PAN-EUROPEAN SOIL EROSION RISK ASSESSMENT

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DELIVERABLE 7B: MODEL VALIDATION AT THE CATCHMENT SCALE

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CHAPTER 1 SUMMARY

The increasing availability of regional scale data layers on climate, topography and land use has recently led to the application of quantitative soil erosion model applications at European scale. At present soil erosion estimates at Pan-European level are available from three erosion models: Universal Soil Loss Equation – USLE, Institut National Recherche Agronomique – INRA, and the Pan-European Soil Erosion Risk Assessment – PESERA.

It is important to assess the accuracy of such soil erosion estimates from models that could be used in the context of soil protection. This is, however, rather problematic at European scale, because it is very difficult, if not impossible to acquire direct soil erosion measures for large areas.

Therefore indirect soil erosion data derived from sedimentation volumes in reservoirs in Belgium, the Czech Republic, Italy and Spain were used to assess the accuracy of the USLE, INRA and PESERA soil erosion estimates.

Firstly, the area contributing to each reservoir was delineated using automatic watershed delineation algorithms. Next, WaTEM/SEDEM was applied in order to assess for each reservoir a Sediment Delivery Ratio (SDR). Erosion estimates were then multiplied with the SDR-values. Finally observed and predicted sediment yield values were compared.

The results show that none of the three models produces accurate soil erosion estimates based on 1km x 1 km data for all European environments. The models are relatively successful in predicting the relative pattern of soil loss from agricultural areas in central Belgium and the Czech Republic. None of the model results however accurately predict the measured soil erosion patterns in Italy and Spain. The main reasons for this are:

1) uncertainty involved in the indirect validation method (i.e. sedimentation data in reservoirs)
2) low resolution of the input data used for model applications at European scale
3) simplified internal model structures that do not take into account all sediment producing and transporting processes.

However, past research has shown that some models perform much better for areas when high quality input data are used (Van Rompaey et al., 2003). For example, runoff is better predicted from a 250m digital elevation model (DEM) than from a 1km DEM. In many cases, these high resolution input data exist in national mapping, meteorological and soil survey institutions but at present are not readily available for the whole of Europe.

An important future role for the JRC in future could be to harmonise, aggregate and facilitate access to these data at European level. It is clear than some attempt must be made to estimate soil erosion losses in Europe for the forthcoming EU Soil Protection Strategy and this could be done best by using a standard model applied to standard data sets. Therefore, the Services of the Commission should put much more effort into
encouraging national and regional administrations to provide the necessary input data for soil erosion models at much higher resolutions than are currently available.

CHAPTER 2 INTRODUCTION

Until the beginning of the 1990’s the scientific community studying soil erosion was mainly focused on the development of physically-based soil erosion models, aiming at a better understanding of erosion processes at the level of plots or individual parcels. However, policy makers need tools to assess soil erosion risk at a regional scale to set up an adequate soil conservation strategy. Furthermore soil erosion is affecting many aspects of the sediment-, nutrient- and hydrological- cycle at a continental scale: the modelling and prediction of its impact on such scales requires an adequate modelling approach.

European scale soil erosion risk assessments in the 1980’s and early 1990’s used expert-bases approaches (e.g. De Ploey et al., 1989, Oldeman, 1990) or factorial scoring methods (e.g. CORINE, 1992). These kinds of methods allowed relative delineation of areas with a high soil erosion risk, but offered very limited possibilities to evaluate the effect of different land management scenarios (see also Gobin et al., 2003). The increasing availability of regional scale data layers on climate, topography and land use has recently led to the application of quantitative soil erosion model application at European scale.

The soil erosion estimates available from model applications at European scale are listed in Table 1.

