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EROSION ASSESSMENT MODELING USING THE SATEEC GIS MODEL ON THE PRISLOP CATCHMENT

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Key words: erosion, soil, GIS, SATEEC, Prislop, catchment.

Abstract. The Sediment Assessment Tool for Effective Erosion Control (SATEEC) acts as an extension for ArcView GIS 3, with easy to use commands. The erosion assessment is divided into two modules that consist of Universal Soil Loss Equation (USLE) for sheet/rill erosion and the nLS/USPED modeling for gully head erosion. The SATEEC erosion modules can be successfully implemented for areas where sheet, rill and gully erosion occurs, such as the Prislop Catchment. The enhanced SATEEC system does not require experienced GIS users to operate the system therefore it is suitable for local authorities and/or students not so familiar with erosion modeling.

Introduction

Accelerated soil erosion is a serious concern worldwide, and it is difficult to assess its economic and environmental impacts accurately because of its extent, magnitude, rate, and complex processes associated with it. Many human-induced activities, such as mining, construction, and agricultural activities, disturb land surfaces, resulting in accelerated erosion.

To estimate soil erosion and to develop optimal soil erosion management plans, many erosion models, such as Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995), Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998), and European Soil Erosion Model (EUROSEM) (Morgan et al., 1998), have been developed and used over the years.

The Sediment Assessment Tool for Effective Erosion Control (SATEEC) system was developed in 2003 (Lim et al., 2003) and has been upgraded with various enhanced modules incorporated into the system (Lim et al., 2005; Park et

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al., 2010). The system requiring only USLE inputs was developed with the philosophy of “very limited dataset for reasonable soil erosion estimation accuracy with commonly available GIS interface” and “easy-to-use”.

1. Study site

The Prislop Valley Catchment is located north of the Somesan Plateau (fig. 1). Over 60% of its surface is characterized by steep slopes covered with forest, while less than 40% is given by gentle slopes covered by arable land, orchards and meadows.

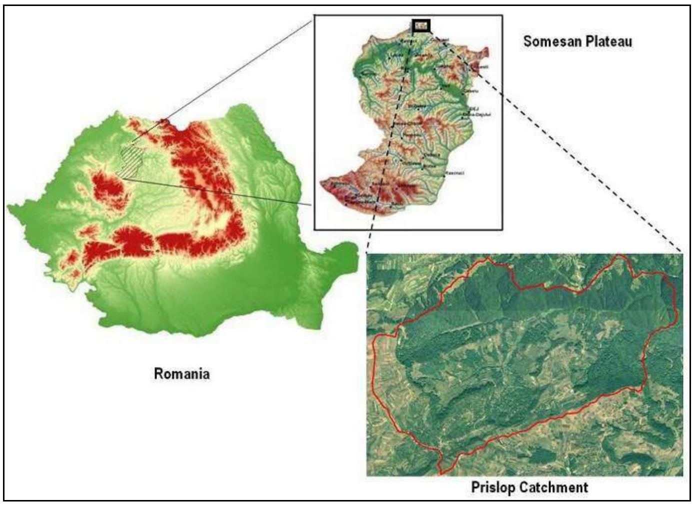

Fig. 1 Location of the Prislop Valley Catchment

The catchment has an area of 15 square kilometers, with altitudes varying between 240 m and 608 m.

The GIS database was made by digitizing the 1:5.000 scale topographic maps, the 1:5.000 aerial photographs, and by collecting and analyzing 14 soil samples.

All the resulting maps have a 10 meter resolution, for a high accuracy modeling.

2. USLE input data & maps

The USLE equation factors are generated by the digital elevation model – (fig. 2) which gives the LS factor (fig. 3), the soil texture (Table 1) which gives the K factor (fig. 4), the land use map (Table 2) for C factor (fig. 5), the precipitation distribution map (R factor) and the erosion management practices map (P factor).

Because of its constancy, the R factor has a value of 100 MJ.mm/ha.hr.year, while the lack of erosion management practices gives the P factor a value of 1.

