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EVK1-CT-2000-00051

DELIVERABLE 2.2 – KEY FACTORS OF SOIL EROSION

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1 INTRODUCTION

Results of Deliverable D2.1 have employed best available data to simulate soil erosion and nutrient loading in the case study areas using different modelling approaches. Although the approaches were quite different all of them used similar input parameters which in general can be identified as being key factors for the description of erosion and nutrient loading. Besides the well known key factors for onsite soil erosion (slope, landuse, soil properties), water flow has been identified to be crucial for the calculation of total loads and soil nutrient contents are a further data source which is needed.

For estimation of sediment and nutrient loads at large scales (national, international) however, the data on key factors which were used for the case study areas are usually not available with the same accuracy and detail. This leads to the question of possibilities to estimate these key factors - which in turn are used as input for the different models – with data of less accuracy. In addition, models applied at coarser scales than those of D2.1 need modifications to account for the new data situation. To check the possibilities of model application using coarse data we introduced coarser data for the key factors landuse and slope into the two main model approaches that have been used in D2.1. A list of key parameters for soil erosion estimation is presented in this deliverable, additional the applicability to the Danube Basin is evaluated and data gaps are listed.

With respect to the MMF approach three major modifications have been implemented in the model structure to account for coarse input data.

1. Landuse can be termed the key factor for estimation of soil erosion risk. Unfortunately the only information of landuse available on a European level is the CORINE dataset. But due to the small scale of CORINE landuse data of 1:100 000 and errors in the class arable land, more information on landuse is necessary. To improve the existing spatial and temporal resolution of landuse data for arable land and divide them into crop species with different influence on soil erosion, the CORINE data were combined with data on the agricultural statistical survey of Austria in 1999.

2. As a second approach the DEM had to be adapted to the CORINE dataset. Therefore the grid size was resampled to 400 m and in addition to 1 000 m, also the only available DEM on European scale. Errors occur by calculation of slope in fact of flatter surface. To take this into account a methodology has been developed to scale back to slope calculation based on better resolutions.
3. Flow processes through the local drain direction can not be simulated proper any more with grids of 400 or even 1000m grid size. The coarse resolution of the maps lead to a wrong reproduction of the geomorphologic structure of the landscape. Therefore routing processes had to be removed. Instead average rates of soil erosion were used for further calculation of sediment yield in the river, phosphorus and nitrogen calculations..

With respect to the USLE derived approaches (in D2.1 the MUSLE as a derivative of the USLE had been used) the main modifications were:

1. Replacement of daily soil loss calculations (as used by the MUSLE) with mean annual calculations. Therefore the flow term in the MUSLE model was replaced by the R-Factor value (as proposed in the original version of the USLE)
2. Replacement of satellite derived data for landuse with coarser information obtained from a combination of CORINE data with statistical data at community level
3. Development of a sediment delivery function to calculate sediment loads

In the final section of this deliverable a list of key parameters and recommendations for data quality for using these models and identified data gaps are given.

2 MMF – CHANGES IN MODEL STRUCTURE

A detailed description of the structure and the necessary parameters required in the model is already given in Deliverable 2.1. Due to the fact that the spatial resolution of model inputs which are available at an European level is low, routing processes included in the model structure do lead to wrong results, e.g. CORINE landcover has a spatial resolution of 500m x 500m, according to the survey scheme. Data on elevation are on a European level available at a precision of no more than 1000m. Generally spoken, the bigger the grid sizes the smoother becomes the surface and transporting processes get less energy due to flatter slopes. Especially in mountainous areas like the Ybbs watershed the effects and the changes in the results are high. Volk et al (2001) suggest grid resolutions of 10 – 50 m for calculation of the slope factor in the USLE, because coarser resolutions lead to errors in the representation of the relief. Effects of coarse grid implementation on slope and slope length are discussed in more detail in section 3.4. To take this into account the model structure of the MMF-Model had to be changed. Given the coarse resolution of input data at an European level the calculation of surface runoff and erosion in a spatially distributed way could not be justified. Therefore, calculations for surface runoff and sediment delivery were done independently for each grid cell and the spatial surroundings do not influence erosion processes below any more. Surface water and sediment are not transported through the local drain direction network by exclusion of the process of steepest descent (Jenson and Domingue, 1988). Soil erosion is calculated for every cell and an average is calculated for the different subcatchments.

In consequence no calibration of surface runoff and sediment yield at different stations in the river Ybbs and Wulka can be done. But the impact is less than the high degree of changes in calibration parameters (effective hydrological depth-EDH and C-Factor) may seem to be. As already mentioned in Deliverable 2.1. the direction of the calibration within the two watersheds of Wulka and Ybbs is opposite. This suggests that the runoff algorithm which is implemented in the MMF model is strongly influenced by the climatic and geomorphological situation of a catchment in general. The values given by Morgan (2001) may therefore be regarded as representing means of different landscapes and climatic conditions. In Austria mountainous river catchments (Ybbs) with high flow conditions need to decrease EDH which leads to an increase of surface runoff. Flat, agricultural areas (Wulka, northern parts of Ybbs) need to increase EDH to obtain lower surface runoff rates. Hence to calculate average soil erosion rates for bigger areas averages of the parameter EDH should be sufficient as suggested in Morgan (2001).

3 USLE - CHANGES IN MODEL STRUCTURE

Results of deliverable D2.1 have shown that the MUSLE approach (incorporated in the SWAT tool) is not suited to predict sediment delivery without adding modules that handle the transport in the river. Although water flow is incorporated in the MUSLE as an extension to the original USLE sediment input into the river is overestimated. In addition, the temporal resolution of days is difficult to obtain for larger areas and the complexity of the SWAT tool makes it very difficult to be applied for larger areas with data lacking. In order to simplify this approach and make it applicable to larger areas we developed a modified version of the USLE which is

$$A = S \times K \times R \times C \times P$$

where

A (t/ha/a)= longterm mean annual soil loss for a plot of 22 m length

S (dimensionless) = factor to characterise slope effects – calculation based on McCool et al. (1989)

$$S = 10.8 \times \sin \Theta + 0.03, \quad s < 9\%$$

$$S = 16.8 \times \sin \Theta - 0.5, \quad s \geq 9\%$$

s = slope in %, Θ = slope in degree

K (t h $ha^{-1}N^{-1}$) = soil erodibility, calculation identical to deliverable D2.1.

R (N/h) = rainfall erosivity

C (dimensionless) = factor to describe the protective influence of soil cover

P (dimensionless) = factor to describe additional effects of soil protection measures

Using these input factors, soil loss risk was aggregated at the level of municipalities using an aerial weighed mean of the different soil losses within the municipalities.

Subsequently aerial weighed means of the different municipalities within a subwatershed were calculated.

From here on, an identical procedure to the calculation of sediment and nutrient load using the MMF model was applied, ie. Sediment delivery ratios (SDR) and enrichment ratios (ER) were calculated and applied to obtain sediment and nutrient loads (see results section).

4 DATABASE

4.1 SOILS

4.1.1 MMF

A detailed description about the used soil data and the process of the establishment of a proper soil map for the two Austrian project areas and the different modelling approaches has already been given in Deliverable 2.1.

4.1.2 USLE

The same database as used for the MMF model was implemented with the difference, that soil information was aggregated at municipality level using an aerial weighed mean.

4.2 CLIMATIC INFORMATION

4.2.1 MMF

The location of climatic stations used for the calculation in the Ybbs and Wulka river catchment can be obtained from the report on Deliverable 1.1 (Water balance calculation). The detailed description about mean annual precipitation amounts were given in Deliverable 2.1, wherein also the procedure of deriving the necessary input data was given.

4.2.2 USLE

A procedure to calculate R-Factors, which are necessary to estimate the impact of rainfall on soil erosion has been developed by Strauss et al. (1995). It is based on a regression between long term annual or summer rainfall and R-Factor values.

4.3 LANDUSE

To estimate erosion risk it is necessary to obtain current landuse especially for arable land. The CORINE (Co-ordination of Information on the Environment, CORINE, 1997) programme proposes a unique methodology for all European States for collecting the same basic data on landcover in the scale of 1 : 100 000. Mainly data of the satellite Landsat TM and SPOT were used for mapping landuse. Furthermore a computer-assisted photointerpretation of the satellite data was done to get a unique landuse map for Europe. The data were mapped according to a nomenclature, which consists of 38 different landcover types (Table 1). The digital CORINE landcover data represent the first actual information about the landuse in Europe in such detail.

Table 1: CORINE landcover nomenclature

1. Artificial Surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, comercial and transport unitsareas	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1. Arable land	2.1.1. Non irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent Crops	2.2.1. Vineyards 2.2.2. Orchards and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation 2.4.3. Land principally occupied by agriculture, with 2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniverous Forest 3.1.3. Mixed Forest
	3.2. Shrub and herbaceous vegetation association	3.2.1. Natural Grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional wooldand shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes and sand plains 3.3.2. Bare rock 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes 4.1.2. Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes 4.2.2. Salines
		4.2.3. Intertidal flats

However, during interpretation of the satellite data there were some difficulties in perceptibility and delimitation of areas. Additionally no areas smaller then 25 ha and narrower then 100 meters can be depicted in the maps. To check the quality of data we contrasted CORINE data with official landuse statistics in Austria. The comparison of the data set of CORINE and statistical data of the "Austrian Agricultural-statistical Survey" (1999) in selected areas showed a significant overestimation for arable land of 10 – 20 % but an underestimation for grassland and water bodies. This is confirmed by the work of Erhard et al. (2004) who also found an overestimation for arable land of about 5000 km² for Germany and an underestimation for grassland (18000 km²), urban areas and water bodies by comparing CORINE data with statistical landcover data from Germany ("Land Survey", StBa 1997). Forests are represented well in the CORINE data set as validated by (Aubrecht, 1998). A comparison with the Austrian "Forest Inventory" statistic data showed a conformity of 98 % to CORINE forest data. Therefore, CORINE data of forest and bushes could be used without problems for this soil erosion estimation. The accuracy of the data had permitted a partitioning of the forest in deciduous forest (3.1.1.), coniferous forest (3.1.2.), mixed woodland (3.1.3.) and shrubs (3.2.). Sealed surfaces and water bodies have also been directly implemented in the erosion model from CORINE data. Additional to the water bodies in the first approach the river Wulka and Ybbs were included in the model since rivers are too small for identification in the CORINE data set but are important for sediment delivery.

To improve the existing spatial and temporal resolution of landuse data for arable land and divide them into crop species with different influence on soil erosion a combination of statistical data and CORINE data was used: A GIS based method was developed and applied to assign statistical data of the "Austria Agricultural-statistical Survey" to the arable land class of the CORINE land cover map (CORINE, 1997). The statistical data provide information about aerial extension of cultivated land on the administrative municipality level for all crops grown in Austria. On the other hand, CORINE data has no information about actual crops and its erosive behaviour, but gives at least a spatial distribution of arable land (group 2 in Table 1), forests and others within a municipality. On that score it is necessary to divide the agricultural areas in erosive crops, non erosive crops, vineyards and orchard and grassland. As the information in the statistical survey is too detailed, grouping into 4 plant groups with different properties in behaviour against soil erosion was done in conformity with plant characteristics (Table 2). Therefore on basis of administrative communities detailed information on percentage distribution of different plant groups could be applied.

Table 2: Grouping of crops into groups of different soil erosion hazard

Simulated plant Group	**Crops**
Erosive crops	corn, sugarbeet, potato
Non-erosive crops	winter and summer grain, wheat, rye, barley, pea, bean, pulse, rape, sunflower, clovers, vegetables, strawberry, pumpkin, tobacco
Vineyards and orchards	vineyard, orchard
Grassland	meadow, grassland,

Second arable land in CORINE data set was summarised into one class. Cultivation areas, grassland and permanent crops joined as agricultural area, because as already mentioned above, errors arose inside these classes. The different years of plant groups are assigned to the arable land in CORINE for different municipalities. Figure 1 for Ybbs and Figure 2 for Wulka show the differences between the two land-cover maps.

Updating process of the database of CORINE is planned every 10 years. Therefore a further advantage of using a combination of remote sensing and statistical data is, to improve information about changes in landuse as well as the spatial distribution. Because for additional analyses statistical data are available more often and can be updated in shorter periods.

Figure 1: Comparison landuse map CORINE and new map including statistical data for the Ybbs watershed.