Table 1 Overview of soil erosion estimates at European scale

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Ploey</td>
<td>Expert based</td>
<td>De Ploey et al., 1989</td>
</tr>
<tr>
<td>CORINE</td>
<td>Factorial scores</td>
<td>CORINE, 1992</td>
</tr>
<tr>
<td>IMAGE</td>
<td>Factorial scores</td>
<td>RIVM, 1992</td>
</tr>
<tr>
<td>GLASOD</td>
<td>Expert based</td>
<td>Van Lynden, 1994</td>
</tr>
<tr>
<td>Hot Spots</td>
<td>Expert based</td>
<td>EEA, 2000</td>
</tr>
<tr>
<td>USLE</td>
<td>Quantitative</td>
<td>Van der Knijff et al., 2000</td>
</tr>
<tr>
<td>INRA</td>
<td>Factorial scores</td>
<td>INRA, 2001</td>
</tr>
<tr>
<td>PESERA</td>
<td>Quantitative</td>
<td>Gobin and Govers, 2003</td>
</tr>
</tbody>
</table>

Although all erosion maps were produced with the most accurate data that were available at European scale, many authors warn about the uncertainties involved in this kind of model application. Therefore such estimates must be used with caution. In fact, it is almost impossible to come to well-founded policy-decisions based on regional scale soil erosion maps if there is no reliable assessment of the error on the predicted soil erosion rates.

The validation of erosion estimates at continental scale is, however, rather problematic. It is technically and financially not feasible to measure soil erosion for large spatial entities. Moreover soil erosion processes are characterized by a significant spatial
and temporal variability. In reality the accuracy of regional and continental scale soil erosion estimates is hardly ever assessed.

In this paper, an alternative validation method based on measured sedimentation volumes in lakes and reservoirs is proposed. Reservoir sedimentation data from Belgium, Czech Republic, Italy and Spain are used to assess the accuracy of the USLE-, INRA- and PESERA-estimates.

CHAPTER 3 SOIL EROSION ESTIMATES FROM USLE, INRA & PESERA MODELS

3.1. USLE estimates

Van der Knijff et al. (2000) made an attempt to estimate erosion in Europe with an Universal Soil Loss equation (USLE) based methodology. The USLE is an empirical soil erosion model that was originally developed for computing estimates at plot-scale. Mean annual soil erosion rates (in t.ha\(^{-1}\).yr\(^{-1}\)) are assessed by multiplying 4 different factors: a rainfall erosivity factor (R), a soil erodibility factor (K), a topographic factor (LS) and crop cover and management factor (C). Van der Knijff et al. assessed these factors for Europe at a 1 km resolution using MARS rainfall data (King et al., 1995), CORINE Land Cover data (Eurostat GISCO) and the European Soil Database at 1:1,000,000 scale (version 1.0) (King et al., 1995; Heineke et al., 1998), see Figure 1.

![Figure 1: USLE model application for Europe (after Van der Knijff et al., 2000)](image)

For each 1km x 1km pixel, a mean annual soil erosion rate in t.ha\(^{-1}\).yr\(^{-1}\) was assessed (Figure 2). For details on the exact procedures used we refer to the original publication.
Van der Knijff et al. (1999, 2002) and Grimm et al. (2003) applied a similar model structure for soil erosion risk assessment in Italy but used more accurate input data: a 250m DEM and rainfall data from 366 meteorological stations compared with 46 stations in Italy for the European assessment (King et al., 1995).

### 3.2. INRA estimates

Subsequent to the application of the USLE, the Institut National Recherche Agronomique (INRA) developed an empirical decision tree-based approach to delineate qualitative soil erosion risk classes (Figure 3). Soil erosion risk is assessed taking into account information on land use (CORINE 9 classes), crust formation (4 classes), slope (8 classes) and soil erodibility (3 classes). For details on the exact procedures used we refer to Le Bissonnais et al. (2002)
In our research presented here, the risk classes of the original INRA-map where translated into quantitative rates as follows (Daroussin, Pers. Comm): very low risk = 0.5 t.ha$^{-1}$.yr$^{-1}$, low risk = 1.5 t.ha$^{-1}$.yr$^{-1}$, medium risk = 6.5 t.ha$^{-1}$.yr$^{-1}$, high risk = 20 t.ha$^{-1}$.yr$^{-1}$, very high risk = 40 t.ha$^{-1}$.yr$^{-1}$). This is an approximate translation for comparison purposes but it has not been calibrated (Figure 4).