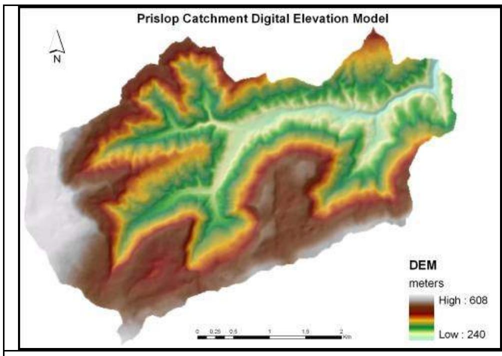

Fig. 2 The Digital Elevation Model

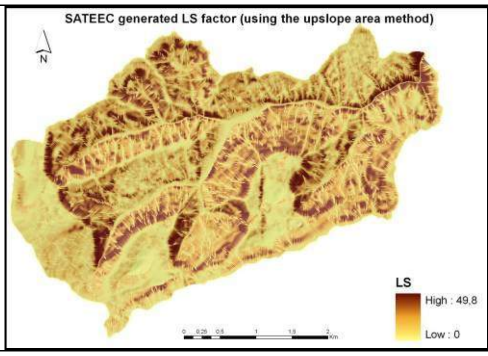

Fig. 3 The LS Factor

Table 1 – Soil texture

Soil texture	USLE K factor
Sand	0.02
Sandy loam	0.13
Silty clay	0.26
Silty clay loam	0.3
Loam	0.3

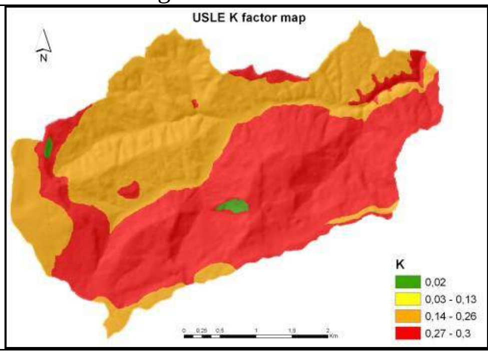

Fig. 4 The K factor

Table 2 – Land use

Land Use	USLE C factor
Urbanization	0
Bare rock	0.02
Pasture	0.02
Orchard	0.1
Forest	0.2
Bare ground	0.5
Agriculture	0.5

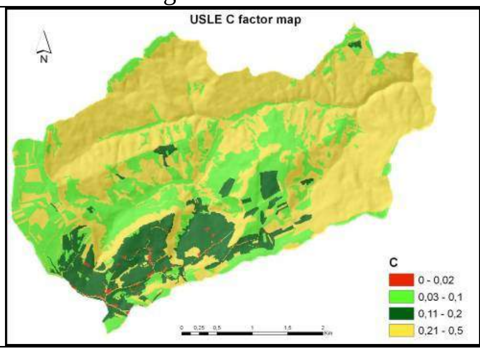

Fig. 5 The C factor

3. Running the SATEEC erosion modules

The SATEEC system acts as an extension for ArcView GIS 3, with easy to use commands. The two erosion modules consist of SATEEC_Soil Loss (fig. 6) and the nLS - Gully head detection (fig. 7). All the procedures are fully automated with Avenue, CGI, and database programming; thus the enhanced SATEEC system does not require experienced GIS users to operate the system.

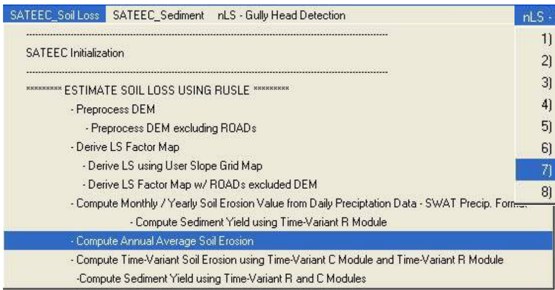

Fig. 7 nLS / Gully Head Detection

Fig. 6 SATEEC_Soil Loss

The SATEEC_Soil Loss generates the Universal Soil Loss Equation, with the following formula (1):

$$E = R * K * LS * C * P \quad (1)$$

E [*ton/(ha.year)*] is the average soil loss,
R [*MJ.mm/ha.hr.year*] is the rainfall intensity factor,
K [*tons per ha per unit R]* = is the soil factor,
LS [*dimensionless*] is the topographic (length-slope) factor,
C [*dimensionless*] is the cover factor
P [*dimensionless*] is the prevention practices factor.