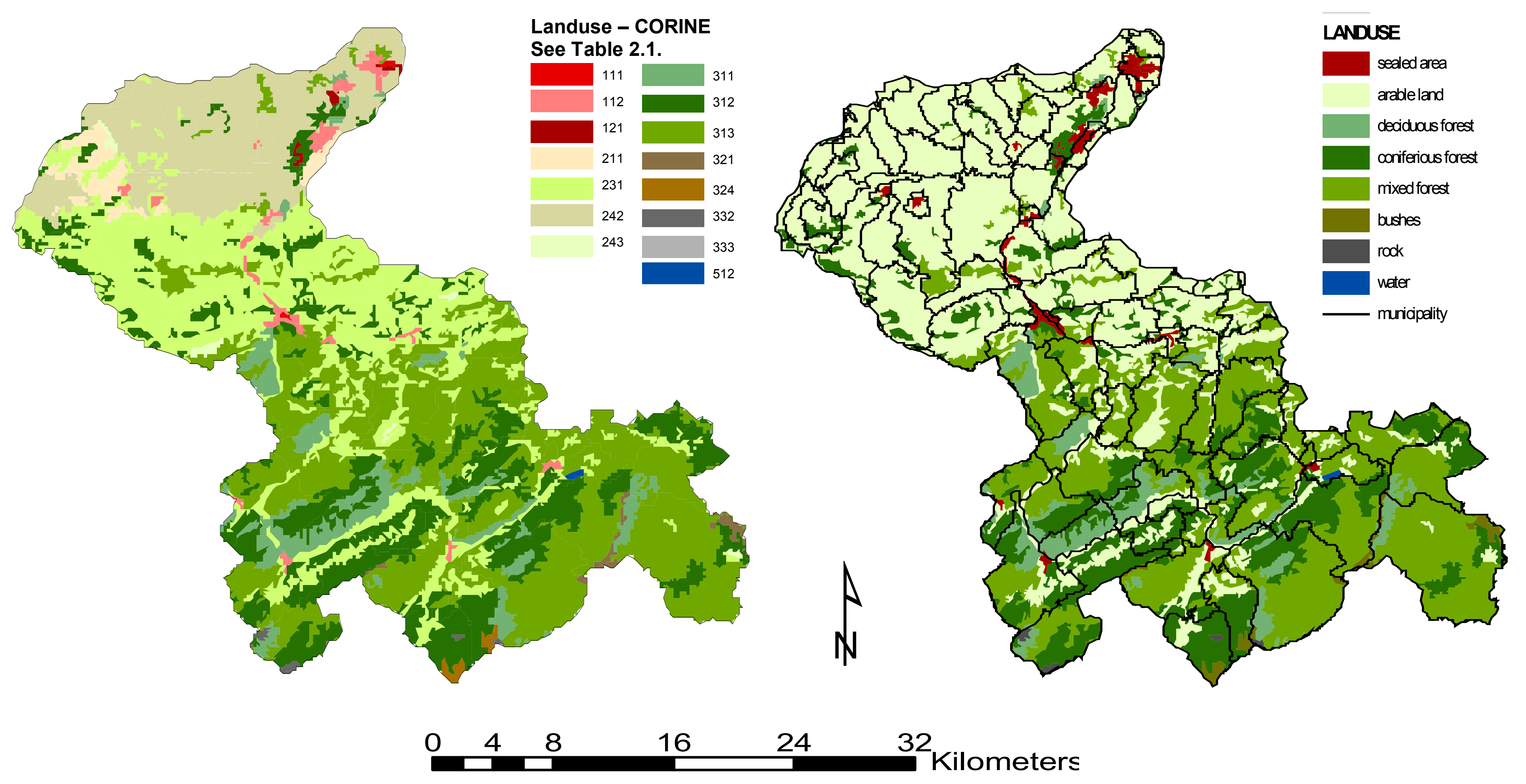
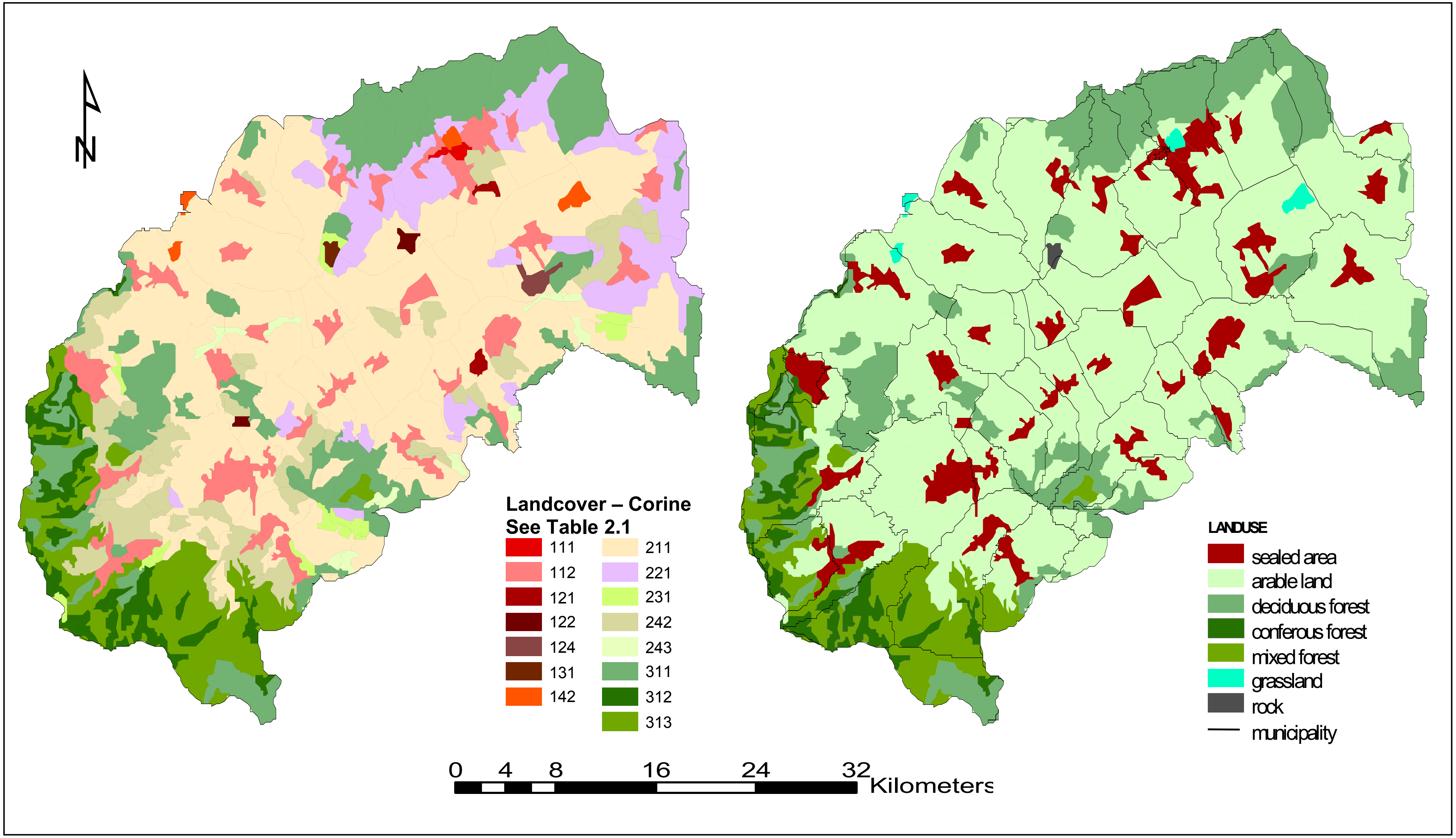


Figure 2: Comparison landuse map CORINE and new map including statistical data for the Wulka watershed.



4.3.1 MMF

Due to the fact that no detailed information about spatial patter of the defined plant group is available a result had been found by using the temporal pattern. Table 3 gives an example for the municipality Rohrbach (municipality number 10610) wherein the percentage of the different plant groups are calculated at an annual base. The simulation period to calculate mean soil erosion rates was 10 years.

Table 3: Percentage of the planted crops on arable land for the municipality Rohrbach bei Mattersburg.

Plant group	% on arable land	years
Erosive crops	10	1
Non-erosive crops	70	7
Vineyards and orchards	10	1
Grassland	10	1

As a result of the changes in the model structure, were the routing processes had been removed, the original parameters recommended by Morgan (2001) were used again. No calibration could be done for surface runoff and sediment yield in the river. The changed parameters are listed below in Table 4 and Table 5. For all other parameters used in MMF the values already applied in the model before could be adopted.

Table 4: Parameter values for C-Factor for different plant groups

Landuse	C-Factor
Erosive plants	0.4
Non-erosive plants	0.1
Vine and orchard	0.59
Grass	0.01
deciduous forest	0.004
Coniferous forest	0.008
Mixed forest	0.004
Bushes	0.01

Table 5: Parameter values for the effective hydrological depth (EDH) for different plant groups.

Landuse	Periode	EDH in m
Unprotected soil	Summer (4-10)	0.24
	Winter (11-3)	0.1
Erosive plants	Summer (4-10)	0.26
Non-erosive plants	Summer (4-10)	0.21
Grassland	Summer (4-10)	0.22
	Winter (11-3)	0.1
Forest	Summer (4-10)	0.2
	Winter (11-3)	0.2

For the effective hydrological depth not the original values recommended by Morgan (2001) were used but values that have been validated in various projects and in different landscapes in Austria. The calibration was done by Swoboda (2004) in a prealpine watershed in lower Austria. Various validations of this parameter have been carried out by Huber et al. (2003) for river basins dominated by the main crops planted in Austria (grain, corn, vine and orchard).

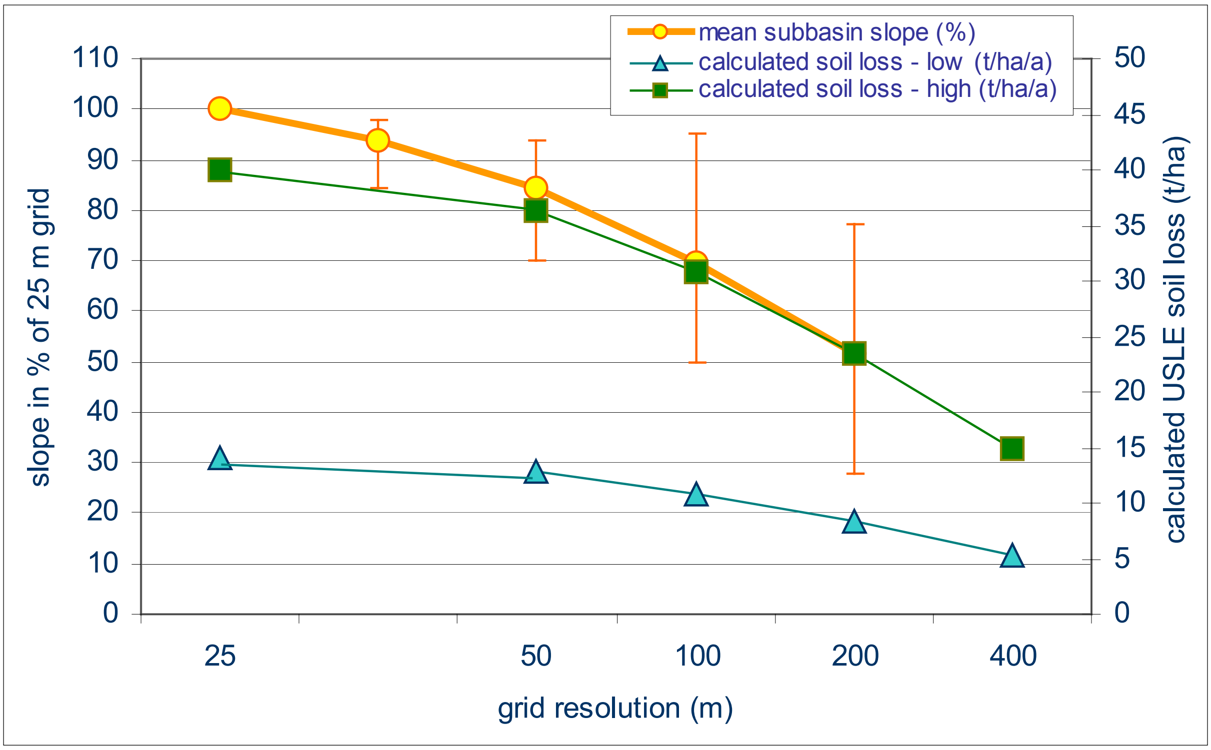
4.3.2 USLE

To calculate input data for the C-Factor of the USLE an area weighed mean of the different C-factors at municipality level (Table 4) was calculated.

4.4 SLOPE

The second step done in this deliverable was to adapt the spatial resolution of the CORINE data set to the rest of the input maps used in the erosion model. Therefore the DEM for the Ybbs river (available at grid size 25°m) was resampled to grid sizes of 400 m and 1 000 m and new slope values calculated. Figure 3 (D2.1) shows the flattening of the landscape as result of a change in spatial resolution. Parallel to this effect of smoothening of the landscape, calculated soil loss rates decrease. As a consequence of these changes, reduction of calculated sediment yield and nutrient loads can be expected. We therefore looked for a possibility to account for these changes in slope due to the various resolutions of DEMs and generated grids of 25 m (original data), 50 m, 100 m, 200 m, 400 m and 1 000 m grid size by resampling using the nearest neighbour method. Based on each resampled grid, new average slopes were calculated for the different subcatchments of the Ybbs river basin.