3.3. PESERA estimates

The Pan-European Soil Erosion Risk Assessment – PESERA is a process-based erosion model developed specifically for application at the European scale under an EU research contract (QLKS-CT-1999-01323). Because it is runoff-based, the model concepts differ fundamentally from empirical models such as the USLE and its derivations (Figure 5). PESERA predicts runoff with a daily time step. Depending on daily rainfall volumes, the soil storage capacity and vegetation interception, runoff occurs. Daily rainfall and temperature data are used to input to a vegetation growth model and to increase or decrease the available soil storage capacity. Runoff is linked with soil loss using equations developed by Kirkby et al. (2000). For more information on the exact procedures used we refer to Gobin and Govers (2003).
PESEERA is constructed such that it can also function as a tool for evaluating land use and climate change scenarios both on a daily basis and over longer timescales. Long term soil erosion rates (in t.ha\(^{-1}\).yr\(^{-1}\)) were assessed using daily rainfall and temperature records from the MARS database (King et al., 1995), see Figure 6. The daily records have been compiled on a 50km x 50km grid using a sophisticated interpolation procedure (Van der Goot, 1998) applied to data for the period 1975-1995. For running the PESERA model, the 50km x 50km daily averages were then interpolated to a 1km x 1km grid, using an inverse spline function and the ARC/INFO GIS software system.

Figure 5: PESERA modelling concept (Gobin and Govers, 2003)
Figure 6: PESERA soil erosion estimates
CHAPTER 4 VALIDATION METHODOLOGY

Given the spatial and temporal variability of soil erosion processes, the direct field-measurement of soil erosion is not feasible for large spatial entities. Two alternative but indirect validation methods are:

- Monitoring of sediment load in rivers;
- Measurement of sediment deposition in lakes and reservoirs.

The second option is in general more suited for the validation of long-term soil loss predictions, though data are only available for areas where reservoirs exist. The sediment that is trapped in a reservoir reflects, after correction with a trapping efficiency coefficient, the net soil loss in the contributing drainage basin since the construction or last clearing of the reservoir. It should however be kept in mind that the mean net soil loss (i.e. the sediment yield at the outlet) in a drainage basins differs from the mean total soil erosion (i.e. the total sediment produced in the drainage basin). Depending on the spatial configuration of topography and land use, a significant part of the eroded soil will deposit again before reaching a river channel or the outlet of the drainage basin. The sediment delivery ratio (SDR) is the ratio of sediment yield at the outlet over the total volume of produced sediment in the drainage basin.

\[
SDR = \frac{\text{net soil loss}}{\text{total soil erosion}} \quad \text{or} \quad \text{net soil loss} = \text{total soil erosion} \times SDR
\]

SDR-values can be assessed with empirical regression equations (in general using lumped drainage basin parameters) or with spatially explicit sediment routing models that link sediment sources with river channels (e.g., CAESAR, Coulthard et al., 2000; WaTEM/SEDEM, Van Rompaey et al., 2001).

Sediment yield datasets for Belgium, Italy, Spain and the Czech Republic were made available by collaborating research groups (Table 2).

Table 2 Catchments with measured sediment yield at the outlet

<table>
<thead>
<tr>
<th>Country</th>
<th>Catchments</th>
<th>Research Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>23</td>
<td>Laboratory for Experimental Geomorphology, K.U.Leuven (G. Verstraeten &amp; J. Poesen)</td>
</tr>
<tr>
<td>Italy</td>
<td>44</td>
<td>Instituto Sperimentale per lo Studio e la Difesa dello Suolo, Firenze (P. Bazzoffi)</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>5</td>
<td>Czech Republic: Department for Land and Water Management, CVUT, Prague (T. Dostal &amp; J. Krasa)</td>
</tr>
</tbody>
</table>
For each of these catchments, sediment delivery ratios were assessed with WaTEM/SEDEM applied at a high resolution. For more details on the SDR-assessments we refer to: Van Rompaey et al. (2001) for Belgium, Van Rompaey et al. (2003a) for Italy and Van Rompaey et al. (2003b) for the Czech Republic. For the Spanish dataset it was not possible to calculate an SDR-correction because the necessary high-resolution data for a WaTEM/SEDEM application were not available.

