WEU and CEU windows, and administrative units in the MOR window. The size of each dot corresponds to the informedness of the experts.

6 Discussion and conclusions

6.1 Objective and procedures

The first objective of WP5, namely to demonstrate the use of e-SOTER for evaluating soil threats, was achieved by evaluating two different soil threats with four different methods, in three windows. One of the windows, namely the Moroccan one, was outside Europe and could thus not use European databases for the legacy evaluation. e-SOTER data were made available for Morocco. Details about how the e-SOTER database was used in the evaluation of soil threats are given in Appendices 2-4, and a summary is included in chapter 3. Although the e-SOTER database is not yet complete, it was demonstrated that it can be used for the evaluation of soil threats.

The performance of the e-SOTER database to improve evaluation of threats to soil quality compared with using data from previous soil maps and databases was investigated in three windows defined within the e-SOTER project (the West-European, Central-European and Moroccan windows). This was done by applying models to simulate the soil threats, and comparing the results obtained with the e-SOTER database and the legacy databases. Expert elicitation was used to validate the model results obtained with both databases.

The most important threats to soil quality and performance in the windows were found to be soil erosion and soil compaction. The models selected to simulate these threats included the MESALES model (Le Bissonnais et al., 2001) and the BGR2 model for soil sensitivity to water erosion (Eberhardt, 2009b), the BGR1 model for potential soil loss (Eberhardt, 2009a), and the Jones (Jones et al., 2003) model for soil compaction. Input data for these models were collected from the European Soil Database (v2.0) for the WEU and CEU windows, and from the Harmonized World Soil Database (FAO/IIASA/ISRIC/ISSCAS/JRC, 2009) as well as the Digital Soil Map of the World (FAO, 2007) for the MOR window. The input variables taken from both the e-SOTER and legacy databases, and thus subject to the comparison of the databases through the modelling, include soil type, soil texture of the topsoil, soil texture of the subsoil, parent material, content of coarse fragments, and packing density of the subsoil, or predictors or derivatives of these.

For each window and target variable simulated by each model, three experts were invited to estimate the spatial coverage of each target variable class in one or two rounds of respectively 10 and 15 administrative units (8 for the MOR window), in terms of the percentage of the unit covered by the variable class. In total 78 units were elicited. The judgments on soil sensitivity to water erosion and potential soil loss were combined into one questionnaire. Specific software was developed to assist the expert elicitation. The software provided auxiliary information on the administrative units to the experts in the form of a satellite image, a topographical map, and maps with the parent material and climatic zone. No information was provided that was included in the e-SOTER or legacy databases, like the soil texture, in order to ensure that the expert's responses would be independent from the databases. This was a requirement to use the expert judgment as a validation of the model results. 12 Experts from different countries inside or outside the windows responded to the questionnaire. The experts used their process knowledge of the soil threats, knowledge on models developed to simulate these soil threats, and field knowledge. A few experts consulted external databases, like Google Earth or national soil maps covering the windows. This means that not all expert judgements were equally independent of the model results. However, in how far this affected the outcomes of the evaluation performed in WP5 cannot be judged. Experts were asked to indicate their confidence in their own assessments as poor, intermediate or good, based on their field knowledge. Experts appeared to be well informed or poorly informed for similar numbers of administrative units.

6.2 Difference between model outputs on soil threats from the e-SOTER and legacy databases

Model input for some of the input variables from the e-SOTER database was available for only a small part of the e-SOTER units. This was the case for the coarse fragments, subsoil texture and packing density for the CEU window and for surface texture, subsoil texture, parent material and bulk density for the MOR window. For the WEU window, subsoil texture and bulk density were not available for the units in the French part of the window, and for part of the units in the UK part. Information on surface texture and parent material was lacking for a large part of the e-SOTER units located in France, but the coverage of the window part in the UK was complete.

For the areas in the windows covered by model input from both databases, the models simulate different outputs when the e-SOTER database or the legacy database is used. Differences in the output variables amount to up to 4 classes, and occur in both directions, i.e. in some areas the e-SOTER database yields higher class values, in other areas the legacy database does. There are also areas where outputs from both databases are similar. This does not necessarily mean that there are no differences in the model inputs, since differences in different input variables in both databases may cancel out in the model output, as was the case with the crusting and erodibility input variables in the MESALES model application.

Differences in model outputs from the BGR models for soil sensitivity to water erosion and potential soil loss relate mainly to differences in soil surface texture class between the e-SOTER and legacy databases. For the MESALES model application, areas where higher erosion sensitivity were simulated using the e-SOTER database could be attributed to a higher sensitivity to crusting reflected in the e-SOTER database, or to a higher erodibility, but since both input variables are determined by the same soil properties (soil type, soil surface texture and parent material), the origin of the difference in sensitivity to erosion could not be determined. Differences in outputs from the Jones model for the MOR window were found to relate to differences in both input variables (subsoil texture and packing density).

A sensitivity analysis of the models used would be required for a more thorough assessment of the differences in input variables directly retrieved from the e-SOTER and legacy databases to point out the cause of the differences in model outputs from both databases. This was outside the scope of this research, and therefore only visual assessments of the differences in model outputs compared to differences in model inputs were made. The differences between the output maps of the model applications using both databases were verified using the spatial distributions and the cumulative spatial distributions of the coverage of output variable classes in the administrative units selected for the expert elicitation. These spatial distributions provided a synthetic overview of the model results in the administrative units. The spatial distributions were used to easily identify the predominance of soil threat classes in the windows, and the cumulative spatial distributions were used to identify the main differences in the coverage of model output classes between the model applications using the e-SOTER and legacy databases.

6.3 Differences between model outputs on soil threats compared to expert elicitation

Differences between expert judgements of the target variables, and differences between the expert judgments and the model outputs were expressed as the maximum difference *D* between the cumulative probabilities of the (discrete) spatial distributions of the model outputs and/or expert assessments. The larger *D*, the more distinct the spatial distributions are. This statistic was developed to overcome some disadvantages of statistics frequently used to compare expert judgments or model outputs, like Cohen's K. These disadvantages pertain to the fact that these statistics apply to counts or singular outputs, and not to spatial distributions, as is required in this study. Second, Cohen's kappa and related statistics may lead to counter-intuitive results, meaning that apparent agreement may be achieved. *D* reflects the maximum difference between the cumulative spatial distributions of model outputs and expert judgments. Because it refers to the cumulative distribution, it reflects the distribution rather than the difference between model output and expert in a single class. However, the visualization in cumulative bar graphs, as given in this report, enables the user to inspect in which class(es) the maximum difference between model output and expert judgment occurs.

Differences between expert judgements expressed as *D* vary between the windows and target variables. In general, larger values and larger variations of *D* were found for all target variables in the WEU window compared to the CEU and MOR windows except for soil compaction, for which a large variation in *D* was also observed in the other windows. This observation implies that experts agreed less on the target variables for the WEU window compared to the other two windows and might also indicate that soil compaction is hard to model and hard to assess by the experts.

In all three windows, larger values of *D* and a larger variation of *D* were observed for soil compaction compared to soil sensitivity to soil erosion and potential soil loss, with values of *D* mostly above 50%. This implies that experts agreed less on the susceptibility to soil compaction than on the target variables referring to soil erosion. The areas of the administrative units that were assessed did not seem to influence the differences between expert judgements very much, except for the potential soil loss in the CEU window, where the experts seemed to agree more for larger NUTS3-units.

Overall, the deviation of the model output for all target variables is large compared to the expert responses, with values of *D* up till 100% for erosion sensitivity and susceptibility to subsoil compaction in the CEU and WEU windows. Four reasons may explain this observation: 1) the experts were provided with less detailed spatial information on the land properties relevant to the soil threat, whereas the models were fed with this information at the level of 1 km^2 pixels, 2) the experts estimated the coverage of the classes of the target variables visually ('eye-ball estimates'), whereas the coverage of classes was exactly determined in the analysis software, 3) the experts used process knowledge, external information and field knowledge, that was not available to or incorporated in the model applications, and 4) the experts were insufficiently informed on the areas selected for the questionnaire.

The deviation between model outputs and expert judgments, as expressed in the value of *D*, was similar for the model applications using the e-SOTER database and for the model applications with legacy data, implying that the e-SOTER database cannot be concluded to yield more reliable simulations of the target variables than the legacy databases. *D* shows no differentiation according to individual experts or administrative units. However, as experts probably knew the legacy data (even if these were not shown to them they are likely to be familiar with them), their assessment is probably indirectly based on these legacy data. Such indirect inclusion of e-SOTER data is not possible, and therefore the fact that the e-SOTER database did not perform worse than the legacy database can be taken as some indication that the e-SOTER database does at least have potential in the assessment of soil threats.

It should also be taken into account that at least part of the models that were used were developed to work with the legacy data (especially ESDB). This was inherent to the selection of the models under the condition that they should be applicable to the research windows in the EU, and preferably also in Morocco. To apply these models with e-SOTER data required that some of the e-SOTER data were transformed to ESDB data. For example, the MESALES method works with the FAO1985 soil classification, and therefore the WRB soil data that are in the e-SOTER database had to be translated back to the FAO1985 classification (see Appendix 2). This translation implies a loss of information, and therefore a failure of e-SOTER to perform better than legacy data can also be due to the fact that methods were developed for legacy data and not for e-SOTER. Hence, for an unbiased evaluation of performance of both databases in this respect, the method applied in this study could be repeated (possibly for other soil threats) using models developed independently from both databases. In that case however care should be taken that the models are applicable to the research windows.

Differences between the value of *D* from model applications using the e-SOTER database (compared to expert judgment, $D_{e\text{-}SOTER}$) versus the legacy databases (compared to expert judgment, D_{legacy}) were calculated to assess if outputs based on the e-SOTER database are more in agreement with the expert assessments than model outputs based on the legacy databases. If these differences would be negative, this would imply that using the e-SOTER database would result in model outputs for the soil threats in better agreement with the expert judgments. The results show that both positive and negative differences between $D_{e\text{-}SOTER}$ and D_{legacy} occur, indicating that model outputs based on the e-SOTER database are not always better according to the experts than those based on legacy databases. This observation applies to assessments from experts irrespective of their informedness, meaning that the results would not change if only experts who considered themselves to be well informed were considered. Model outputs for the susceptibility to soil compaction show the largest differences in the use of the e-SOTER or the legacy database when compared to the expert assessments. This may be due to the larger disagreement between the experts with regard to the susceptibility to soil compaction and that it is probably harder to model/estimate soil compaction than the other properties.

The results of this study showed that the model outputs for the soil threats concerned based on the e-SOTER database are not always better than those based on legacy databases. This may be due to the identified differences in the soil properties in both databases that are input to the models, which in some e-SOTER units result in model outputs more in agreement to the expert judgment using the e-SOTER database, and in other e-SOTER units in model outputs more in agreement to the expert judgement if the legacy database is used. Furthermore, several other reasons may explain the result:

- Contrary to the legacy databases, the e-SOTER database does not fully cover the administrative units in the windows. As a consequence, estimates by the experts often pertain to a larger (and therefore different) area than the model outputs based on the e-SOTER database.
- The models only use a part of the soil data in the databases, and therefore the comparison of the databases only refers to the input variables of the models that differed between the databases.
- Model outputs are on ordinal scales (ordered classes). Differences between the databases providing the model inputs may therefore be tempered.

Based on this research, the following recommendations are made for further improvement of the e-SOTER database for the evaluation of soil threats:

- Provide a complete coverage of the e-SOTER units with the input data required to run the models. It would be recommended to achieve at least a full coverage of frequently used soil properties, like the soil texture of the surface and subsoil, and the parent material. Such as full cover will also allow a more complete assessment of how the e-SOTER database performs compared to legacy databases.
- Optimize the data quality of soil properties to which model outputs are most sensitive. These can be identified by sensitivity analyses of frequently used models used to evaluate soil threats.
- Some of the models that have been used were developed to work with the legacy data. Other models using data independent from both databases could be used to perform a more complete evaluation of the performance of the legacy and e-SOTER databases.

7 References

References on the model applications are placed in Appendices 1-4.

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8 Appendix 1 Descriptions of models used

8.1 MESALES : a method developed by INRA (France)

Threat: soil erosion by water

Definition: When the term ‘soil erosion’ is used in the context of being a threat to soil, it refers to ‘accelerated soil erosion’, i.e. “Soil erosion, as a result of anthropogenic activity, in excess of accepted rates of natural soil formation, causing a deterioration or loss of one or more soil functions" (ENVASSO 2008).

Method: decision tree, automated using e.g. AML scripts in Arc/Info

Scale: Can be used with various grid sizes, so far mostly applied for 1 km pixels. Can also be applied to SOTER units without problem.

Result: Erosion sensitivity in 5 ordinal classes:
1. very low erosion sensitivity
2. low erosion sensitivity
3. moderate erosion sensitivity
4. high erosion sensitivity
5. very high erosion sensitivity

Input data:

Input	Derive from	Atribute name in SGDBE	Classes
Land use	e.g. Corine or GLC2000		Arable land Permanent crops Heterogeneous agricultural land Forest and scrub Grassland/pasture Degraded natural land Artificial land Bare land Water surface/wetland
Crusting	Soil Geographical database of Europe, using full 1974 (modified CEC 1985) FAO-UNESCO legend	Soil name: SN1, SN2, SN3 Parent material: PM11, PM12, PM13 Surface texture: TEXT1, TEXT2	5 classes (6 if 0 is included), calculated from parameters in SGDBE using pedotransfer rules.
Slope	DEM		Differs for different combinations of land use and crusting. If following classes are available all combinations can be made (%): 0-1 1-2 2-5

Erodibility			5-10 10-15 15-30 30-75 >75
	Soil Geographical database of Europe, using full 1974 (modified CEC 1985) FAO-UNESCO legend	Soil name: SN1, SN2, SN3 Parent material: PM11, PM12, PM13 Surface texture: TEXT1, TEXT2	5 classes (6 if 0 is included), calculated from parameters in SGDBE using pedotransfer rules.

Data for evaluation: mostly expert opinion. Data on erosion rate could be used if it can be assumed that areas with the highest sensitivity will also have the highest current erosion rates. Such data on erosion rate would need to be classified (using arbitrary class boundaries) to be able to compare with MESALES results.

References:

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8.2 Potential soil loss by water erosion

Threat: soil erosion by water

Definition: When the term 'soil erosion' is used in the context of being a threat to soil, it refers to 'accelerated soil erosion', i.e. "Soil erosion, as a result of anthropogenic activity, in excess of accepted rates of natural soil formation, causing a deterioration or loss of one or more soil functions" (ENVASSO 2008).

Method: linking several soil and precipitation parameters

Scale: Can be used with various grid sizes. Can also be applied to SOTER units without problem.

Result: soil erosion $[t \cdot ha^{-1} \cdot a^{-1}]$

Input data:

Input	Derive from	Atribute name in SGDBE	Classes
Texture class (German texture and sand texture triangles) of topsoil	soil database	surface texture	see Fig. 1 and 2, black labels
coarse fragment content in topsoil	soil database		1: < 2 % (v/v) 2: 2- <10 % 3: 10 - <25 % 4: 25 - <50 % 5: 50 - <75 % 6: >= 75 %
Slope	DEM		(%): 0-<=1 >1-5 >5-9 >9-18 >18-36 >36
mean annual precipitation			

(1) $Efw = K_B * K_S * S * R * 2{,}0$

1. K_B

Texture Class	K_B	Texture Class	K_B
Tt	0.02	fSms, fSgs	0.25
Ts2	0.04	Sl3, Lt2	0.26
Ts3	0.06	Ls3	0.28
gS, gSms, mSgs, mS	0.07	Tu3	0.32
Ts4	0.08	fS	0.34
Tl	0.09	Su3, Ls2	0.35
St3	0.10	Slu	0.40
St2	0.11	Lu	0.41

Tu2	0.14	Su4, Tu4	0.45
Lts	0.15	Uls	0.50
mSfs, gSfs	0.16	Ut4	0.53
Ls4	0.19	Ut3	0.56
Sl2, Lt3	0.21	Ut2	0.61
Su2	0.23	Us	0.63
Sl4	0.24	Uu	0.71

2. K_S

coarse fragment content class (topsoil)	K_S
1	1,00
2	0,87
3	0,64
4	0,39
5	0,19
6	0,10

alternative: use equation (2) if volume percentage of coarse fragments (as x) is available

(2) $K_S = 0{,}973 - 0{,}0187 * c + 0{,}0001 * x^2$

3. S

Slope [%]	S	Slope [%]	S
3	0.2	16	2.4
4	0.3	17	2.6
5	0.5	18	2.9
6	0.6	19	3.2
7	0.7	20	3.5
8	0.8	21	3.8
9	1.0	22	4.1
10	1.2	23	4.4
11	1.3	23	4.7
12	1.5	26	5.4
13	1.7	28	6.1
14	2.0	30	6.8
15	2.2		

4. R

(3) $R = 0{,}152 \cdot N_{summer} - 6.88$; $r = 0.854$

N_{summer} as mean precipitation between May - October

Equation (3) is assumed to be valid for the whole of Germany. (according to Deumlich 1993)

Data for evaluation: Data on erosion rate could be used if it can be assumed that areas with the highest sensitivity will also have the highest current erosion rates.

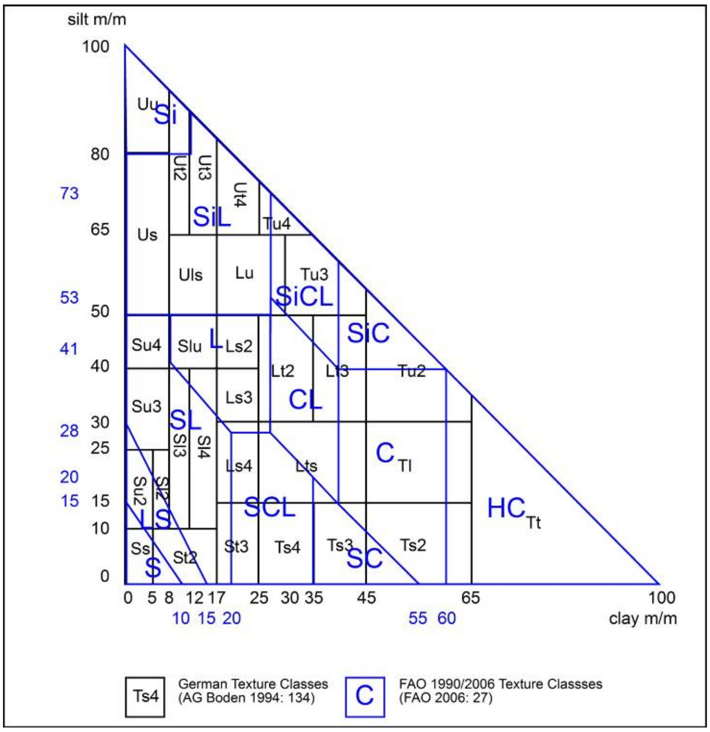

Figure 8-1:Texture classes (FAO classes as orientation)

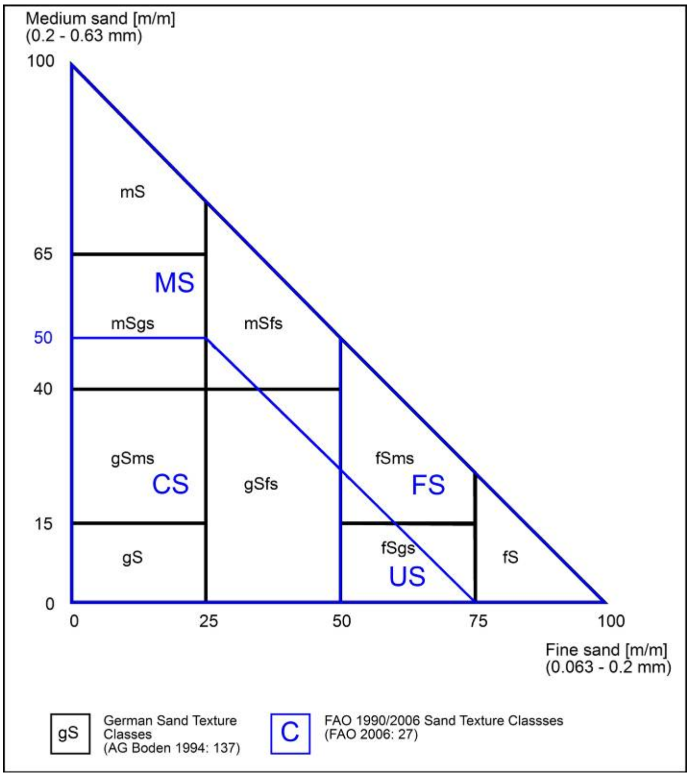

Figure 8-2: Sand textures (subdivision of texture class "Ss", see Fig. 1)

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Deumlich, D. (1993): Beitrag zur Erarbeitung einer Isoerodentkarte Deutschlands. - Arch. f. Acker- u. Pflanzenb. u. Bodenkunde, 37: 17-24.

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8.3 The Jones (2003) model for soil compaction

Threat: soil compaction.

Definition: the densification and distortion of soil by which total and air-filled porosity are reduced, causing a deterioration or loss of one or more soil functions[9]

Target variable: inherent susceptibility of subsoil to compaction

Method: knowledge matrix

		Packing density t m^{-3}		
		Low	Medium	High
Texture		< 1.40	1.40 – 1.75	> 1.75
Code	Texture Class			
1	Coarse	VH	H	M[1]
2	Medium	H	M	M
3	Medium fine	M(H)	M	L[3]
4	Fine	M[2]	L[4]	L[3]
5	Very fine	M[2]	L[4]	L[3]
9	Organic	VH	H	

Susceptibility classes: L low; M moderate, H high, VH very high

[1] except for naturally compacted or cemented coarse (sandy) materials that have very low (L) susceptibility.

[2] these packing densities are usually found only in recent alluvial soils with bulk densities of 0.8 to 1.0 t m^{-3} or in topsoils with >5% organic carbon.

[3] these soils are already compact.

[4] Fluvisols in these categories have moderate susceptibility

Scale: Can be used with various scales, has been applied for Europe 1:1M.

Result: inherent susceptibility of subsoil to compaction in 4 ordinal classes:
- low
- moderate
- high
- very high compaction susceptibility

Input data:

Input	Derive from	Attribute name in SGDBE or PTRDB	Classes
Subsoil Packing Density (PD)	European Soil database (1 km rasters)	PD_SUB: packing density of subsoil, derived from SGDBE input attributes: STR_SUB - Subsoil structure class TD - Subsoil textural class	3 classes: Low <1.4 Medium 1.4 – 1.75 High > 1.75 If PD is not available, it can be calculated from Bulk Density (BD, tm-3) and Clay content (C, wt. %):

[9] ENVASSO Procedures and Protocols Final Report

		SN - FAO soil name (FAO-85, FAO-90) WRB soil name Calculated using PTR08 Rule, revised in SINFO	PD = BD + 0.009C
Subsoil Texture	European Soil database (1 km rasters)	TD: subsoil textural class, derived from SGDBE input attributes: SN - FAO soil name (FAO, 1975 and CEC, 1985) TEXT - Topsoil textural class DR - Depth to rock OR TEXT-SUB-DOM : Dominant sub-surface textural class of the STU	6 classes: 1: coarse (<18% Clay, > 65% Sand) 2: medium (<35% Clay, > 15% sand; if more than 18% Clay > 65% Sand) 3: medium fine (< 35% Clay, < 15% Sand) 4: fine (30 – 60 % Clay) 5: very fine (> 60% Clay) 9: organic (no mineral texture)

Data for evaluation: data on actual soil compaction are difficult to compare to the inherent susceptibility to subsoil compaction, since the actual state of soil compaction is influenced by wetting and drying and loads. Therefore expert judgment is recommended for evaluation purposes.

References:

Jones, R.J.A., G.Spoor, A.J.Thomasson 2003. Vulnerability of subsoils in Europe to compaction: a preliminary analysis. Soil & Tillage Research 73, 131-143.

ENVASSO Procedures and Protocols Final Report (2008)

9 Appendix 2 – MESALES model application

9.1 Mesales

The MESALES method (Le Bissonnais et al, 2001) was applied to the ESDB and to the e-SOTER database for 2 areas (windows) in Europe, one located in Western Europe, covering part of western France and part of eastern Great Britain, and the other in Central Europe, covering parts of Germany, Austria, Slovakia, Ukraine, Hungary, and almost the whole of the Czech republic. In addition, 1 area in Morocco was also modelled using the Digital Soil Map of the World.

The Mesales method was developed to work with ESDB. Therefore, its input parameters that relate to soil are derived using the parameters of ESDB (Table 1).

Table 1. Input data for MESALES

Input	**Derive from**	**Atribute name in SGDBE**	**Classes**
Land use	e.g. Corine or GLC2000	Not in ESDB	Arable land Permanent crops Heterogeneous agricultural land Forest and scrub Grassland/pasture Degraded natural land Artificial land Bare land Water surface/wetland
Crusting	Soil Geographical database of Europe, using full 1974 (modified CEC 1985) FAO-UNESCO legend	Soil name: SN1, SN2, SN3 Parent material: PM11, PM12, PM13 Surface texture: TEXT1, TEXT2	5 classes, calculated from parameters in SGDBE using pedotransfer rules (Daroussin & King, 1996).
Slope	DEM	Not in ESDB	Differs for different combinations of land use and crusting. If following classes are available all combinations can be made (%): 0-1, 1-2, 2-5, 5-10, 10-15, 15-30, 30-75, >75
Erodibility	Soil Geographical database of Europe, using full 1974 (modified CEC 1985) FAO-UNESCO legend	Soil name: SN1, SN2, SN3 Parent material: PM11, PM12, PM13 Surface texture: TEXT1, TEXT2	5 classes, calculated from parameters in SGDBE using pedotransfer rules (Daroussin & King, 1996).

Thus, the method uses 9 land use classes, 5 crusting classes, 8 slope classes and 5 erodibility classes. Based on this, a table is created in which all possible combinations of classes for these 4 parameters are listed, and in which a corresponding erosion sensitivity class is assigned. Sensitivity is given in 5 ordinal classes: very low, low, moderate, high and very high.

The MESALES method is executed by determining for each 1 km pixel which combination of input parameter classes exists; based on this the corresponding erosion sensitivity class is assigned from the table that contains all possible parameter combinations.

INRA (France) assisted in making MESALES operational. The Kaleidos tool box for ArcInfo GIS software was provided by INRA, and was installed with their assistance. INRA also converted the available soil data for Morocco and in the e-SOTER database to input data for MESALES.

databases
As the new e-SOTER database has a structure that differs from that of ESDB, the parameters in ESDB had to be linked to the new parameters in e-SOTER. Table 2 shows the conversion for the MESALES input data. Note that the actual input data for MESALES are SN1-3 (derived from SOIL) and PM11-13 (derived from MAT1). MESALES input was created only for those polygons in which representative soil profiles were available for the upper soil horizon of soil component 1 (the soil covering the largest part of the polygon).

Table 2. ESDB and e-SOTER data used to apply MESALES

Input MESALES	**ESDB**	**e-SOTER**
SOIL	FAO1985	WRBC (profile table)
MAT1	MAT1	LITH (profile table)
TEXT1	TEXT1	TCTS (soil component table, soil component 1), and if empty SDTO, STPC and CLPC (representative horizonvalues table)
TEXT2	TEXT2	TCTS (soil component table, soil component 2), and if empty SDTO, STPC and CLPC (representative horizonvalues table)

Another difference between ESDB and e-SOTER are the spatial units. In ESDB, these are based on the soil map of Europe, while in e-SOTER they are based on a combination of soil and terrain. It is assumed that units based on soil and terrain will be more relevant to the evaluation of threats to soil, and that therefore, an evaluation of such a threat using e-SOTER units will perform better than an evaluation using ESDB data. Terrain data include landform data (derived from digital elevation model) and parent material data.

Slope angle was dealt with in a different manner. It is available at 1 km resolution, and therefore this resolution was also used in application of MESALES. The DEM that was used in combination with both ESDB and e-SOTER was the USGS HYDRO 1K DEM. This DEM was reclassified according to the classes given in table1. Within the e-SOTER project, the SRTM DEM was corrected, amongst others to remove the effect of vegetation height on elevation. In the creation of the e-SOTER spatial units, slope angle was also used, which means that it can be expected that e-SOTER spatial units are more homogeneous for slope angle than the ESDB spatial units. Hence, the corrected SRTM DEM was used in defining e-SOTER units, but was not used in MESALES application.

A final difference between ESDB and e-SOTER is that in e-SOTER additional data have been used to fill the database. Existing soil profile data from the study windows were translated to WRB classification, and were added to the database by WP2.

In order not to introduce other differences in the comparison, the same land use data (Global Land Cover 2000; GLC) were used with both databases. GLC was chosen because CORINE land use data are only available for Europe and not for Morocco.

Application of MESALES with legacy data

As MESALES was developed for Europe, it could be applied to Europe using the data that have been described in the previous section. For Morocco, there is no information in ESDB. Furthermore, there is also no CORINE for land use. Therefore, other data had to be used as input. Table 3 shows the difference in application between Europe and Morocco. For Morocco, DSMW (Digital Soil Map of the World) spatial units were used, and DSMW also provided information on SN1,2 and TEXT1,2. For the Moroccan window, DSMW contains 50 spatial units. The main difficulty for Morocco was the lack of data on parent material. The geological map of Morocco provided some information on parent material. It was used in WP1 of e-SOTER to create a map of parent material that contained 4 classes: sand, loam, clay and consolidated rock. Because of this limited information, rule 621 of the PTR (Daroussin & King, 1996) had to be adapted. Classes sand, loam and clay were used as defined in rule 621, although it should be noted that the classes on the parent material map probably also contained alluvial material and detrital material, which are treated separately in rule 621. However, rule 621 does not contain a unit comparable to consolidated rock; instead rocks are incorporated in several classes, namely calcareous rocks, sandstone (part of sandy!), crystalline, volcanic and other. As information on rock type was not available, and as neglecting the class consolidated rock altogether would leave out information that is relevant for erosion sensitivity, consolidated rocks were used in rule 621 in the same way in which crystalline rocks are treated, i.e. they were given a TEXT-EROD class that was one class lower than that of non-consolidated materials. PM11 values were calculated by determining which of the parent material classes covered the largest part of the DSMW spatial units; this value was then taken as the dominant parent material (MAT11), which is used to determine PM11.

To apply MESALES with GLC data, the GLC land use classes were converted into the 9 land use classes that are used in MESALES (table 1); this conversion is shown in Annex 1.

Table 3. Application of MESALES in Europe and Morocco, legacy data

	Europe	**Morocco**
Soil data		
SN	ESDB	SN1,2 from DSMW SN3 lacking
PM	ESDB	PM11 based on geological map of Morocco (ref) PM11,12 lacking
TEXT	ESDB	DSMW
Land use data	Corine and GLC2000	GLC2000
DEM	HYDRO1K	HYDRO1K
Slope angle	Derived from DEM	Derived from DEM

Application of MESALES with e-SOTER

To apply MESALES with e-SOTER data, the ESDB parameters were linked to the new e-SOTER parameters (described above), as described in table 2. Maps of these input parameters were then created using the e-SOTER database and the e-SOTER unit maps for the 3 windows. TEXT1 could be calculated from the data in e-SOTER, but for SOIL and MAT1 conversion tables were needed. These are given in Annex 2 and Annex 3.