Figure 3: Changing of soil loss depending on grid resolution for all subwatersheds in Ybbs river catchment. Yellow bars indicate the variability of change



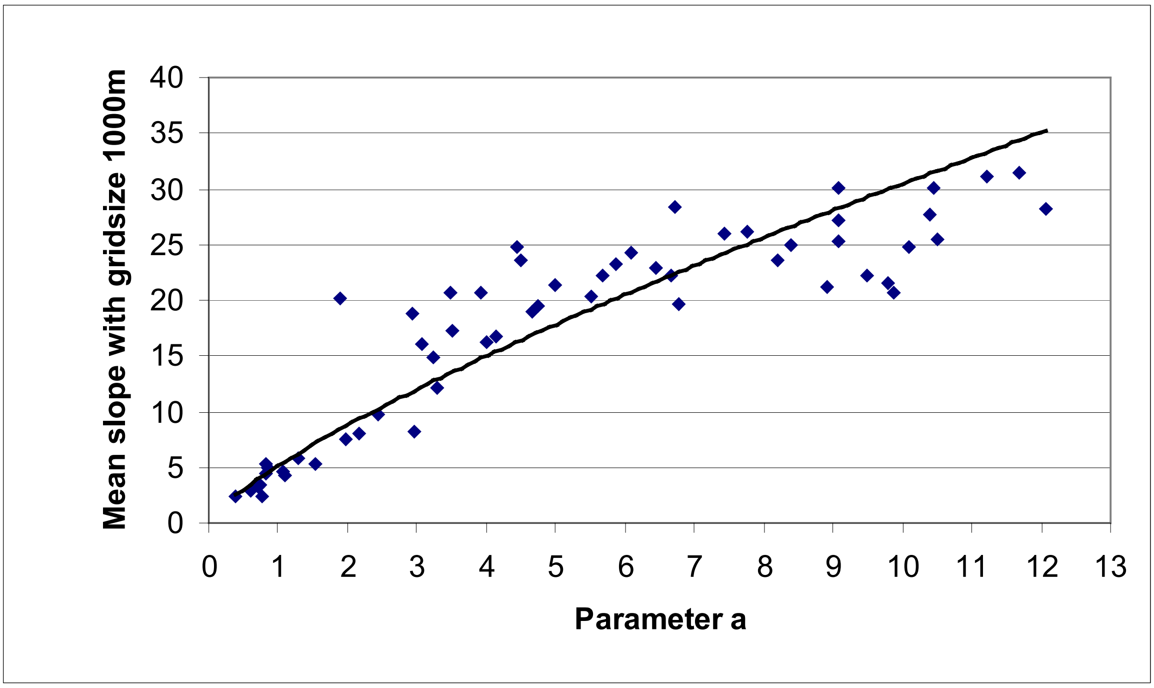
For all subwatersheds of the Ybbs river, mean slope of a subbasin at different grid sizes correlated by a quadratic relationship:

$$\text{Slope}_{25} = a + b*\text{Slope}_{(grid)} + c*\text{Slope}_{(grid)}^2 \tag{1}$$

Wherein Slope_{25} = average slope (°) using 25 m grid
$\text{Slope}_{(grid)}$ = average slope (°) of any available grid with coarser resolution
a, b and c = parameters

Equation 1 enables to calculate back to a more precise slope The parameters of this equation do highly depend on the average slope calculated in the subbasin, therefore these factors are specific for the subcatchment and depend on the particular grid size used. The task therefore is to develop equations to estimate the parameters a, b, and c for different grid sizes. Here, the grid sizes 400 m and 1000 m are used, because they are certainly the most relevant for the application of erosion estimations at large scales. However, it is also possible to obtain parameters for the calculation of different grid sizes. Due to the fact a 25 m DEM was available for the subbasins the calculation was counted back to the 25 m grid for comparison reasons. Thus other connections exist of the parameters to calculate slopes for other grid sizes.
As an example, Figure 4 gives the relationship between parameter a and the mean slope of the various subwatersheds of the Ybbs river.

Figure 4: Dependency of the parameter a of equation 1 on mean slope of the subcatchment



Calculate slope from a 1000m grid back to converging a 25m grid:

$a = 5.131 * (Slope_{grid1000}{}^{0.7736})$ ($r^2 = 0.89, n=73$) (2)

Wherein $Slope_{grid1000}$ = mean slope at the cell size of 1000m (°)

To scale from a grid of 1000m cell size to 25m cell size the parameters b and c are too small to be implemented.

Calculate slope from a 400m grid back to converging a 25m grid:

$a = 1.564 + 3.048 * Slope_{grid400}$ ($r^2 = 0.93, n=73$) (3)

$b = 0.00555 * Slope_{grid400} - 0.0049 * a$ ($r^2 = 0.99, n=73$) (4)

$c = 1.39 * 10^{-6} * Slope_{grid400} - 0.00143 * b$ ($r^2 = 0.99, n=73$) (5)

Wherein $Slope_{grid400}$ = mean slope at the cell size of 400m (°)

The results of the implementation of these equations are presented in Figure 5 and Figure 6 together with the slopes obtained from the original data set and the slopes obtained without implementation of this correction procedure at grid sizes of 400 m and 1000 m. Due to the big grid size of 400m the average slope of the subbasins is almost 8° lower than the slope calculated with a cell size of 25 m. A 1000 m grid leads to a slope averagely 12° lower then the slope of a 25 m grid. This of course has strong consequences for the calculation of erosion and nutrient movement due to erosion.

In general, the implemented methodology overestimates slopes slightly. For the 400 m grid in the Ybbs watershed the average slope is about 0.02° too high and for the 1000 m grid the new slope is about 1° too high, compared to the original data set of slopes derived with a 25 m grid.

Figure 7 gives a graphical view of the results obtained with the proposed methodology. A correlation coefficient of $r^2 = 0.82$ between the slope calculated with a 25 m grid and corrected slope calculated with 1000 m grid implies a good agreement. At higher slopes however, higher deviations occur and the slopes tend to become overestimated. However this takes place mainly at slopes above 20° were usually no intensive agriculture is done any more. Of course the smaller the grid cell size the better is the correlation to the original data. The correlation coefficient of the slope calculated with the 400 m grid to the 25 m slope is for instance already $r^2 = 0.93$.

Figure 5: Comparison of calculation of mean slope within the Ybbs river watershed at the level of subbasins for the original 25m grid (1), 400m grid (2) and the 400m grid including the correction methodology (3)

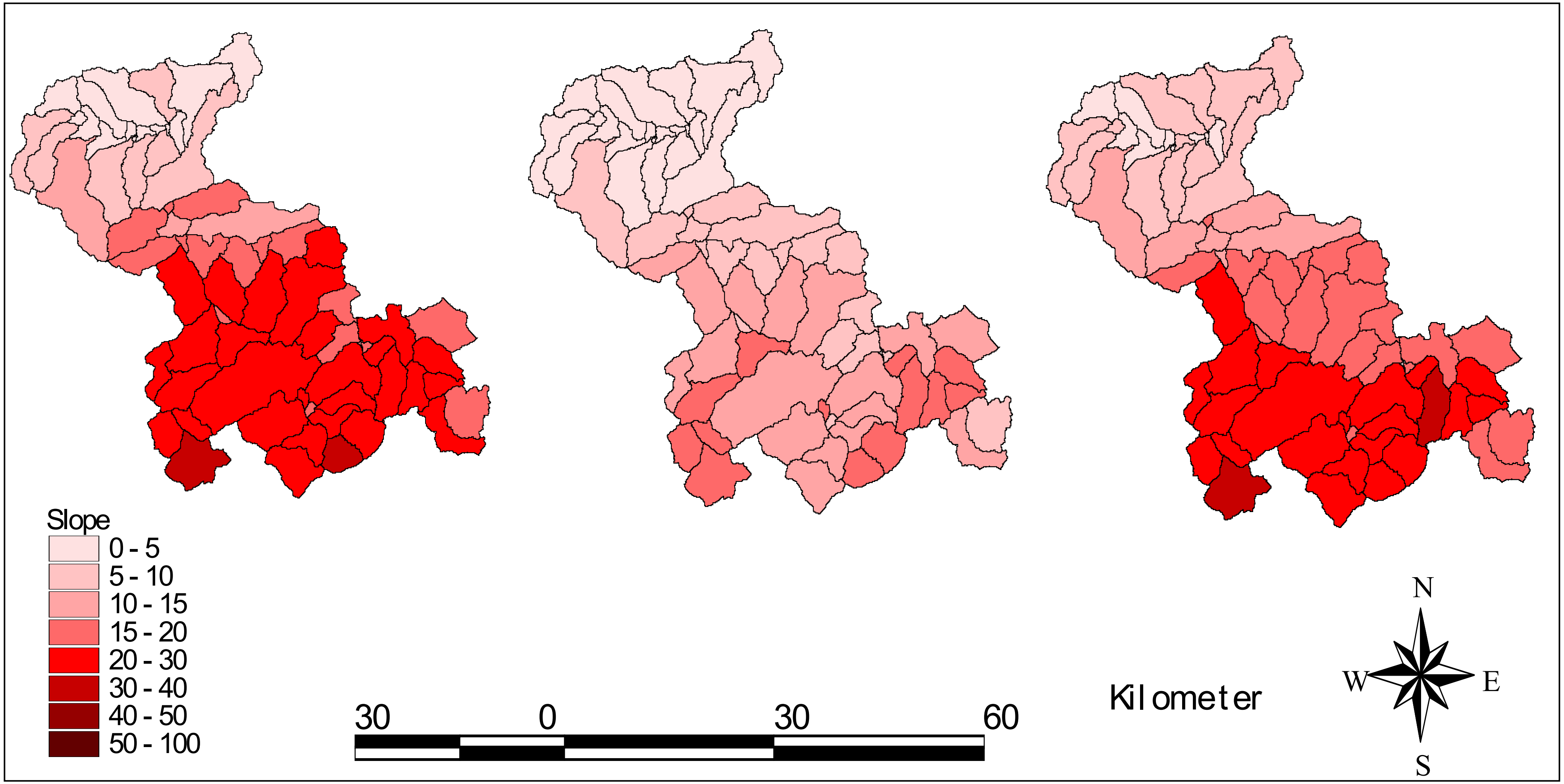


Figure 6: Comparison of calculation of mean slope within the Ybbs river watershed at the level of subbasins for the original 25m grid (1), 1000m grid (2) and the 1000m grid including the correction methodology (3)