Only 3 steps are required for running the USLE model: DEM preprocessing, LS Factor generation and Soil Erosion computing. After running the model, the Annual Average Soil erosion map was generated (fig. 8)

The modeling results show an average annual soil loss less than 3 tons / ha / year for less than forty percent of the catchment’s surface while sixty percent is affected by higher values.

USLE is a field-scale model to estimate soil erosion by sheet and rill erosion, therefore excluding gully erosion which is the main form of soil erosion occurring in this watershed.

To estimate soil erosion containing all of the erosion stated above, nLS model (McCuen & Spiess, 1995) for gully head detection and Unit Stream Power-based

Erosion/Deposition (USPED, Mitas, L. & Mitasova, 1998; Mitasova et al., 1996) model for gully erosion was integrated with the SATEEC system. Kang et al. (2010) applied the SATEEC with nLS and USPED to estimate sheet/rill and gully erosion.

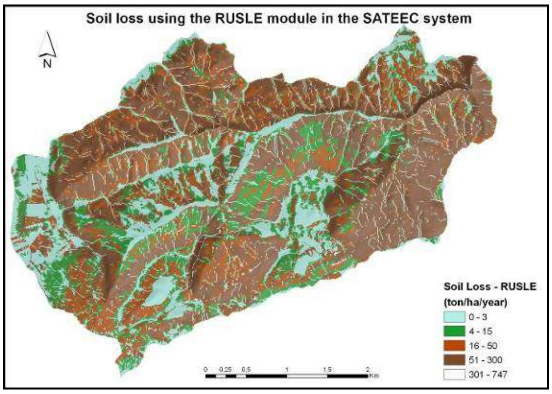

Fig. 8 Annual Average Soil erosion map

The nLS model detects gully head location based on the estimated nLS values, it requires Manning's n coefficient (fig. 9), length of overland flow, and slope for gully head detection as described below (2).

$$Gullyhead = \frac{3{,}3 * n * L}{\sqrt{S}} \quad (2)$$

Where, n is Manning's n coefficient, L is the length of overland flow, and S is slope (m/m).

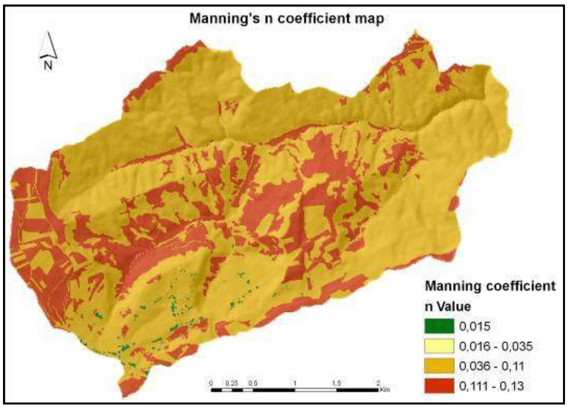

Fig. 9 Manning's n coefficient map

The nLS model (fig. 10) detects the gully locations based on the equation and the user chosen value inputs.

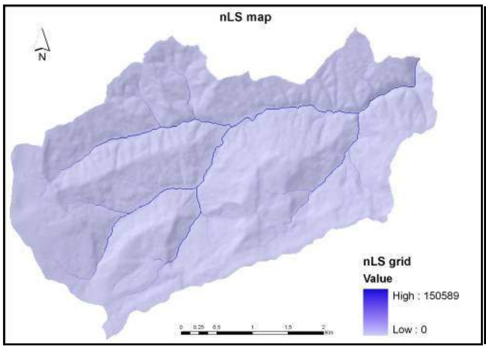

Fig. 10 The nLS map

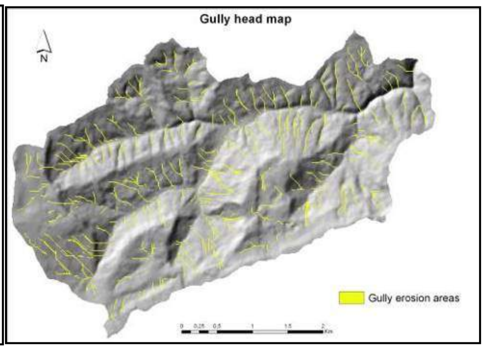

Fig. 11 The gully head map

The gully head map was derived from nLS map of which cell values are greater than 100m but less than 1000m, which indicates potential gully head location (fig. 11).