As the e-SOTER database did not contain soil data for all e-SOTER units, the resulting maps only had partial cover.

Evaluation
To evaluate the results of MESALES, field data on erosion sensitivity would be needed. In Europe, there are many plot data about erosion rates, and there are also data about sedimentation in reservoirs that could be used to validate erosion models (Van Rompaey et al., 2003).
Plot data provide a wealth of information about actual erosion rates although plot size, methodology and length of measurement period vary (Cerdan et al., 2010). However, these data are not directly suitable to evaluate the results of MESALES, for several reasons. First, because the outcome of MESALES is sensitivity to erosion rather than erosion rate. Erosion sensitivity cannot be measured, but only estimated based on other parameters. To use data on erosion rate, one has to assume that areas with high erosion rates will also be sensitive to erosion, and that areas with low erosion rates are less sensitive to erosion. This assumption might be valid in some cases, but not always. Second, plot data might not be representative for 1 km pixels as on larger scales different erosion processes might dominate, and because at larger scale there is more opportunity for deposition. Finally, plot studies have usually been carried out were erosion was identified as a problem (Verheijen et al, 2009), such as on relatively steep slopes. Therefore, these data are biased and use of them would result in overestimation of erosion (Cerdan et al., 2010).

Like erosion plots, sedimentation rates in reservoirs provide data on erosion rate rather than sensitivity and can therefore also not be used to validate sensitivities as determined by MESALES. Besides, to be able to use reservoir data the sediment delivery ratio of the reservoir catchment should be known.

For these reasons, expert opinion was used in this study to evaluate which data base was performing better in the evaluation of soil erosion by water. The procedures that were used are described fully in section 4.2.2., and can be summarised as follows:

- For each of the windows, 3 experts with local knowledge were asked to estimate for NUTS3 units which percentage of that particular NUTS3 unit would be covered by the different sensitivity classes. The MESALES results were not shown to the experts to make their expert estimate independent.
- The estimates from the 3 experts were compared to the model outcome for ESDB and for e-SOTER. It was assumed that the data base that resulted in a closer correspondence with the data obtained from the experts was performing better.

9.2 Results

Initial run
An initial run was performed with MESALES, using the ESDB data and the slope classes based on the HYDRO 1K DEM. The results of this run were compared with MESALES runs that were previously performed for Europe. This comparison confirmed that the results obtained with the initial run of MESALES were equal to those obtained previously, thus demonstrating that the model was correctly installed and was working properly. After this, the land use map that was used in the MESALES database (based on Corine - CLC) was replaced with a map derived from Global Land Cover data. Figure 1 shows the map of erosion sensitivity that was obtained with the GLC land use map.

Some observations can be made about this map:

- The map contains some pixels for which there is no information. This is in almost all cases due to the fact that the soil map of Europe indicates that these are urban areas, whereas the GLC map indicates that they are not urban (or otherwise built-up). As the soil map does not contain data for these areas, MESALES is unable to generate a result. The same occurred also in the previous application of MESALES to Europe (Grimm et al, 2002).

- Comparison with the CLC based MESALES map of Europe shows that there are some differences with the current map. The patterns in the current map are comparable to the ones in the previous map, although they are generally a bit coarser. A comparison of the CLC and GLC maps shows that this is a direct consequence of differences in patterns between these two maps.

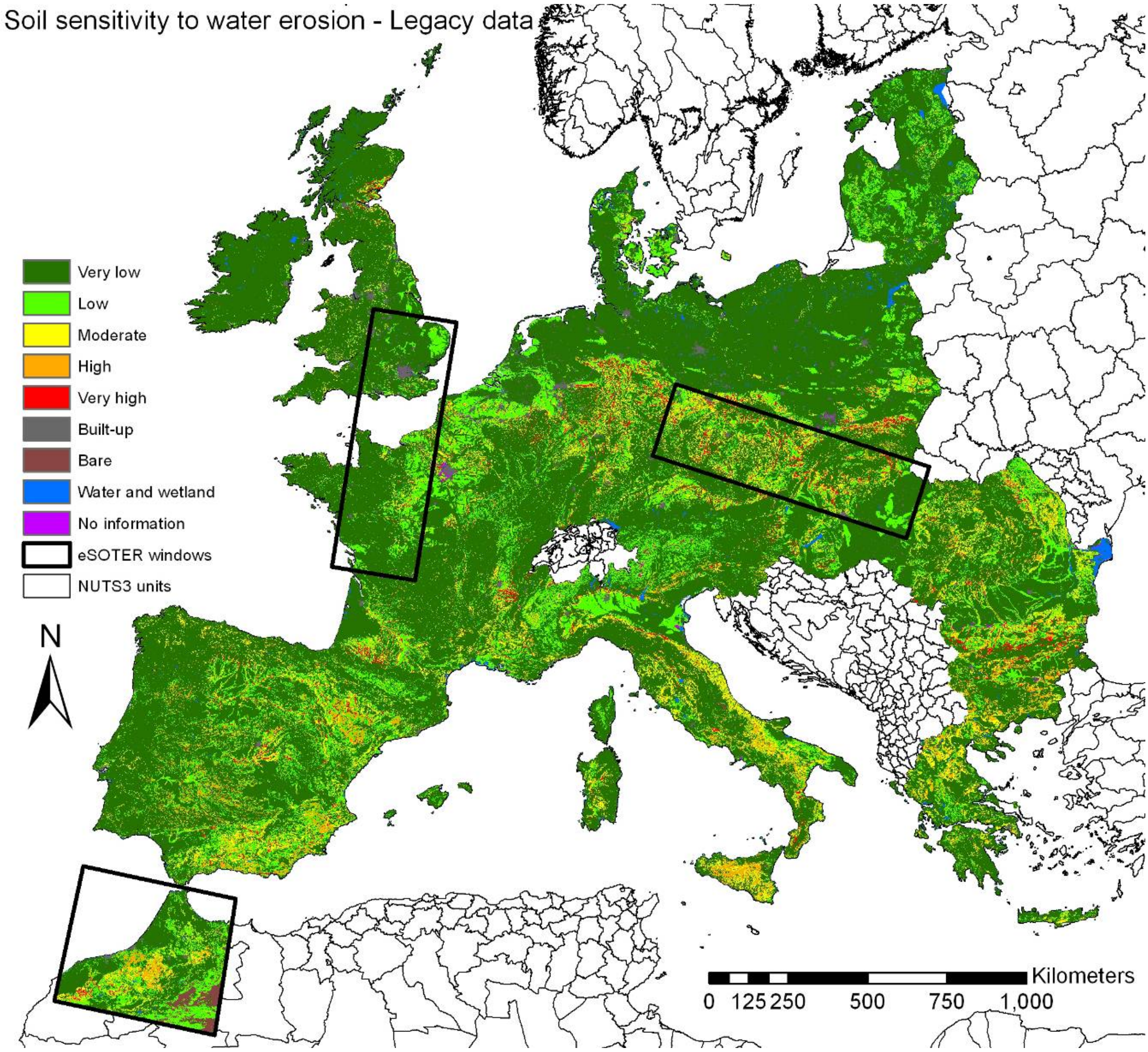


Figure 1. Soil erosion sensitivity using the MESALES method with GLC land use data

Effect of database

MESALES was also applied with the new e-SOTER database, for all 3 windows. The results are shown in figures 2-4 for each of the windows. From these maps it is clear that the e-SOTER database has, as yet, a rather incomplete cover for two of the three windows. It is also clear that there are considerable differences in the results that have been obtained with both databases. As the land use data and slope class data have not been changed between the Legacy run and the e-SOTER run, these differences are due to differences in crusting and erodibility. Figure 5 shows crusting and erodibility data for the Central European window. The results of soil sensitivity to water erosion maps based on ESDB and based on e-SOTER data also compared in table 4 and table 5. These tables show that despite the obvious differences in the maps (fig 2-4), correspondence of the erosion classes in the different maps is 67-79 % overall. This is mainly due to the pixels that have very low erosion sensitivity in both maps. The value of the kappa index is variable despite a similarity in overall correspondence. For WEU it is even below 0; the reason is that for that window most pixels are in the class 'very low' for both maps, and few pixels have higher classes in these maps. As a result, chance-expected agreement is high, which results in a very low value for the kappa index.

Table 4. Correspondence between ESDB based and e-SOTER based estimates of soil erosion sensitivity (% of pixels).

	ESDB				
e-SOTER	**Very Low**	**Low**	**Moderate**	**High**	**Very high**
WEUR					
Very Low	68.0	11.1	0.9	0.0	0.0
Low	13.7	0.9	0.5	0.0	0.1
Moderate	2.5	0.7	0.4	0.0	0.1
High	0.1	0.2	0.1	0.0	0.0
Very high	0.1	0.2	0.3	0.0	0.0
CEUR					
Very Low	52.7	6.8	0.4	0.0	0.0
Low	6.9	5.5	4.1	0.0	0.2
Moderate	3.3	2.5	6.5	0.7	1.8
High	0.0	0.2	0.7	0.7	0.4
Very high	0.1	1.0	3.0	0.3	2.0
MOR					
Very Low	46.9	4.6	1.1	0.1	0.0
Low	3.8	24.3	1.8	0.3	0.0
Moderate	1.5	1.9	5.1	1.6	1.5
High	0.0	1.4	1.9	2.2	0.1
Very high	0.0	0.0	0.0	0.0	0.0

Table 5. Summary comparison

	WEUR	**CEUR**	**MOR**
Total number of pixels	62038	169352	36702
% pixels with higher value e-SOTER	18.0	18.0	10.4
% pixels with lower value e-SOTER	12.7	14.5	11.1
Total correspondence[1]	69.3	67.4	78.5
Kappa index	-0.012	0.43	0.649

[1] defined as the total % of pixels that has the same value in the ESDB and e-SOTER applications

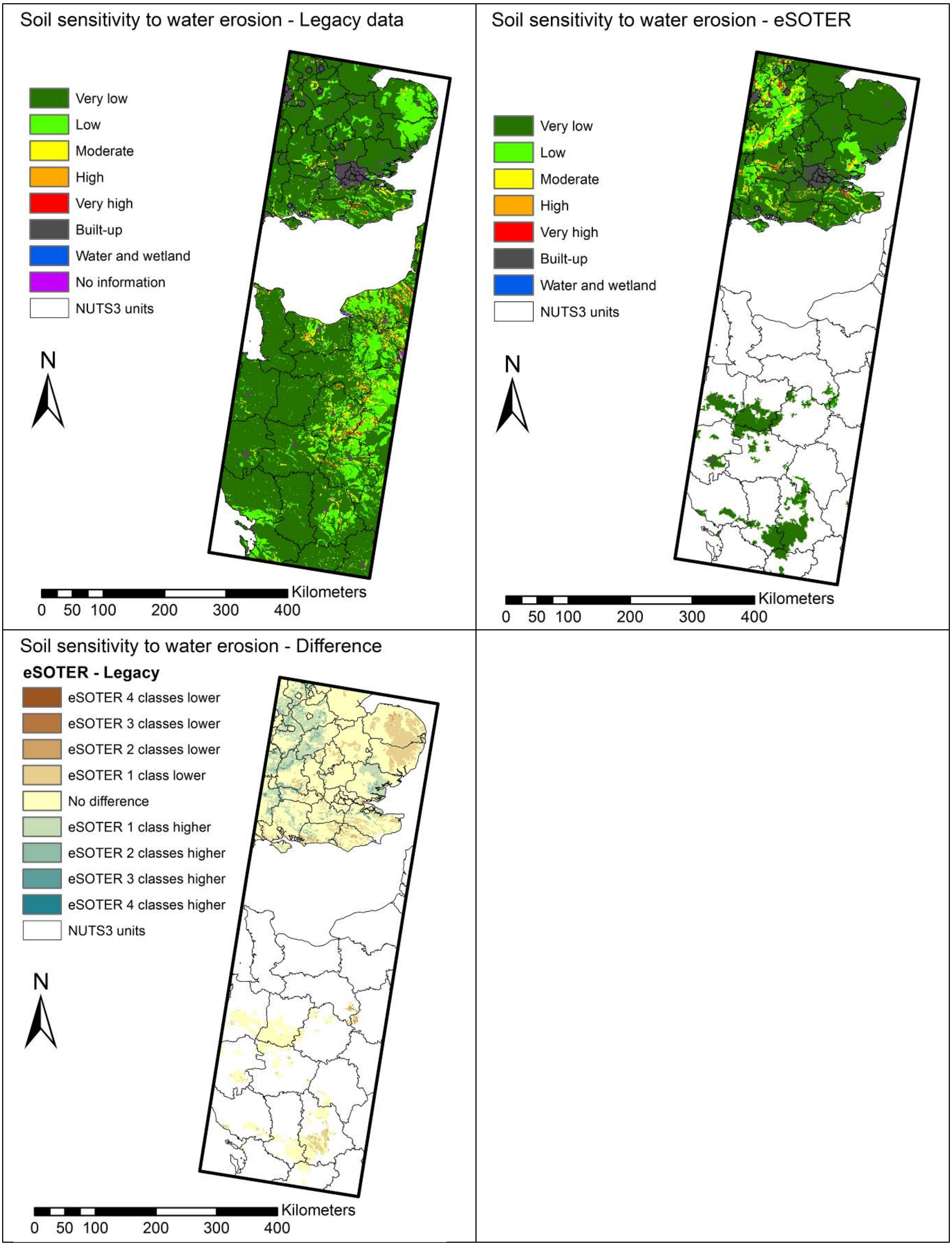


Figure 2. MESALES results for the Western European window a) Run with ESDB data b) Run with e-SOTER data c) Difference between e-SOTER and ESDB, only pixels for which both methods contain results

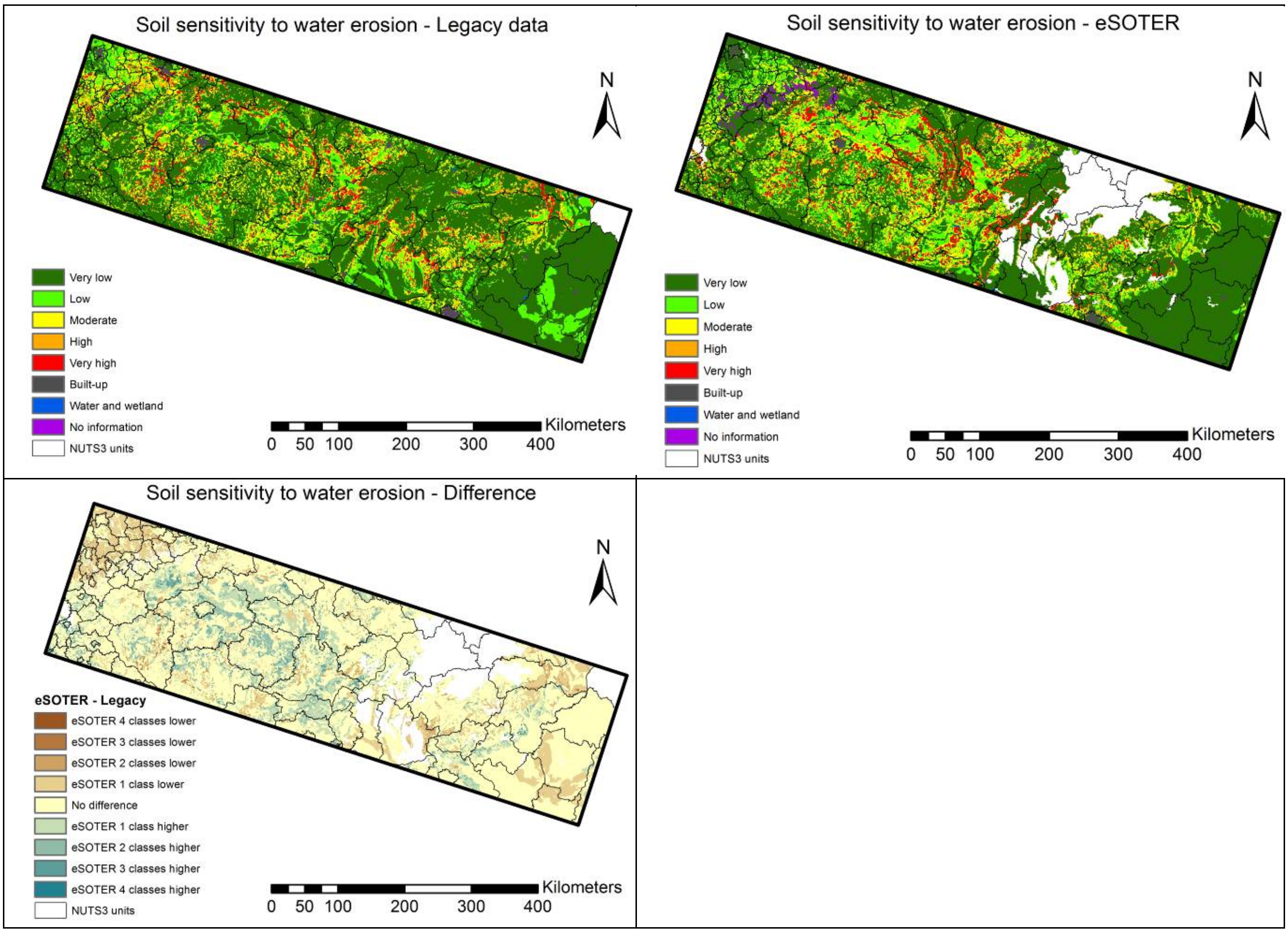
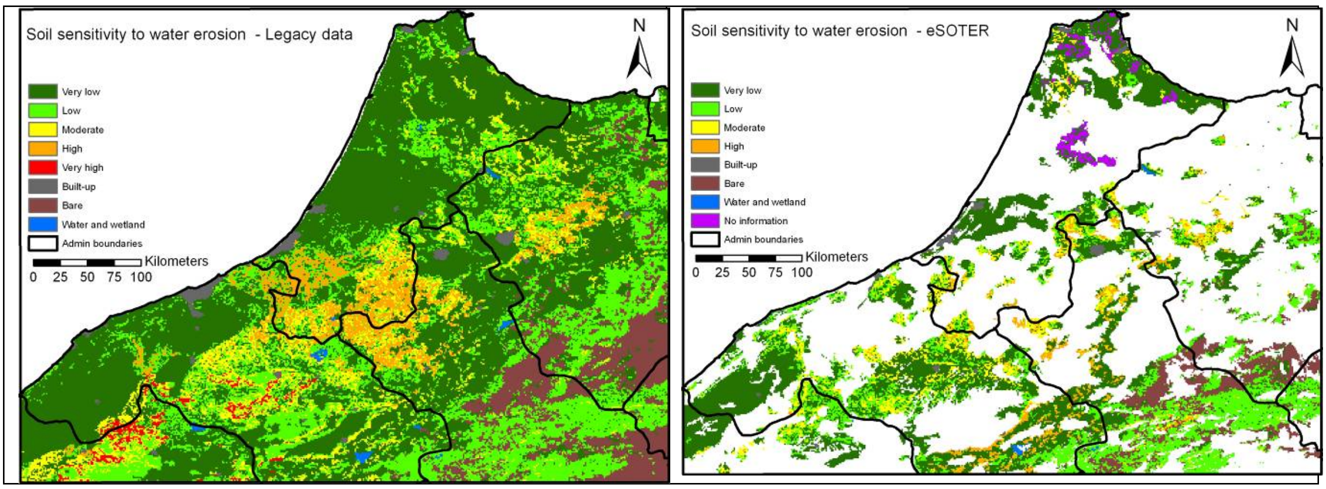


Figure 3. MESALES results for the Central European window a) Run with ESDB data b) Run with e-SOTER data c) Difference between e-SOTER and ESDB, only pixels for which both methods contain results



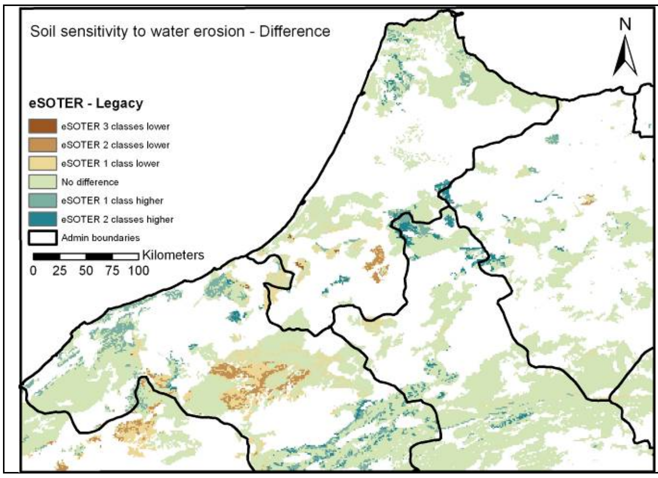
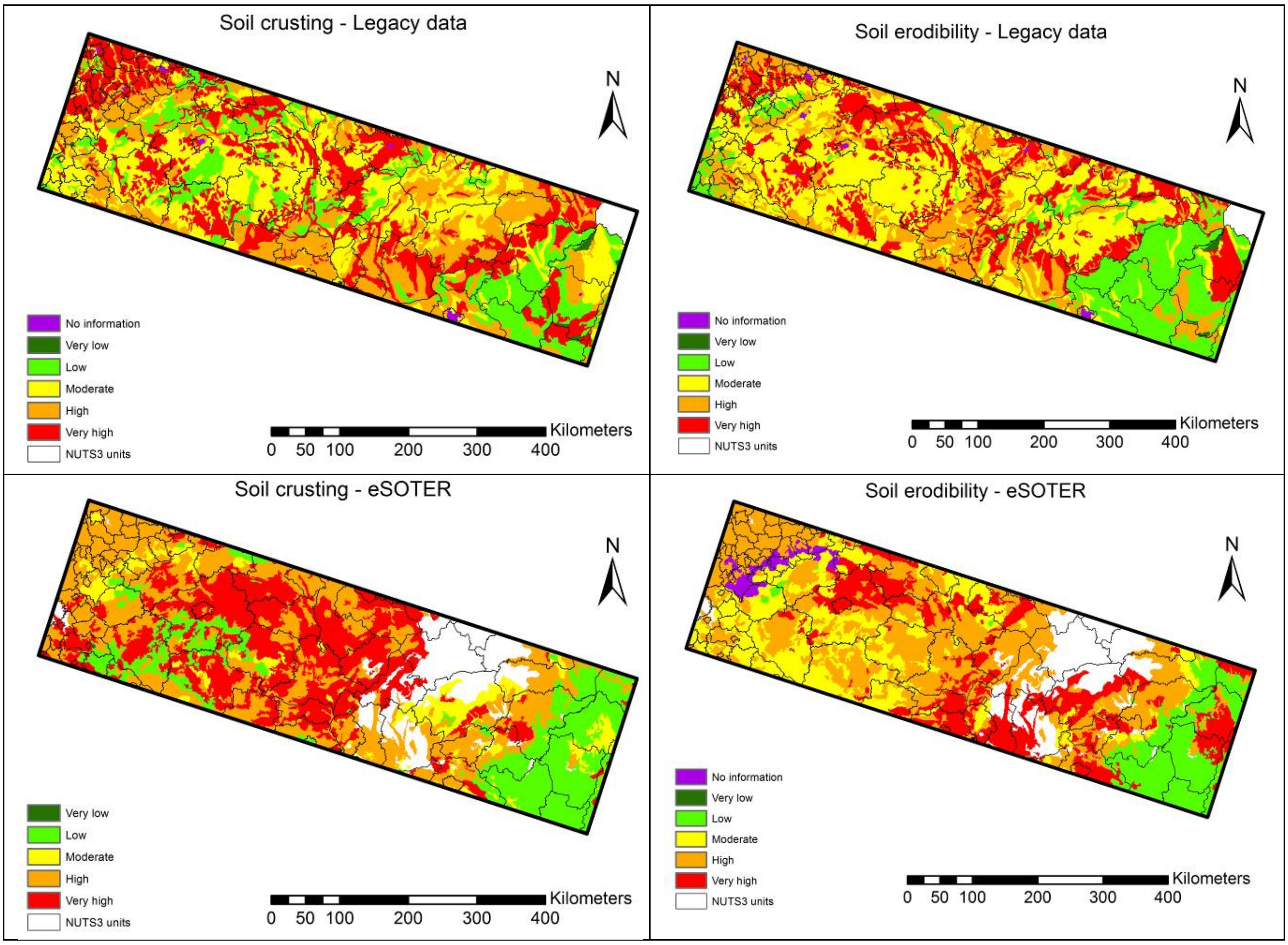


Figure 4. MESALES results for the Moroccan window a) Run with Legacy data b) Run with e-SOTER data c) Difference between e-SOTER and Legacy data, only pixels for which both methods contain results



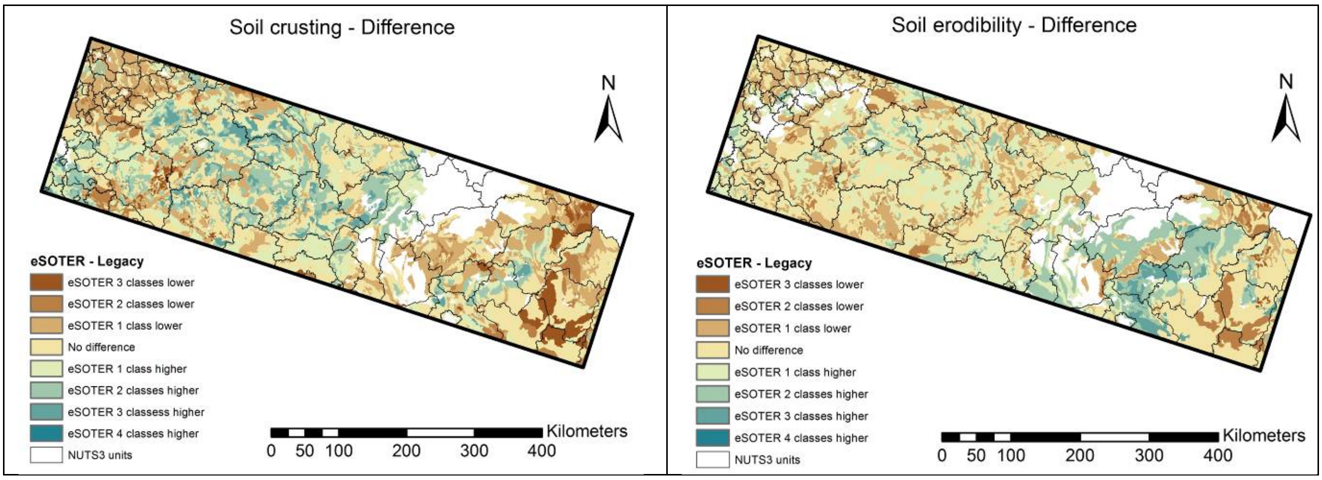


Figure 5. Crusting and erodibility data for the Central European window a) ESDB data, b) e-SOTER data c) Difference between e-SOTER and ESDB, only pixels for which there are ESDB and e-SOTER data

Figure 5 shows that there are large differences in crusting and erodibility as they are derived from the Legacy data and from the e-SOTER data. These differences are larger than those that were observed in erosion sensitivity (figure 3), probably because 1) the effects of crusting and erodibility are moderated by land use class en slope class, which have not changed between the legacy data application and the e-SOTER data application 2) In some cases the trend in difference between crusting and erodibility is opposite, so that differences in crusting and erodibility partly cancel out. Similar observations could be made by comparing the crusting and erodibility maps for the Western European and Moroccan windows (not shown here).

Expert evaluation

The results of the evaluation using data obtained from soil erosion experts is described in chapter 5.

Discussion

Possible causes

As was shown before, there are large differences in the results obtained using the Legacy data and using the e-SOTER database. These differences are caused by differences in crusting and erodibility, which in turn are caused by different soil data in the tested databases. As the crusting and erodibility maps are generated using a series of pedotransfer rules it is not straightforward to determine which soil properties had the largest influence on this large change. However, the most likely candidate appears to be topsoil texture as texture is the main input used in the PTRs.

Implications

The large observed differences between the results obtained with Legacy data and with e-SOTER data show that the choice for a certain database can have large consequences for the evaluation of soil threats. This implies that it is important to use the best available data for such an evaluation. However, for the time being there is no hard scientific evidence that indicates which data are the best. Such data do not exist for the model input data that are used, and they are also not available for the model results. Hence, any judgement about the quality of the data or the quality of the prediction can, for the time being, only be based on expert judgement.