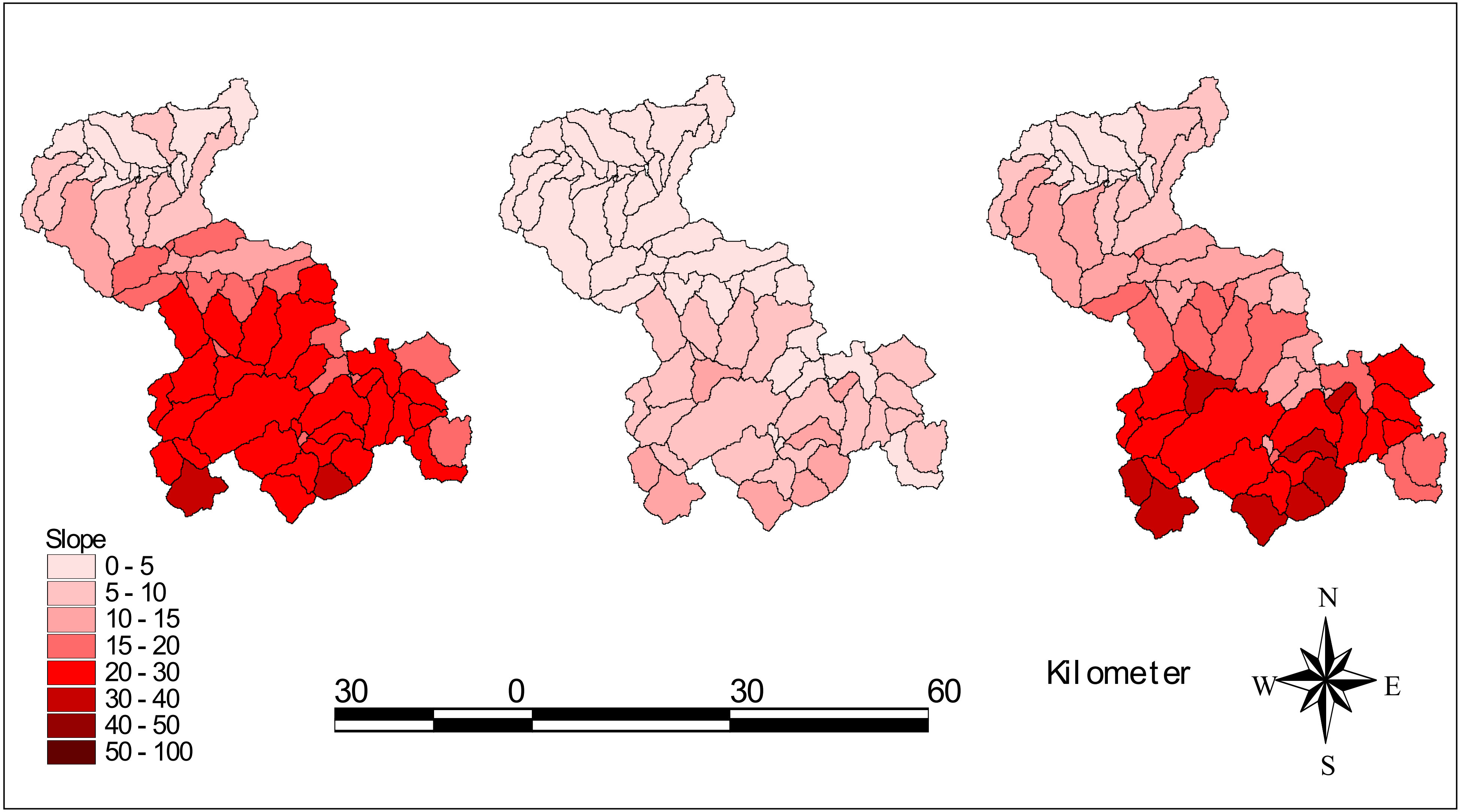
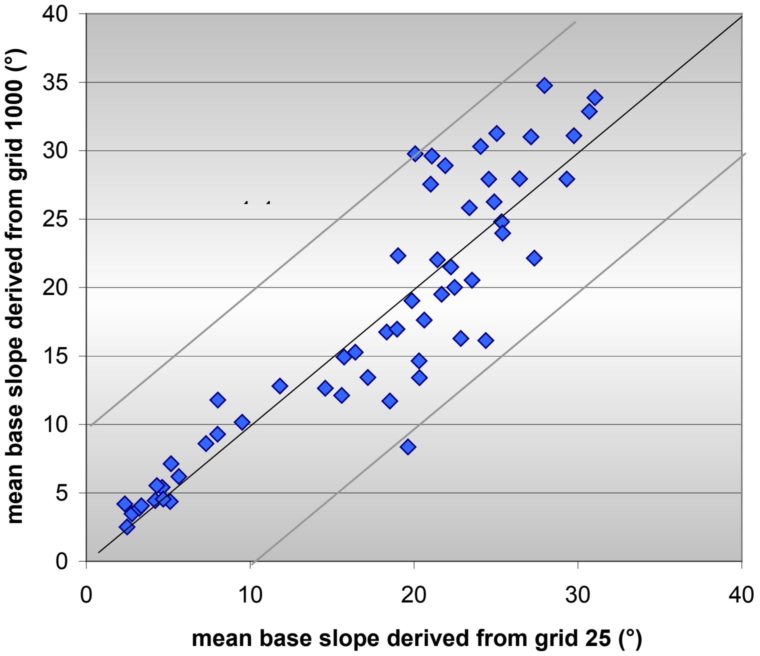


Figure 7: Comparison of calculated slope of the 1000m grid including all error correction and slope of 25 m grid (for comparison: 1:1 line and 25% deviation)

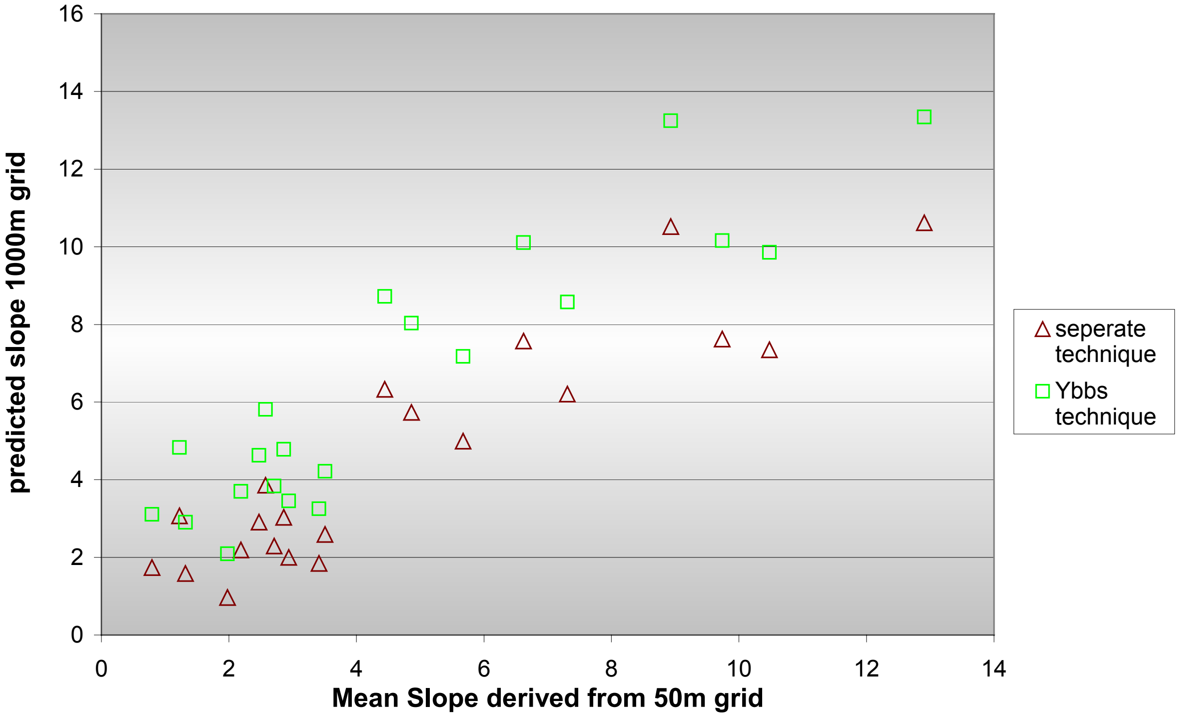


In a further step the methodology estimated above in the Ybbs River basin was evaluated in the Wulka basin. Therefore firstly new equations for the Wulka basin for each parameter were developed and secondly the same technique than applied in the Ybbs basin were used. Both methods were compared. Figure 8 shows the results for calculation of precise slope with both techniques: unique equation for the Wulka River basin and the implementation of equal equation of the Ybbs River basin. However whereas the methodology developed in the Ybbs basin calculates back to a slope of a 25 m grid, in the Wulka only a 50 m grid exists. This doesn't matter for calculation but comparison is more complicated by the fact that the equation for the Wulka could only be done trough a 50 m grid. Whether Figure 8 proves the similarity between both methodologies. A directed error is demonstrated in the figure. The method developed within the Ybbs subbasins overestimates the corrected slope in the Wulka subbasins, wherein in steeper slopes the error tend to become greater.

New calculation of parameter a for the Wulka basin to upgrade slope to a 50 m grid:
$a = 2.9708 * (\mathrm{Slope}_{\mathrm{grid1000}}{}^{0.9022})$ ($r^2 = 0.7, n=43$) (3)

with $\mathrm{Slope}_{\mathrm{grid1000}}$ = mean slope at the cell size of 1000m (°)

Figure 8: Comparison of the methodology of slope upgrades calculated for the Wulka basin (Ybbs technique: 1000 m – 25 m grid; separate Wulka technique: 1000 m – 50 m)



5 RESULTS

5.1 SIMULATED SEDIMENT LOADS

5.1.1 MMF

Runoff and soil erosion were calculated for individual grids (see model description in deliverable D2.1). Due to the fact that sediment yield could not be transported trough the local drain direction to the nearest stream, the sediment amount fed into the river could not be simulated directly. Therefore average amounts of soil erosion for the different subbasins were calculated.

Soil erosion is the first step in the sedimentation process which consist of erosion, transportation and deposition of sediment. A fraction of eroded soil passes through the channel system and contributes to sediment yield while some of it gets deposited in water channels. As the transportation and deposition process throughout the subbasins cannot be simulated any more, sediment yields can only be quantified using a sediment delivery ratio (SDR), expressed as the percentage of the gross soil erosion by water that is delivered to a particular point in the drainage system. SDR is sometimes referred as a transmission coefficient. It is computed as the ratio of sediment yield at the watershed outlet (point of interest) to gross erosion in the entire watershed.

In terms of the definition of sediment delivery ratio, the expression for computing sediment delivery ratio can be written as follows:

$$SDR = SY / E \qquad (6)$$

where SDR = the sediment delivery ratio
SY = the sediment yield
E = the average erosion per unit area in a subbasin

As the calculation of average erosion per unit area in a subbasin is based on independent cells (for the MMF as well as for the USLE), the calculation of the SDR includes all other uncertainties (field shape, connection between field and river, instream processes in the river, other forms of erosion such as river bank erosion..). Therefore it may conceptually be seen as nothing more than a regression relationship to scale down calculated erosion rates (usually much higher) to sediment loads (usually much lower). However, it may be useful to include parameters into the calculation of SDR's, which might be able to physically reflect the actual situation in watershed in order to account for at least some of the variations that drive the sediment delivery.

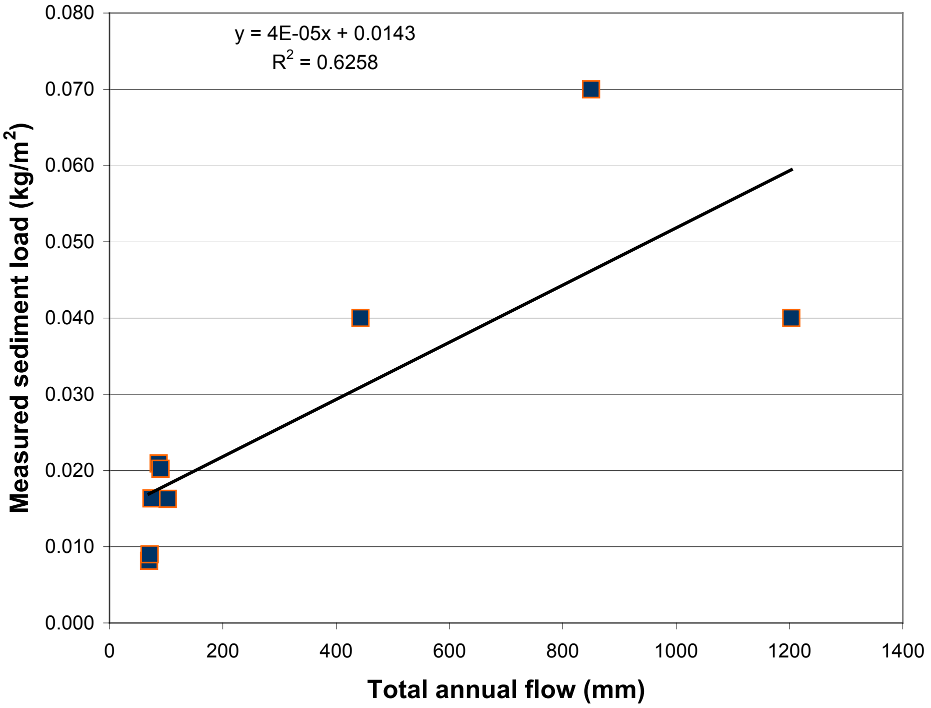
A number of factors such as drainage area size, basin slope, climate, land use/land cover has been attributed to affect sediment delivery processes (Williams and Berndt, 1977; Walling, 1983; Khanbilvardi et al., 1984; Novotny and Chesters, 1989). As an example, a watershed with short and steep slopes is likely to deliver more sediment to a channel than a watershed with a long flat landscape. As drainage area size and geomorphological characteristics in this model approach were excluded (routing process) the potential slope length (Emmett, 1978) which is based on the drainage density of a watershed was used as a surrogate for the flow lengths of water within a landscape.

$$potSlope = \frac{1}{2} * DR \qquad (7)$$

where potSlope = potential Slope length
DR = drainage density (Area [km²] / river length [km])

Water flow is a key variable for the description of the delivery process of sediment from a watershed. Total flow and surface runoff were taken from Deliverable D1.1 (Water Balance), where total flow has been measured and direct flow has been calculated using the Difga2000 model. Figure 9 gives the relationship between total flow rates and measured sediment loads for the different subwatersheds of the river Ybbs and Wulka. It can be deduced, that only from the knowledge of flow rates a large part of the differences between the various subwatersheds can be explained. Station Opponitz is an exemption with already very high runoff in the upper reaches of the River Ybbs, due to very high precipitation in the alpine parts of the watershed but very dense forested landuse. We therefore included surface runoff in the function to calculate a SDR. Station Opponitz is negligible because in mountainous areas no soil erosion occurs. A similar approach has been done in the MUSLE (Williams and Berndt, 1977). Rates of surface runoff for the different subwatersheds were taken from results of deliverable D1.1.

