Sediment yield modelling in transboundary river basins: Application to the Nestos River Basin

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1. Introduction

The aim of this paper is to estimate soil erosion rates in Nestos basin as well as the mean annual sediment yield, using empirical models such as the Universal Soil Loss Equation (USLE) for the soil erosion estimation and sediment discharge rating curves for the sediment yield estimation. Three major hydroelectric projects in cascade had been built and are in operation in the Greek part of the catchment. The aim of the research presented here is to assess the expected sediment delivery of the catchment upstream of the first hydroelectric reservoir (the Thessauros Reservoir). This has been carried out by implementing for the whole catchment the Universal Soil Loss Equation (USLE) in a GIS environment for determining the mean annual soil erosion in conjunction with a suspended measurement program (114 measurements in total) taken between 1965 and 1983 at the site of the reservoir for the associated mean annual sediment discharge and also mean daily discharges are measured constantly.

Nestos/Mesta Basin – Basic characteristics

The total area of its catchment is around 6200 km^2 of which the 3800 km^2 belongs to Bulgaria and the mean annual precipitation is about 680 mm. The catchment may be divided into three elevation zones according to its main characteristics: (a) The mountainous zone (600-3000 m) which is mostly formed by rocky geological formations, (b) the central zone (200-600 m) where the biota appears to be individual, and (c) the flat zone (0-200 m) which is mostly formed by deltaic deposits.

2. Soil Erosion estimation

The spatial distribution of soil erosion in Nestos basin was derived using the Universal Soil Loss Equation (USLE) as part of a hydrological model named SEAGIS (v.1.0) which is produced by Danish Hydraulic Institute (DHI). The SEAGIS model computes soil loss for every grid cell of a region, such as Nestos basin.

The USLE formulation is given by the simple equation:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P \qquad (1)$$

where, A, is the mean annual soil loss [t/ha], R is the rainfall erosivity factor [MJ mm ha^{-1} h^{-1}year^{-1}], K is the soil erodibility factor [t h MJ^{-1} mm^{-1}], LS is the topographic factor, C is the land use factor and P is the support practice factor against erosion.

The R-factor was computed for every grid cell of Nestos basin using the equation (Van der Kniff et al, 2000): $R = \alpha P$ (2)

where α = 1.3 and P is the mean annual rainfall (mm). The spatial distribution of mean annual rainfall was determined by applying Kriging interpolation method on the data of mean annual rainfall from 35 meteorological stations that have been located in the greater Nestos basin.

In order to determine the K-factor, the geological formations were grouped in five soil categories according to parent material. Values of K factor were assigned in every soil category (Van der Kniff et al, 2000) and finally were computed for every grid cell. The five soil categories and the corresponding K factor are shown in Table 1.

The LS factor was determined in SEAGIS model by using spatial distribution of a detailed Digital

Elevation Model (DEM). The *C* factor was assigned in every land use category and finally was computed for every grid cell. Finally all the factors were imported in GIS and soil loss results were produced by simply multiplying the five different raster datasets. The spatially distributed mean annual soil loss is 1078 t/km^2/year. The spatial distribution of all the factors as well as the soil loss results in Nestos basin, is shown in Figure 1.

Table 1: *Soil categories and K-factor*

Soil category	K-factor
18%<clay<35% and sand >15%, or clay<18% and 15%<sand<65%	0.0315
clay>60%	0.02
35%<clay<60%	0.339
clay<35% and sand <15%	0.438
clay<18% and sand>65%	0.0115