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9.3 Annex 1 : Conversion of GLC2000 land use classes into MESALES land use classes

GLC2000 (Neumann et al., 2007)	CORINE (Neumann et al., 2007)	MESALES
1: Tree cover, broadleaved evergreen, closed to open (>15%)	311 broad-leaved forests	Forest and scrub
2: Tree cover, broadleaved deciduous, closed (>40%)	311 broad-leaved forests	Forest and scrub
3: Tree cover, broadleaved deciduous, open (15-40%)	311 broad-leaved forests	Forest and scrub
4: Tree cover, needleleaved evergreen, closed to open (>15%)	312 coniferous forests	Forest and scrub
5: Tree cover, needleleaved decidous, closed to open (>15%)	312 coniferous forests	Forest and scrub
6: Tree cover, mixed leaftype, closed to open (>15%)	313 mixed forests	Forest and scrub
7: Tree cover, closed to open (>15%), regularly flooded, fresh or brackish: swamp forests	31x forests *411 inland marshes*	Forest and scrub
8: Tree cover, closed to open (>15%), regularly flooded, saline water: mangrove forests	31x forests	Forest and scrub
9: Mosaic of tree cover and other natural vegetation	324 transitional woodland-scrub 31x forests	Forest and scrub
10: Tree cover, burnt (boreal forests)	334 burnt areas	Forest and scrub
11: Shrubcover, closed to open (>15%), evergreen	322 moors and heathland 323 sclerophyllous vegetation 324 transitional woodland-scrub	Forest and scrub
12: Shrubcover, closed to open (>15%), deciduous (broadleaved)	322 moors and heathland 324 transitional woodland-scrub	Forest and scrub
13: Herbaceous cover, closed to open (>15%)	231 pastures 321 natural grasslands	Grassland/pasture
14: Sparse herbaceous or shrubcover (0-15%)	333 sparsely vegetated areas *322 moors and heathland*	Degraded natural land

	332 bare rocks	
15: Regularly flooded (>2 month) Shrub and/or Herbaceous cover, closed to open	411 inland marshes 412 peat bogs 421 salt marshes	Water surface/wetland
16: Cultivated and managed areas	21x arable land 22x permanent crops 241 annual crops associated with permanent crops 242 complex agricultural pattern 244 agro-forestry areas *231 pastures*	Arable land
17: Mosaic of cropland/tree cover/other natural vegetation	243 land principally occupied by agriculture, with significant areas of natural vegetation *231 pastures*	Heterogeneous agricultural land
18: Mosaic of cropland/ shrub cover/herbaceous cover	243 land principally occupied by agriculture, with significant areas of natural vegetation *231 pastures*	Heterogeneous agricultural land
19: Bare areas	331 beaches, dunes, and sand plains 332 bare rocks *333 sparsely vegetated areas*	Bare land
20: Water bodies (natural and artificial)	5xx water bodies *423 intertidal flats*	Water surface/wetland
21: Snow and ice (natural and artificial)	335 glaciers and perpetual snow	Bare land
22: Artificial surfaces and associated areas	1xx artificial surfaces *422 salines*	Artificial land

Corresponding CORINE classes in standard letters indicate an ''agreement'', classes marked in italics indicate a similarity

9.4 Annex 2. Conversion table from WRBC to FAO1985 (SOIL in MESALES)

WRBC soil type	FAO85	FAO85 soil type
Albic Luvisol	La	Albic Luvisol
Albic Stagnic Luvisol	La	Albic Luvisol
Alic Endogleyic Planosol	W	Planosol
Alic Stagnosol	Ldg	Gleyo-Dystric Luvisol
Calcic Chernozem	Ck	Calcic Chernozem
Calcic Luvic Chernozem	Cl	Luvic Chernozem
Calcic Luvic Gleysol	Gl	Luvic Gleysol
Calcic Luvic Kastanozem	Kl	Luvic Kastanozem
Calcic Luvic Stagnosol	Lgs	Stagno-Gleyic Luvisol
Calcic Luvisol	Lk	Calcic Luvisol
Calcic Mollic Vertisol	V	Vertisol
Calcic Phaeozem	Hc	Calcaric Phaeozem
Calcic Stagnic Gleyic Luvisol	Lgs	Stagno-Gleyic Luvisol
Calcic Vertic Chernozem	Ckb	Vermi-Calcic Chernozem
Carbic Endogleyic Podzol	Pg	Gleyic Podzol
Cutanic Albic Luvisol	La	Albic Luvisol
Cutanic Gleyic Endocalcic Luvisol	Lg	Gleyic Luvisol
Cutanic Leptic Luvisol	L	Luvisol
Cutanic Luvisol	L	Luvisol
Cutanic Vertic Calcic Luvisol	Lv	Vertic Luvisol
Cutanic Vertic Luvisol	Lv	Vertic Luvisol
Endofluvic Gleysol	Gf	Fluvic Gleysol
Endogleyic Cambisol	Bge	Eutri-Gelyic Cambisol
Endoleptic Cambisol	B	Cambisol
Epifluvic Gleysol	Gf	Fluvic Gleysol
Epistagnic Luvisol	Lgs	Stagno-Gleyic Luvisol
Fibric Histosol	O	Histosol
Folic Gleysol	G	Gleysol
Folic Histosol	O	Histosol
Gleyic Luvisol	Lg	Gleyic Luvisol
Gleyic Mollic Vertisol	Vg	Gleyic Vertisol
Haplic Alisol	Ld	Dystric Luvisol
Haplic Arenosol	Q	Arenosol
Haplic Cambisol	B	Cambisol
Haplic Chernozem	C	Chernozem
Haplic Gleysol	G	Gleysol
Haplic Leptosol	I	Lithosol
Haplic Luvisol	L	Luvisol
Haplic Phaeozem	H	Phaeozem
Haplic Regosol	R	Regosol
Haplic Solonetz	S	Solonetz

Haplic Stagnosol	Lgs	Stagno-Gleyic Luvisol
Haplic Vertisol	V	Vertisol
Leptic Regosol	R	Regosol
Leptic Vertic Luvisol	Lv	Vertic Luvisol
Luvic Calcic Gleysol	Gl	Luvic Gleysol
Luvic Chernozem	Cl	Luvic Chernozem
Luvic Gleysol	Gl	Luvic Gleysol
Luvic Planosol	W	Planosol
Luvic Stagnosol	Lgs	Stagno-Gleyic Luvisol
Luvic Vertic Phaeozem	Hlv	Verti-Luvic Phaeozem
Mollic Calcic Luvic Gleysol	Gmc	Calcaro-Mollic Gleysol
Mollic Calcic Vertisol	V	Vertisol
Mollic Gleysol	Gm	Mollic Gleysol
Mollic Vertisol	V	Vertisol
Ruptic Regosol	R	Regosol
Sapric Rheic Histosols	O	Histosol
Sodic Calcic Vertisol	V	Vertisol
Sodic Mollic Calcic Vertisol	Vpn	Sodi-Pellic Vertisol
Stagnic Calcic Chernozem	Ck	Calcic Chernozem
Stagnic Calcic Luvic Chernozem	Cl	Luvic Chernozem
Stagnic Cambisol	Bgg	Stagno-Gleyic Cambisol
Stagnic Endogleyic Cambisol	Bgg	Stagno-Gleyic Cambisol
Stagnic Gleyic Luvisol	Lgs	Stagno-Gleyic Luvisol
Stagnic Luvisol	Lgs	Stagno-Gleyic Luvisol
Stagnic Regosol	R	Regosol
Umbric Gleyic Folic Podzol	Pg	Gleyic Podzol
Umbric Luvic Gleysol	Gl	Luvic Gleysol
Vertic Alisol	Lv	Vertic Luvisol
Vertic Calcic Chernozem	Chv	Verti-Haplic Chernozem
Vertic Calcic Luvic Chernozem	Chv	Verti-Haplic Chernozem
Vertic Calcic Luvic Kastanozem	Kkv	Verti-Calcic Kastanozem
Vertic Calcic Luvisol	Lvk	Calci-Vertic Luvisol
Vertic Cambisol	Bv	Vertic Cambisol
Vertic Chernozem	Chv	Verti-Haplic Chernozem
Vertic Gleyic Calcic Luvic Chernozem	Cg	Gleyic Chernozem
Vertic Luvic Phaeozem	Hlv	Verti-Luvic Phaeozem
Vertic Luvic Stagnosol	Lgs	Stagno-Gleyic Luvisol
Vertic Luvisol	Lv	Vertic Luvisol
Vertic Stagnic Cambisol	Bv	Vertic Cambisol
Vertic Stagnic Luvisol	Lv	Vertic Luvisol
Vertic Stagnosol	Lv	Vertic Luvisol

9.5 Annex 3 Conversion table from LITH to MAT1

LITH	Parent material LITH	MAT1	Parent material MAT1
IA1	Granite	711	Granite
MA2	Gneiss	731	Gneiss
MA3	Phyllite, slate	742	Slates
MA4	Granulite	730	Crystalline metamorphic rocks
MA4	Mica schists	741	Micaschists
MB2	(mica) schists	740	Schists
MB2	Greenschists	745	Green schists
MB5	Amphibolite	730	Crystalline metamorphic rocks
PA1	Granite	711	Granite
PB1	Gabbro	722	Gabbro
SA1	Sandstone	450	Sandstone
SC2	Breccia	620	Breccia and puddingstone
SC3	Sandstone	450	Sandstone
SC4	Arkose	610	Arkose
SL3	Shale	743	Shales
SL4	Mudstone	340	Claystone, mudstone
S	Sedimentary rocks	901	Sedimentary rocks
SO1	Limestone, chalk, dolomite and other carbonate rocks	210	Limestone
SO2	Marl, marlstone and other mixtures	230	Marl
U	Unconsolidated deposits	100	Undifferentiated alluvial deposits (or glacial deposits)
UC	Slope deposits	150	Colluvium
UE	Eolian loess	521	Loess
UF	Fluvial deposits	110	River alluvium
UG	Glacial deposits/glacial drift/glaciofluvial deposits	100	Undifferentiated alluvial deposits (or glacial deposits)
UL	Unconsolidated deposits - Lacustrine and lake deposits	100	Undifferentiated alluvial deposits (or glacial deposits)
UM	Marine and estuarine deposits	120	Estuarine/Marine alluvium
UO	Peat and organic rich sediments	910	Organic materials
UO2	Groundwater fed peat	910	Organic materials
UQ	Unconsolidated deposits, gravelly	422	Sandy gravelly materials
UQ0C	Unconsolidated deposits, gravelly, colluvial	150	Colluvium
UQ0F	Unconsolidated deposits, gravelly, fluvial	110	River alluvium
US	Unconsolidated deposits, sandy	420	Alluvial or glaciofluvial sands
US0	Unconsolidated deposits, sandy	420	Alluvial or glaciofluvial sands
US0E	Unconsolidated deposits, sandy, eolian	430	Eolian sands
US0F	Unconsolidated deposits, sandy, fluvial	420	Alluvial or glaciofluvial sands
US2	Unconsolidated deposits, sandy, calcareous	420	Alluvial or glaciofluvial sands
UT0F	Unconsolidated deposits, silty/loamy, fluvial	500	Loamy materials
UT0T	Unconsolidated deposits, silty/loamy, glacial till	500	Loamy materials
UT2	Unconsolidated deposits, silty/loamy, calcareous	500	Loamy materials
UT2E	Unconsolidated deposits, silty/loamy, calcareous, eolian	520	Eolian loam
UU	Diamiction (unsorted)	100	Undifferentiated alluvial deposits (or glacial

			deposits)
UY	Unconsolidated deposits, clayey	300	Clayey materials
UY0	Unconsolidated deposits, clayey	300	Clayey materials
UY0F	Unconsolidated deposits, clayey, fluvial	320	Alluvial or glaciofluvial clay
UY1	Unconsolidated deposits, clayey, non calcareous	300	Clayey materials
UY2	Unconsolidated deposits, clayey, calcareous	350	Calcareous clay
V	Volcanic rocks	800	Volcanic rocks
VB1	Basalt	822	Basalt
VI1	Andesite, trachanesite	800	Volcanic rocks
VP1	Tuff, tuffstone, tuffite, pumice	825	Volcanic tuff
VU1	picrobasalt	822	Basalt

10 Appendix 3 – Jones model application

By Yusuf Yigini (JRC)

WP5

E-Soter Model Applications

Threat: Soil Compaction

Reporting Period: March-September 2011

Updated: 31.01.2012

1. Introduction

Compaction:

The densification and distortion of soil by which total and air-filled porosity are reduced, causing a deterioration or loss of one or more soil functions (ENVASSO, 2008).

In the frame of WP5, applicability of subsoil compaction susceptibility model on e-SOTER database (e-SOTER_v20110620_mdb_corrected) and on other previous databases (ESDB V2.0 , HWSD v1.1). For this purpose, Jones method (Jones, 2003) has been applied on European Soil Database (ESDB V2.0 -WEur, CEur), E-Soter Database (WEur, CEur and Ma - delivered by WP2) and World Harmonized Soil Database (HWSD - for only MA window) to produce inherent susceptibility of subsoil to compaction map/data in windows.

Table 1. Inherent susceptibility to compaction according to texture and packing density

		Packing density t m^{-3}		
		Low	Medium	High
Texture		< 1.40	1.40 – 1.75	> 1.75
Code	Texture Class			
1	Coarse	VH	H	M[1]
2	Medium	H	M	M
3	Medium fine	M(H)	M	L[3]
4	Fine	M[2]	L[4]	L[3]
5	Very fine	M[2]	L[4]	L[3]
9	Organic	VH	H	

Susceptibility classes: L low; M moderate, H high, VH very high

[1] except for naturally compacted or cemented coarse (sandy) materials that have very low (L) susceptibility.

[2] these packing densities are usually found only in recent alluvial soils with bulk densities of 0.8 to 1.0 t m^{-3} or in topsoils with >5% organic carbon.

[3] these soils are already compact.

[4] Fluvisols in these categories have moderate susceptibility

Classification:

Inherent susceptibility of subsoil to compaction in 4 ordinal classes:

1 Low (L)
2 Moderate (M)
3 High (H)
4 Very High compaction susceptibility (VH)

2. Model Application

2.1. European Soil Database (ESDB V2.0)

In order to evaluate subsoil compaction vulnerability, Jones Model has been applied on ESDB. Compaction is evaluated based on soil attributes defined for Soil Typological Units (STU) in the database (Table 2). Subsoil texture (TEXT_SUBDOM) was input from the STU_SGDBE part of the ESDB, TD (Subsoil Textural Class) was used as input the STU_PTRDB of the ESDB (for only WEur window) and packing density (PD) data originated from STU_PTRDB.

Subsoil Texture attribute (TEXT_SUBDOM) is not available for most of the STU's in the database for WEur window even then TD (Subsoil texture) is present in %80 of the STUs in ESDB Pedotransfer Rules database. TD is based on FAO soil name, topsoil textural class and depth to rock attributes.

Table 2. Input data to evaluate subsoil compaction susceptibility (SGDBE):

Input	*Derive from*	*Attribute name in SGDBE or PTRDB*	*Classes*
Subsoil Packing Density (PD)	European Soil database	**PD_SUB**: packing density of subsoil, derived from SGDBE input attributes:	3 classes: Low <1.4 Medium 1.4 – 1.75 High > 1.75
Subsoil Texture	European Soil database	**TD**: subsoil textural class, derived from **SGDBE STU_PTRDB** *Based on;* ***SN*** - FAO soil name (FAO, 1975 and CEC, 1985) ***TEXT*** - Topsoil textural class ***DR*** - Depth to rock OR **TEXT-SUB-DOM** : Dominant sub-surface textural class of the STU	6 classes: 1: coarse (<18% Clay, > 65% Sand) 2: medium (<35% Clay, > 15% sand; if more than 18% Clay > 65% Sand) 3: medium fine (< 35% Clay, < 15% Sand) 4: fine (30 – 60 % Clay) 5: very fine (> 60% Clay) 9: organic (no mineral texture)

2.1.1 WEur Window:

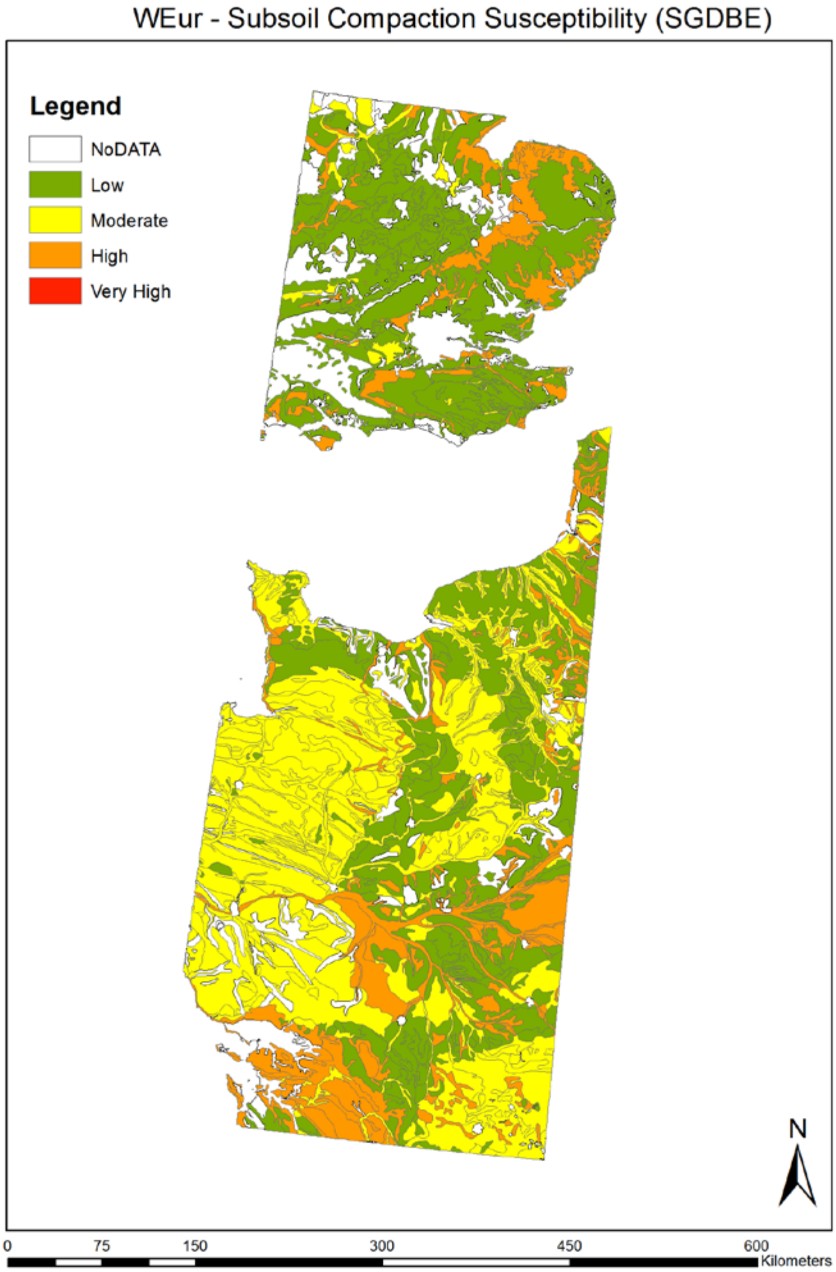


Figure 1. WEur window - Subsoil compaction susceptibility based on European Soil Database (ESDB v2.0)

2.1.2 CEur Window:

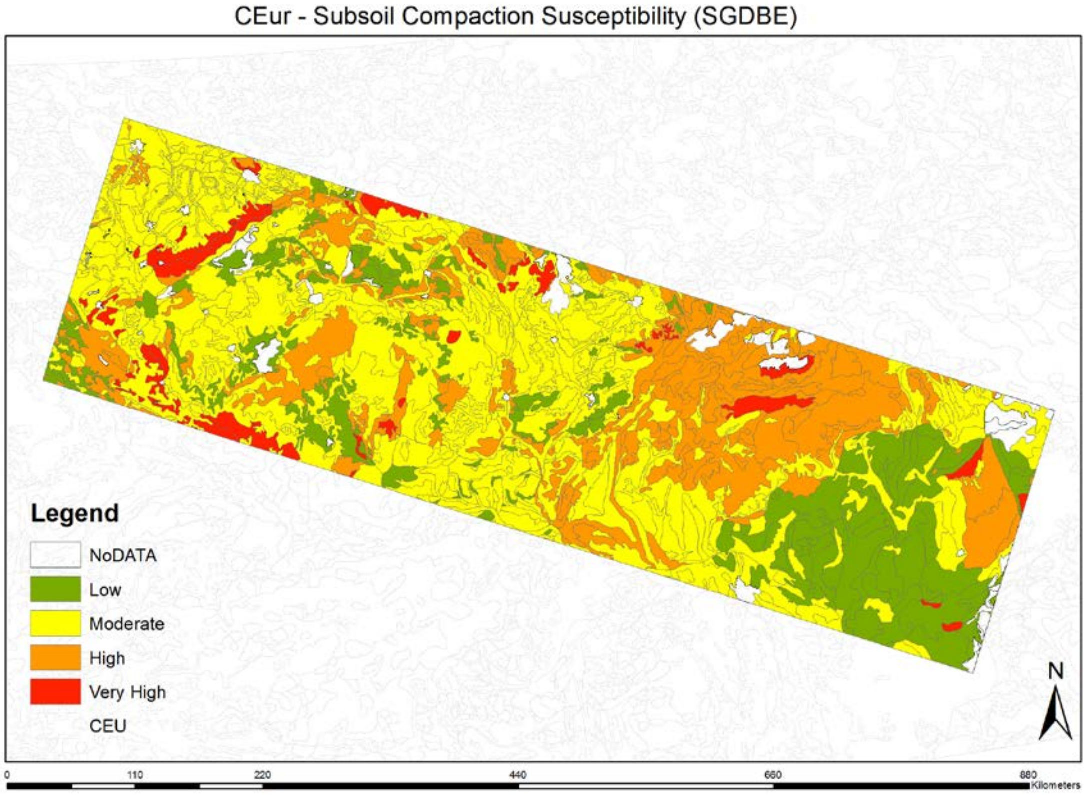


Figure 2. CEur window - Subsoil compaction susceptibility based on European Soil Database (ESDB v2.0)

2.1.3 Ma Window:

Morocco is not covered by European Soil Database. The compaction model has been run on E-Soter database and World Harmonized Soil Database of FAO (HWSD).

E-Soter Database

In order to run the model on subsoil compaction on the e-Soter database the soil information were used from 'representative soil profiles' as stored in the database. Soter Units having soil components with soil profiles allocated cover at most 64% of the windows, and soil components with soil profiles allocated cover at most 42% of the windows (Table 3 and Figure 3).

Table 3. Soil Information Coverage in E-Soter Database *(S. Verzandvoort)*

Window	*% Coverage SUID*	*% Coverage SCID*

CEur	33.4%	32.8%
WEur	64.0%	37.0%
Ma	59.3%	41.7%

Window: (full size provided with database), %Coverage SUID: Covered by SUIDs with soil profile information, % Coverage SCID: Covered by SCIDs with soil information

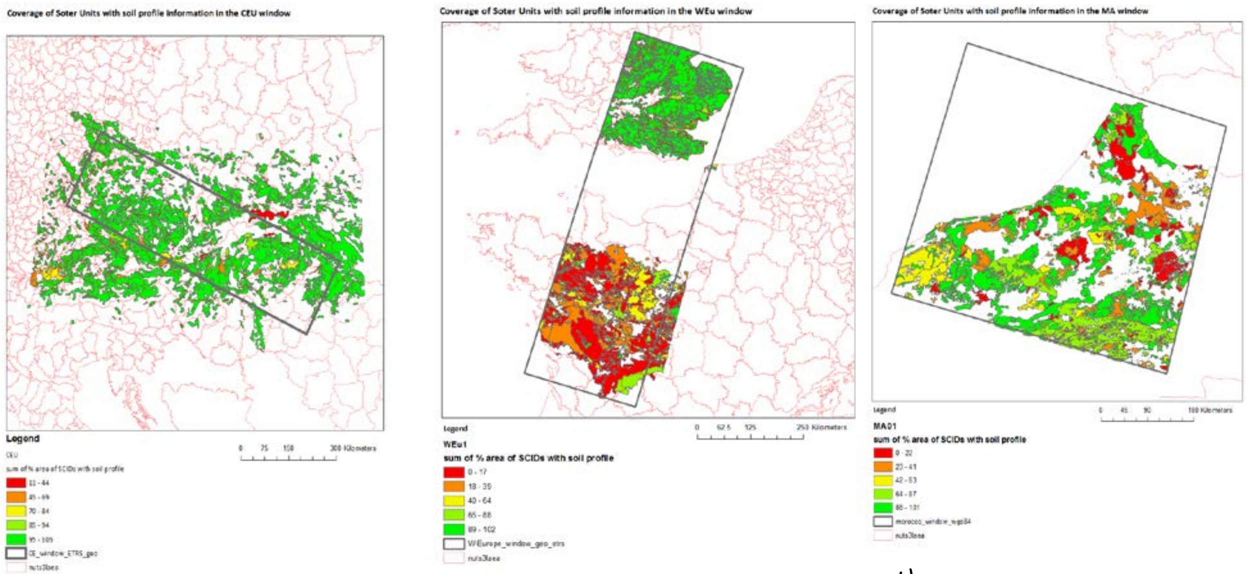


Figure 3. Soil information Covera[illegible]ort)

As agreed in last WP5 meeting, the soil profile data of the largest Soil Component within each soter unit was used for Jones Model applications for soil compaction threat. The largest soil component (SCID=1) has been selected in each soter unit even if it does not cover more than 50% of the soter unit and horizons below A# horizons were selected as subsoil (HONU: 2). The subsoil data; Total sand (SDTO%), Silt (STPC%), Clay (CLPC%) and Bulk Density were taken from the corresponding profiles (PRID) in the e-soter database.

The compaction model requires certain attributes to be present in the database. Therefore a query has been run on the e-soter database to select required attributes from RepresantativeHorizonValues table in the database. After all filters (SCID=1, HONU=2, BULK= Not NULL, Texture = Not NULL (STDO, STPC, CLPC)) have been applied to e-soter database, very limited soil information has remained available. Soter Units having soil components with soil data (Textural data and Bulk Density) allocated cover at 19% of the Ceur window, %3 of the Morocco window and %13 of WEur window. Even though the coverage problem, the model has been run on WEur, CEur and Ma windows and subsoil compaction maps were produced (Figures 4-5-6).

2.2.1 WEur Window:

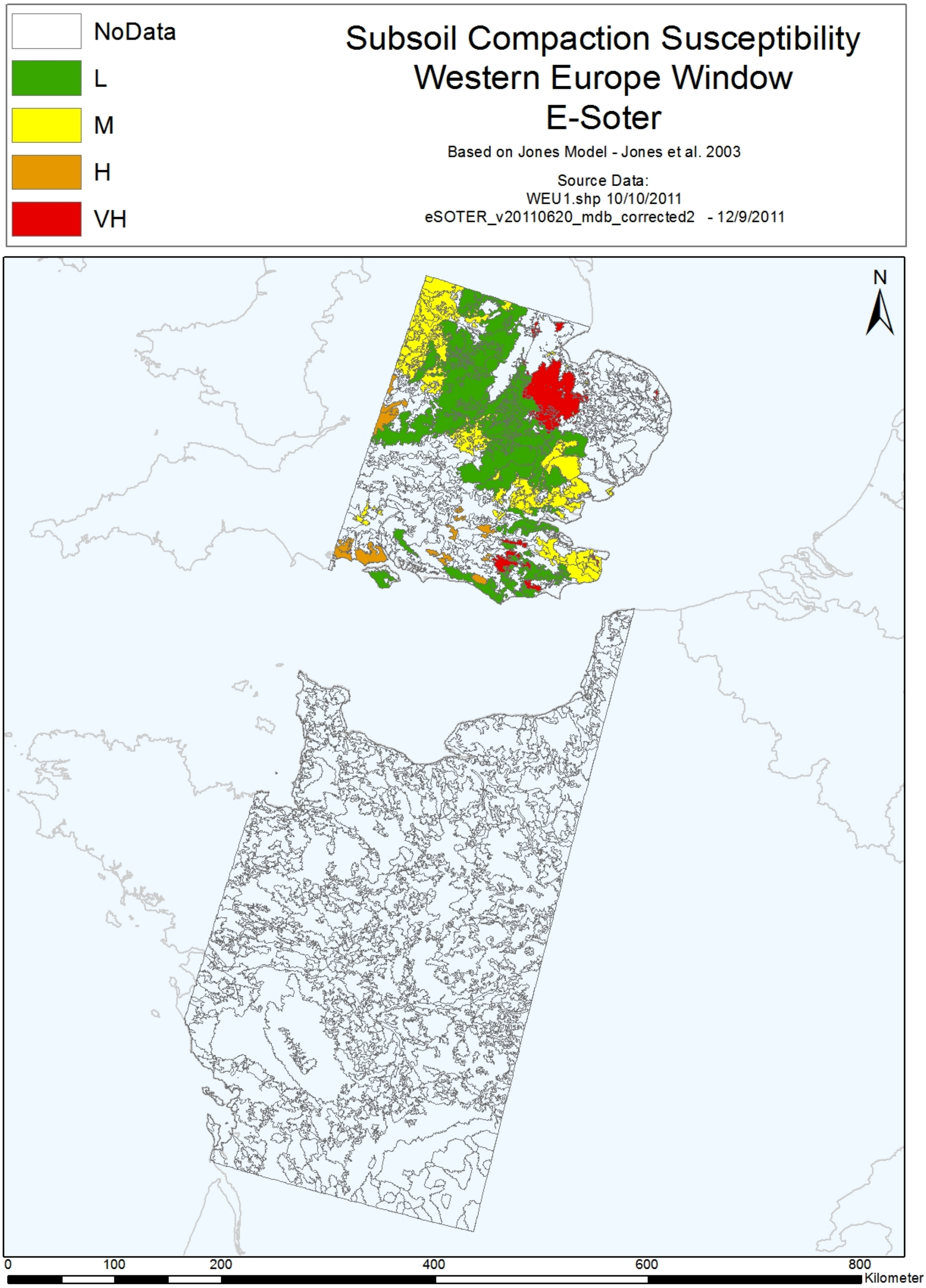


Figure 4. WEur window - Subsoil compaction susceptibility based on E-Soter Database

2.2.2 CEur Window:

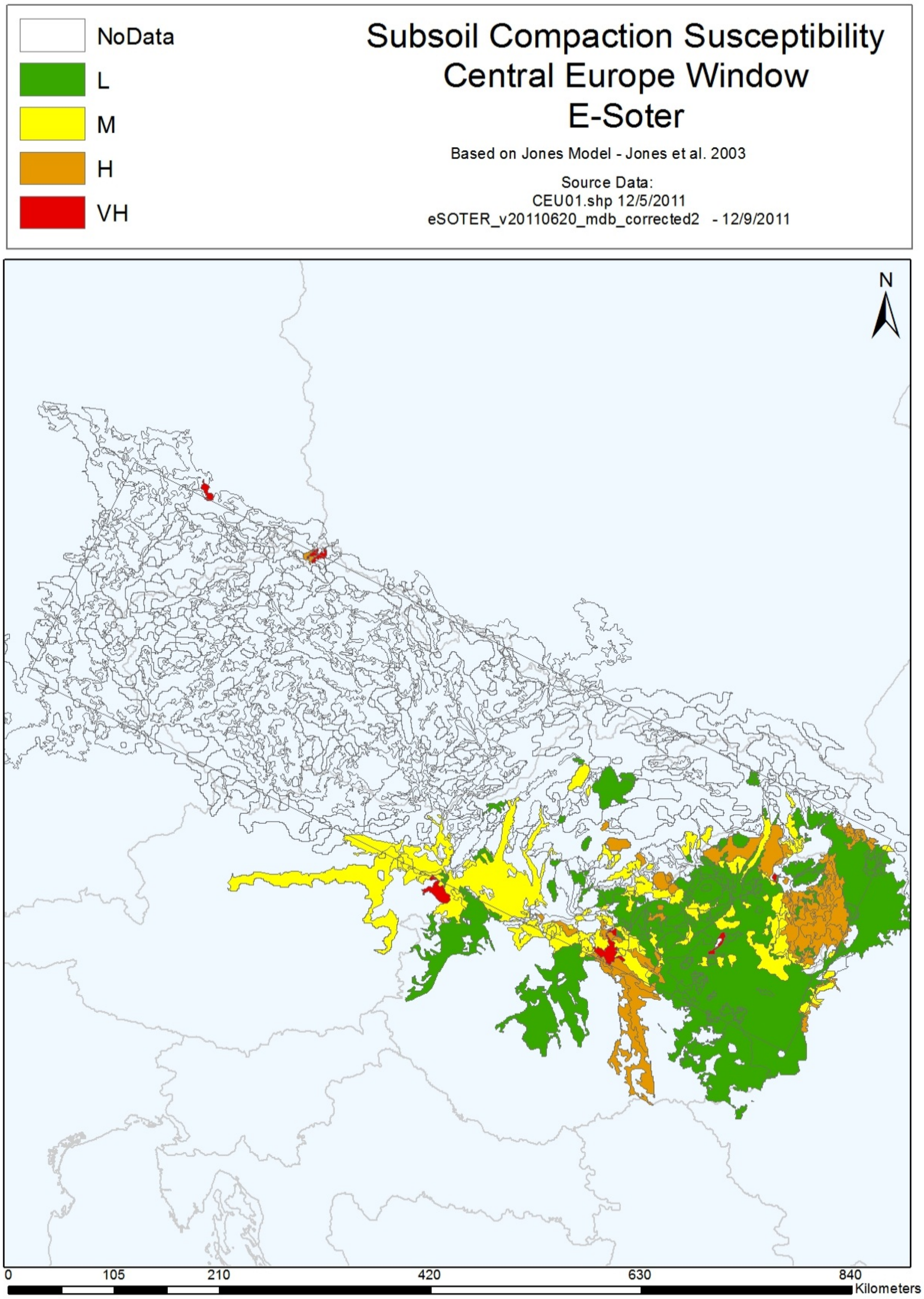


Figure 5. CEur window - Subsoil compaction susceptibility based on E-Soter Database