For each of these catchments predicted erosion rates were multiplied by predicted SDR-values. Finally, the predicted sediment yield values were compared with the measured sediment yield values.
CHAPTER 5 RESULTS

The Belgian sediment yield (SY) dataset was compiled by Verstraeten and Poesen (2001) and consists of data from 15 drainage basins situated in the loess belt of central Belgium (Figure 7). The original database consists of 23 drainage basins but those that are smaller than 1 km² (= 1 pixel) were excluded from this analysis.

The Czech SY-dataset was made available by the Department of Irrigation and Land Management of the CVUT (Technical University Prague). It consists of 5 drainage basins in the with an average size 180 km² (see Figure 9). The height difference in the catchments is < 500m. The dominant land use is pasture and arable land. Landscapes and land cover are at present changing very rapidly because of a de-collectivization of the agricultural production. The observed SY-values represent a 10 to 30 year period before the de-collectivization (Dostal et al., 2001, 2002).

The Italian SY-dataset was made available by Bazzoffi et al. (1996). Sediment volumes were measured in 44 reservoirs with direct sonar sub-bottom profile techniques or derived from excavation volumes done by ENEL (Italian Electricity Power Company). Data from 34 drainage basins were used in this study (see Figure 11). The average size of the selected basins is 170 km².

Avendano Salas et al. (1997) provide a list of mean annual sediment deposition rates for 60 Spanish reservoirs for a time span of at least several decades. Verstraeten et al. (2003) delineated contributing areas of 22 of these reservoirs, which are used in this analysis (see Figure 13). The average size of the drainage basins is 680 km². The height difference in the drainage basins ranges from 500 to 1200m. The dominant land use categories are forest and arable land. The assessment of SDR-values with WaTEM/SEDEM was not possible for this data set because the necessary high resolution data on land cover and topography were not available.

5.1. The Belgian SY-dataset

Sediment volumes were measured directly when the reservoirs were cleared or estimated from manual measurements with a theodolite.

The observed SY-values represent an accumulation over a 5 to 10 year period. The basins are situated on loamy and sandy loam soils and are characterized by a rolling topography (height difference < 100m). The dominant land use is arable land. The average size of the drainage basins is 10 km². More information on this dataset can be found in Verstraeten and Poesen (2001). Observed versus predicted SY-values are plotted in Figure 8, Figure 10, Figure 12 and Figure 14.
Figure 7: Soil erosion estimates for Belgium and location of the validation basins
The average of the observed net soil loss in the Belgian catchments is 2.4 t.ha\(^{-1}\).yr\(^{-1}\).

With an average predicted value of 0.13 t.ha\(^{-1}\).yr\(^{-1}\) the USLE clearly underestimates soil erosion in Belgium.

The average of the INRA-model predictions in the Belgian catchments is 2.3 t.ha\(^{-1}\).yr\(^{-1}\).

The PESERA model seems to overestimate erosion with a predicted average net soil loss of 5.9 t.ha\(^{-1}\).y\(^{-1}\).

The PESERA estimates have the best correlation with the observed values with a Pearson’s correlation coefficient of 0.64. The correlation between the INRA estimates and the observed values is 0.61 and that between the USLE estimates and the observed values is 0.53.

Figure 8: Predicted versus observed net soil loss in Belgium (in t/ha/yr)
5.2. The Czech SY-dataset

![Map of Czech Republic showing soil erosion estimates for USLE, INRA, and PESERA](image)

**USLE**
- (t/ha/yr)
  - no data
  - < 0.5
  - 0.5 - 1
  - 1 - 2
  - 2 - 5
  - 5 - 10
  - 10 - 20
  - 20 - 50
  - > 50

**INRA**
- (t/ha/yr)
  - no data
  - < 1
  - 1 - 3
  - 3 - 10
  - 10 - 30
  - > 30

**PESERA**
- (t/ha/yr)
  - no data
  - < 0.5
  - 0.5 - 1
  - 1 - 2
  - 2 - 5
  - 5 - 10
  - 10 - 20
  - 20 - 50
  - > 50

Figure 9: Soil erosion estimates for the Czech Republic and location of validation basins.
The average of the observed net soil loss in the Czech catchments is 0.52 t.ha\(^{-1}\).yr\(^{-1}\).

The USLE model also underestimates soil losses in the Czech catchments with average predicted values of 0.11 t.ha\(^{-1}\).yr\(^{-1}\). The correlation between observed and predicted net soil loss rates is 0.77 for the USLE.