Figure 9: Relationship between total flow and measured sediment load for the subcatchments of the rivers Ybbs and Wulka



Three Approaches

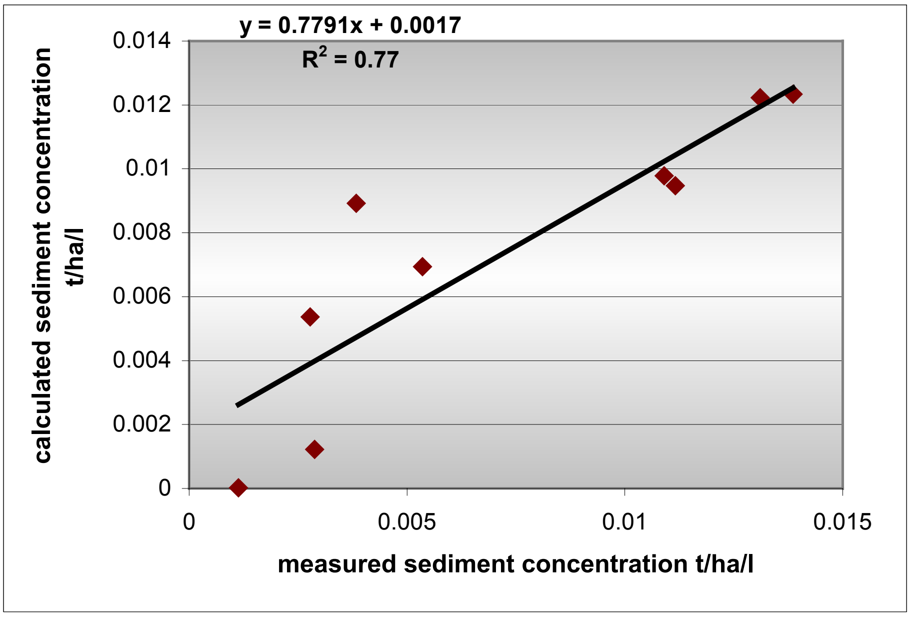
Measured values of sediment yield were available at two different station for the Ybbs catchment and five station for the Wulka catchment and additionally at the outlets of the watersheds. The SDR was developed against measured sediment yield and the average of soil erosion using the drainage density. The following relationships were tested:

Sed = (-0.0005+(20.35*pS*SedConc)) (n = 9; $r^2 = 0.77$) (8)

where Sed = Mean measured sediment concentration (t/ha/l) in the surface runoff pS = potential Slope length (m)

SedConc = Mean simulated sediment concentration (t/ha/l) in the surface runoff

Figure 10: Measured sediment concentration against simulated sediment concentration; linear function relationship



Sed = 0.0023+(-11.287* pS*SedConc)+(49921.8*(pS*SedConc **2)) (9)

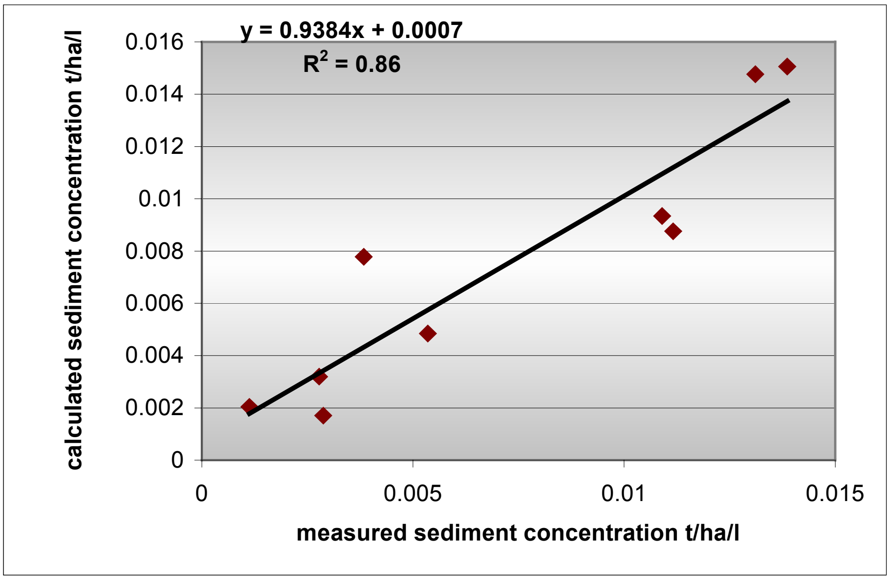
(n=9; r^2 = 0.86)

where Sed = Mean measured sediment concentration (t/ha/l) in the surface runoff

pS = potential slope length (m)

SedConc = Mean simulated sediment concentration (t/ha/l) in the surface runoff

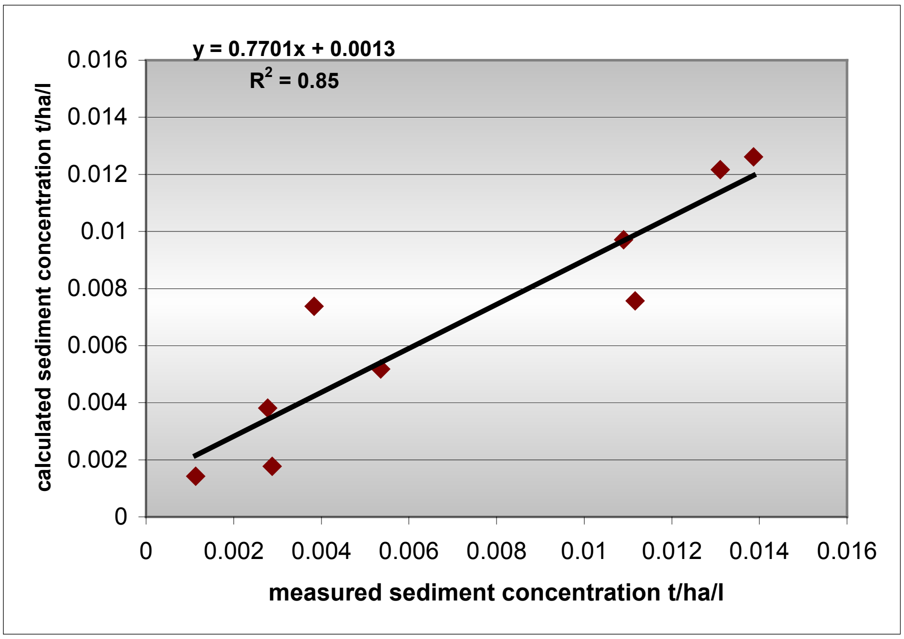
Figure 11: Measured sediment concentration against simulated sediment concentration; quadratic function relationship



Sed =0.0013*e**(3775.19*pS * SedConc) (10)

where Sed = Mean measured sediment concentration (t/ha/l) in the surface runoff
pS = potential slope length (m)
SedConc = Mean simulated sediment concentration (t/ha/l) in the surface runoff

Figure 12: Measured sediment concentration against simulated sediment concentration; exponential function relationship



Equations (9) and (10) yielded higher R^2 values and it was also strongly confirmed that runoff and potential slope length has an essential role in predicting the SDR Without using the potential slope length R^2 are about 0.5 – 0.7, an order of magnitude lower then inclusive the slope length. Equation (8) is based on a linear regression and therefore suggests that the concentration of sediment in the surface runoff increases proportional, whereas equations (9) and (10) with an exponential and quadratic fit suggest that that the SDR for higher calculated sediment concentrations leads to overproportional higher sediment yields. This may lead to problems of application of this equation in rivers with high sediment rates (e.g. Po river). However, for this data set the exponential function regression gives the best relationship as it needs less parameters (higher degrees of freedom). We therefore decided to use this equation for further analyses. The calculated loads using the different approaches are given in Table 6.

Table 6: Measured and calculated sediment yields at different subwatersheds of the river Ybbs and Wulka (t/ha/a)

	Calculated Sediment Yield			Measured Sediment Yield
	Linear (8)	Quadratic (9)	Exponential (10)	
Ybbs				
Greimpersdorf	0.30	0.41	0.43	0.69
Krenstetten	0.77	0.46	0.55	0.39
Opponitz	0.01	0.72	0.50	0.40
Wulka:				
Schuetzen	0.19	0.23	0.19	0.21
Walbersdorf	0.18	0.17	0.18	0.16
Wulkaprodersdorf	0.18	0.22	0.18	0.16
Trausdorf	0.17	0.16	0.14	0.20
Oslip	0.23	0.20	0.19	0.08
Nodbach	0.13	0.09	0.10	0.09

Table 6 gives the values for the calculated sediment yield at different stations obtained after including the different types of SDR for the Ybbs and Wulka basin. A comparison of calculated versus measured loads at the three stations in the Ybbs watershed and the six stations in the Wulka watershed where a detailed monitoring programme had taken place reveals good results for the simulations in Wulka. With all three SDR equations sediment yield in the river Wulka could be well simulated with the exception of the station Oslip, where problems in calculation of sediment yield had already been appeared in former simulations (Deliverable 2.1.). However the difference between measured and calculated sediment yield decreased compared to former model approaches, where routing processes were included.

Due to high geomorphologic, climatic and landuse pattern differences within the Ybbs catchment it is difficult to reflect the sediment yield in the river. Calculated sediment yields underestimated the amounts of sediment at the watershed outlet Greimpersdorf, although the stations upstream overestimated the situation. This may be explained by the fact, that sediment yields were calculated on basis of runoff and the flow rate at Greimpersdorf is very high compared to the measured sediment yield.

5.1.2 USLE

Table 7 gives the basic properties of the different subcatchments, that have been used for the calculation of sediment load. Total flow and direct flow rates were taken from Deliverable D1.1 (Water Balance), where total flow has been measured and direct flow has been calculated using the Difga2000 model. Sediment load has been taken from Deliverable D1.3 (Loading calculations). Slope length has been derived using equation 7). Calculated soil loss is the results of the USLE application as described in section 3.

Table 7: Basic properties of the different subcatchments used for the calculation of sediment delivery

Ybbs	Size (km^2)	Total flow (mm/a)	Direct flow (mm/a)	Measured sediment load ($kg/m^2/a$)	Measured mean sediment concentration ($g/l/m^2/a$)	Pot. Slope length (km)	Calculated soil loss ($kg/m^2/a$)
Greimpersdorf	1117	850	243	0.070	0.08	1.03	0.24
Krenstetten	159	443	163	0.040	0.09	1.04	0.62
Opponitz	504	1203	356	0.040	0.03	1.01	0.10
Wulka							
Schuetzen	391	87	15	0.021	0.24	1.14	0.22
Walbersdorf	76	103	18	0.016	0.16	1.40	0.23
Wulkaprodersdorf	214	74	15	0.016	0.22	1.25	0.26
Trausdorf	228	90	18	0.020	0.22	1.20	0.22
Oslip	65	70	24	0.008	0.12	1.21	0.22
Nodbach	47	71	18	0.009	0.13	0.69	0.24

The relationship between calculated soil loss rates and measured sediment loads is very weak (Figure 13). Identically to the procedures used for the calculation of the sediment delivery ratio for the MMF model we therefore included water flow into the considerations and based our relationships on sediment concentrations (load/flow) in the surface runoff. Figure 14 and Figure 15give the relationships between measured and calculated sediment concentrations. In contrast to the MMF model, inclusion of the potential slope length did not improve these relationships. Therefore a sediment delivery ratio only using surface runoff as characteristic parameter for the subbasins were developed. Based on the delivery equations obtained for Figure 14and Figure 15mean sediment concentrations and subsequently annual loads could be calculated.