2.2.3 Ma Window:

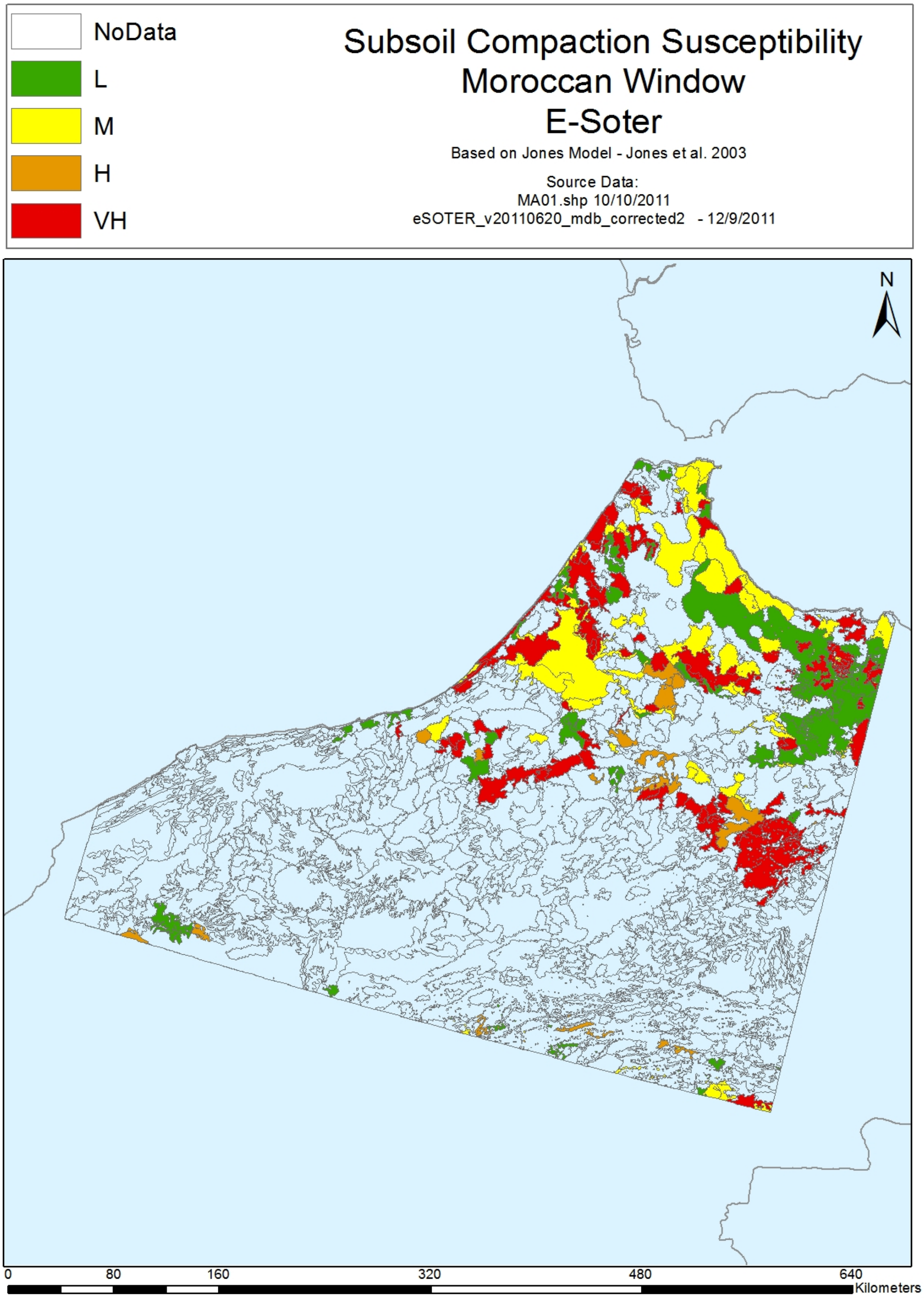


Figure 6. Ma window - Subsoil compaction susceptibility based on E-Soter Database

2.3 World Harmonized Soil Database (HWSD – FAO)

Morocco is not covered by European Soil Database. Therefore the model has been run on E-Soter database (Figure 6) and World Harmonized Soil Database (HWSD) (Figure 7).

Two mapping units of Moroccan part of the HWSD have no soil information to soil compaction (Texture and Bulk Density). In order to evaluate the subsoil compaction susceptibility for Ma window, subsoil bulk density (S_Ref_Bulk_Density kg/dm3), subsoil textural data (S-Sand, S_Silt, S_Clay - % wt) and FAO90 have been taken from the World Harmonized Soil Database, FAO90 attribute has been used to see if there are any organic soils (Histosol) in the window (Table 4).

Table 4. Input data to evaluate subsoil compaction susceptibility in Ma Window (HWSD - FAO):

Input	*Derive from*	*Attribute name in HWSD*	*Classes*
Subsoil Packing Density (PD)	Harmonized World Soil Database.	**S_REF_BULK_DENSITY:** Subsoil Reference Bulk Density	3 classes: Low <1.4 Medium 1.4 – 1.75 High > 1.75
Subsoil Texture	Harmonized World Soil Database	**S_SAND: Subsoil Sand Fraction % wt.** **S_SILT: Subsoil Silt Fraction % wt.** **S_CLAY : Subsoil Clay Fraction % wt.** **FAO90 – FAO 90 Soil Name**	6 classes: 1: coarse (<18% Clay, > 65% Sand) 2: medium (<35% Clay, > 15% sand; if more than 18% Clay > 65% Sand) 3: medium fine (< 35% Clay, < 15% Sand) 4: fine (30 – 60 % Clay) 5: very fine (> 60% Clay) 9: organic (no mineral texture)

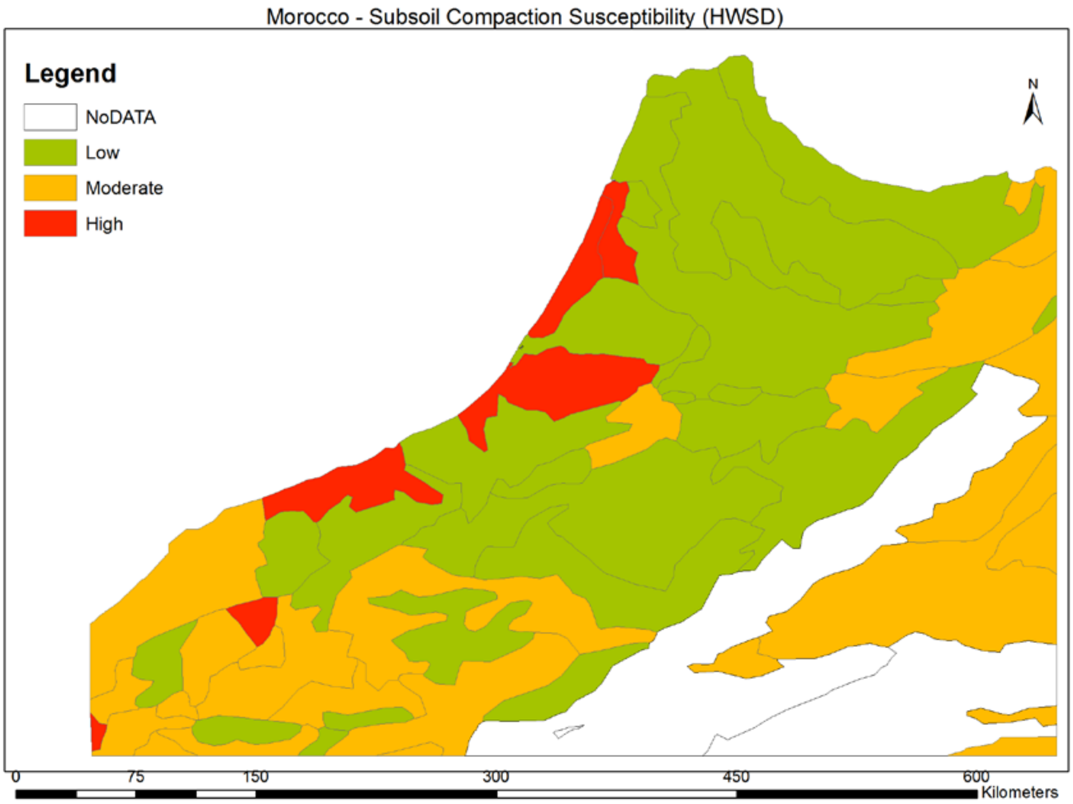


Figure 7. Ma window - Subsoil compaction susceptibility based on World Harmonized Soil Database (HWSD)

2. Results

The compaction evaluation is done based on ESDB attributes for Ceur and WEur windows and based on HWSD attributes for Ma window. Considering of subsoil compaction evaluation in windows on the e-Soter database; Soter Units having soil components with soil profile data (Textural Data and Bulk Density) allocated by representative profiles cover at 19% of the Ceur window, %3 of the Morocco window and %13 of WEur window. And this coverage of the e-Soter database is still insufficient for compaction application at window scale.

4. References:

ENVASSO Procedures and Protocols Final Report (2008)

Jones, R.J.A., G.Spoor, A.J.Thomasson 2003. Vulnerability of subsoils in Europe to compaction: a preliminary analysis. Soil & Tillage Research 73, 131-143.

FAO/IIASA/ISRIC/ISSCAS/JRC, 2009. Harmonized World Soil Database (version 1.1). FAO, Rome, Italy and IIASA, Laxenburg, Austria

11 Appendix 4 – BGR model applications

By Ulrich Schuler (BGR)

In the frame of WP5 the applicability of e-SOTER has been tested. Therefore, two methods estimating the threat of soil erosion by water (Eberhardt, 2009a,b) were applied for the Central European window of the e-SOTER project (Figure 1) using an e-SOTER dataset (delivered by WP2). To control the plausibility, the applications were also carried out with the European soil data base (ESDB) dataset (JRC, 2003), and the outputs were compared. Due to a lack of data, a validation was not feasible. Expert judgment was used as an approximate validation of the model results.

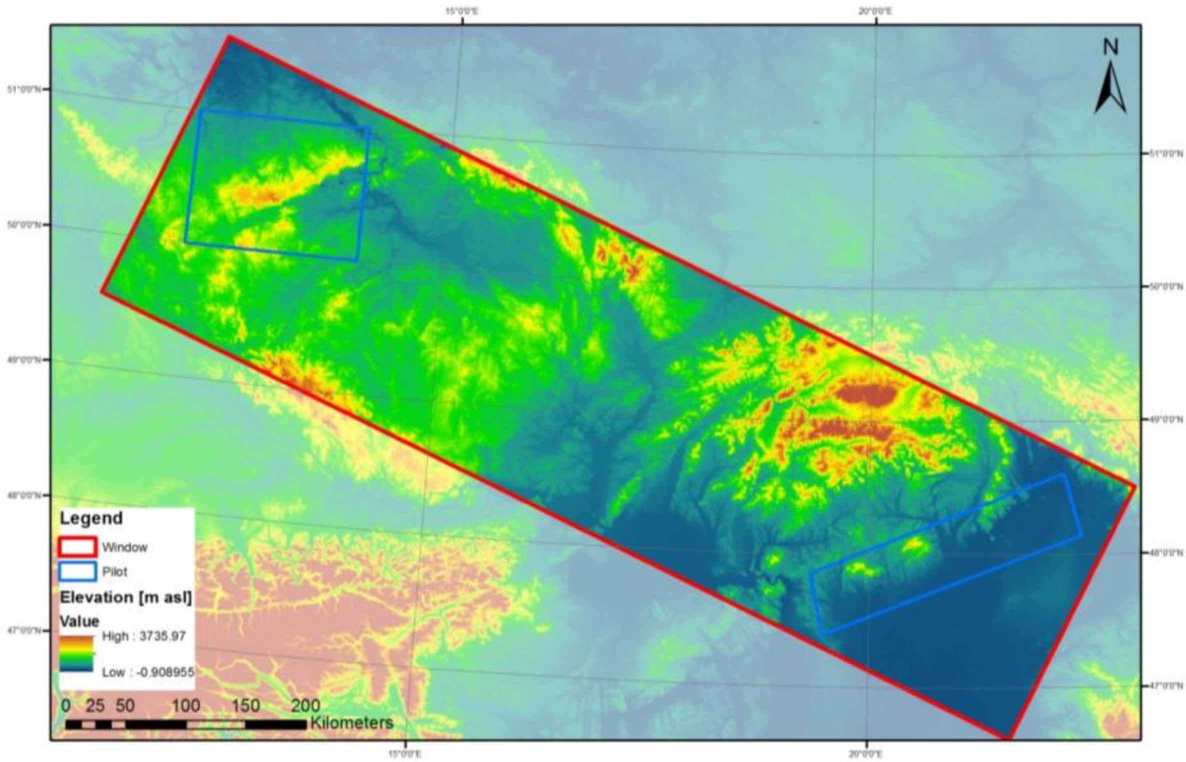


Figure 1 Topographic map of the Central European window and pilot area of the e-SOTER project.

The term 'soil erosion' is used in the context of being a threat to soil, it refers to 'accelerated soil erosion', i.e. soil erosion, as a result of anthropogenic activity, in excess of accepted rates of natural soil formation, causing a deterioration or loss of one or more soil functions (Dumitru et al., 2010).

11.1 Potential soil loss by water

The potential soil loss by water can be estimated with legacy data such as a digital elevation model, soil information about texture and stone content, precipitation during summer. The following equation was used to compute the potential soil loss by water erosion:

$Efw = K_B * K_S * S * R * 2.0$ (Equation 1)

where:

Efw = soil loss by water [t ha^{-1} a^{-1}]
K_B = soil factor
K_S = stone content factor
S = slope factor
R = precipitation factor

Soil factor K_B

Based on soil texture the K_B factor can be estimated. For the Central European window, information about soil surface texture was available for the e-SOTER and ESBD dataset. For the application the attributes with the largest surface percentages were chosen and reclassified to K_B values according to Table 1.

Table1: K_B classes for the dominant soil surface texture

Texture class		Description	KA5 texture class	KB
SOTER	ESBD			
-	0	No information		
0	9	No mineral texture (Peat soils)		0
1	1	Coarse (<18% clay and > 65% sand)	St2	0.11
2	2	Medium (18% < clay < 35% and >= 15% sand, or <18% clay and 15% < sand < 65%)	Uls	0.50
3	3	Medium fine (< 35% clay and < 15% sand)	Ls3/Ls2	0.32
4	4	Fine (35% < clay < 60%)	Tl	0.09
5	5	Very fine (clay > 60 %)	Tt	0.02

In comparison to the ESDB, the e-SOTER dataset is more incomplete as some areas are not covered with information, and the K_B values of both datasets are different for some areas, especial in the Hungarian pilot (Figure 2 and 3).

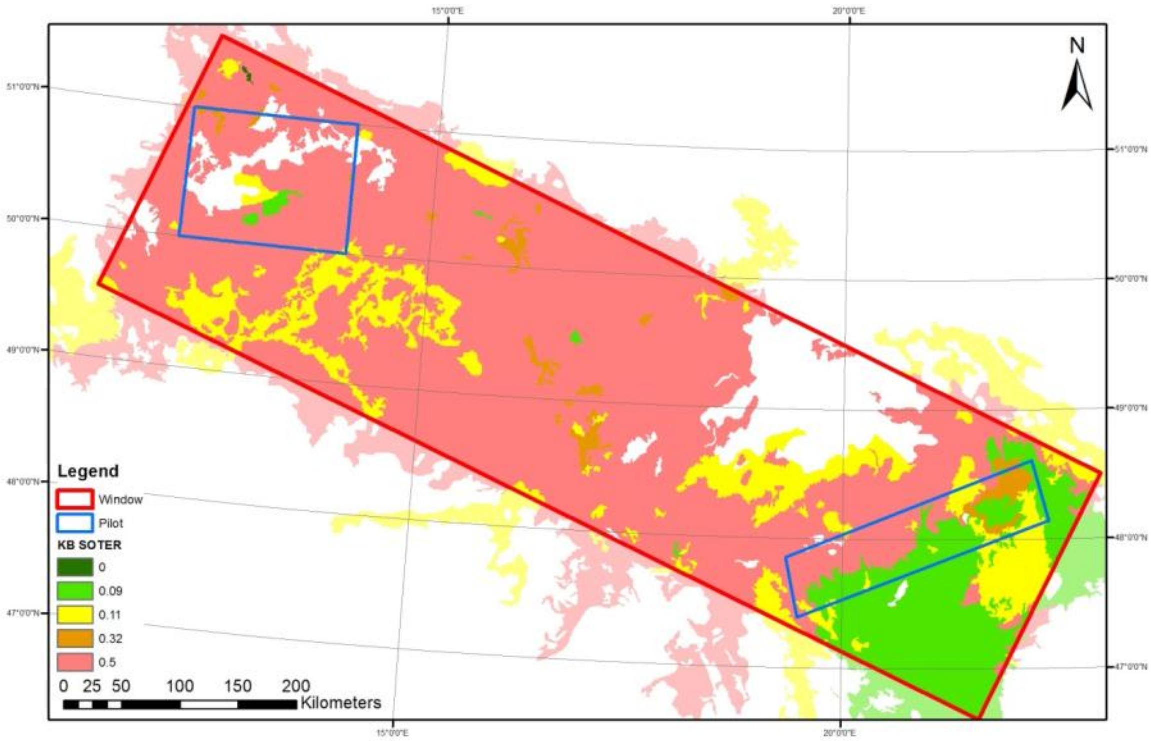


Figure 2: KB values derivable from the e-SOTER map of WP2.

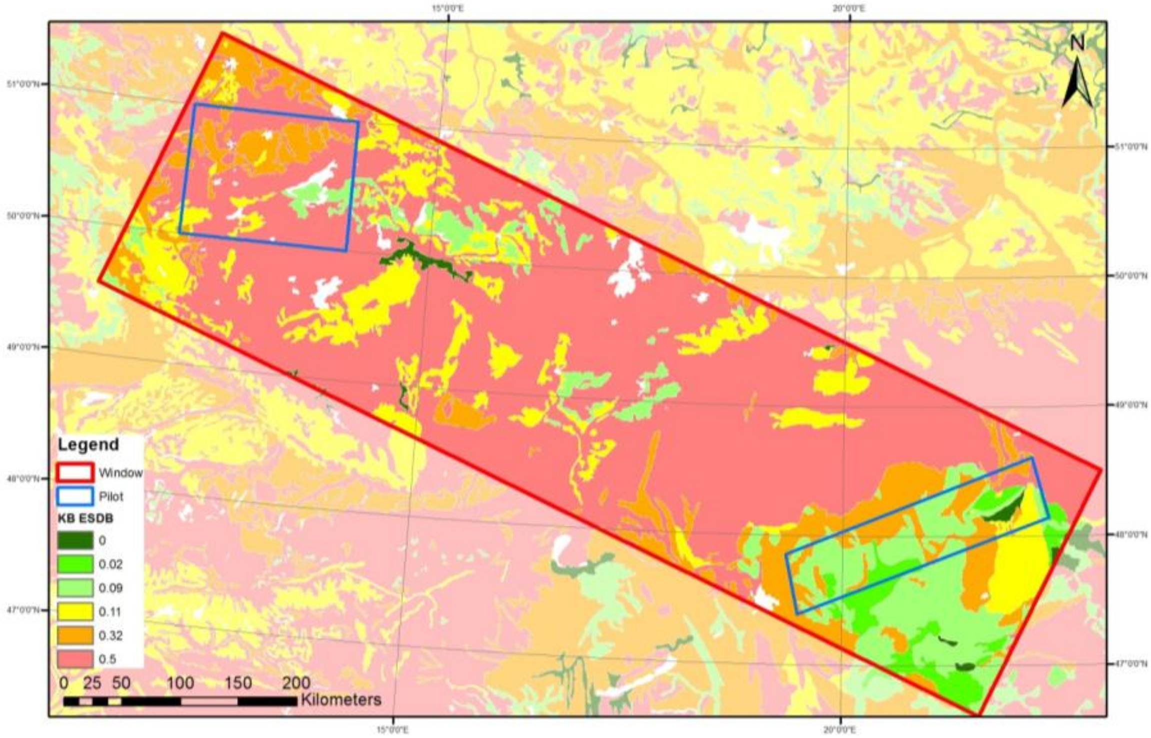


Figure 3: KB values derivable from the ESDB map.

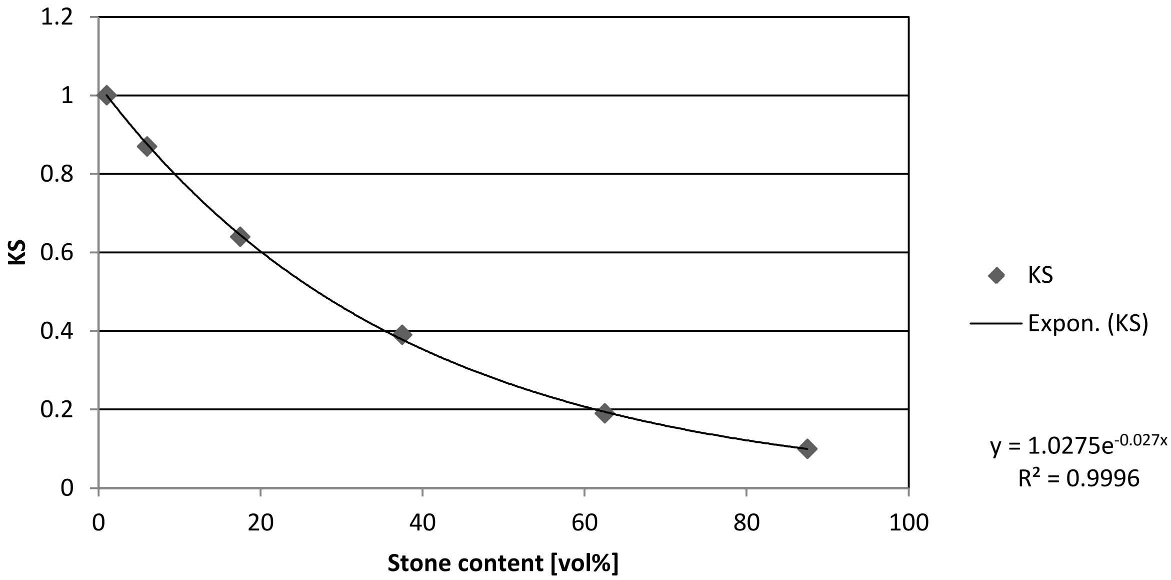
Stone factor K_S

The K_S factor can be computed with the stone volume concentration of the soil using the following exponential equation:

$K_S = 1.0275e^{-0.027x}$ (Equation 2, Figure 4))

where

x = stone volume [%]



The e-SOTER dataset did not provide any information about the stone content. Therefore, a stone content of 0% was assumed for this dataset. In contrast, the ESBD database is rather complete, and Ks values were computed according to equation 2.

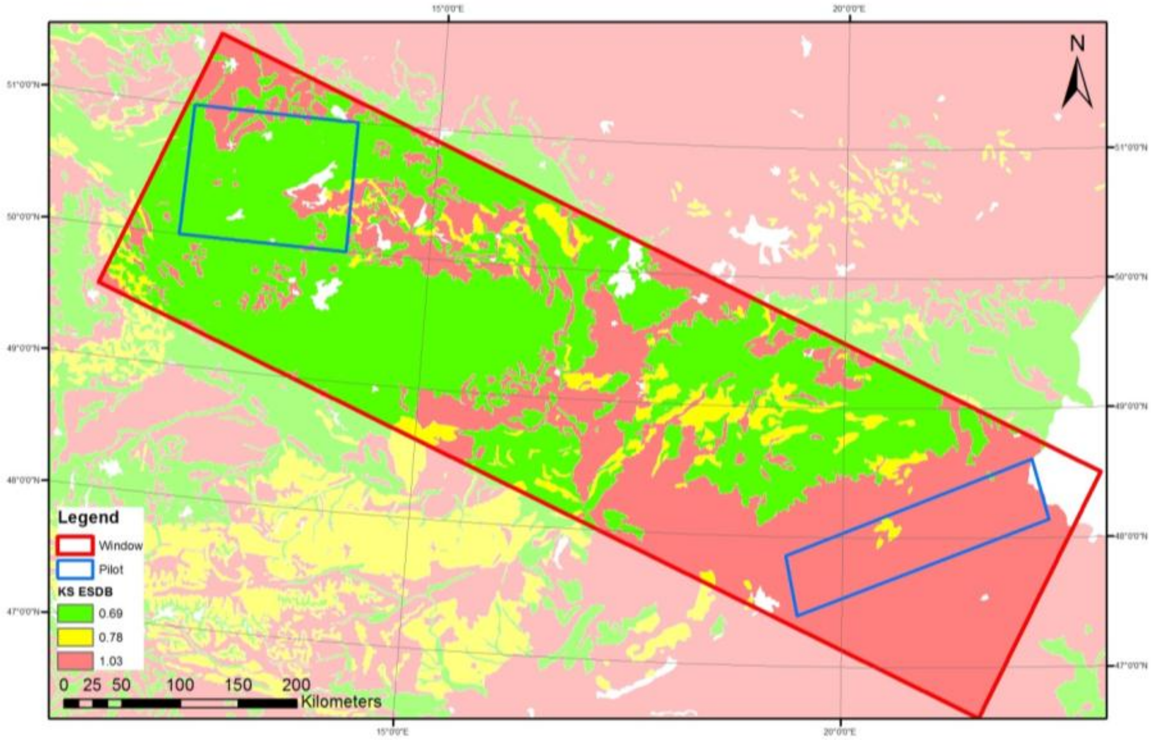


Figure 4: K_S values derivable from the ESDB map.

Slope factor S

The slope factor was derived from a processed SRTM 90 elevation model (Jarvis et al., 2008), by computing the slope and applying the following equation:

$S = -1.5 + (17/(1+e^{2.3-6.1\sin\alpha}))$ (Equation 3)

where

α = slope inclination in radians (trigonometric functions of ArcGIS require radians instead of degree)

However, the method is restricted to slopes with an inclination of less than 30% or 16.7°.

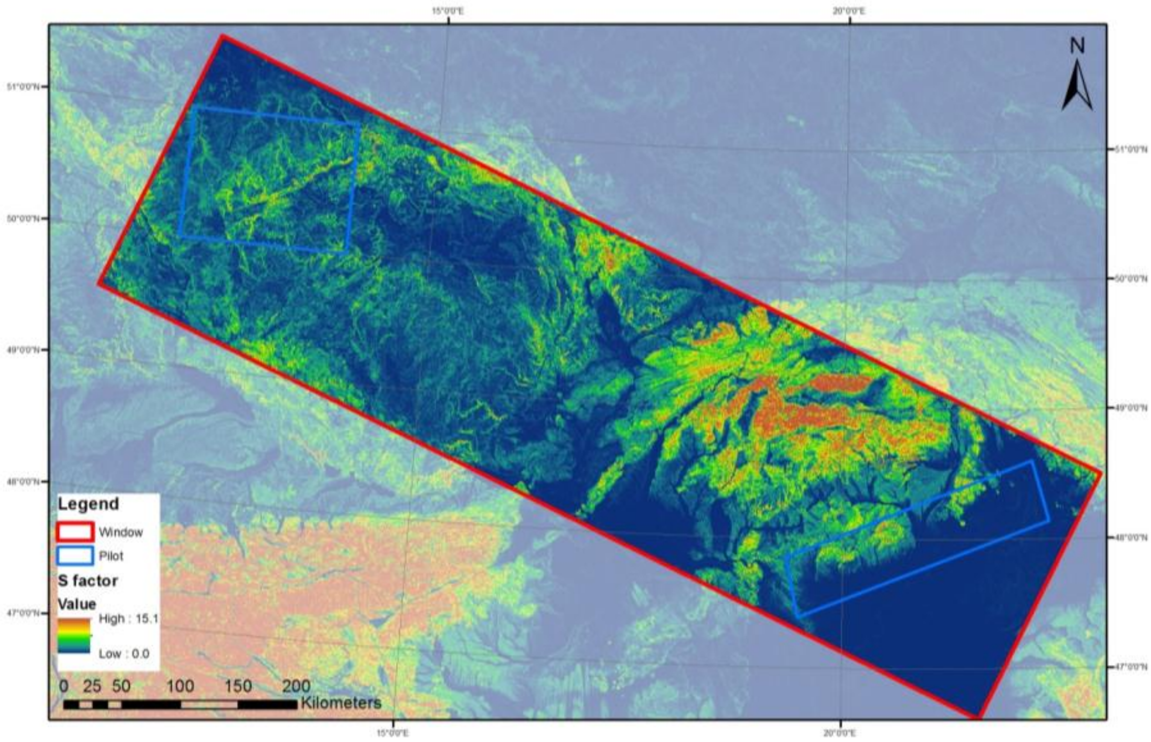


Figure 5: Slope factor S derived from the SRTM90 map processed in WP1.