The average of the estimates from the INRA approach is 0.49 t.ha\(^{-1}\).yr\(^{-1}\), which is much closer to the average of the observed values. However, the correlation between the observed and predicted net soil losses is 0.50 for the INRA-model.

The PESERA model underestimates soil losses in this area with average predicted values of 0.14 t.ha\(^{-1}\).yr\(^{-1}\). If we look at the relative pattern of soil losses, it is clear that PESERA performs the best with a Pearson’s correlation coefficient of 0.95.

Figure 10: Observed versus predicted net soil loss in the Czech Republic.
5.3. The Italian SY-dataset

Figure 11: Soil erosion estimates for Italy and location of the validation basins.
The dataset from Italy consists of:

- mountain basins of north Italy: height difference >1000m, dominant land use forest, pasture and bare rock
- hilly basins of central Italy: height difference < 1000m, dominant land use forest, arable land, humid conditions
- hilly basins of south Italy: height difference <1000m, dominant land use arable land, forest, semi-arid conditions

The mean observed SY-value in the Italian catchments is 5.00 t.ha$^{-1}$.yr$^{-1}$. All the models underestimated soil losses in Italy, with average values of 1.00 t.ha$^{-1}$.yr$^{-1}$ estimated using USLE.

Mean soil losses of 0.64 t.ha$^{-1}$.yr$^{-1}$ were estimated by the INRA-approach.

Estimated soil losses were 2.77 t.ha$^{-1}$.yr$^{-1}$ for the PESERA model.

However, the estimated losses correlate poorly with measured data, with correlation coefficients of 0.10 for the USLE, 0.23 for INRA and 0.20 for PESERA models.
5.4. The Spanish dataset

Figure 13: Soil erosion estimates for Spain and location of the validation basins.
The average observed net soil loss in the Spanish catchments is 4.78 t.ha\(^{-1}\).yr\(^{-1}\). As SDR-correction was not possible for the Spanish dataset it makes no sense to compare average values. Under the assumption that SDR-values are more or less similar in all catchments, the correlation between the observed net soil loss and the predicted erosion may be taken into consideration.

In this respect, the USLE performs the best with a correlation coefficient of 0.61 between observed and predicted values.

Second are the INRA estimates with a correlation of 0.13 though this is virtually no correlation.

The PESERA model produced the poorest correlation with a coefficient of 0.04.

Figure 14: Predicted versus observed net soil loss in Spain (in t/ha/yr).
CHAPTER 6 DISCUSSION

A summary of the validation results is given in Table 3. For each model, four statistical parameters were calculated: the average, the Pearson’s correlation coefficient (R), the model efficiency (ME) and the Relative Root Mean Square Error (RRMSE). Values for ME range from $-\infty$ to 1. The closer ME approximates to 1 (= the perfect model), the better the model performance. Values for RRMSE range from 0 to $\infty$. The closer RRMSE approximates 0 (= the perfect model), the better the model performance.

\[
ME = 1 - \frac{\sum(Y_{obs} - Y_{pred})^2}{\sum(Y_{obs} - \bar{Y}_{mean})^2}
\]

\[
RRMSE = \frac{\sum(Y_{obs} - Y_{pred})^2}{\frac{n}{\bar{Y}_{mean}}}
\]

The ME and the RRMSE are error indicators that do take into account the absolute deviations from the line of perfect agreement. In the case of a systematic error (under or over-prediction) ME will be low and RRMSE will be high, though there may be a good correlation between observed and predicted values.