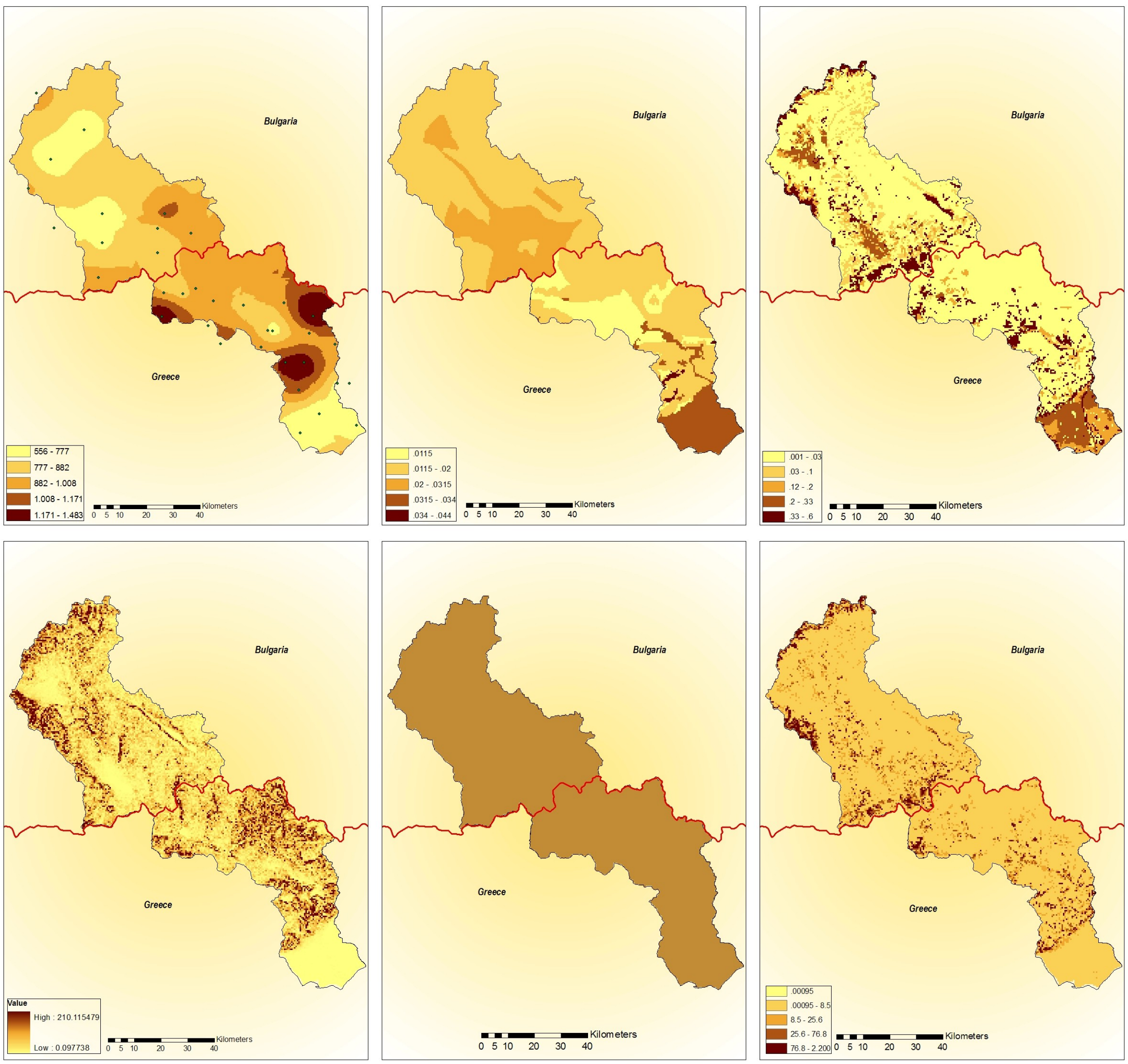

Figure 1: *Spatial distribution of USLE factors and soil loss results (from top left and clockwise R factor, K factor, C factor, LS factor, P factor and Soil erosion grid)*

3. Sediment Yield Estimation

Mean annual sediment yield was estimated by using 114 available simultaneous measurements of sediment and river discharge from *Temenos* hydrometric station (catchment area of 4950 km^2), where a dam have been constructed and is being used for energy production.

The sediment discharge rating curve in a power form ($Q_s=aQ^b$) has been constructed using 6 alternative techniques, namely (a) the linear regression of the log-transformed variables (river and sediment discharge), (b) the same as previously but with the Ferguson correction, (c) different ratings for the dry-wet season of the year, (d) ratings for the rising - falling limb of the runoff hydrograph, (e) the non-linear regression, and (f) the broken line interpolation (Figure 2) that uses different exponents for two discharge classes. It is shown that the mean annual sediment yield, except from the linear regression of the log-transformed variables, is almost equal for the rest of the different rating curves and varies from 178.5 t/km^2 to 203.4 t/km^2, where the highest value results from the broken line interpolation method. Accordingly the sediment delivery ratios vary slightly from 17% to 19% of the gross erosion.

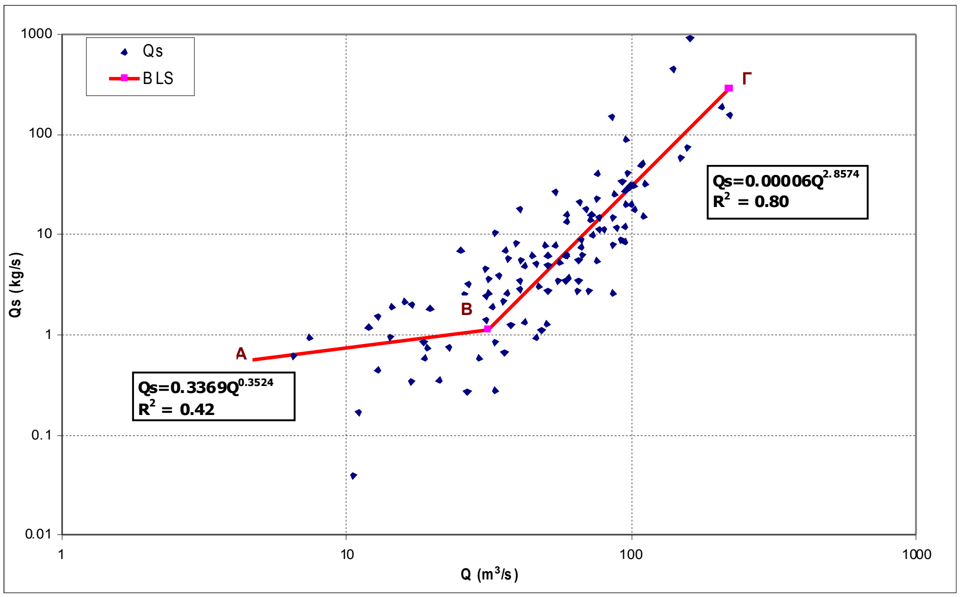

Figure 1: *The broken line interpolation method as a sediment rating curve formulation*

4. Conclusions

The Broken Line Smoothing has been proved to be the more representative of all methods mainly because the prevailing fluvial form in upstream Greek rivers is the gravel bed form. In such a fluvial form, there is a distinct threshold discharge for sediment motion, which is attributed to the development of the well – known armour layer. Below this threshold there is no exchange of the suspended sediment with the river bed. Once the surface coarse material, armour layer fully breaks up beyond the threshold discharge and exposes a larger range of particle sizes underneath, the transport rate significantly increases. Therefore the mean annual sediment yield of Nestos River basin is equal to 203.4 t/km^2 and the sediment delivery ratio equal to 19% of the gross erosion.

References

Kniff, J. M.van Der, Jones, R.J.A., Montanarella, L., Soil risk Assessment in Italy. European Commission, European Soil Bureau. 2000.