Precipitation factor R

The calculation of the precipitation factor was based on a world climate data set of Hijmans et al., 2005. The following equation was used:

$R = 0.152 * P_{summer} - 6.88$; $r = 0.854$ (Equation 4)

where

P_{summer} = mean precipitation between May and October

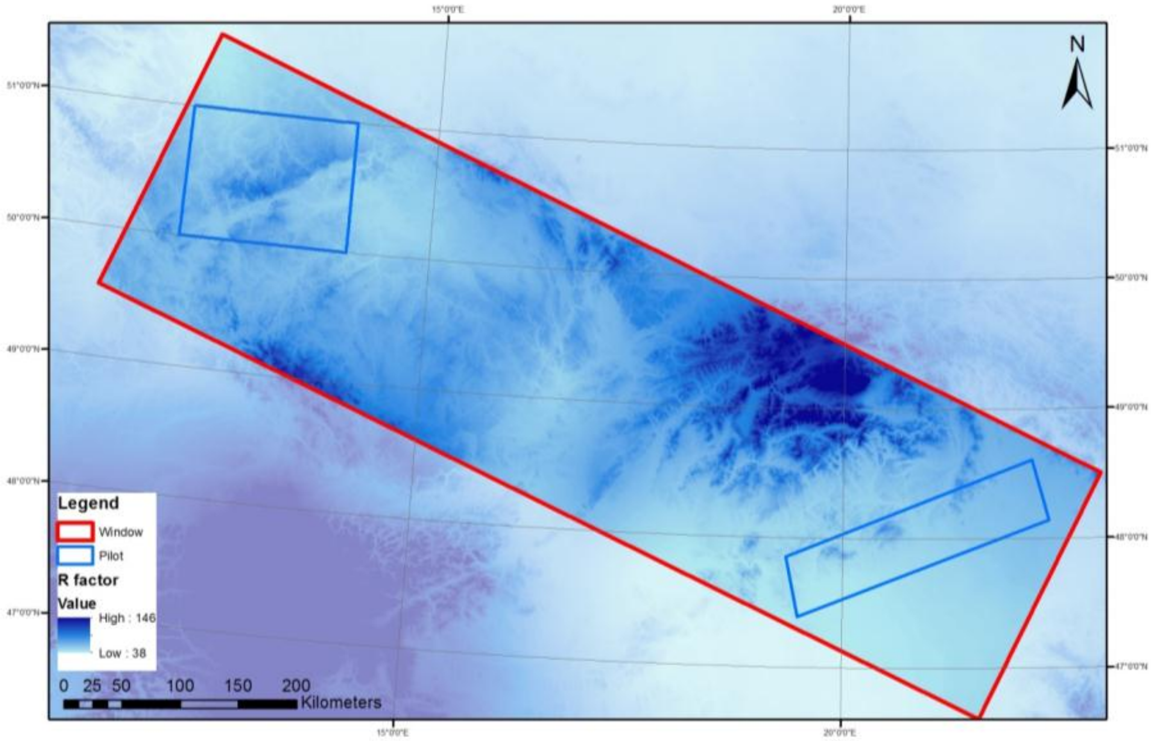


Figure 6: Precipitation factor R derived from the world climate data set of Hijmans et al., 2005.

Results – Potential soil loss by water

Both databases lead to different erosion rates (Figure 7-9). The erosion rates of the e-SOTER based approach are twice of the ESDB approach. The main reason for this difference is a lack of information about the content of coarse fragments in the e-SOTER database, allowing only an estimation of soil loss by water by assuming a coarse fragment free soil matrix at the soil surface. But there are also clear differences in the KB factor due to different information on soil texture in both databases. This is supported by the fact that the pattern of the difference map does not correspond that much to the map of the Ks factor, with lower values in the North-Western part. It is also supported by the observation that also negative differences occur, i.e. soil erosion rates simulated using the e-SOTER database are lower than using the ESDB database (the blue areas in the difference map). The blue areas seem to correspond to areas where the soil factor in the e-SOTER database is lower (soil texture coarser) than in the ESDB.

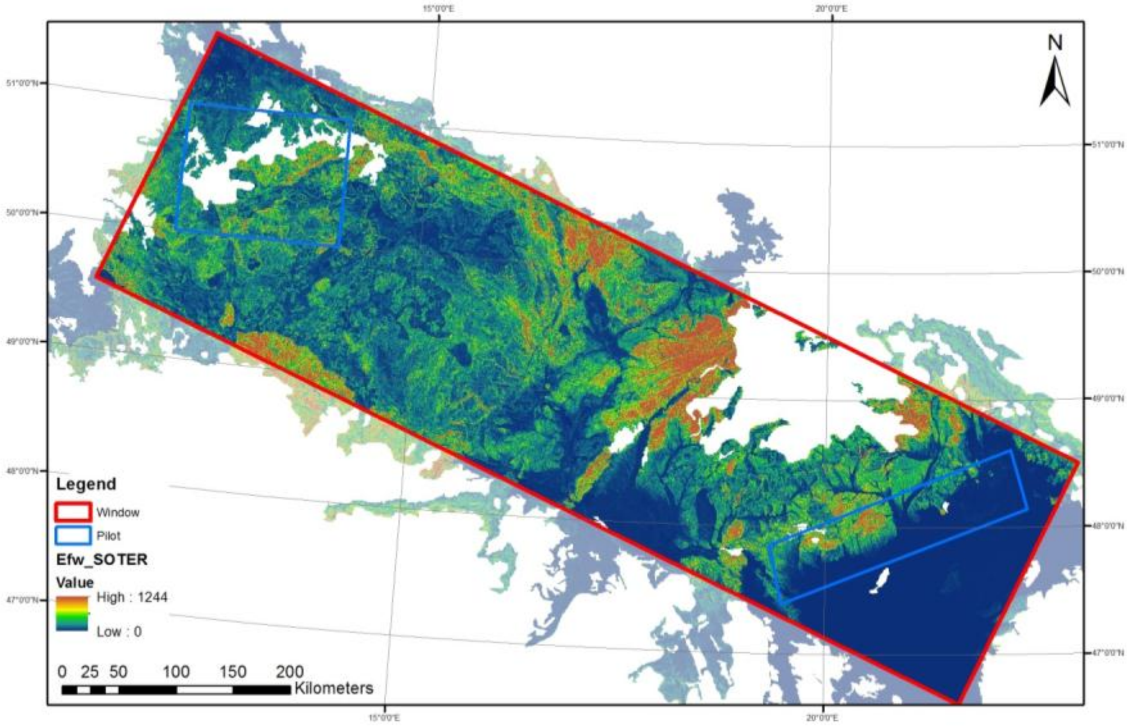


Figure 7: Soil loss by water in t ha^{-1} a^{-1} using the e-SOTER map as baseline information.

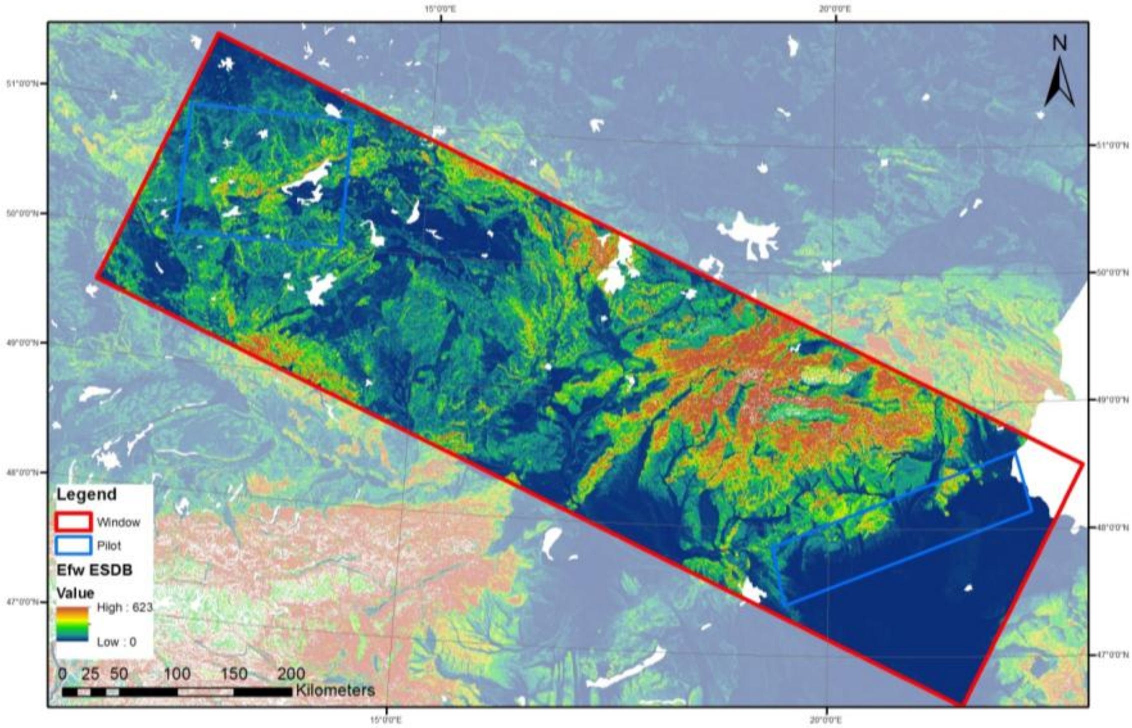


Figure 8: Soil loss by water in t $ha^{-1} a^{-1}$ using the ESDB map as baseline information.

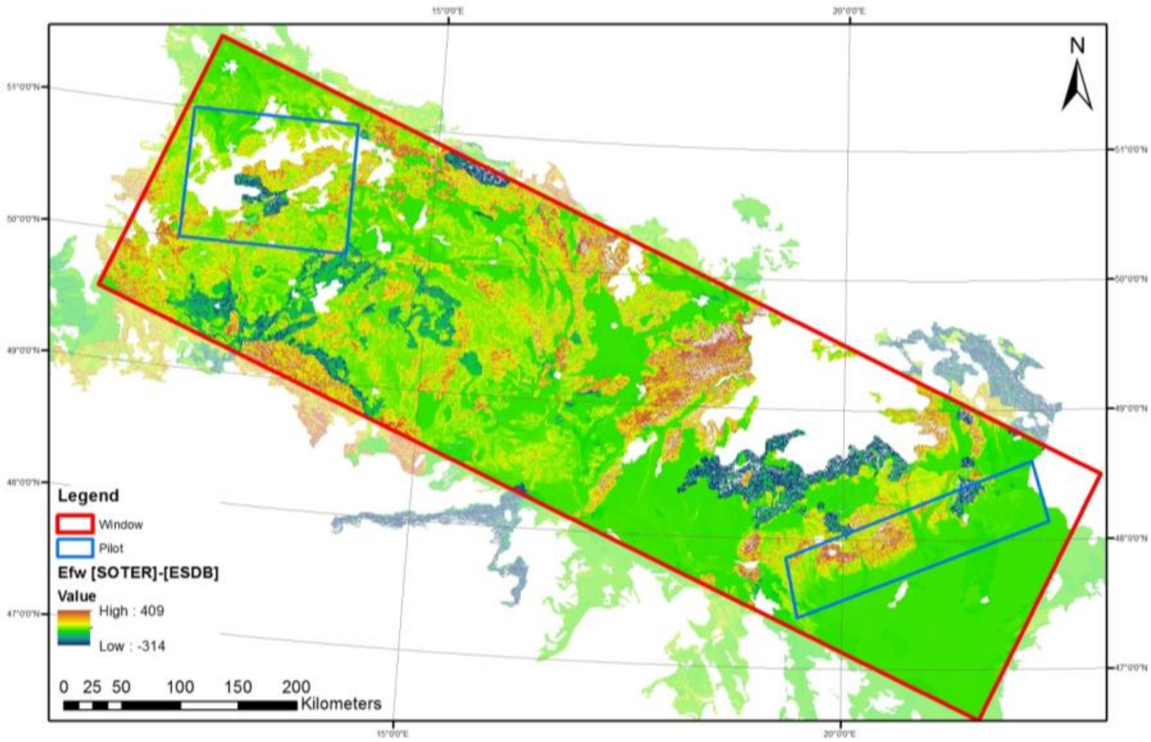


Figure 9: Differential map of soil loss by water subtracting the ESBD based map from the e-SOTER based map.

11.2 Soil sensitivity to water erosion

Basics

The soil sensitivity to water erosion can be estimated with the combination of soil texture and slope inclination.

The result of this evaluation consists of 6 ordinal classes (Table 2):

class 0 = not sensitive
cass 1 = very low erosion sensitivity
class 2 = low erosion sensitivity
class 3 = moderate erosion sensitivity
class 4 = high erosion sensitivity
class 5 = very high erosion sensitivity

Table2: Ordinal erosion classes for the dominant soil surface texture and different slope classes

Texture class		KA5 texture class	Slope class [%]					
e-SOTER	ESDB		<= 1	>1-5	>5-9	>9-18	>18-36	>36
-	0	no information	-	-	-	-	-	-
0	9	- (peat soils)	0	0	-	-	-	-
1	1	St2	0	0	1	2	4	5
2	2	Uls	0	2	3	4	5	5
3	3	Ls3/Ls2	0	1	2	3	5	5
4	4	Tl	0	0	0	2	4	5
5	5	Tt	0	0	0	2	4	5

Results – Soil sensitivity to water erosion
Both the e-SOTER ESDB based applications generally lead to comparably similar sensitivity classes (Figure 10-12); a large part of the area has 0 difference between classes of soil sensitivity. Differences in both directions also occur: where the model simulates higher sensitivity based on the e-SOTER database than on the ESDB, and vice versa.

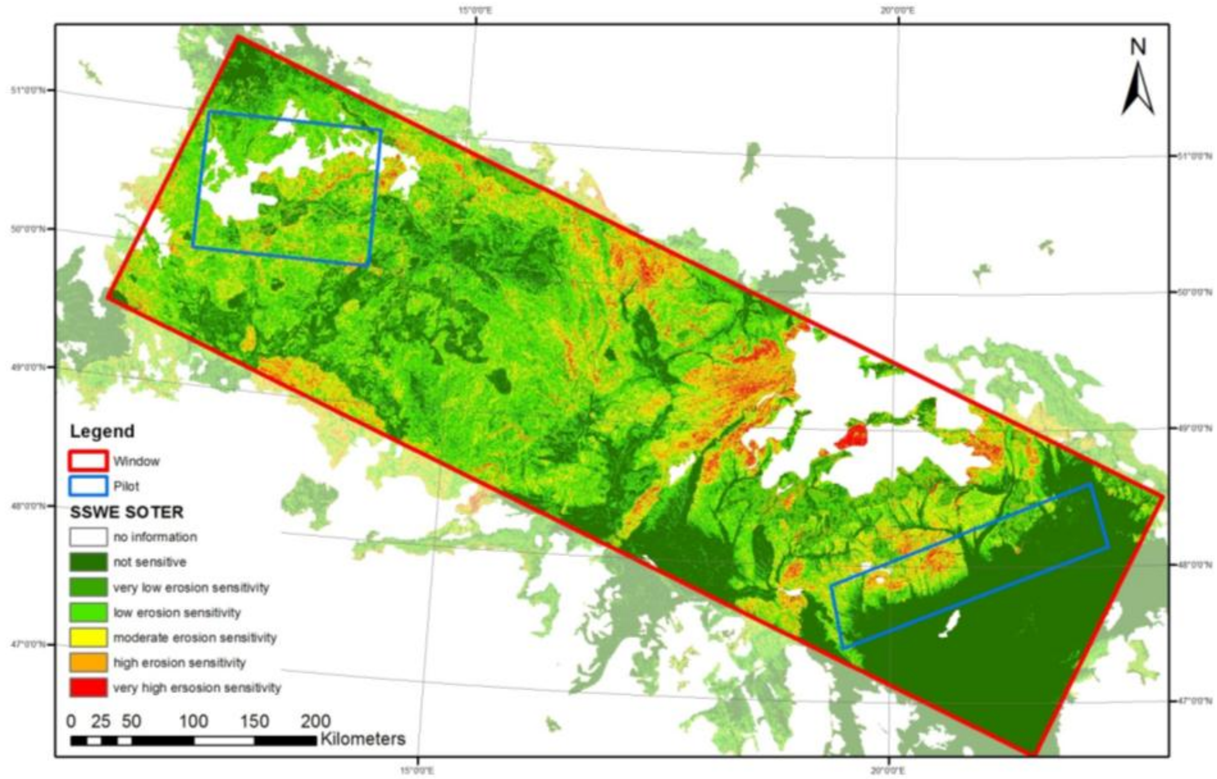


Figure 10: Soil sensitivity to water erosion based on the e-SOTER map.

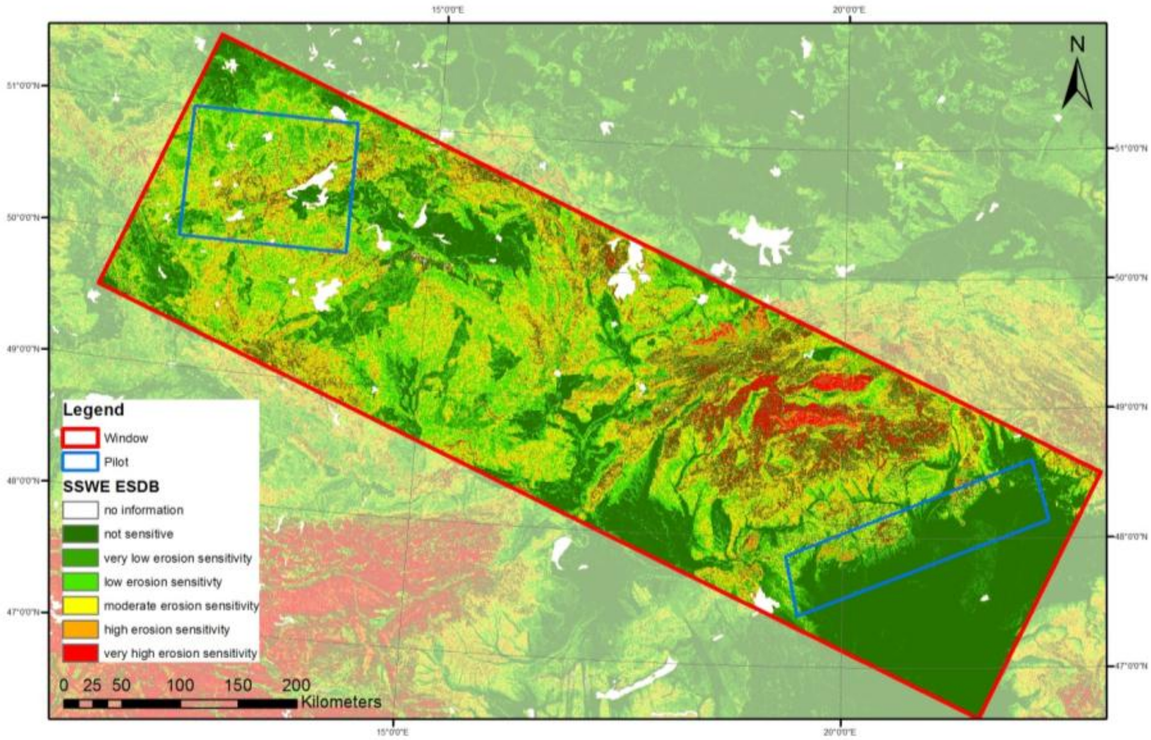


Figure 11: Soil sensitivity to water erosion based on the ESBD map.

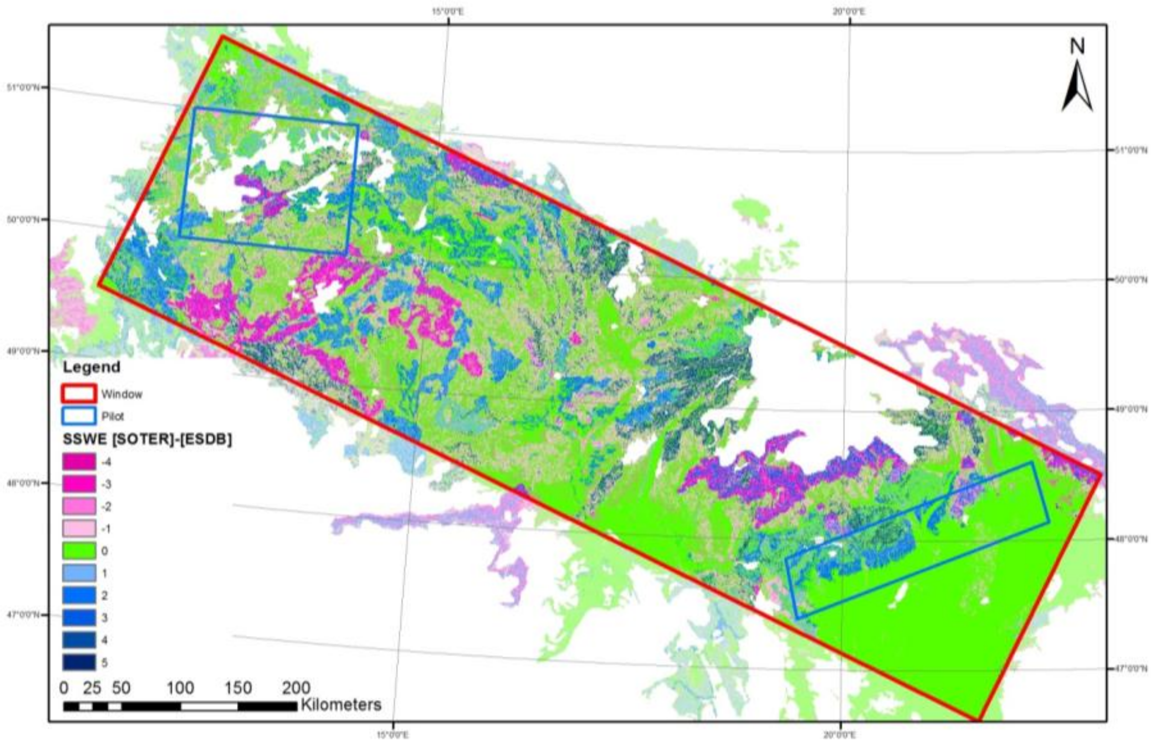


Figure 12: Differential map of soil sensitivity subtracting the ESBD based classes from the e-SOTER ones.

11.3 Conclusions

The approach (Eberhardt, 2009a) to determine potential soil loss by water leads to high erosion rates with maximum values of 623 and 1244 t ha^{-1} a^{-1} for the ESDB and e-SOTER database respectively. In comparison, the average actual (?) European soil erosion rate for tilled agricultural land ranges between 4.5 and 38.8 t ha^{-1} a^{-1} (Verheijen et al., 2009). The higher values for potential soil loss simulated in this study are inherent to the concept of potential soil loss, which is defined as soil loss that would occur in the absence of any coverage of the soil surface by vegetation or other materials. The disregard of land use type and vegetation cover is inherent to the target variable 'potential soil loss'. Deficiencies of the model for erosion sensitivity are that structure stability and organic matter content are not considered. The e-SOTER database is less suitable for prediction of soil loss by water using the model for potential soil loss applied in this study, due to the sparse information about coarse fragments. The approach to determine soil sensitivity to water erosion (Eberhardt, 2009b) is applicable using both databases, and seems to provide comparable results.

11.4 References

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12 Appendix 5 - Estimated Susceptibility to Subsoil Compaction in Selected NUTS3 areas in England

Expert report by RJA Jones, NSRI Cranfield University

eSOTER

Estimated Susceptibility to Subsoil Compaction in Selected NUTS3 areas in England

R J A Jones

(GIS data provided by C A Keay

NSRI Cranfield University

February 2012

Estimation of soil susceptibility to compaction.

This section describes the procedure adopted to estimate soil susceptibility to compaction (4 classes) for the eSOTER Project.

1. On the topographical maps provided by the eSOTER Questionnaire Interface, the proportion (%) of NUTS3 area that is marked as urban was visually estimated. These estimates are included in the results but they have not been checked quantitatively.
2. Using the National Soil Map of England and Wales (Soil Survey Staff, 1983) the non-urban land areas covered by the most obvious soil map units (e.g. 411d Hanslope association (Hodge et al., 1984) were visually assessed and estimated.
3. Using Table 2 in Jones et al. (2003, p.137), the National Soil Map Units, as listed in the National Legend compiled by Mackney et al. (1983), were assigned (classified) to the 4 susceptibility to compaction classes – Low (L), Moderate (M), High (H) and Very High (VH).
4. The proportions (%) of the different soil units identified were summed to produce the proportion of the non-urban land in each NUTS3 unit belonging to one of the 4 soil compaction classes.
5. The National Soil Map Units (associations) were assigned to a susceptibility to compaction class on the basis of the soil texture and structure (including packing density) in the subsoil as described by Jones et al. (2003).
6. Thus the themes used to estimate the areas were the topographical maps provided by the Interface, the National Soil Map of England and Wales (Keay et al, 2009), and the accompanying National Legend (Mackney et al, 1983). The parent material maps that were provided in the Interface were not used, because the information on texture and parent material on the National Soil Map was much more detailed (and therefore provided more accurate results?).
7. The National Soil Map data are stored in relationally structured databases that have a GIS interface provided by ArcGIS™ (v 10.0); these data are rasterised to 100m x 100m, and agglomerated to 1 km x 1 km. The 1km data set was used to extract the proportions of all map units within selected NUTS3 units to calculate the total area belonging to each of the 4 compaction classes.
8. National Soil map data were not extracted for NUTS3 units with a large proportion of urban land for comparison with the visual estimates. This is because in the digital National Soil Map data set, the soil map unit (association) boundaries were delineated through the urban areas and then digitised, whereas on the published National Soil Map (paper) used in this study, the soil map unit boundaries stop at the urban boundary.

Assigning a susceptibility to compaction class to a soil type is a judgment whether or not the soil can be compacted; i.e. if the soil is a dense clay with a small air space (capacity,) e.g. <5% v/v, then it is unlikely to be compactable much more by normal field loads? Such a soil will of course be deformable when wet but the bulk density will not be increased significantly by further compression.

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Appendix I

Areal estimates of compaction classes

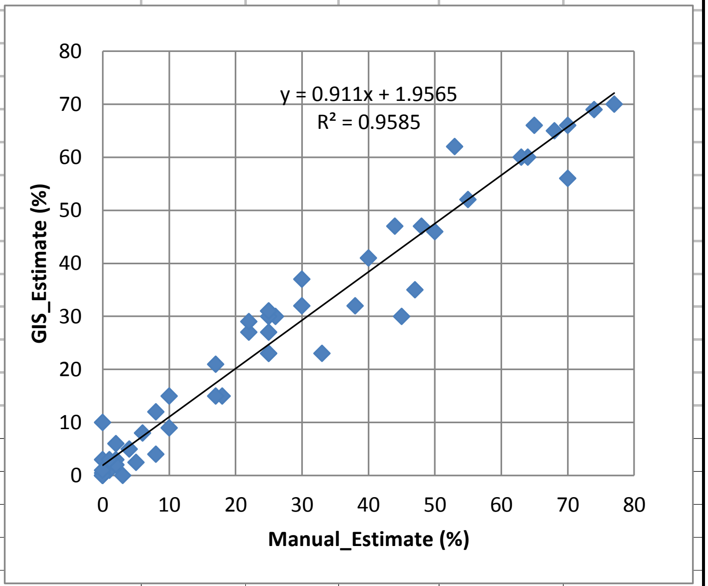
Comparison of manual (eyeball) estimates with areas calculated using GIS

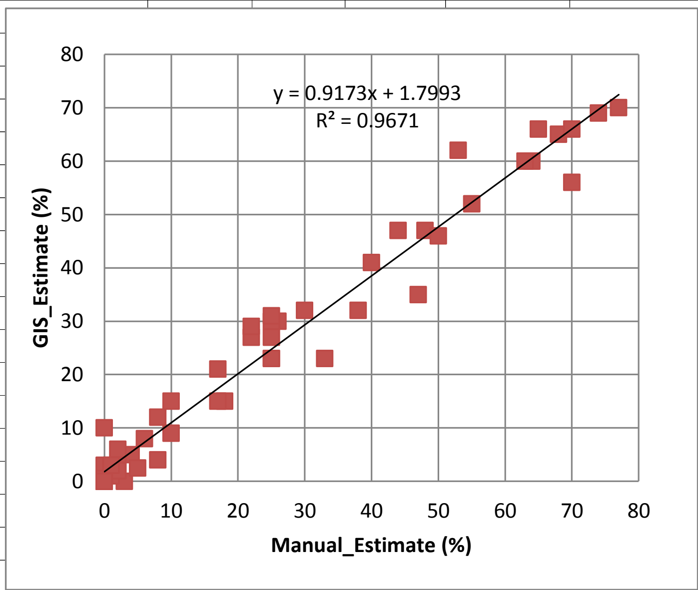
NUTS3_Unit	Topic	Param	Man_Est	GIS_Est	Expert	Urban (%)	Confidence
UKF11_eli	compaction	**Derby**	1		11		
UKF11_eli	compaction	comment	-999		11	85	3
UKF11_eli	compaction	low	40	41	11		
UKF11_eli	compaction	moderate	22	27	11		
UKF11_eli	compaction	high	38	32	11		
UKF11_eli	compaction	very high	0		11		
UKF16_eli	compaction	**S Notts**	1		11		
UKF16_eli	compaction	comment	-999		11	not-est	3
UKF16_eli	compaction	low	62		11		
UKF16_eli	compaction	moderate	5		11		
UKF16_eli	compaction	high	33		11		
UKF16_eli	compaction	very high	0		11		
UKF23_eli	compaction	**Northants**	1		11		
UKF23_eli	compaction	comment	-999		11	5	3
UKF23_eli	compaction	low	68	65	11		
UKF23_eli	compaction	moderate	25	27	11		
UKF23_eli	compaction	high	4	5	11		
UKF23_eli	compaction	very high	3		11		
UKG31_eli	compaction	**Birmingham**	1		11		
UKG31_eli	compaction	comment	-999		11	95	3
UKG31_eli	compaction	low	60		11		
UKG31_eli	compaction	moderate	0		11		
UKG31_eli	compaction	high	0		11		
UKG31_eli	compaction	very high	40		11		
UKG33_eli	compaction	**Coventry**	1		11		
UKG33_eli	compaction	comment	-999		11	85	3
UKG33_eli	compaction	low	25		11		
UKG33_eli	compaction	moderate	54		11		
UKG33_eli	compaction	high	0		11		
UKG33_eli	compaction	very high	21		11		
UKH11_eli	compaction	**Peterboro**	1		11		
UKH11_eli	compaction	comment	-999		11	3	3
UKH11_eli	compaction	low	0		11		
UKH11_eli	compaction	moderate	62		11		
UKH11_eli	compaction	high	38		11		
UKH11_eli	compaction	very high	0		11		
UKH13_eli	compaction	**Norfolk**	1		11		
UKH13_eli	compaction	comment	-999		11	1	3
UKH13_eli	compaction	low	18	15	11		
UKH13_eli	compaction	moderate	30	32	11		
UKH13_eli	compaction	high	44	47	11		
UKH13_eli	compaction	very high	8	4	11		
UKH14_eli	compaction	**Suffolk**	1		11		
UKH14_eli	compaction	comment	-999		11	2	3
UKH14_eli	compaction	low	55	52	11		
UKH14_eli	compaction	moderate	17	15	11		
UKH14_eli	compaction	high	26	30	11		
UKH14_eli	compaction	very high	2	3	11		
UKH21_eli	compaction	**Luton**	1		11		