Figure 13: Relationship between erosion rates calculated with the USLE and measured sediment loads for the different subwatersheds of the river Ybbs and Wulka

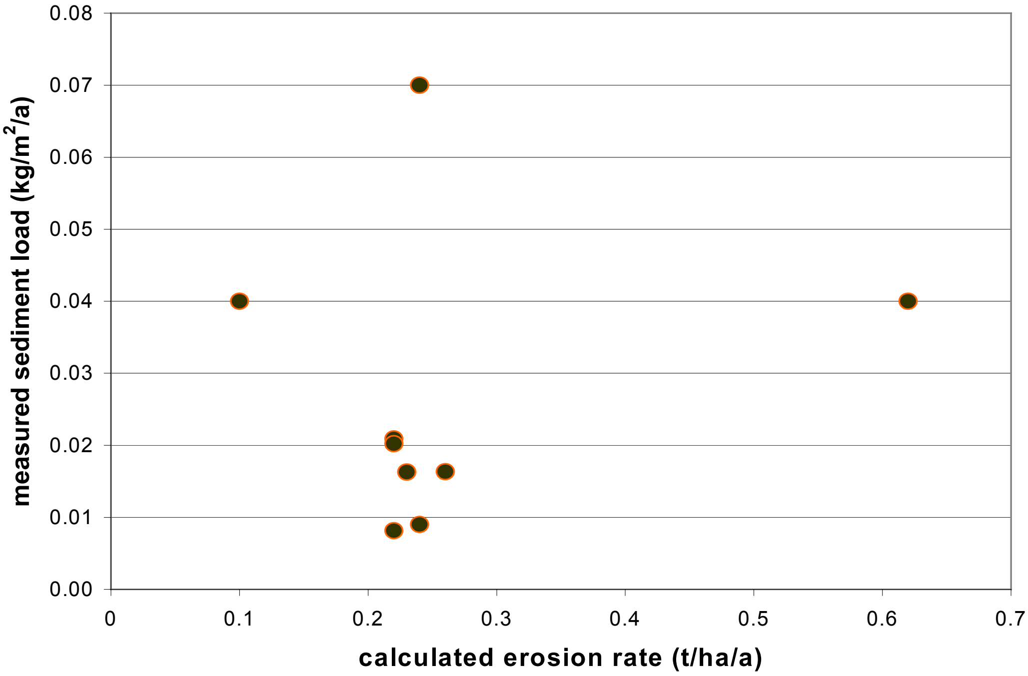


Figure 14: Sediment delivery function to calculate mean sediment concentration based on total flow

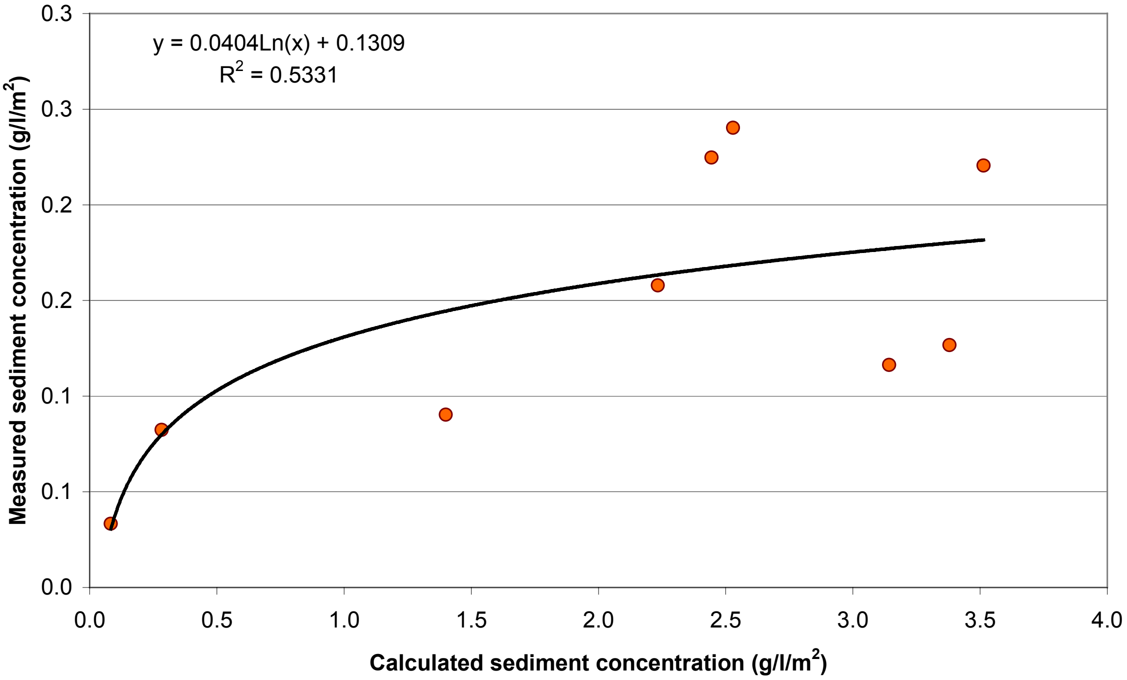
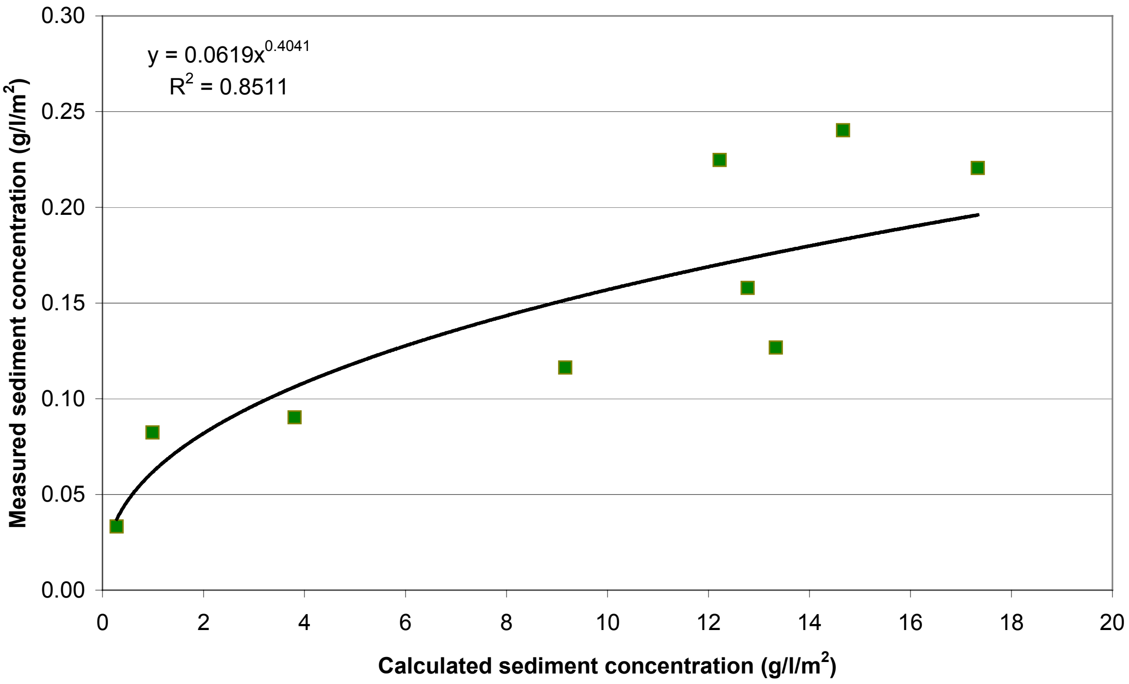


Figure 15: Sediment delivery function to calculate mean sediment concentration based on direct flow

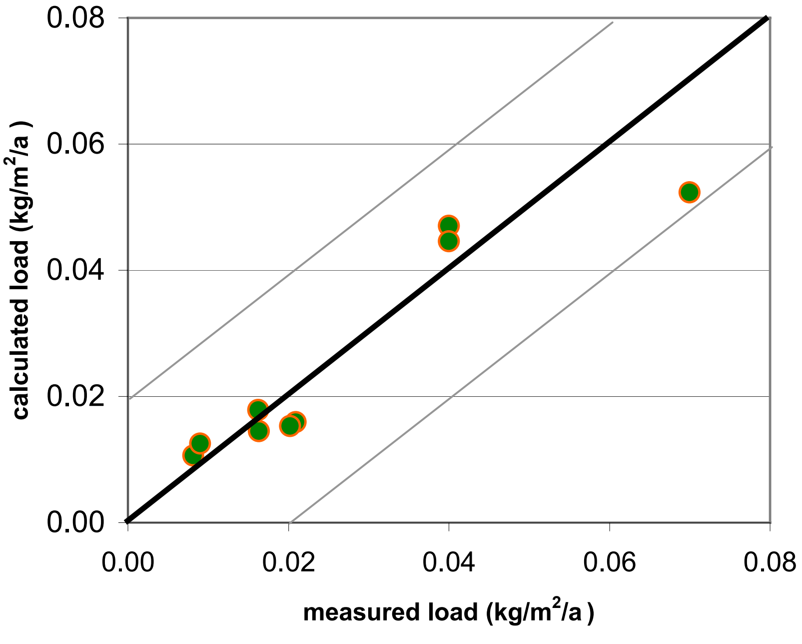


Calculated loads are given in Table 8. From Figure 14, Figure 15 and Table 8 it can be deduced, that the use of direct flow rates increases the accuracy of the load calculation. The fit between calculated and measured loads for the direct flow sediment delivery function is displayed in Figure 16.

Table 8: Calculated mean sediment concentrations (before application of the sediment delivery function) based on total flow and direct flow, and calculated sediment loads using the sediment delivery functions of Figure 14 and Figure 15.

	Calculated mean sediment concentration		**Calculated sediment load**	
	Based on total flow ($g/l/m^2/a$)	Based on direct flow ($g/l/m^2/a$)	Based on total flowFigure 14 ($kg/m^2/a$)	Based on direct flowFigure 15 ($kg/m^2/a$)
Greimpersdorf	0.28	0.99	0.07	0.05
Krenstetten	1.40	3.80	0.06	0.05
Opponitz	0.08	0.28	0.04	0.04
Schuetzen	2.53	14.67	0.01	0.02
Walbersdorf	2.23	12.78	0.02	0.02
Wulkaprodersdorf	3.51	17.33	0.01	0.01
Trausdorf	2.44	12.22	0.01	0.02
Oslip	3.14	9.17	0.01	0.01
Nodbach	3.38	13.33	0.01	0.01

Figure 16: Relationship between calculated and measured sediment loads for the different subcatchments of the river Ybbs and Wulka (for comparison: 1:1 line and 25% deviation)



5.2 SIMULATED PHOSPHORUS LOADS

5.2.1 MMF

For calculation of the amount of phosphorus loads transported out of the subwatersheds by soil erosion the phosphorus content of soil is needed. Here, the same data base as employed in Deliverable 2.1. was used.

Due to the fact that routing processes were excluded aerial weighed means of the soil phosphorus content were calculated for the different subwatersheds.

The change in model structure made it necessary to develop new values for the enrichment ratios. Similarly to the comments for the calculation of SDRs, the enrichment ratio for phosphorus conceptually contains all the influences that may occur along the pathway of phosphorus from the soil to the river sediment and even the uncertainty of phosphorus contents of the soils in the watersheds.

A linear regression (11) between sediment yield and phosphor load was used to characterise the relationship of phosphorus and sediment, to paraphrase an equation for the enrichment ratio of phosphor.

$$ER = 1.458 * Sed_{conc} + 1.612 \qquad (r^2 = 0.51, n = 8) \qquad (11)$$

Wherein ER = enrichment ratio for P

Sed_{conc} = Sediment concentration in the surface runoff ($kg/l/m^2$)

Obtained enrichment ratios for the different subcatchments and measured and calculated phosphorous loads are displayed in Table 6. The calculation of the P loads is based on the sediment yields calculated using equation (10).

Analyses of the individual gauging stations show that subwatersheds of the Wulka River in general predicted better P loads compared to the Ybbs river catchment (Table 9). This reflects the situation of predicted sediment delivery in the rivers. Whereas sediments at the outlets of the subcatchments Krenstetten and Opponitz were overestimated, the sediment yield and phosphorus load at the main outlet Greimpersdorf was too small. In conformity to a higher P enrichment in the eroded sediments, the undercharged P loads were higher compared to the differences in measured and calculated sediment yields. The enrichment ratios in the river Ybbs was lower compared to those of the Wulka river.

In the Wulka catchment the P load tended to be underestimated. The exact prediction of the P load for Oslip is surprising, due to the fact that in all prior simulations the models overestimated the loads. However, the small enrichment ratio led to correct loading calculations. In reality though, the very small sediment amounts of the river Oslip have a very high enrichment of phosphorus. In fact, the model error leads to the result, that for station Oslip, measured and predicted P loads are equal (correct results for the wrong reason).

Table 9: Measured and calculated Phosphor loads and ascertained enrichment ratios at different subwatersheds of the river Ybbs and Wulka (in kg/ha/a)

	Measured P load kg/ha/a	**Simulated P load kg/ha/a**	**Enrichment ratio**
Ybbs			
Greimpersdorf	0.74	0.46	1.9
Krenstetten	0.47	0.77	2.2
Opponitz	0.29	0.44	1.8
Wulka			
Schuetzen	0.46	0.41	3.4
Walbersdorf	0.4	0.31	3.0
Wulkaprodersdorf	0.26	0.41	3.4
Trausdorf	0.34	0.24	2.7
Oslip	0.33	0.33	2.7
Nodbach	0.16	0.15	2.4

Figure 17 indicates that for both the measured and the simulated phosphorus loads a (more or less) linear relationship between sediment yield in the river and the respective phosphorus loads exists and Figure 18 gives a graphical impression on the fit between simulated and measured phosphorus loads. It appears that, though sediment load was simulated quite well, phosphorus loads exhibit a greater degree of variation.