Table 3 Summary of the validation results

<table>
<thead>
<tr>
<th></th>
<th>Observed values</th>
<th>USLE</th>
<th>INRA</th>
<th>PESERA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BELGIUM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>2.37</td>
<td>0.13</td>
<td>2.34</td>
<td>5.89</td>
</tr>
<tr>
<td>Correlation Coeff</td>
<td>0.53</td>
<td>0.61</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>Model Efficiency</td>
<td>-2.68</td>
<td>-2.50</td>
<td>-18.07</td>
<td></td>
</tr>
<tr>
<td>RRMSE</td>
<td>1.11</td>
<td>1.08</td>
<td>2.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CZECH REPUBLIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.52</td>
<td>0.11</td>
<td>0.49</td>
<td>0.14</td>
</tr>
<tr>
<td>Correlation Coeff</td>
<td>0.77</td>
<td>0.50</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>Model Efficiency</td>
<td>-2.62</td>
<td>-0.56</td>
<td>-2.08</td>
<td></td>
</tr>
<tr>
<td>RRMSE</td>
<td>0.87</td>
<td>0.57</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ITALY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>5.00</td>
<td>1.00</td>
<td>0.64</td>
<td>2.77</td>
</tr>
<tr>
<td>Correlation</td>
<td>0.10</td>
<td>0.23</td>
<td>0.20</td>
<td></td>
</tr>
</tbody>
</table>
For Belgium and the Czech Republic, all model predictions have a relatively high correlation with the observed sediment yield values. This means that all the models are able to estimate, with an acceptable accuracy, the relative difference between the sediment yield in those catchments. There is however no good agreement between the absolute values of the model estimates and the observed values across the different environments studied.

The USLE underestimates sediment yield values by a factor 20 in Belgium and a factor 5 in the Czech Republic. PESERA over-predicts sediment yield by a factor of 2 in Belgium but under-predicts sediment yield by a factor of 4 in the Czech Republic. Assigning soil losses to risk classes, the average values of the INRA estimates for Belgium and the Czech Republic correspond relatively well with the observed values. Because of these systematic errors model efficiency is in all case lower than 0, and the relative root mean square error is higher than 100%. Systematic errors are, however, essentially a problem of calibration.

The accuracy of the predictions in the Mediterranean (Italy and Spain) is generally poor for all three models both in terms of relative patterns as well as absolute values. All models underestimate the observed sediment yield values in Italy, the INRA and the USLE models by a factor 5 and the PESERA model by a factor 2. Correlation between predicted and observed values is also poor for the three models with correlation coefficients lower than 0.25.
It should however be kept in mind that the erosion measurements for Spain were not corrected with sediment delivery ratios and therefore the same comparison as for Belgium, Czech republic and Italy was not possible. If we assume that the average sediment delivery ratio for the Spanish catchments is 20%, it is clear that all models significantly under-predict erosion in Spain.

In general, the results show that none of the three models presented in this study produce accurate soil erosion estimates across all European environments. The models are relatively successful in predicting the relative pattern of soil loss from agricultural areas in central Belgium and the Czech Republic.

None of the model results accurately predict the measured soil erosion patterns in Italy and Spain.

There are several reasons for the discrepancies between the model results and the observed sediment yield values.

Firstly, the validation methodology chosen is indirect. All models estimate soil erosion of which only a fraction of the sediment is transported to the outlet of the catchment. The SDR-coefficient, which is necessary to convert erosion rates into sediment yield values, was calculated with WaTEM/SEDEM. Although the SDR-assessment was done with the best data available at the scale of these catchments, the potential errors can be significant. Moreover the sediment yield measurements themselves are not error-free. Verstraeten et al. (2001) estimated the error on sediment yield measurements at 20%. It should also be kept in mind that sediment volumes in lakes and reservoirs cover only a limited time span in which extreme events rainfall events or exceptionally dry periods may have occurred.

Secondly all models were run with low resolution input data (1km x 1km). The 1km resolution DEM, which is available for Europe is almost certainly not sufficiently detailed to capture the important characteristics of the topography, even when upscaling techniques and fractal methods are applied. This problem was already identified by Van der Knijff et al. (2000). Furthermore, Van der Knijff et al. (2000) and Grimm et al. (2003) assessed soil erosion rates in Italy using the same USLE-model as presented above but with more accurate topographic (250m DEM), climate (rainfall data from 366 stations instead of 46 MARS stations and pedological (at 250,000 scale) input data. Van Rompaey et al. (2003a) used the same measured dataset as presented here for accuracy assessment of the Grimm et al. estimates and found a 64% correlation (Pearson’s R) between observed and predicted values. Using exactly the same model but with input data at 1km x 1km resolution in a correlation coefficient of only 10% was found.
Figure 15: Available mean annual rainfall data in Wales (UK).