NUTS3_Unit	Topic	Param	Man_Est	GIS_Est	Expert	Urban (%)	Confidence
UKH21_eli	compaction	comment	-999		11	98	3
UKH21_eli	compaction	low	0		11		
UKH21_eli	compaction	moderate	100		11		
UKH21_eli	compaction	high	0		11		
UKH21_eli	compaction	very high	0		11		
UKH23_eli	compaction	**Herts**	1		11		
UKH23_eli	compaction	comment	-999		11	28	3
UKH23_eli	compaction	low	47	35	11		
UKH23_eli	compaction	moderate	53	62	11		
UKH23_eli	compaction	high	0	3	11		
UKH23_eli	compaction	very high	0		11		
UKH31_eli	compaction	**Southend**	1		11		
UKH31_eli	compaction	comment	-999		11	90	3
UKH31_eli	compaction	low	0		11		
UKH31_eli	compaction	moderate	100		11		
UKH31_eli	compaction	high	0		11		
UKH31_eli	compaction	very high	0		11		
UKH32_eli	compaction	**Thurrock**	1		11		
UKH32_eli	compaction	comment	-999		11	30	3
UKH32_eli	compaction	low	45	30	11		
UKH32_eli	compaction	moderate	25	31	11		
UKH32_eli	compaction	high	30	37	11		
UKH32_eli	compaction	very high	0	1	11		
UKH33_eli	compaction	**Essex**	1		11		
UKH33_eli	compaction	comment	-999		11	4	3
UKH33_eli	compaction	low	70	56	11		
UKH33_eli	compaction	moderate	22	29	11		
UKH33_eli	compaction	high	8	12	11		
UKH33_eli	compaction	very high	0		11		
UKI12_eli	compaction	**London_E**	1		11		
UKI12_eli	compaction	comment	-999		11	98	3
UKI12_eli	compaction	low	100		11		
UKI12_eli	compaction	moderate	0		11		
UKI12_eli	compaction	high	0		11		
UKI12_eli	compaction	very high	0		11		
UKJ12_eli	compaction	**MiltonKeynes**	1		11		
UKJ12_eli	compaction	comment	-999		11	25	3
UKJ12_eli	compaction	low	77	70	11		
UKJ12_eli	compaction	moderate	17	21	11		
UKJ12_eli	compaction	high	6	8	11		
UKJ12_eli	compaction	very high	0		11		
UKJ13_eli	compaction	**Bucks**	1		11		
UKJ13_eli	compaction	comment	-999		11	5	3
UKJ13_eli	compaction	low	48	47	11		
UKJ13_eli	compaction	moderate	50	46	11		
UKJ13_eli	compaction	high	2	6	11		
UKJ13_eli	compaction	very high	0		11		
UKJ22_eli	compaction	**East Sussex**	1		11		

NUTS3_Unit	Topic	Param	Man_Est	GIS_Est	Expert	Urban (%)	Confidence
UKJ22_eli	compaction	comment	-999		11	3	3
UKJ22_eli	compaction	low	25	30	11		
UKJ22_eli	compaction	moderate	64	60	11		
UKJ22_eli	compaction	high	10	9	11		
UKJ22_eli	compaction	very high	1	1	11		
UKJ32_eli	compaction	**Soton**	1		11		
UKJ32_eli	compaction	comment	-999		11	98	3
UKJ32_eli	compaction	low	80		11		
UKJ32_eli	compaction	moderate	0		11		
UKJ32_eli	compaction	high	0		11		
UKJ32_eli	compaction	very high	20		11		
UKJ33_eli	compaction	**Hants**	1		11		
UKJ33_eli	compaction	comment	-999		11	6	3
UKJ33_eli	compaction	low	33	23	11		
UKJ33_eli	compaction	moderate	65	66	11		
UKJ33_eli	compaction	high	0	10	11		
UKJ33_eli	compaction	very high	2	2	11		
UKJ34_eli	compaction	**IoW**	1		11		
UKJ34_eli	compaction	comment	-999		11	not_est	3
UKJ34_eli	compaction	low	25	31	11		
UKJ34_eli	compaction	moderate	70	66	11		
UKJ34_eli	compaction	high	5	2.5	11		
UKJ34_eli	compaction	very high	0	0.5	11		
UKJ42_eli	compaction	**Kent**	1		11		
UKJ42_eli	compaction	comment	-999		11	6	3
UKJ42_eli	compaction	low	25	23	11		
UKJ42_eli	compaction	moderate	63	60	11		
UKJ42_eli	compaction	high	10	15	11		
UKJ42_eli	compaction	very high	2	2	11		
UKK14_eli	compaction	**Swindon**	1		11		
UKK14_eli	compaction	comment	-999		11	25	3
UKK14_eli	compaction	low	43		11		
UKK14_eli	compaction	moderate	57		11		
UKK14_eli	compaction	high	0		11		
UKK14_eli	compaction	very high	0		11		
UKK15_eli	compaction	**Wilts**	1		11		
UKK15_eli	compaction	comment	-999		11	1	3
UKK15_eli	compaction	low	25	23	11		
UKK15_eli	compaction	moderate	74	69	11		
UKK15_eli	compaction	high	1	3	11		
UKK15_eli	compaction	very high	0		11		
UKK21_eli	compaction	**Bournemouth**	1		11		
UKK21_eli	compaction	comment	-999		11	85	3
UKK21_eli	compaction	low	0		11		
UKK21_eli	compaction	moderate	28		11		
UKK21_eli	compaction	high	12		11		
UKK21_eli	compaction	very high	60		11		

NUTS3_Unit	Topic	Param	Man_Est	GIS_Est	Expert	Urban (%)	Confidence
Man_Est	**GIS_Est**						
40	41						
22	27						
38	32						
0	0						
68	65						
25	27						
4	5						
3	0						
18	15						
30	32						
44	47						
8	4						
55	52						
17	15						
26	30						
2	3						
47	35						
53	62						
0	3						
0	0						
70	56						
22	29						
8	12						
0	0						
77	70						
17	21						
6	8						
0	0						
48	47						
50	46						
2	6						
0	0						
25	30						
64	60						
10	9						
1	1						
33	23						
65	66						
0	10						
2	2						
25	31						
70	66						
5	2.5						
0	0.5						
25	23						
63	60						
10	15						
2	2						
25	23						
74	69						
1	3						
0	0						
45	30						
25	31						
30	37						
0	1						
r=	0.978617254						

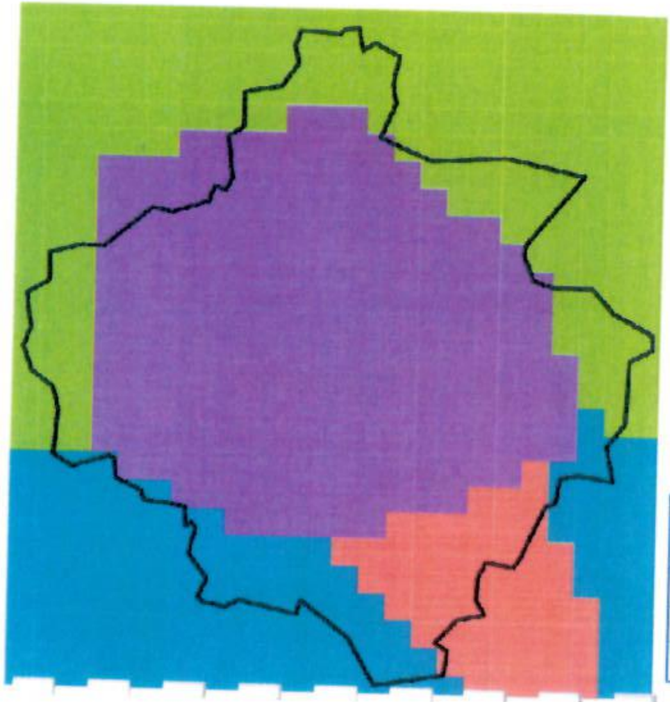




Excludes Thurrock data

Appendix II

NUTS3 areas (maps) with estimates of compaction classes



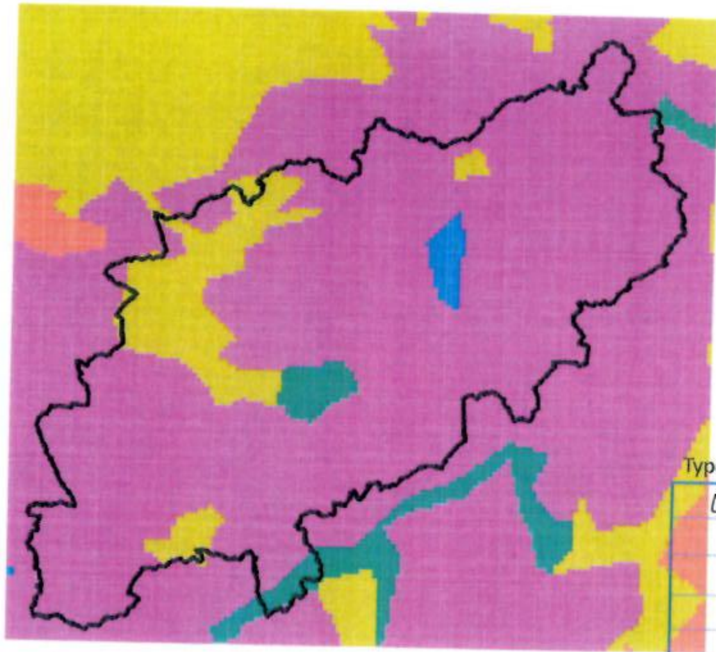
Derby

parent material

- calcereous roc[k]
- glaciofluvial de[p]
- river alluvium
- soft loam

Type	Area%	Class	% Area (GIS)
Urban	85	-	
	40	L	41
	22	M	27
	38	H	32
		VH	

Inform 3



Northants

parent material

- calcereous
- glaciofluvia
- river alluviu
- sandstone
- soft clayey

Type	Area%	Class	% (GIS)
Urban	5		
	68	L	65
	25	M	27
	4	H	5
	3	VH	

Inform 3

Derby

Northants

S Notts

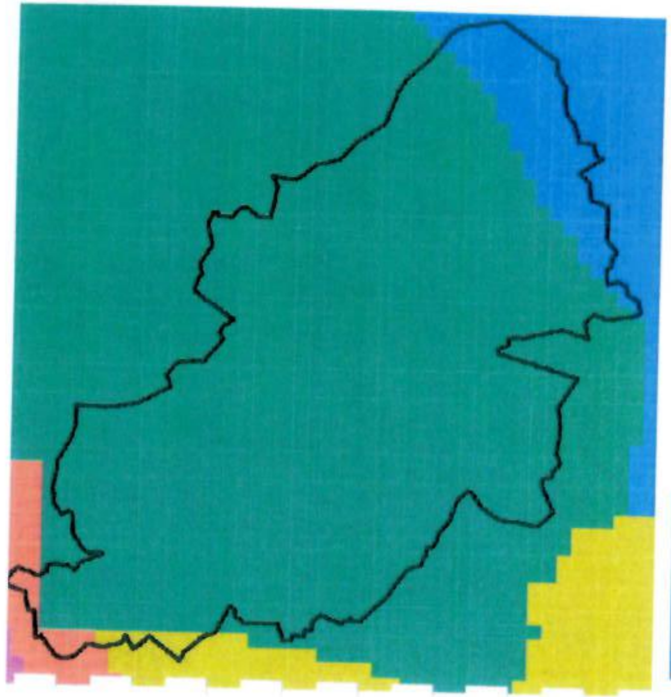
parent material

- calcereous ro
- glaciofluvial d
- river alluvium
- sands
- sandstone
- soft clayey ma

Type	Area%	Class
Urban	?	
	62	L
	5	M
	33	H
		VH

Inform 3

Birmingham



parent material

- calcereous rocks
- glaciofluvial depc
- marine alluvium
- river alluvium
- sands

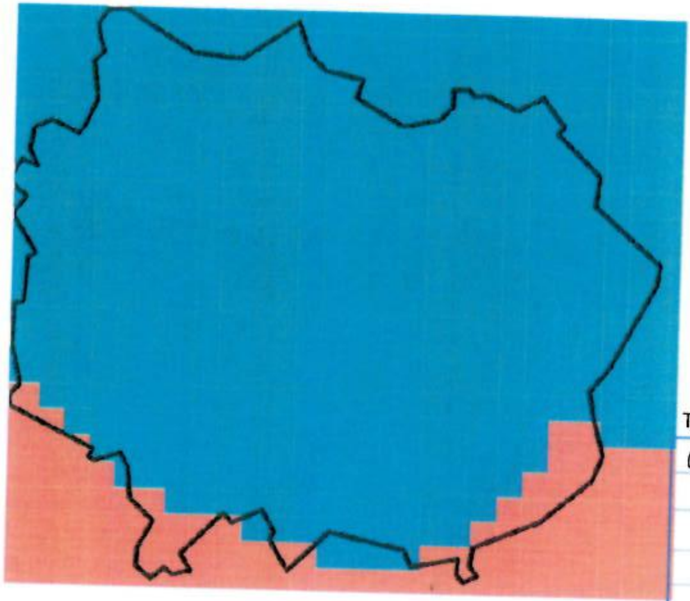
Type	Area%	Class
Urban	95	
	60	L
		M
		H
	40	VH

Inform 3

S Notts

Birmingham

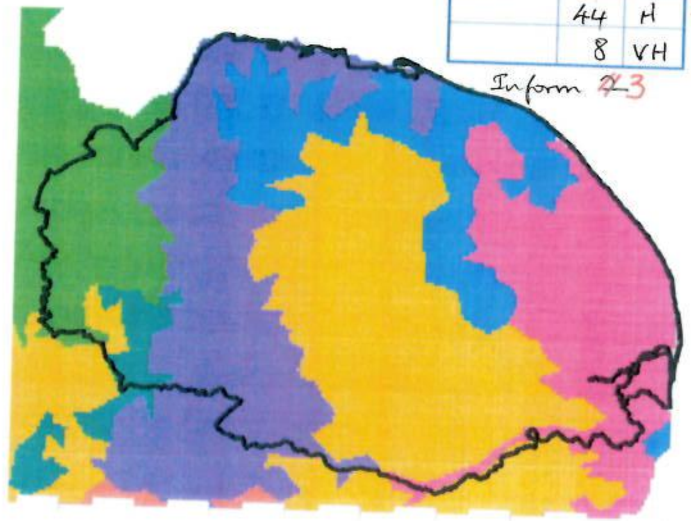
Coventry



Type	Area%	Class
urban	85	
	25	L
	54	M
	21	H
		VH

Inform 3

Norfolk

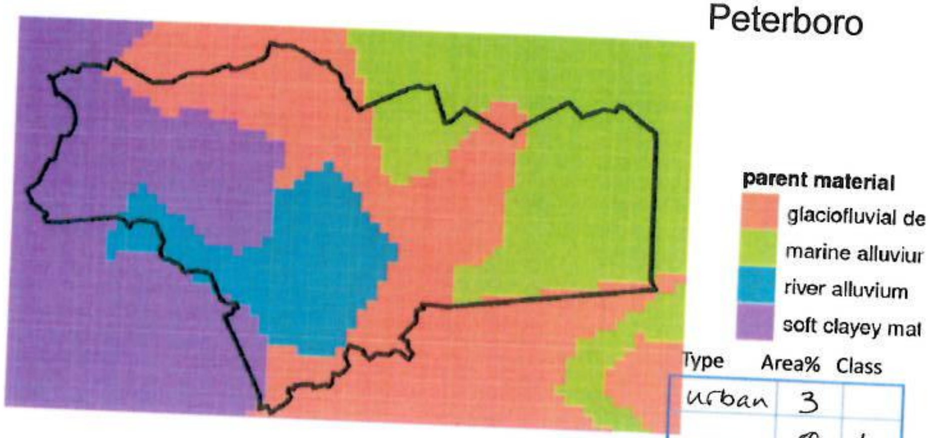


Type	Area%	Class	Area %(GIS)
urban	1		
	18	L	15
	30	M	32
	44	H	47
	8	VH	4

Inform ~~2~~ 3

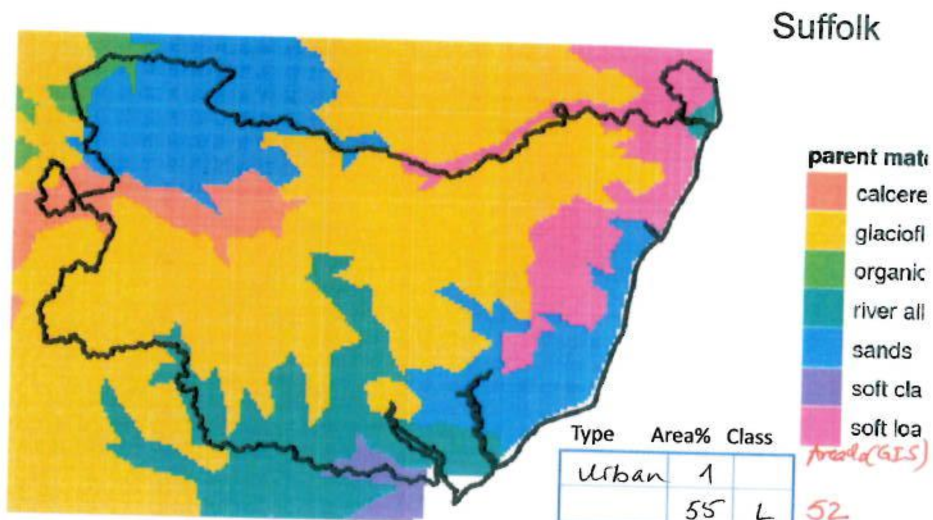
Coventry

Norfolk



Type	Area%	Class
Urban	3	
	Ø	L
	62	M
	38	H
		VH

Inform 3



Type	Area%	Class	Area (GIS)
Urban	1		
	55	L	52
	17	M	15
	3	H	30
	26	VH	3

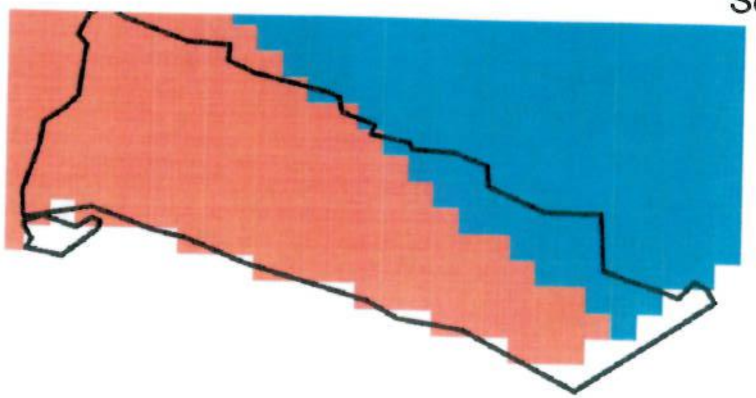
Inform ~~2~~ 3 6

Luton

Type	Area%	Class
Urban	98	
		L
	100	M
		H
		VH

Inform 3

Southend

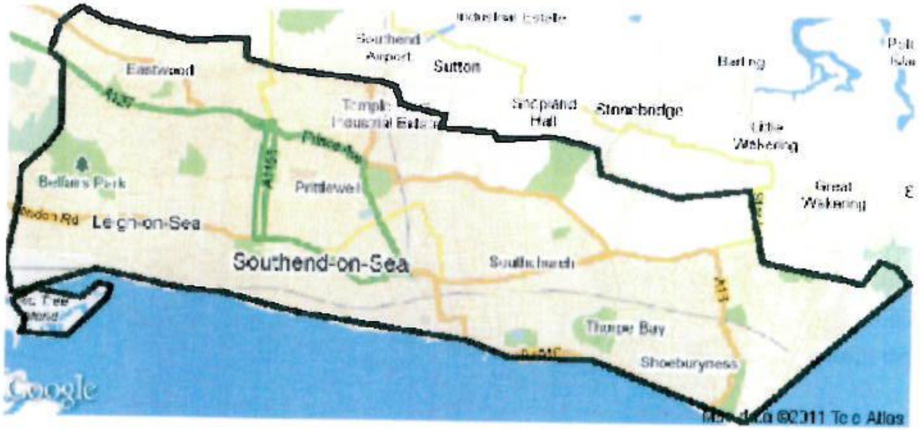


Type	Area%	Class
urban	90	
		L
	100	M
		H
		VH

Inform 3

Luton

Southend



Thurrock

parent ma
- marin
- river a
- sands
- soft cl

Estimates not so good because GIS will include urban soil boundaries whereas manual assessment focussed only on non-urban areas

Type	Area%	Class	Area % GIS
urban	30		
	45	L	30
	25	M	31
	30	H	37
		VH	

Info rm 3

London_E

parent material
- river alluvium
- soft clayey materials

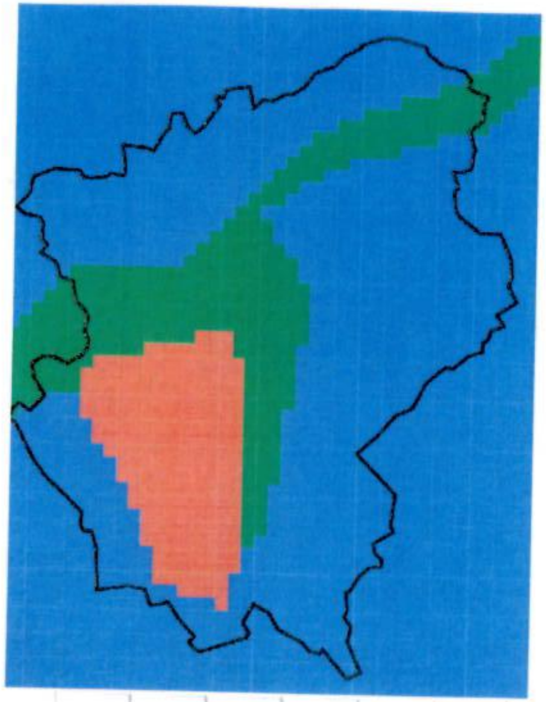
Type	Area%	Class
urban	98	
`	100	L
		M
		H
		VH

Inform 3

Thurrock

London_E

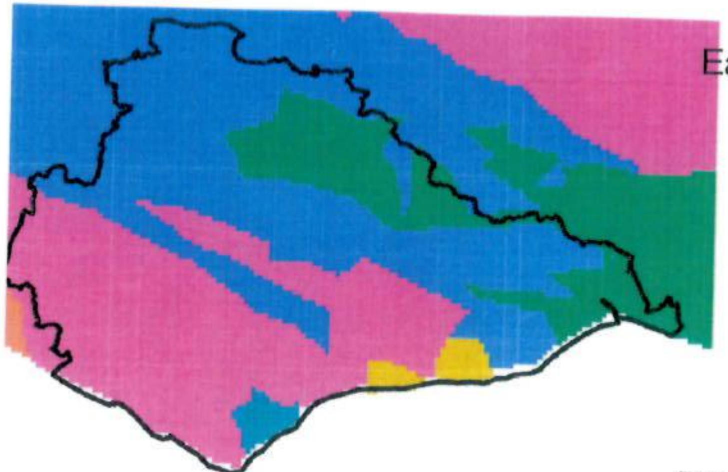
MiltonKeynes



Type	Area%	Class	Area% Cols
urban	25		
	77	L	70
	17	M	21
	6	H	8
		VH	

In form 3

EastSussex

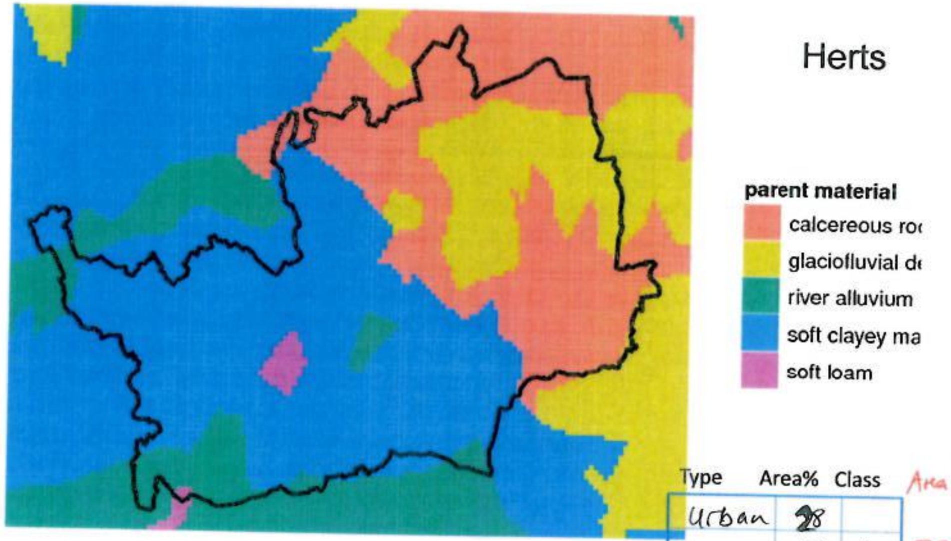


Type	Area%	Class	Area% GI
urban	3		
	25	L	30
	64	M	60
	10	H	9
	1	VH	1

In form 3

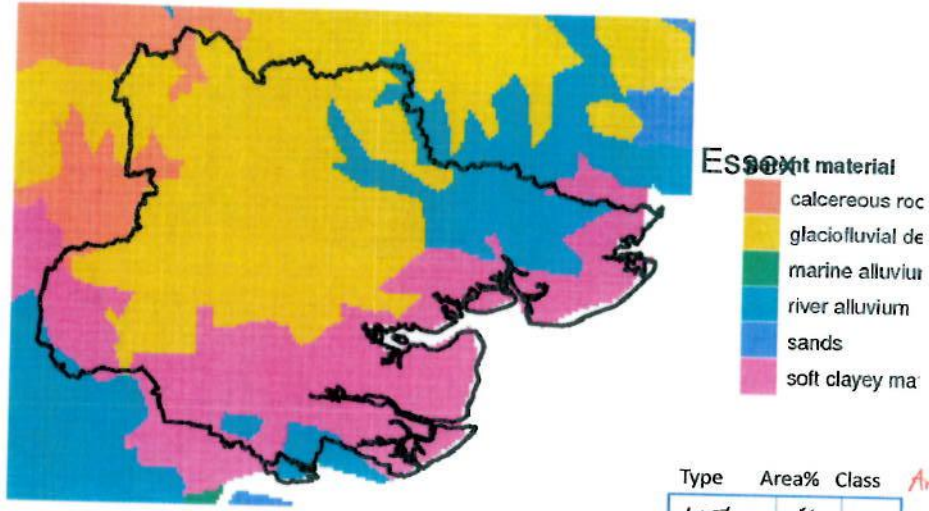
MiltonKeynes

Herts



Type	Area%	Class	Area% (GL)
Urban	28		
	47	L	35
	53	M	62
		H	3
		VH	

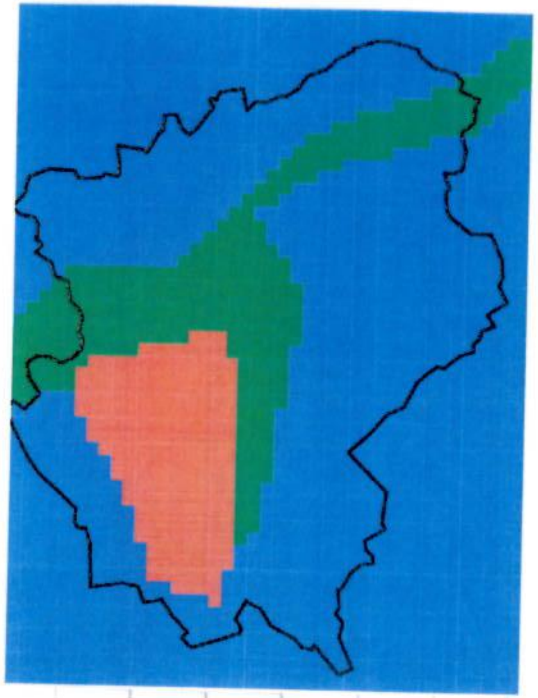
Inform3



Type	Area%	Class	Area% (GL)
Urban	4		
	70	L	56
	22	M	29
	8	H	12

Inform 3

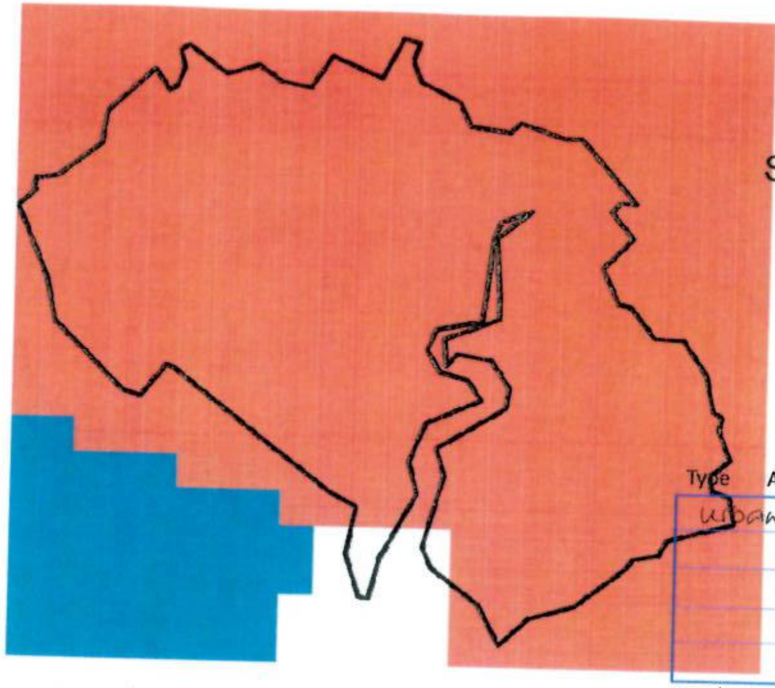
Bucks



Type	Area%	Class	Area%(GIS)
urban	5		
	48	L	47
	50	M	46
	2	H	6
		VH	

In form 3

Soton



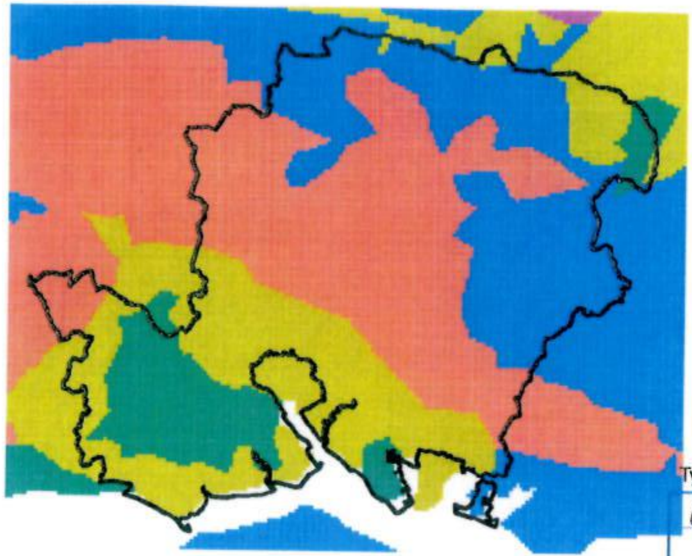
Type	Area%	Class
urban	98	
	80	L
		M
		H
	20	VH