Figure 17: Measured and calculated sediment yield (exponential regression) against measured and simulated Phosphor loads kg/ha/a

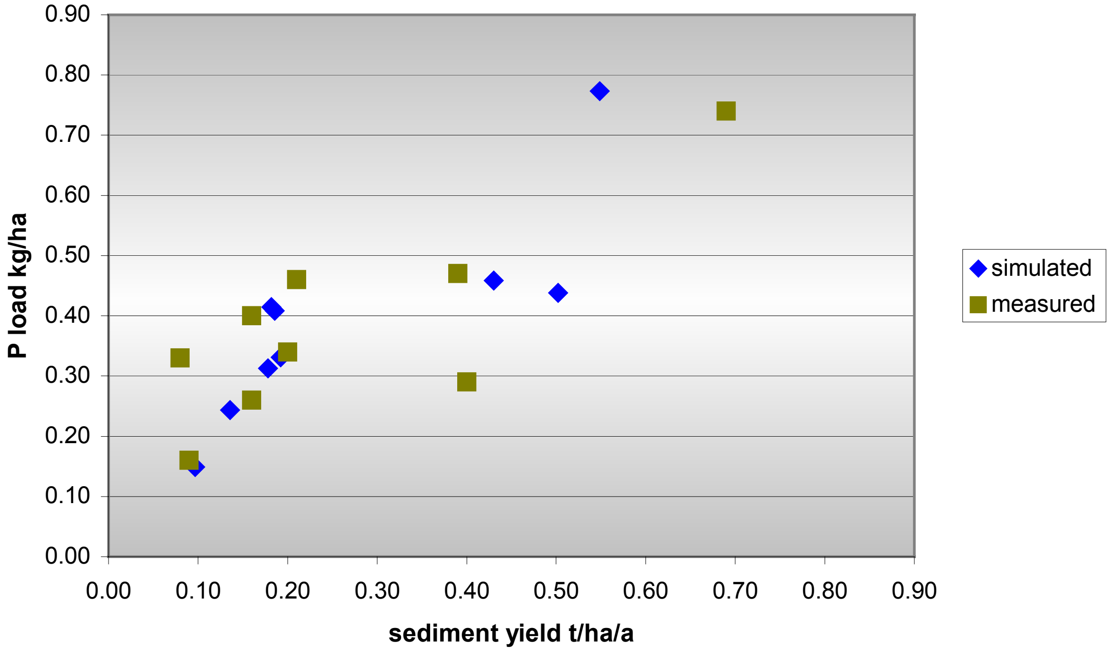
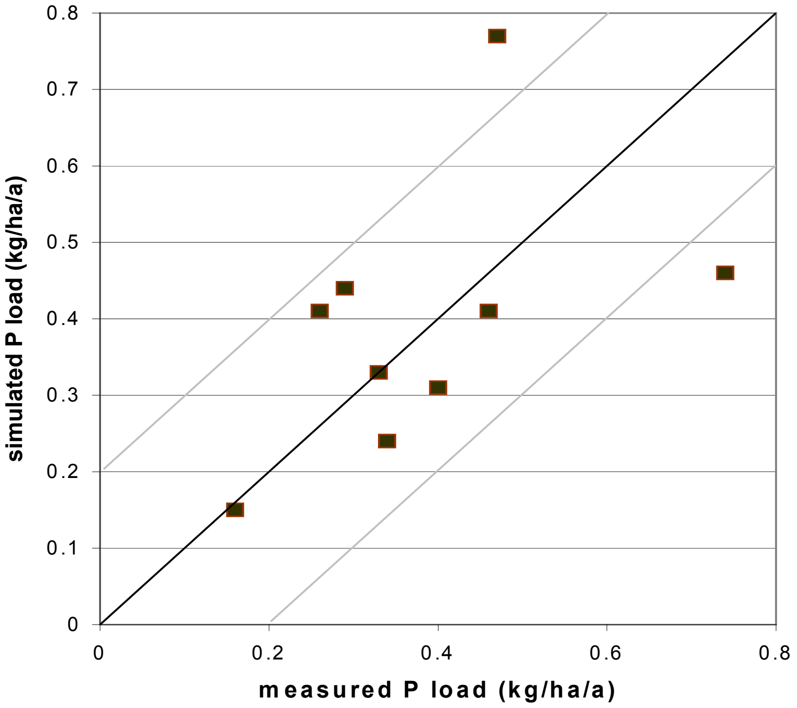


Figure 18: Relationship between calculated and measured phosphorus loads for the different subcatchments of the river Ybbs and Wulka – MMF approach



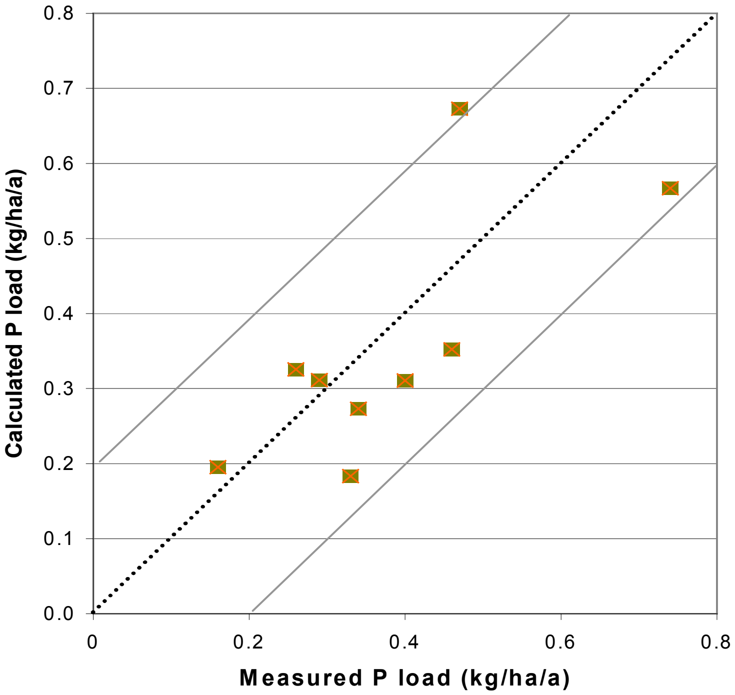
5.2.2 USLE

Phosphorus load was calculated following the same methodology as used for the MMF model. Soil phosphorus contents of the different grid cells in the various subcatchments were averaged and are given in Table 10 together with the results of the P load calculations. P contents behave according to the different landuse intensities with low values for station Opponitz and high values for stations with high amounts of agriculturally used land. Such as Wulkaprodersdorf. Figure 19 gives the graphical realisation of the fit between measured and simulated phosphorus loads using the USLE approach. As the approach for calculation of P loads was identical for both models, the differences in P loads are only due to the preliminary calculation of sediment loads. Especially for the station Greimpersdorf this leads to a considerable error. In addition, the way of calculating enrichment ratios introduces more variation in the results. Different values for soil P contents (which are one basis for the enrichment equation) would lead to other parameters for the enrichment equation or even to other relationships. Here, better information and/or better procedures to derive P enrichment are certainly needed.

Table 10: Averaged soil P contents of the soils in the different subcatchments of the river Ybbs and Wulka and calculated phosphorus loads using the procedures described in section 5.2.1.

Ybbs	Soil P (mg/kg)	Calculated P load (kg/ha/a)
Greimpersdorf	570	0.57
Krenstetten	650	0.67
Opponitz	388	0.31
Wulka		
Schuetzen	650	0.35
Walbersdorf	580	0.31
Wulkaprodersdorf	660	0.33
Trausdorf	660	0.27
Oslip	640	0.18
Nodbach	650	0.20

Figure 19: Relationship between calculated and measured phosphorus loads for the different subcatchments of the river Ybbs and Wulka – USLE approach



5.3 SIMULATED NITROGEN LOADS

In addition to the calculation of phosphorus loads, nitrogen loads associated with sediment delivery have been calculated using the MMF model. Whereas in inland rivers, nitrogen loading is usually not a problem for eutrophication (because phosphorus is the limiting element for biomass production), nitrogen frequently becomes the limiting element of biomass production in coastal areas. However, the main pathway of delivery is via dissolved forms and nitrogen which is attached to soil particles is usually negligible. To test this assumption and prove the possibilities of loading calculations with models we calculated nitrogen loads which are associated with sediment transport for the different subcatchments of the river Ybbs and Wulka. The same SDR as used for calculation of P loads was employed. Aerial weighted nitrogen contents of soil were used (Table 13, Table 12). Data for this analysis were taken from Austrian soil state survey.

Table 11: Areal weighted nitrogen content for different landuse classes in the watersheds of the river Ybbs

	Total Nitrogen (%)			
Landuse	n	Mean	Median	Std.dev
Forest	924	0.41	0.18	0.47
Pasture	869	0.27	0.24	0.2
Arable	2266	0.14	0.13	0.08

Table 12: Areal weighted nitrogen content for different landuse classes in the watersheds of the river Wulka

	Total Nitrogen (%)			
Landuse	n	Mean	Median	Std.dev
Forest	77	0.32	0.11	0.41
Pasture	61	0.18	0.14	0.12
Arable	406	0.12	0.12	0.07

As no measured nitrogen loads for both rivers are available at the moment (planned for D1.3.) no actual comparison is possible, but even without this comparison it becomes clear, that sediment bound nitrogen loads are relatively small Table 13.

Table 13: Calculated nitrogen loads (sediment bound nitrogen) for different subwatersheds of the river Ybbs and Wulka in kg/ha/a

	N load
Ybbs	
Greimpersdorf	1.25
Krenstetten	1.61
Opponitz	1.58
Wulka	
Schuetzen	0.67
Walbersdorf	0.56
Wulkaprodersdorf	0.67
Trausdorf	0.39
Oslip	0.54
Nodbach	0.24

6 EFFECT OF GRID SIZE ON SOIL EROSION ESTIMATES

To test the influence of changes in grid size on the results of soil erosion estimates, a further step was to change size of the input grids and calculate new estimates for soil erosion. Exactly the same calculations were done on basis of three different cell sizes (25 m, 400 m, 1000 m) of input maps. All input maps had upgraded to a bigger cell size using the nearest neighbour method, as best adapted statistical method for this usage (Tankagi, 1996). This was followed by corrections for slope according to the procedure described in 4.4. Soil erosion modelling was done using the MMF model only. Model results may also be compared to measured data at those locations, where monitoring had taken place. The exponential SDR developed with the data set on basis of a 25m grid and discussed in 5.1 was used for the calculation of the sediment yield at the three monitoring stations in the Ybbs and Wulka river catchments. (Table 14).

Table 14: Comparison of simulated and calculated sediment yield for three grid sizes at the three monitoring stations in the Ybbs river catchment (t/ha/a)

	Sediment yield (t/ha/a)			
	Measured	**Calculated**		
		25 m grid	**400 m grid**	**1000 m grid**
Ybbs				
Greimpersdorf	0.69	0.43	0.43	0.43
Krenstetten	0.39	0.55	0.55	0.55
Opponitz	0.40	0.50	0.51	0.51
Wulka				
Schuetzen	0.21	0.19	1.01	0.44
Walbersdorf	0.16	0.18	0.24	0.24
Wulkaprodersdorf	0.16	0.18	0.49	0.49
Trausdorf	0.2	0.14	0.29	0.29
Oslip	0.08	0.19	0.19	0.19
Nodbach	0.09	0.10	0.26	0.26

The difference in the slope size of 1° between a 25 m grid and a 1000 m grid affected the calculation of sediment yield. Especially forested areas, areas with high slopes, remain in equal sediment discharge. Flat areas (Wulka excluding Oslip) do have more problems and tend to increase soil erosion. Consequently very little changes in loads of phosphorus and nitrogen are to be expected in forested areas, whereas in arable land phosphorus and nitrogen was increased.

This comparison of calculated sediment yield with different cell sizes versus measured loads at the different gauging stations reveals the necessity of adopting SDR’s on the basis of a particular grid size implemented for soil erosion calculation.

7 LIST OF KEY PARAMETERS FOR ESTIMATION OF NUTRIENT FLOWS DUE TO EROSION

Results of all simulations have been presented in detail in previous chapters and deliverables. Conclusions of the previous work can also be drawn on key parameters for the estimation of sediment and nitrogen flows due to erosion and runoff for the Danube River. Data gaps of necessary input data had tried to be eliminated by various algorithms, however if not possible this is pointed out in previous chapters.

7.1 SOIL DATA

7.1.1 Physical soil properties

The spatial resolution of the soil map determines the accuracy of the results, because soil erodibility effects detachment processes a lot. Therefore the scale of the European soil map (ESB, 1998) is too large and it is not suitable for an application and modelling of soil erosion within the case study watersheds. However for simulation of sediment delivery in the entire Danube River catchment the European soil map may be sufficient but this was not validated in the previous work.

To calculate soil erosion especially soil texture is important, because texture is the main factor influencing erodibility (see also results on the calculation of K factors in Deliverable 2.1). All soil parameters in the MMF model (soil detachability, bulk density, field capacity, cohesion, effective hydraulic depth) connected to soil can also be generated in some way out of soil texture. For any model application therefore texture has to be identified as good as possible in spatial and quality resolution. For our work, the Austrian soil mapping system at a scale of 1:25 000 proved to be sufficient. Nationally available data in other countries may do as well (see the Hungarian case study in Deliverable D2.1). However, a unified approach to obtain the necessary input data would be highly desirable. For sediment and nutrient estimation in the Danubs River the data of the European Soil Thematic Strategy map is to coarse, more detailed information would be desirable.