Thirdly, European data layers interpolated from existing databases on land use and climate are not always reliable. A comparison of rainfall estimates interpolated for the UK, but at European scale (MARS), and the national-scale long term rainfall records shows that in some cases the error on mean annual rainfall estimates at European scale is more than 100%. As most erosion models are very sensitive to the rainfall input, such errors can have an enormous impact on the model output. Figure 15 shows the average annual rainfall (in mm) for Wales derived from national scale meteorological data (left) and from the European dataset (middle), in relation to the PESERA erosion estimates (right). It is clear that, by comparison with the true mean annual rainfall (from the national data set), the interpolated European data underestimate rainfall in north Wales by a factor between 1.5 and 3. This will have had a significant impact on the predicted soil losses for Europe obtained by running the PESERA model at 1km resolution (Figure 6).

Fourthly, errors in the CORINE land cover map can lead to erroneous model estimates. For example, Figure 16 shows some land cover classification problems in Italy. In the centre of Sardinia, a block of several square kilometers are mis-classified as arable land resulting in unrealistically high erosion estimates from applying the model. In the north of Italy, land is wrongly classified as water because there is a large area of rice cultivation and the land use was assessed from satellite imagery flown at the time (April/May) when the rice fields were flooded. This results in the models estimating zero erosion.
Finally the poor performance in Mediterranean areas may also be because important sediment transport processes are operating that are not included in any of the models. The USLE, INRA and the PESERA models were developed essentially to assess soil loss by rill– and inter-rill erosion. These are the dominant soil erosion processes on arable land in most of temperate Europe. In addition to measurements from dominantly arable catchments, the Italian and the Spanish datasets include measurements from semi-natural mountain catchments where mass movements, landslides, avalanches, river storage and bank erosion are very important agents in the total sediment budget. Gully erosion, on the other hand, is the dominant erosion process in the semi-arid catchments in Spain and South-Italy. It is obvious that models that do not include such processes, cannot perform well in these areas and it is important to note that PESERA-estimates are shown to be more accurate ($R = 0.59$) when only data from the catchments with more than 50% arable land are analysed (Figure 17).
Figure 17: Observed versus predicted soil losses (in t/ha/yr) in catchments in Italy with more than 50% of the land in arable cultivation.
CHAPTER 7 CONCLUSION

It is important to assess the accuracy of soil erosion estimates from any model that could be used in the context of soil protection in Europe (EC, 2002). However, it is very difficult, if not impossible, to acquire direct soil erosion measurements for large areas of land (at European scale) for validating model results.

Therefore an indirect validation method, based on more widely available data, was adopted. Such data exist as measures of sediment accumulation in lakes and reservoirs and these were made available by researchers for a number of catchments in four European countries. For each of the contributing areas, an sediment delivery ratio – SDR-value was calculated in order to convert the observed sediment yield values to soil erosion rates.

The accuracy of three soil erosion models: the USLE, an INRA-model and the PESERA-model was assessed. The results presented above show that none of the three models used in this study accurately predicts soil erosion across all European environments. However, the models are relatively successful in predicting the relative pattern of soil loss from agricultural areas in central Belgium and the Czech Republic.

However, none of the models accurately predicts the measured soil erosion patterns in Italy and Spain.

The main reasons for this are:

1) Uncertainty involved in the indirect validation method
2) Low resolution of the input data used for model applications at European scale
3) the simplified model structures that do not take into account all sediment producing and transporting processes.

Furthermore, our research shows that some models perform much better for areas where high quality input data are available (Van Rompaey et al., 2003a). For example, runoff is better predicted from a 250m digital elevation model (DEM) than from a 1km DEM. In many cases, these high resolution input data exist in national mapping, meteorological and soil survey institutions, though these are at present not readily available at European level.

An important future role for the JRC therefore, could be to harmonise, aggregate and facilitate access to these data at European level. It is clear than some attempt must be made to estimate soil erosion losses in Europe for the forthcoming Soil Protection Strategy. This could be done best using a standard model applied to standard data sets. Therefore it is recommended that the Services of the Commission put much more effort in to encouraging national and regional administrations to provide the necessary environmental data (for input to soil erosion models) at much higher resolutions than are currently available.
CHAPTER 8 REFERENCES