In form 3

Bucks

Soton

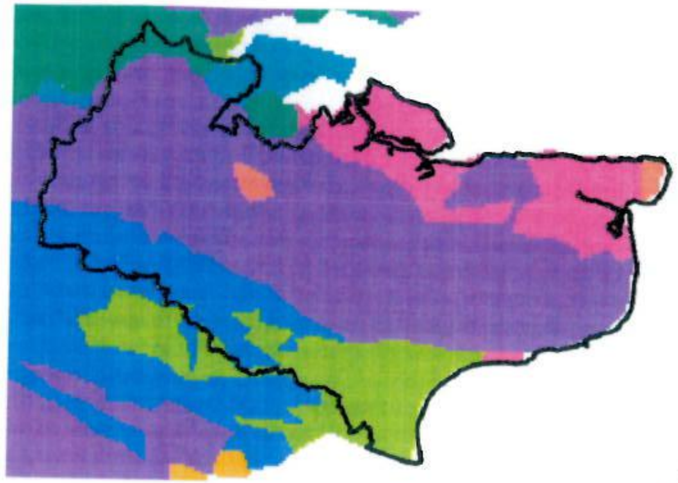
Hants



parent material
- calcereous roc
- river alluvium
- sands
- soft clayey mat
- soft loam

Type	Area%	Class	Area%(GIS)
urban	6		
	33	L	23
	65	M	66
		H	10
	2	VH	2

Inform 3



parent material
- calcereous roc
- glaciofluvial de
- marine alluviu
- river alluvium
- sands
- siltstone
- soft clayey ma
- soft loam

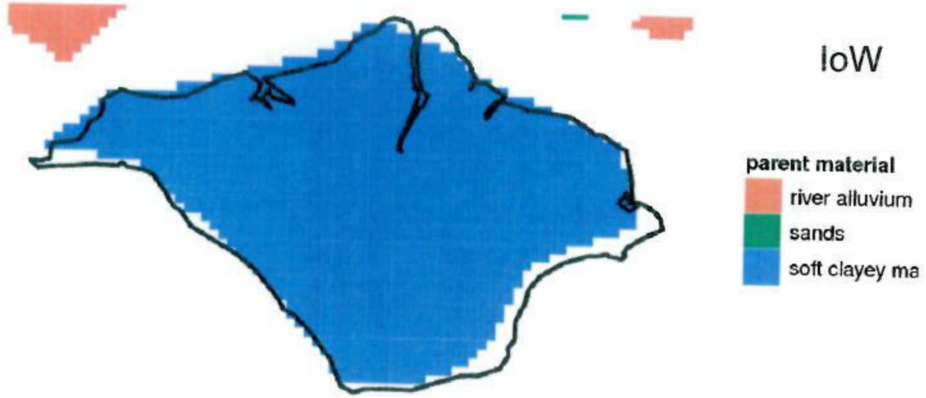
Type	Area%	Class	Area%(GIS)
urban	6		
	25	L	23
	63	M	60
	10	H	15
	2	VH	2

Inform 3

Hants

Kent

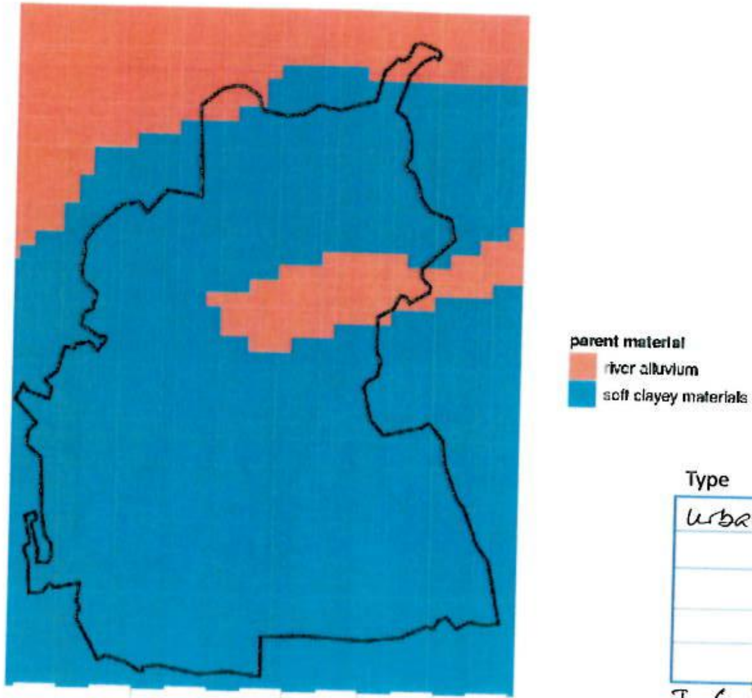
IoW



Type	Area%	Class	Area % (GIS
urban	-		
	25	L	31
	70	M	66
	5	H	2.5
		VH	0.5

Inform 3

Swindon



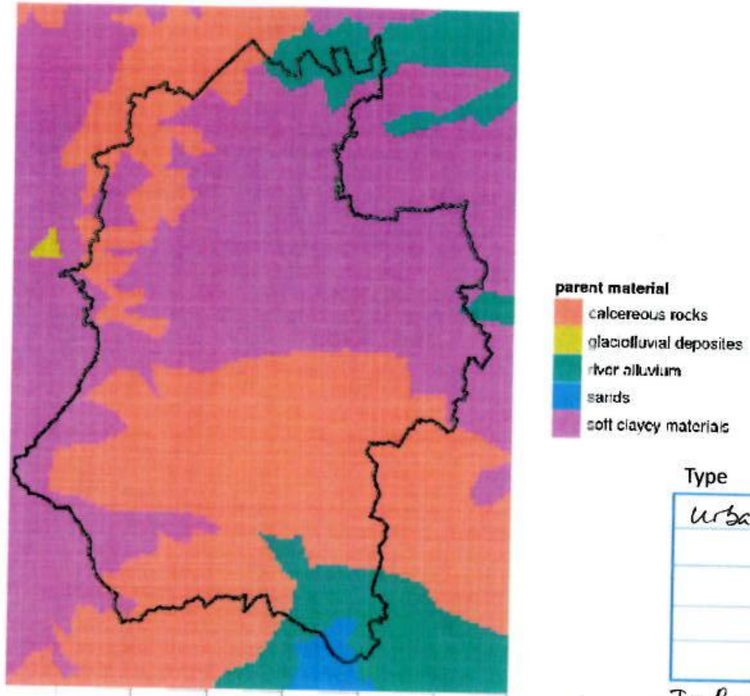
Type	Area%	Class
urban	25	
	43	L
	57	M
		H
		VH

In form 3

IoW

Swindon

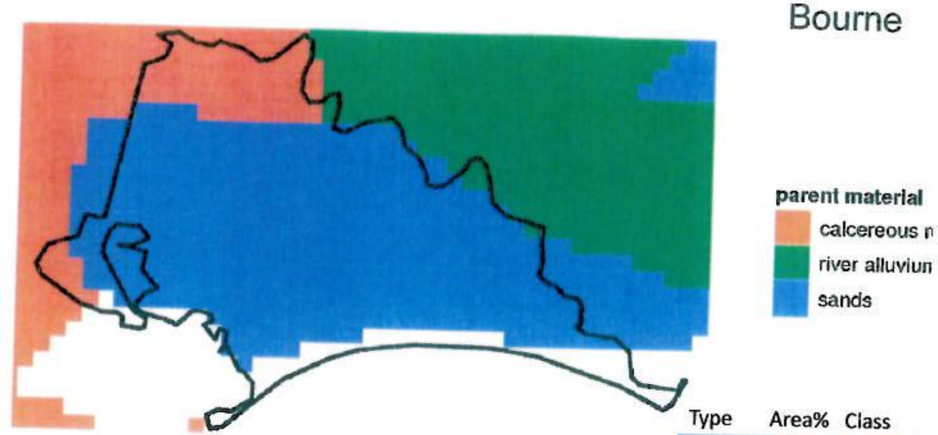
Wilts



Type	Area%	Class	
urban	1		
	25	L	23
	74	M	69
	1	H	4
		VH	3

In form 3

Bourne



Type	Area%	Class
urban	85	
	Ø	L
	28	M
	12	H
	6Ø	VH

In form 3

Wilts

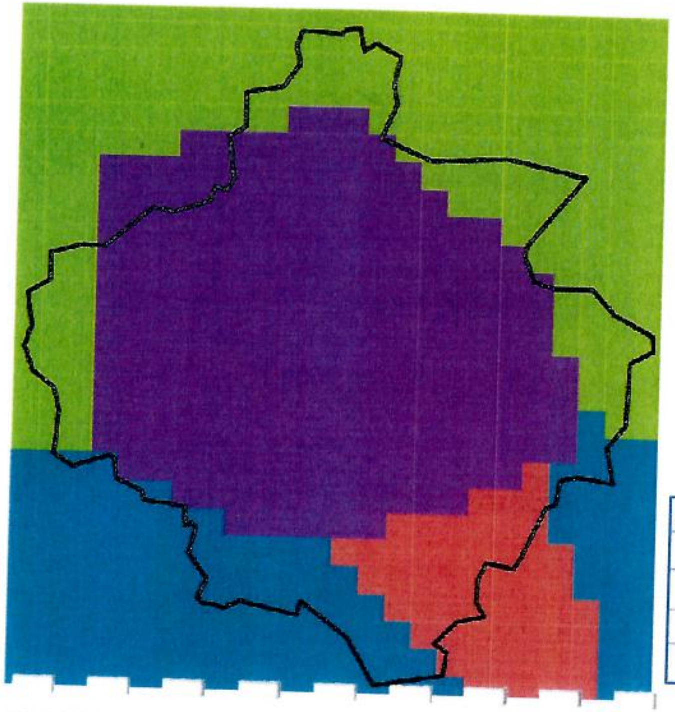
Bourne -mouth

Appendix III

NUTS3 areas (maps)
with estimates of compaction classes

Working document

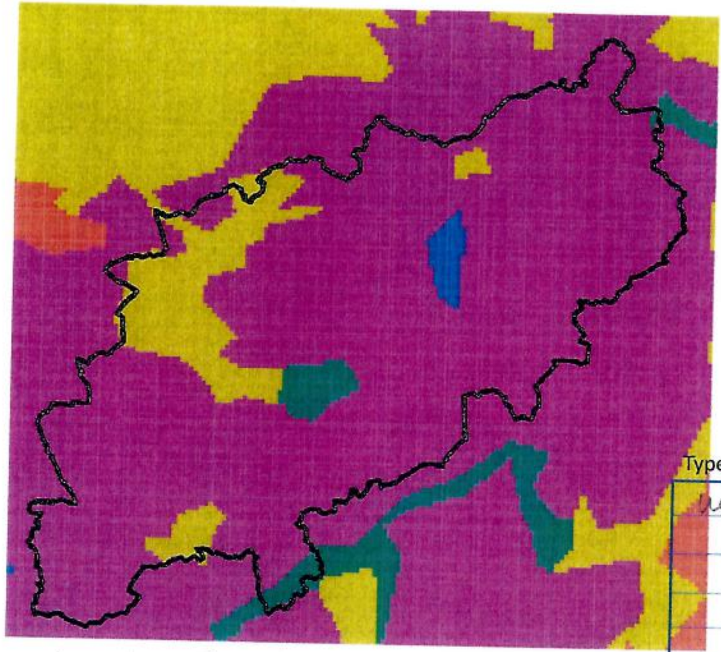
Derby



parent material
- calcereous rock
- glaciofluvial de
- river alluvium
- soft loam

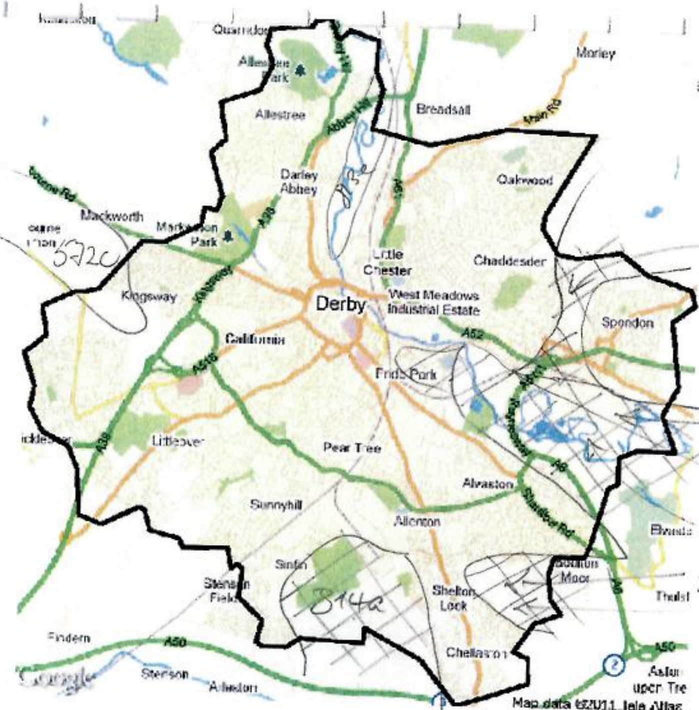
Type	Area%	Class	
urban	85	–	
	40	L	41
	22	M	27
	38	H	32

Northants



parent material
- calcereous
- glaciofluvia
- river alluviu
- sandstone
- soft clayey

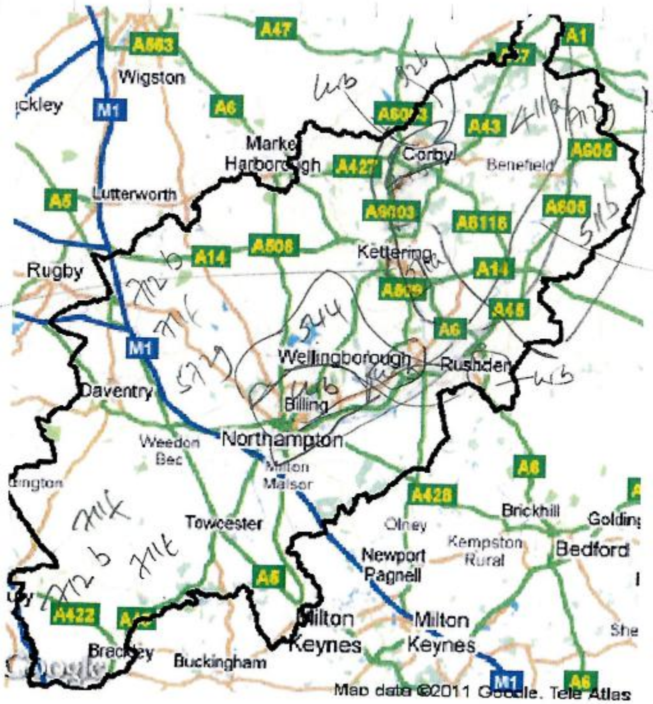
Type	Area%	Class	
urban	5		
	68	L	65
	25	M	27
	4	H	5
	3	not class.	



Derby

	%	
(M) 561a	22	M
(M) 572.e,f,m	15.	L
711m	25	L
814a	25	H
813d	13	H
	100 (38)	

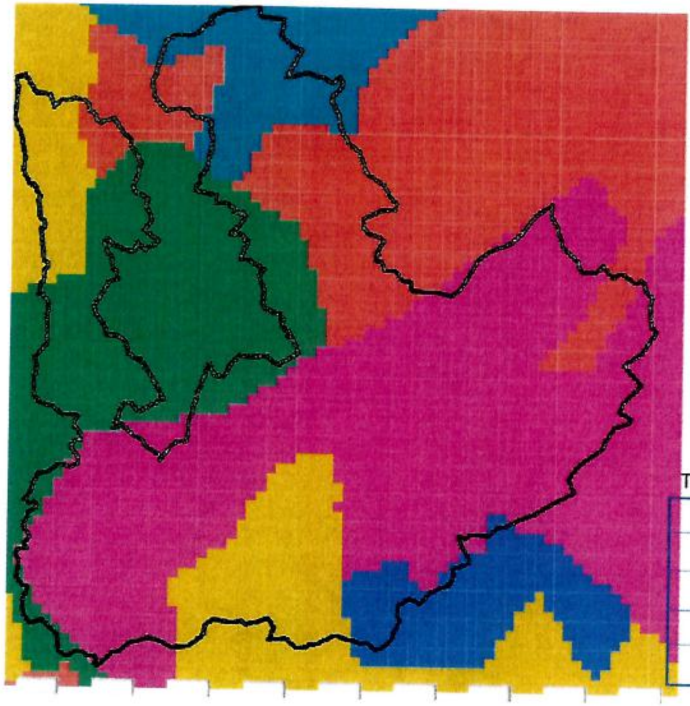
572m M
572f L
572c
572m M
561a M (→H)
572m Salwick M
711m Salop L
814a



Northants

411a 511b 544	25	M
572f 572g	30	L
711f 712b 712g	38	L
813b	4	H
92c 920	3	not classified

S Notts

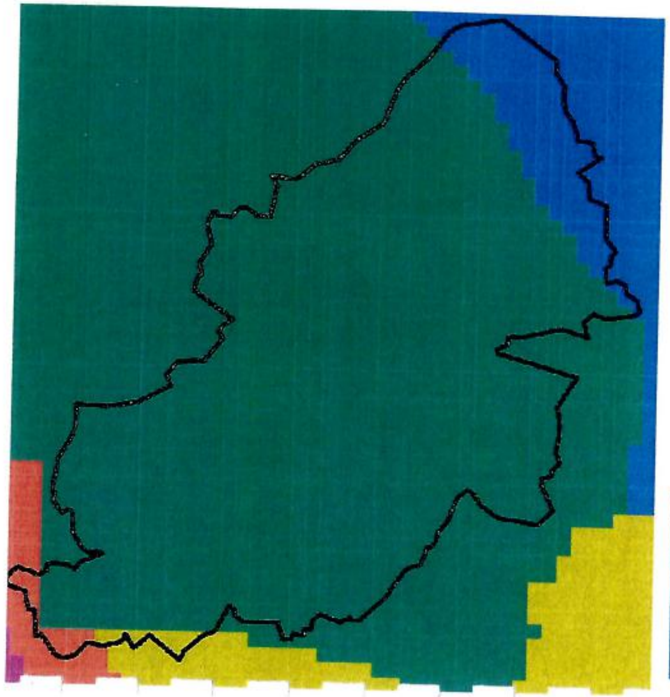


Type	Area%	Class
urban	-?	
	62	L
	5	M
	33	H

S Notts

411b	15 L
431	10 L
511b	5 M
551b	25 H
572f,d,g	15 L
712b,g	22 L
813b,c	8 H
	100

Birmingham



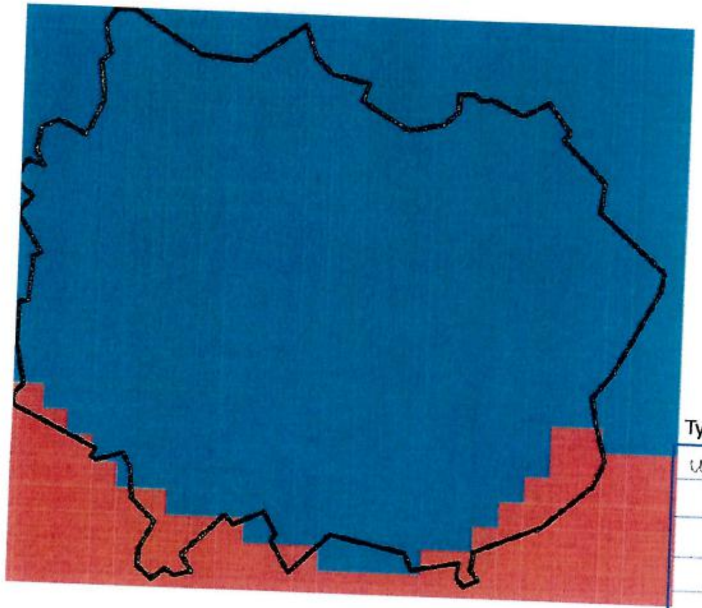
Type	Area%	Class
urban	95	
	60	L
		M
		H
	40	VH

Birmingham

711n,c

551g	2	40% VH
711n,c	3	60% L

Coventry



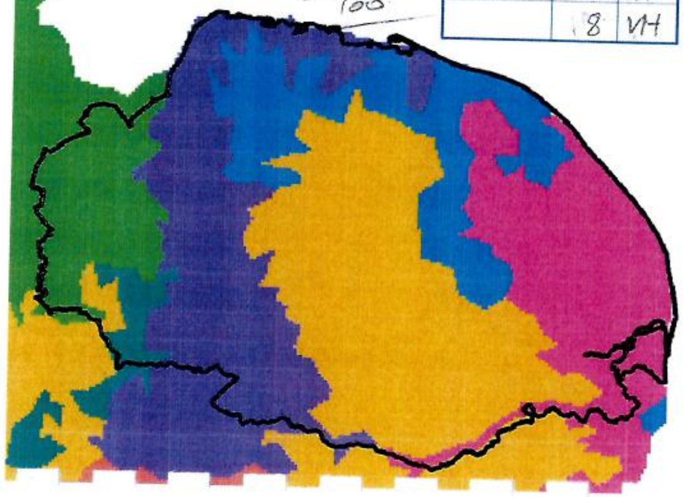
parent material
calcereous ro
glaciofluvial d

Type	Area%	Class
urban	85	
	L	25
	M	54
	H	21

343g,t 15 M 572n 8 M
581f 7 M
52 r 2 VH 711r 18 L
541f,t 18 H 812b M
815a,g H
851a 8 H
551a,f,g H-VH 814e H
552b 20 H 1022a,b
554b 1023b 4 VH
1025
100

Type	Area%	Class
urban	1	
	18	L
	30	M
	44	H
	8	VH

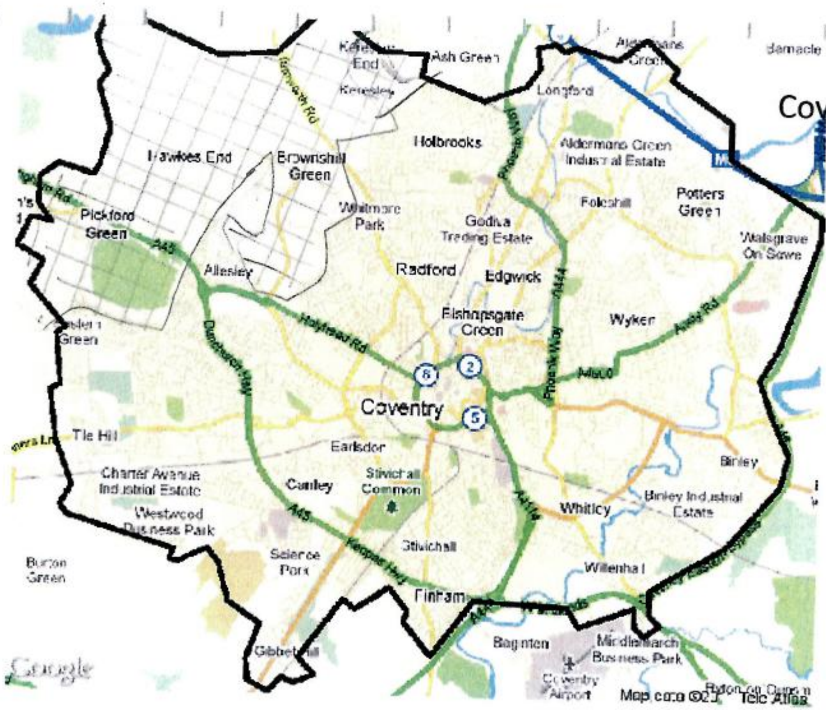
Norfolk
15
32
47
4



parent material
calcereous
glaciofluvial
marine alluv
organic mat
river alluviu
sands
soft loam

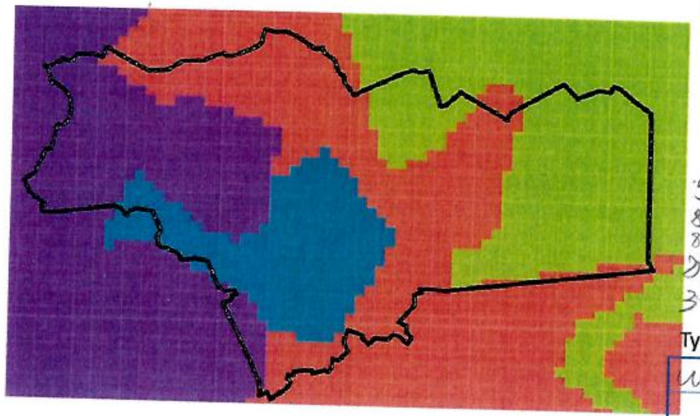
Coventry

541b 20 H
543 1 H
572c 54 M
711m 25 L



Norfolk

Peterboro

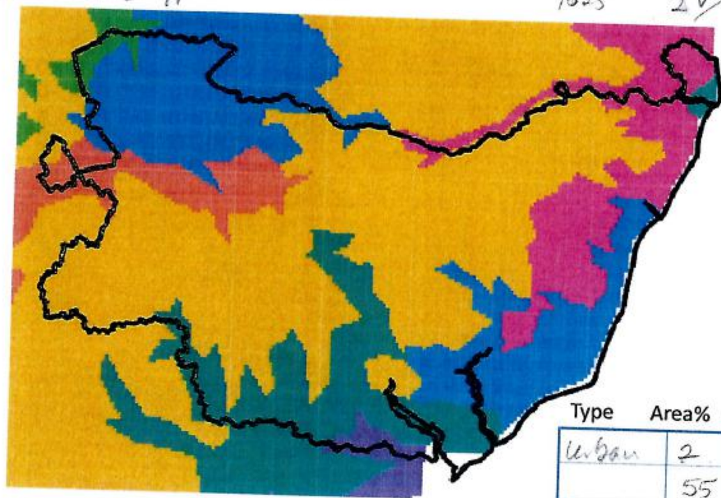


parent material

- 511i — glaciofluvial de — 27 (M)
- 813c 851a — marine alluviur — 38 (H)
- 813b — river alluvium — 38 (H)
- 343 — soft clayey mat (Limestone) — 35 (M)

Type	Area%	Class
urban	3	
	0	L
	62	M
	38	H

Suffolk



parent mat

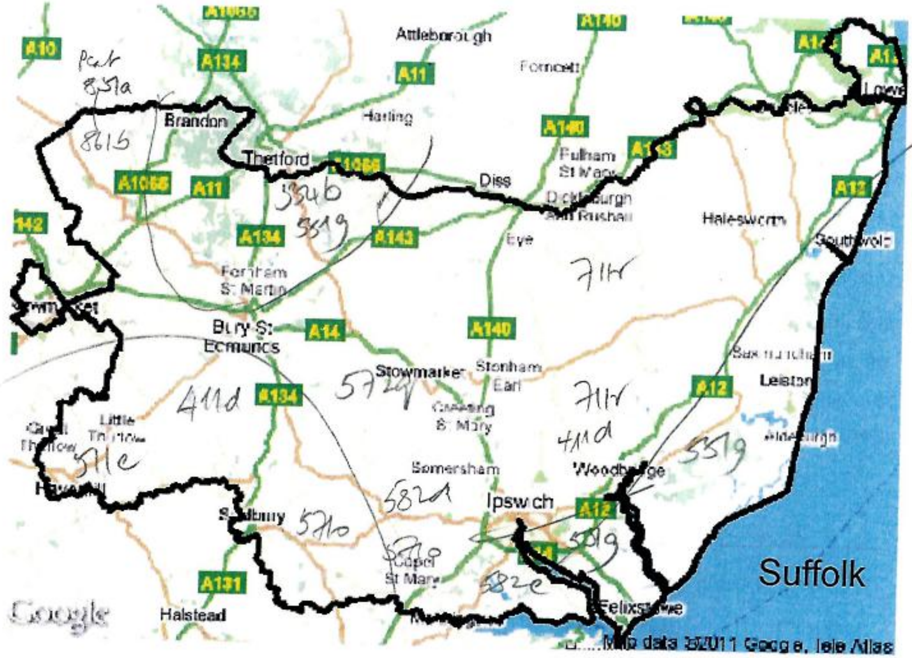
- calcere
- glaciofl
- organic
- river all
- sands
- soft cla
- soft loa

Type	Area%	Class	
urban	2		
	55	L	52
	17	M	15
	26	H	30
	2	VH	3 peat

error.