7.1.2 Chemical soil properties

Amount of total phosphorus in the topsoil (mg/100g)

To calculate phosphorus loads the total amount of total phosphor for the topsoil is needed. The application of the simulation models in Austria indicated the mayor problem in the availability of phosphor data. As the model uses the amount of total phosphor this information is mostly not accessible. In the national soil databasis contains different P loads except total P. That might well be so in all other European Counties. Therefore we developed a methodology (D2.1) to calculate total P out of CAL P.

Amount of total nitrogen in the topsoil (mg/100g)

Availability of data on total nitrogen contents in topsoil is usually better due to the high importance of nitrogen for plant growth. However, nitrogen loading due to soil erosion is relatively unimportant.

7.2 LANDUSE DATA

Due to the fact that landuse is one of the main factors which influence the distribution of elements in the landscape, the spatial resolution and the content of landuse information is highly important and in consequence specifies the spatial resolution of a model. The only information of landuse available on a European level is the CORINE dataset. In this project the methodology of collecting the landcover data was the same for all European countries. Therefore the maps can be used as basis for landcover. To improve the existing spatial and temporal resolution of landuse data for arable land, the CORINE data may be combined with agricultural surveys (as we did in our work on a municipality level). Class two of the CORINE classification scheme has to be divided into crop species with different influence on soil erosion at least into 4 groups (erosive plants, non erosive plants, vine and orchard and grassland). Having obtained the information about specific landuse, the necessary parameter values for the input data of MMF (land cover, ground cover, plant height, ratio of actual to potential evapotranspiration, C-factor, rainfall interception) and USLE (C-factor) may be calculated using transfer functions.

7.3 CLIMATE DATA

Precipitation represents the driving force of the water and energy circle and should be used with caution. For application of the MMF model monthly rainfall data are necessary. In our study, they have been taken from available gauging stations. For areas with rapid changes in climatic conditions (such as the Ybbs river catchment) the spatial resolution of climatic data certainly plays a much higher role in calculation of soil erosion but to give a recommendation on net density is difficult. A possibility to enter changes in precipitation due to changes in elevation (a precipitation-laps-factor) is given in Deliverable 1.1. In addition to monthly precipitation, mean rainfall amount per rainy day and a typical rainfall intensity are needed for MMF. For application of the USLE functions are available to relate mean rainfall amounts to rainfall erosivity.

7.4 HYDROLOGICAL DATA

7.4.1 Surface runoff (mm)

For using the sediment delivery concept developed within the framework of this deliverable concentration of sediments in the surface runoff are used. Therefore the amount of surface runoff in a particular watershed is needed. Different techniques exist to separate the different flow components (Deliverable D1.1) which may be used to estimate the amount of surface runoff out of the total river discharge. With regard to a quite dense system of river discharge measuring points in the Danube River this should not be a problem. The accuracy of the separation techniques is to be discussed elsewhere (see deliverable 1.1).

7.5 LANDFORM

7.5.1 Slope

To simulate soil erosion in a GIS, spatial information of landform and relief energy is necessary. The proposed algorithm to overcome errors that occur due to spatial inadequate accuracy is trying to handle the problem that for all adjacent states of the Danube River only a digital elevation model with grid resolution of 1000 m is available.

7.5.2 Potential slope length (m)

The potential slope length (Emmett, 1978) which is based on the drainage density of a watershed is used as a surrogate for the flow lengths of water within a landscape in the calculation of sediment delivery ratios. As potential slope length is the basis for sediment yield calculation the accuracy of river length and the watershed size has to be high.

8 EVALUATION OF DATA GAPS FOR ESTIMATION OF NUTRIENT FLOWS DUE TO EROSION

8.1 SOIL DATA

8.1.1 Physical and chemical soil properties

Only available data on soil texture for entire Europe is the European Soil Map. This map proposes a unique methodology for all European States for collecting the same basic data on soil characteristics in the scale of 1 :1000000. However this map might be to coarse. Due to the fact the final competition on the Soil Geographical Database of Europe 1 :250000 (Dudal, R. et al., 1993) is still not foreseeable, more detailed information on texture is necessary on a national level. Examples of data available at national scale (Austria, Hungary) show, that type and amount of information is much better compared to the European soil map. It is however an enormous task to compile this information. In consequence chemical information of soil types are not available on a appropriate scale too. To give an example a lot of soil chemical data are available for a grid of 4 km x 4 km covering the whole Austrian territory with the exception of total P. Various algorithms has been developed to obtain the needed values from other sources of information, but this is not really satisfactory. In addition some information on the dissolved fraction of phosphorus in soil is necessary. Various monitoring points all over Europe exist, but the measuring procedures and consequently the measured phosphorus values differ. It would be desirable to bring these measurements to an unique level. However, as the different procedures to obtain plant available (as a surrogate for dissolved) phosphorus is linked to national tests for optimisation of fertilisation, no such harmonisation is to be expected (see results of COST action 832). Therefore a methodology to link the different analytical methods to amounts of dissolved phosphorus in surface runoff has to be developed.

8.2 LANDUSE DATA

As already mentioned in the previous chapter the only spatial information of landuse available on a European level is the CORINE dataset. But the resolution of this data set as well as the big uncertainty included in the maps because of map errors and a improper classification of landuse, CORINE data alone are not suitable for the estimation of soil erosion as proposed in our approach. Furthermore a serious drawback is that arable land is not portioned sufficiently in different landuse management groups, thus more information on landuse is necessary. To overcome some of the problems a combination of the CORINE dataset and national agricultural surveys is proposed. A similar approach has already been done for Germany (Erhard et al., 2004). Agricultural surveys or statistics are available in all Danube countries. However the problem in using them is that surveys in the different European countries are based on different principles, of spatial resolutions and accuracy. Table 15 tries to give an overview about the available Agricultural Surveys in the different Danube states, their spatial resolution and their applicability. In order to use them they have to be brought on a unique level. Therefore we recommend to develop a project in which an unique methodology for agricultural surveys may be generated. Nevertheless there is still an important gap of information due to grassland. In

CORINE data the definition and the delimitation of grassland is rough.. In the methodology presented in this deliverable various insecure landuse classes are subsumed, therefore cultivation may also be simulated on areas were only meadows are located, e.g. steep slopes. One possibility to obtain identical coverage information would be the usage of remote sensing technologies, probably combined with other ground based information. However, at present there is no such known activity.

Table 15: Availability of Agricultural Surveys in the Danube Countries

Country	**Agricultural Survey**	**Resolution**	**Applicability**
Albania	FAO statistics	-	-
Austria	Austrian Agricultural-statistical Survey, 1999	municipality	+
Bosnia Herzegovina	Yugoslav Daily Survey 1998	~	-
Bulgaria	Agricultural Census 2003	~	~
Croatia	Agricultural Census 2003 Yugoslav Daily Survey 1998	municipality	-
Czech Republic	Agricultural Census, 2000	region	+
Germany	Land Survey, StBA 1997	municipality	+
Hungary	Agricultural Census, 2000; Fruit tree and vineyard basic survey, 2001	municipality	+
Italy			
Yugoslavia	Yugoslav Daily Survey 1998	~	-
Macedonia	FAO statistics	-	-
Moldavia	no	-	-
Poland	Agricultural Census 2002	+	-
Romania	General Agricultural Census, 2003	~	~
Serbia	Yugoslav Daily Survey 1998	~	-
Slovak Republic	Farm structure Census, 2002; Fruit and wine statistic, 2002	municipality	+
Slovenia	Agricultural Census, 2000	~	-
Switzerland	Agrarstatistik 2001		
Ukraine	Agricultural Survey, 2003	~	+

+ quality of information is very good, for either the classification of different crop groups and the spatial resolution at least at municipality level
- spatial resolution is too small, data availability only per region or classification of crop groups is too small
~ provided information on the survey is not clear

8.3 CLIMATE DATA

All over Europe there is quite a dense net of climatic stations, therefore the applicability of this data to a sediment estimation of the Danube Basin in general is deemed good. However additional measurements on rainfall intensity is more loose, but still in an accurate resolution for applicability to Danube Basin calculations for soil erosion. The main problem again is to unify the data obtained at national level for a European wide application.

8.4 HYDROLOGICAL DATA

Hydrological data are sufficiently available in the Danube basin. There is quite a dense net of gauging station measuring water discharge of the Danube River and its tributaries. At 94 stations alongside the Danube River water discharge is measured. However it would be desirable for calibration propose to have additional data on sediment yield, phosphorus and nitrate loads in the Danube River at the tributary outlets. At present flow proportional sediment and nutrient data, which are essential for estimation of total loads are rare. The Austrian water quality ordinance (WGEV, BGBl. Nr. 338/1991) for instance requires water quality sampling at two months intervals. This is not sufficient to catch amounts of sediment and phosphorus which mainly leave the watersheds during high flow events.

8.5 LANDFORM

At the time of writing this deliverable, the only digital elevation model available at European scale was with a spatial resolution of 1 000 m. Without correcting for slope, application of this grid leads to huge differences in the evaluation of actual soil erosion risk. Using the proposed methodology to correct for these differences is making the best of available data. However, still considerable errors apply. The more detailed a DEM the better the results of the models, therefore a better resolution on a European DEM would be highly desirable to reduce errors associated with slope estimation. For an additional including of routing processes for water or sediments, a spatial resolution of the digital elevation model of at least 50 m is required. Results of model application have shown, however, that this is not a prerequisite to obtain good model results. Therefore, smaller resolutions of DEM's may be sufficient as well.

For calculation of the potential slope length per subbasin a precise length of the river and the size of the watershed, wherein the sediment yield is calculated, is needed. To define the size of the watershed a digital elevation model is necessary. As already discussed above this is only available at a coarse scale of 1 :1000000 and therefore not suitable for watershed calculations. National DEM's usually are available at finer scales but as river catchments do not match with country borders there is a big problem in connecting DEM's of different countries with different spatial resolution (unification of available data).

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10 APPENDIX:

Table 16: Calculated parameters a, b and c of a quadratic regression for the different subbasins of the Ybbs river catchment

subbasin	a	b	c
1	4.962	-0.016	2.10E-05
2	8.443	-0.022	2.80E-05
3	5.454	-0.014	1.30E-05
4	5.988	-0.014	1.40E-05
5	3.048	-0.011	1.40E-05
6	3.498	-0.012	1.50E-05
7	4.443	-0.009	8.00E-06
8	8.486	-0.020	2.00E-05
9	4.530	-0.012	1.20E-05
10	1.416	-0.005	6.70E-06
11	3.137	-0.007	5.20E-06
12	5.606	-0.017	2.20E-05
13	3.637	-0.011	1.30E-05
14	12.414	-0.027	2.60E-05
15	2.355	-0.005	6.10E-06
16	2.610	-0.006	8.00E-06
17	10.018	-0.023	2.10E-05
18	7.822	-0.021	2.30E-05
19	5.107	-0.015	1.20E-05
20	2.447	-0.006	7.20E-06
21	17.087	-0.032	3.10E-05
22	16.566	-0.034	2.90E-05
23	16.406	-0.036	3.40E-05
24	14.690	-0.033	3.00E-05
25	15.420	-0.036	3.80E-05
27	16.519	-0.032	2.60E-05
28	17.982	-0.041	4.50E-05
29	20.871	-0.044	4.40E-05
30	25.700	-0.059	6.00E-05
31	17.015	-0.031	2.40E-05
32	23.684	-0.050	4.40E-05
33	22.926	-0.052	5.50E-05
34	19.310	-0.042	3.80E-05
35	24.909	-0.058	5.80E-05
36	21.647	-0.058	6.60E-05
37	26.204	-0.065	8.00E-05
38	25.977	-0.043	4.00E-05
39	22.065	-0.072	9.20E-05
40	19.697	-0.050	5.90E-05
42	15.604	-0.022	4.00E-06
43	20.013	-0.035	3.20E-05
44	26.174	-0.032	1.50E-05
45	20.606	-0.041	3.40E-05
46	25.786	-0.052	4.70E-05
47	30.449	-0.050	3.90E-05
49	27.375	-0.037	2.40E-05
50	27.991	-0.028	-5.00E-06
51	23.349	-0.045	3.90E-05
52	20.835	-0.017	4.10E-06
53	24.081	-0.053	4.80E-05
54	20.071	-0.045	4.40E-05
55	22.654	-0.034	3.30E-05
56	22.363	-0.038	2.80E-05
57	24.153	-0.037	3.70E-05
58	19.388	-0.044	5.40E-05
59	25.335	-0.050	4.90E-05
60	26.436	-0.043	3.50E-05
61	29.114	-0.053	6.20E-05
62	32.323	-0.060	6.30E-05
63	31.188	-0.064	7.10E-05
64	32.261	-0.068	7.80E-05
65	21.752	-0.029	2.30E-05
66	20.863	-0.034	2.80E-05
67	27.653	-0.025	9.20E-06
68	21.265	-0.014	3.60E-06
69	21.716	-0.044	3.90E-05
70	20.178	-0.061	9.10E-05
71	17.588	-0.033	3.40E-05
72	2.726	0.001	-1.00E-05
73	4.614	-0.017	2.40E-05