The USPED model (fig. 12) estimates soil erosion considering erosion and deposition based on tractive force (3) (Mitas, L. & Mitasova, 1998; Mitasova et al., 1996), most parameters are available to be defined with USLE input parameters.

$$T = R \times K \times C \times P \times A^{m} \times (\sin b)^{n} \quad (3)$$

Where, T is tractive force, A is area in square kilometer, and both m and b are coefficient for types of soil erosion.

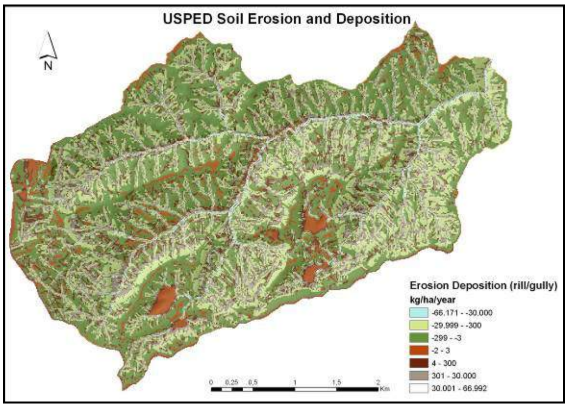

Fig. 12 USPED soil erosion and deposition

The negative values in the map indicate deposition, and positive values indicate erosion.

Using the Gully head map and soil erosion map by USPED, the map representing only gully erosion was derived (fig. 13).

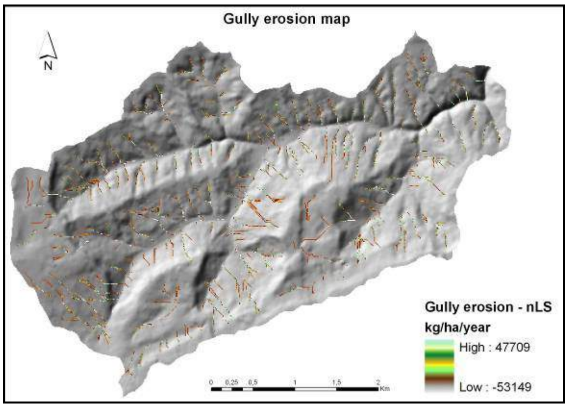

Fig. 13 The gully erosion map

The soil erosion map considering sheet/rill and gully erosion map was derived by combining the gully erosion map with the USLE erosion map. (fig. 14) The negative values in the maps indicate deposition, and positive values indicate erosion.

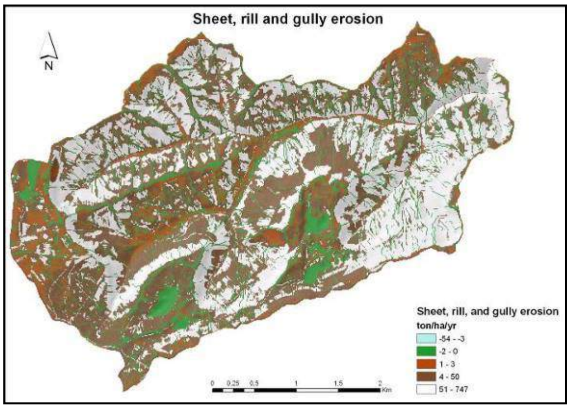

Fig. 14 The sheet, rill and gully erosion map

The total soil erosion map does not show significant differences from the USLE soil loss map, but marks the rill/gully influence in the catchment.

The map comprising all the erosion types is very suitable for those catchments where gully erosion is prevailing.

Conclusions

The SATEEC erosion modules can be successfully implemented for areas where sheet, rill and gully erosion occurs. The enhanced SATEEC system does not require experienced GIS users to operate the system therefore it is suitable for local authorities and/or students not so familiar with erosion modeling.

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