Peterboro

Map data ©2011 Tele Atlas



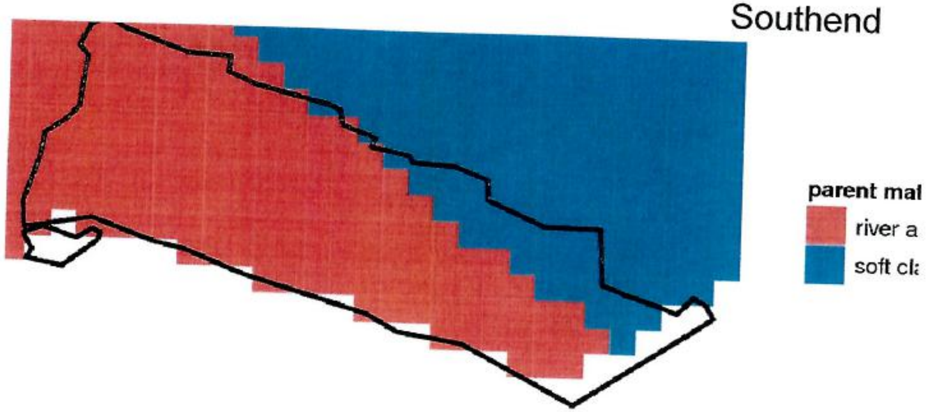
Suffolk

Map data ©2011 Google, Tele Atlas

Luton

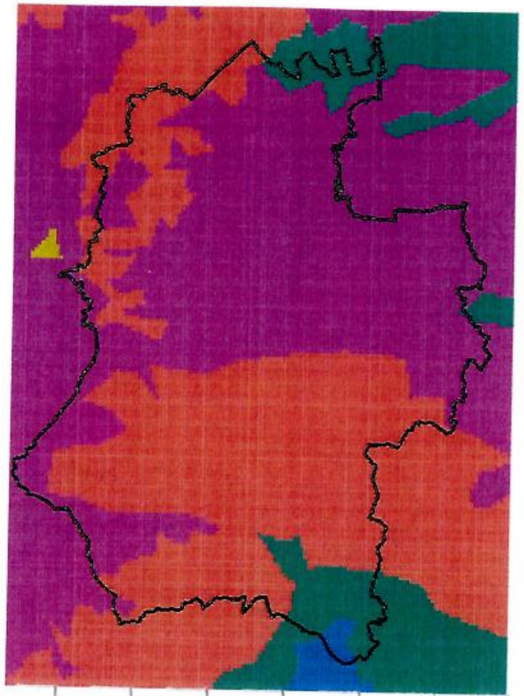
Type	Area%	Class
Urban	98	
		L
	100	M
		H

Southend



Type	Area%	Class
Urban	90	n/a
		L
	100	M
		H

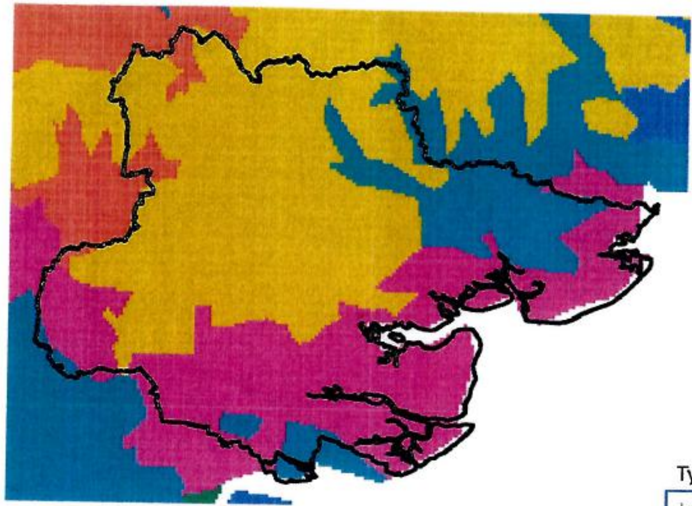
5712 100% (M)



Wilts

parent material
- calcereous rocks
- glaciofluvial deposites
- river alluvium
- sands
- soft clayey materials

Type	Area%	Class	
urban	1		
	25	L	23
	74	M	69
	1	H	4
		VH	3



Essex

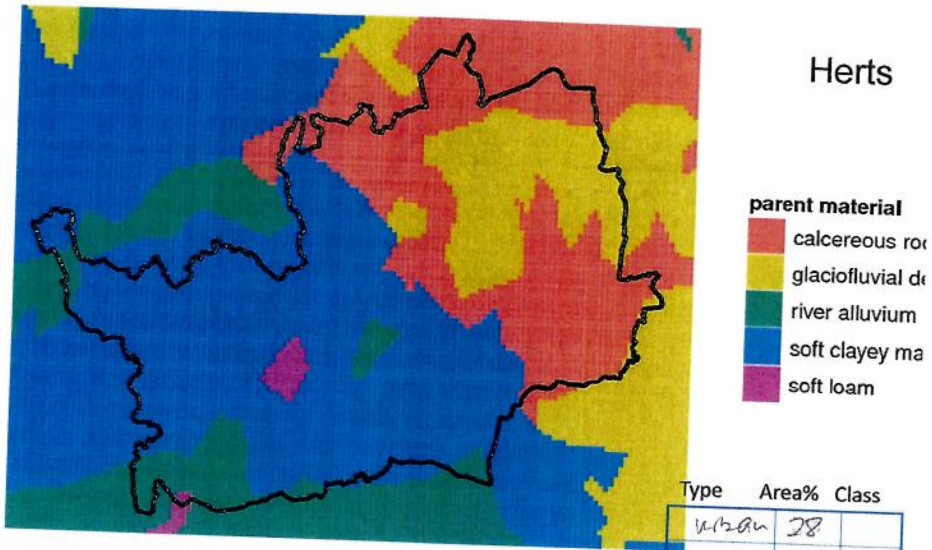
parent material
- calcereous roc
- glaciofluvial de
- marine alluviu
- river alluvium
- sands
- soft clayey ma

571x 573b 3 (M) 582e,d 10 (M) 712c 40 (L)
511j 9 (M) 411d 30 L 813g 812c 841b 8 (H)

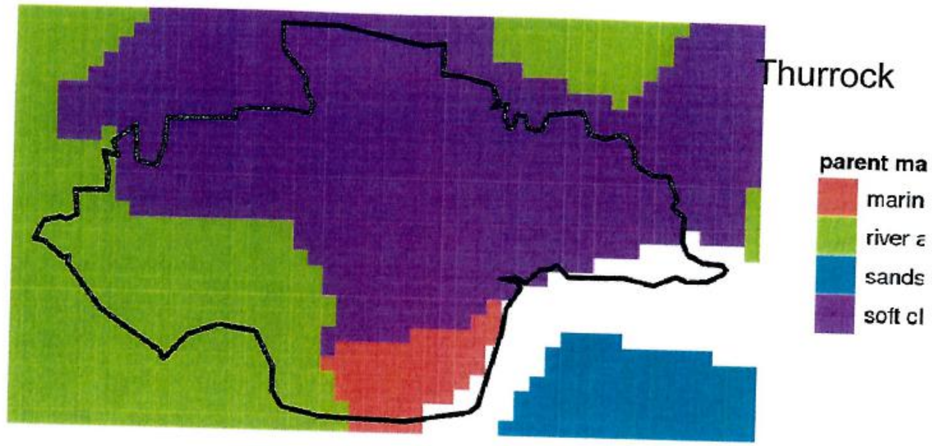
Type	Area%	Class	
urban	4		
	70	L	56
	22	M	29
	8	H	12

Wilts

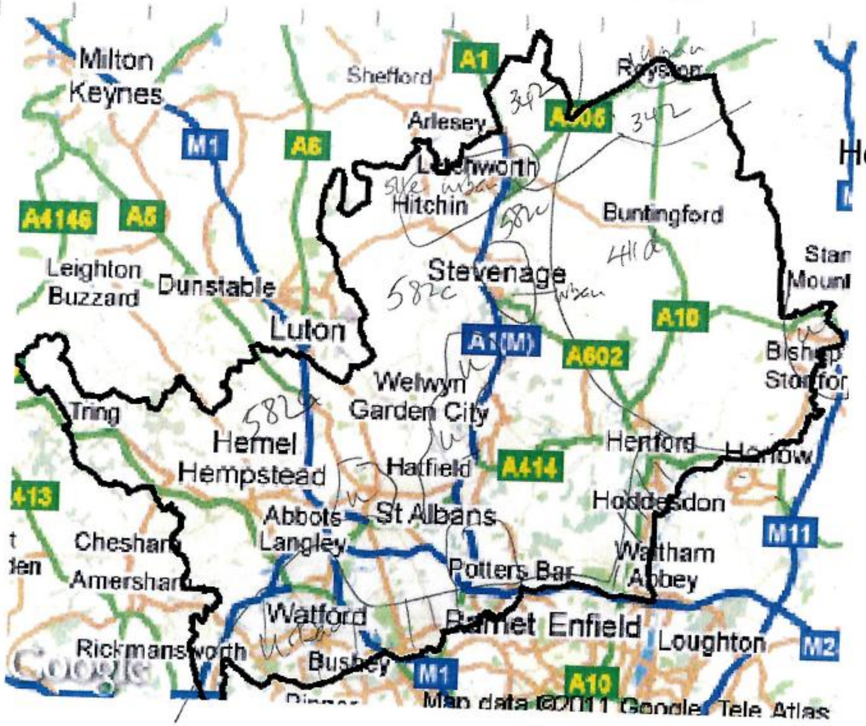
341	18	M
342a		M
343a,d,h,i	30	M
511d	10	M
572a+544a	1	H
581a	11	M
571h, 572i	3	7 M
711g,t	2	M
	10	L
712b	15	L
	100	



Type	Area%	Class	
urban	28		
	47	L	35
	53	M	62
	.	H	3



Type	Area%	Class	Area % GIS
urban	30		
	45	L	30
	25	M	31
	30	H	37
		VH	1

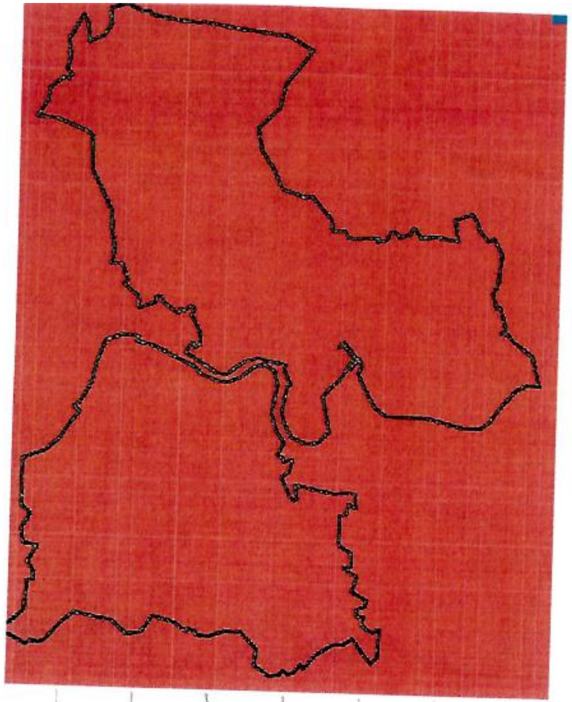


%
342a 10 M
d
411a 37 L
582 38 M
a, c, d
571e 5 M
712c 10 L

571g 25% (M)
571w
712c 45% (L)

813c
813f 25.2 (H)
841b,d 5.8 (H)

London_E

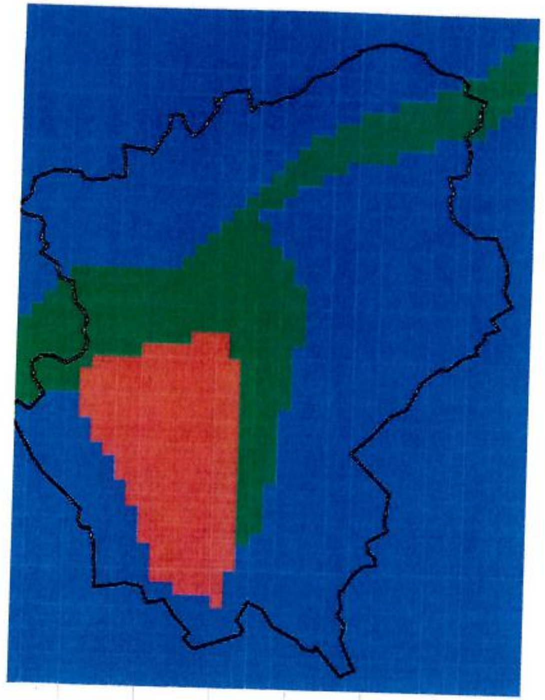


Type	Area%	Class
urban	98	
	100	L
		M
		H

London_E

712c 100% (L)

Bucks



Type	Area%	Class	
urban	5		
	48	L	47
	50	M	46
	2	H	6
		VH	

Bucks

343h 15 M

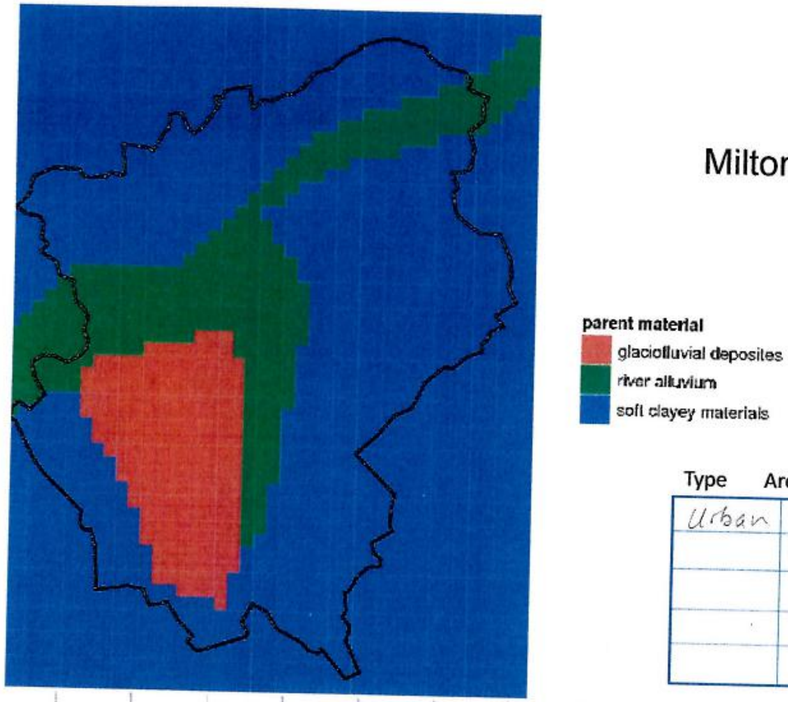
411d 18 L

511b, f, g 5 M
512 [illegible] 3 H
581 b, c, e 8 M

582a, c 15 M

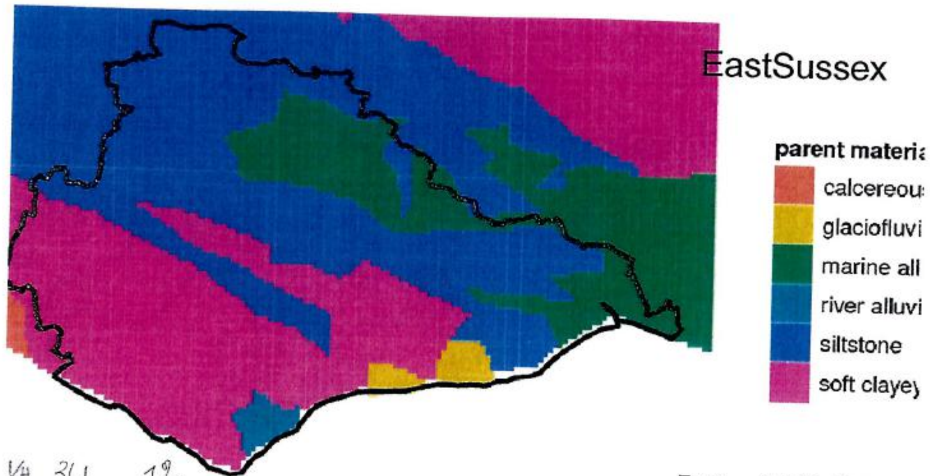
712b 20 L
714d 10 L

100



MiltonKeynes

Type	Area%	Class	
Urban	25		
	77	L	70
	17	M	21
	6	H	8



VA 361 1%
M 343h 19%
L 711e + 712b 25%

572i 40 M
643b 5 (M)
814b 10 (H)

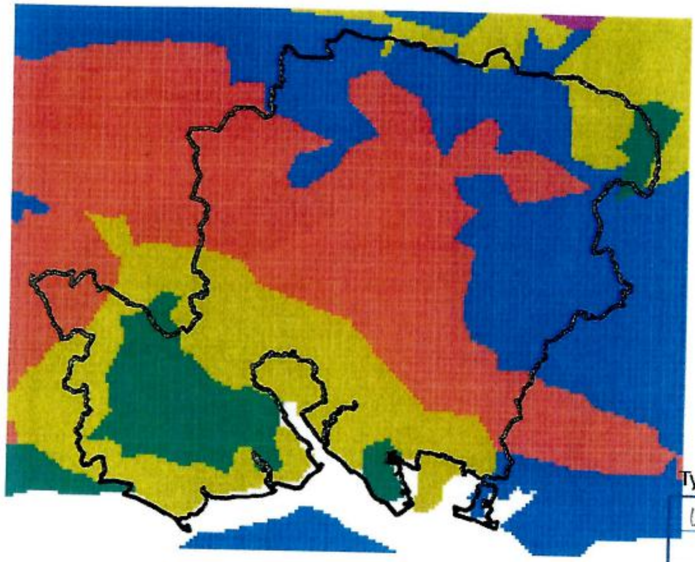
Type	Area%	Class	
urban	3		
	25	L	30
	64	M	60
	10	H	9
	1	VH	1

MiltonKeynes

411d 62 L
511a,b 15 (M)
554a 1 H
572h,t 5 3 M
711f 2 L
712b 6 L
712g 4 L
813a,b 5 H

100

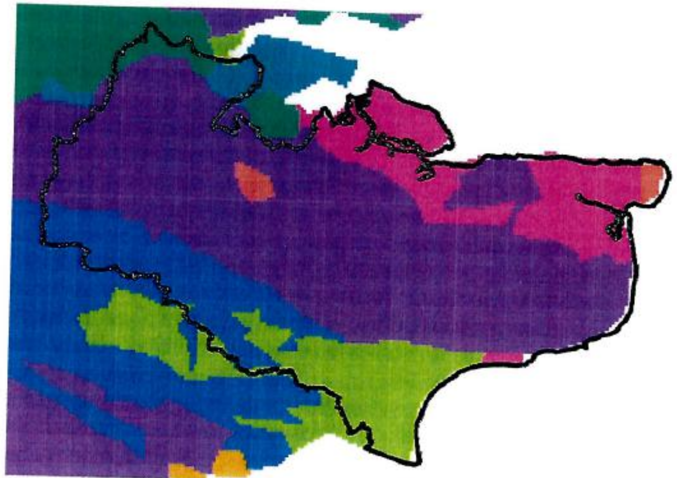
Hants



parent material
- calcereous roc
- river alluvium
- sands
- soft clayey mat
- soft loam

Type	Area%	Class	
Urban	6		
	33	L	23
	65	M	66
		H	10
	2	VH	2

Kent



parent material
- calcereous roc
- glaciofluvial de
- marine alluviu
- river alluvium
- sands
- siltstone
- soft clayey ma
- soft loam

361 2 VH
343h 10 M
571f,g 8 M
571g,h,Y 10 M
572i 15 M
582a,e,i 15 M
581c,g 5 M

711c 20 L
712c 5 L
813(f,g) 10% H
814c
100

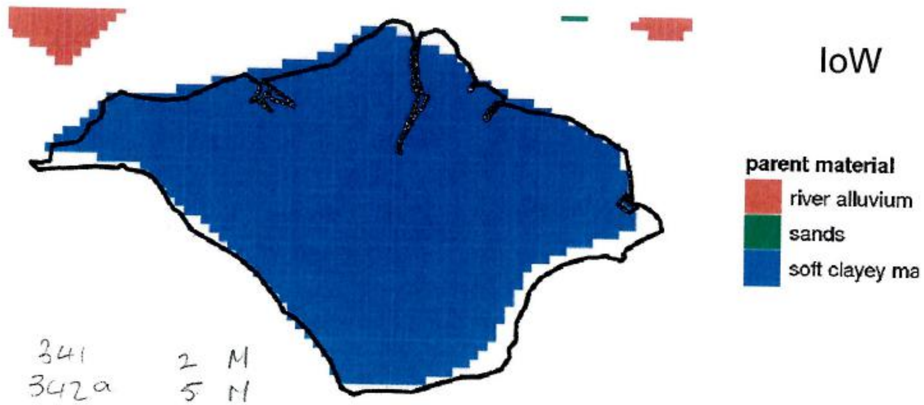
Type	Area%	Class	
Urban	6		
	25	L	23
	63	M	60
	10	H	15
	2	VH	2

Hants

343h 30 M

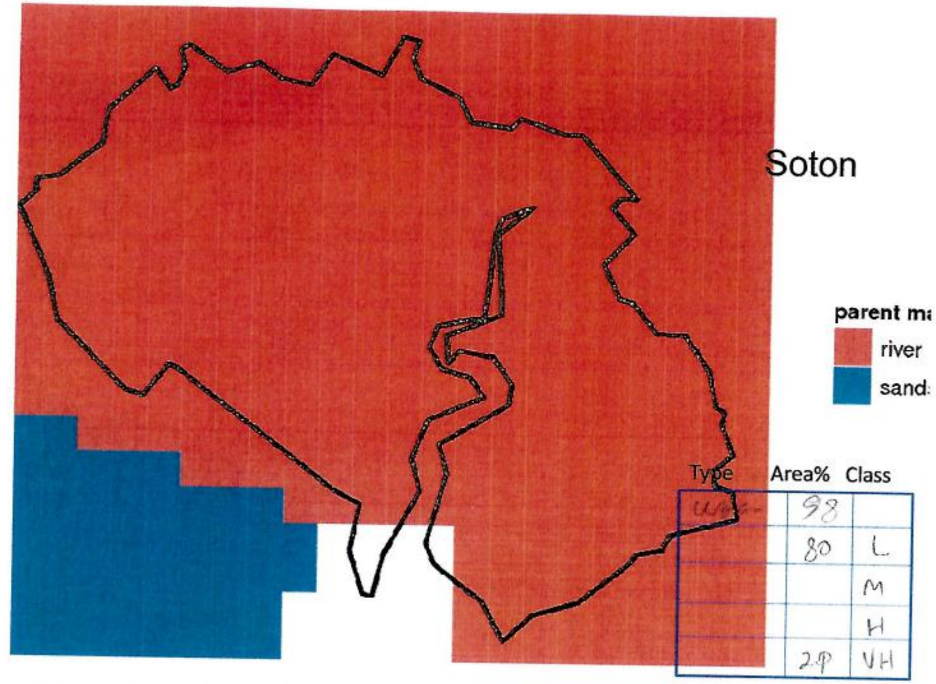
571f 2 M
581d 25 M
643a,c 8 M
711h 12 L
711g 18 L
712c 3 L
1024c 2 VH

Kent

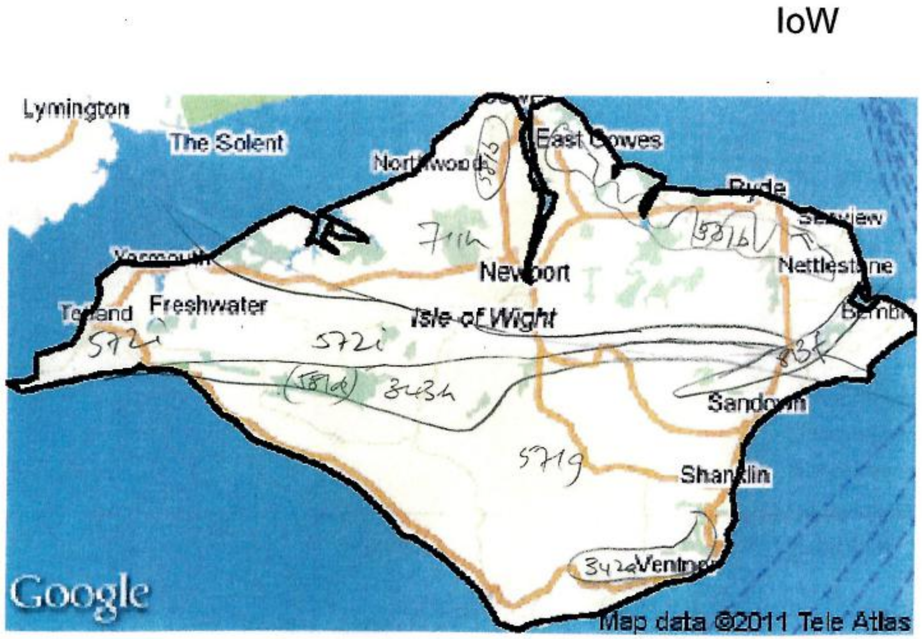


341	2	M
342a	5	M
343h	3	M
511a	3	M
5719s	30	M
572jk	15	M
5816,c,d	12	M
711h	25	L
813f	5	H
	100	

Type	Area%	Class	
Urban	-	-	
	25	L	31
	70	M	66
	5	H	2.5
		VH	0.5

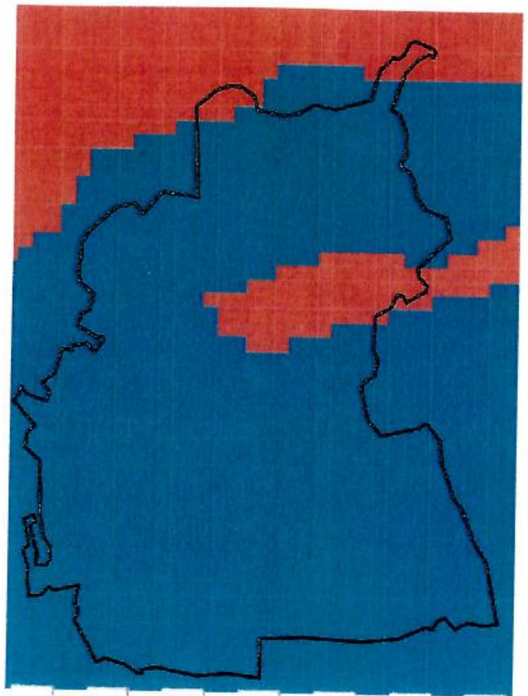


Type	Area%	Class
Urban	98	
	80	L
		M
		H
	20	VH



711g 80% L 1024r. 20% VH

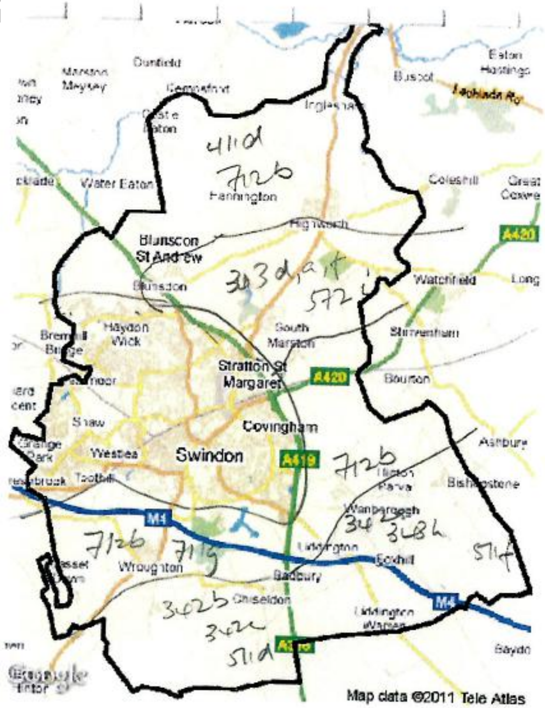
Swindon



parent material
- river alluvium
- soft clayey materials

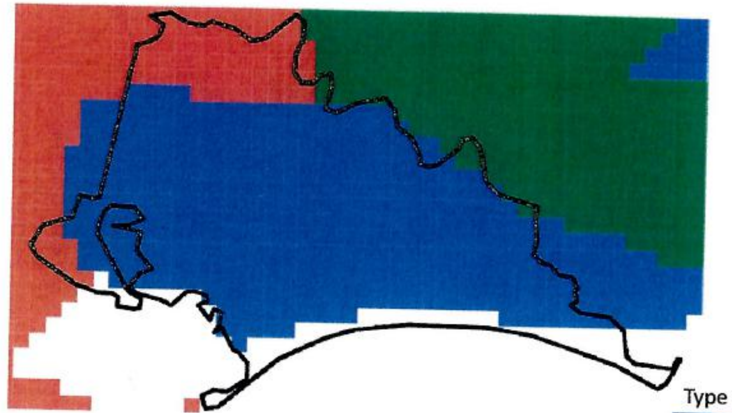
Type	Area%	Class
urban	25	–
	43	L
	57	M
	0	H

Swindon



342g b	21	M
343a, d, f, h	19	M
411d	8	L –
571d, f	7	M
572e	5	M
572i	5	M
711g	5	L –
712b	30	L –

Bourne-mouth

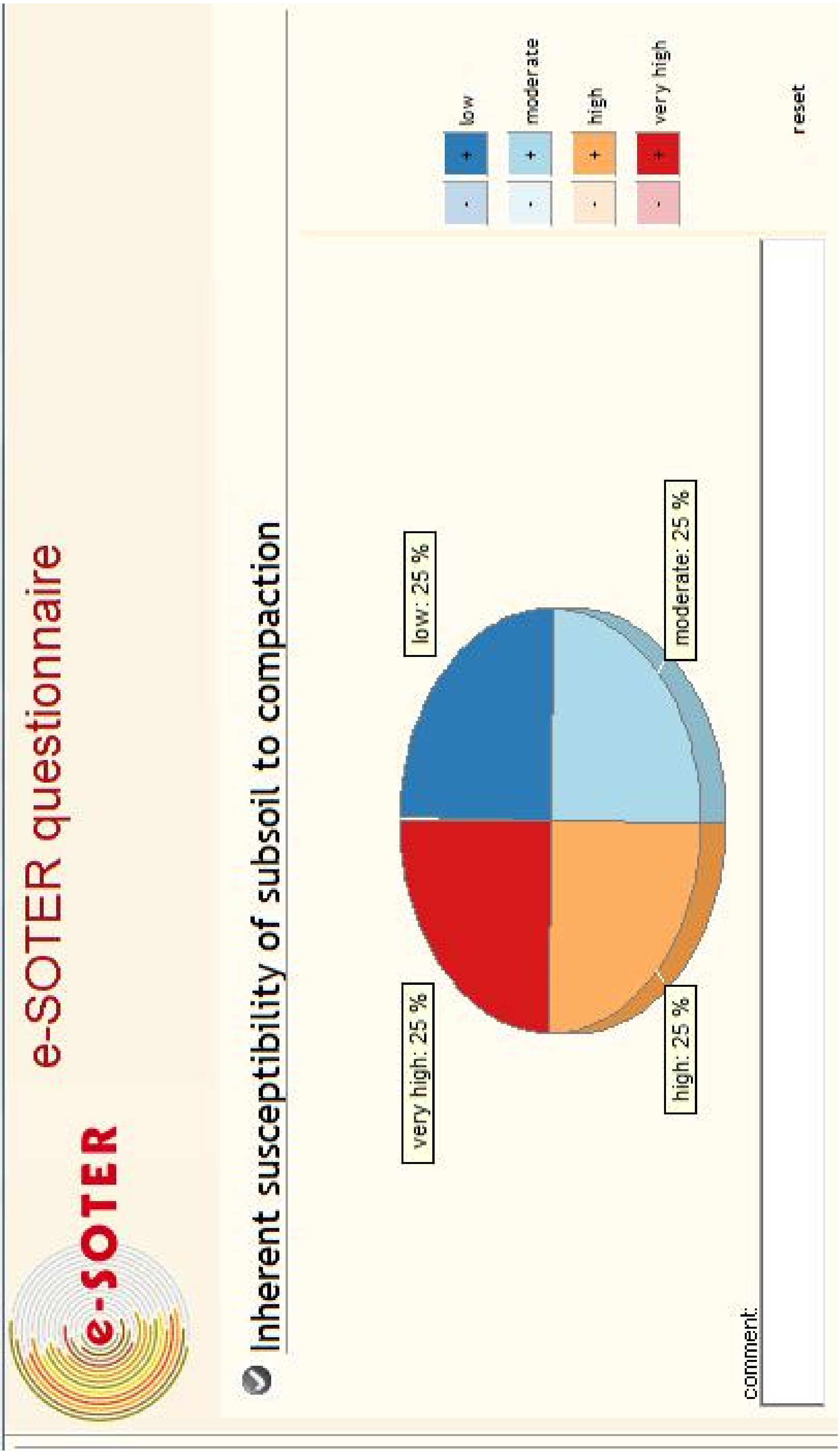


parent material
- calcereous [illegible]
- river alluvium
- sands

571w	8	M	634	15	VH
581b	20	M	641b	45	VH
			813b	12	H

Type	Area%	Class
urban	85	
	0	L
	28	M
	12	H
	60	VH

Bourne -mouth


e-SOTER
e-SOTER questionnaire
Inherent susceptibility of subsoil to compaction
low: 25 %
moderate: 25 %
very high: 25 %
high: 25 %
low
moderate
high
very high
reset
comment: