Sustainable Earth Review 2(3) 2022 1-9

Shahid Beheshti University

Sustainable Earth Review

Journal homepage: http://sustainearth.sbu.ac.ir

Determining of the most appropriate method for calculation of LS factor of RUSLE3D model in a typical semi-arid mountainous watershed

Aliakbar Nazari Samani[a*], Behnaz Zarin[a], Shahram Khalighi Sigarudi[a], Mohammad Jafari[a]

[a] Faculty of Natural Resources, University of Tehran, Karaj, Iran

A B S T R A C T

Assessing of topographic effects for erosion modelling and model calibration can differ in terms of complexity, considered processes and data availability. The topographic factor is the most sensitive parameter of RUSLE3D model for predicting of the soil loss, where a higher relative effect of the steepness factor is observed in a simple analysis of sensitivity. Due to wide spread application of USLE family models, finding the most accurate method for calculating of LS factor is a key point in each environmental condition. Therefore, This research was conducted to find the accurate method and suitable geodata to calculate the LS factor based on using of DEM with two resolutions 10 & 30 meter, three methods for calculation specific catchment area and calibration of m parameter to create a distributed model different erosion features (facies). Results indicates that the m & n exponents of runoff and slope terms in LS's equation reflect soil detachment and sediment transport capacity concerned to the relationship between hydraulic characteristics of overland flow More spatial data analysis revealed that the validation analysis showed that calculation of LS factor based on the contribution area per **unit** contour length through 30*30m DEM is more closer to estimated erosion in the study area. However, for better calibration of RUSLE3D model in the study watershed the new value for m parameter m was estimated. Due to nature of LS equation the results of erosion rate is more sensitive to m and the new values of m for different erosion facies were estimate to estimate more accurate soil erosion under semi-arid condition.

A R T I C L E I N F O

Keywords:
Calibration
Erosion
Fashand
Iran
LS factor
Rill and splash

Article history:
Received: 02 Apr 2022
Accepted: 04 May 2022

*corresponding author
E-mail address:
aknazari@ut.ac.ir
(A.A. Nazari Samani)

1. Introduction

Soil erosion and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Foster and Meyer, 1977; Wischmeier and Smith, 1978; Julien, 1998). The rate and potential of soil erosion varies from watershed to watershed depending on the configuration of the watershed (topography, shape), the soil characteristics, the local climatic conditions such as rainfall regime, hydrographic network, and the land use and management practices implemented on the watershed. Soil erosion processes play a significant role in land degradation phenomenon that affects the Mediterranean regions at different scales (Hill et al., 1995; Imbrenda et al., 2014; Rendell, 1986; Salvati et al., 2013).

Modelling soil erosion can provide a quantitative and consistent estimation of the phenomenon under various conditions. A wide range of models exists for use in simulating soil erosion. Over the last decades, estimation of soil erosion using empirical models has long been an active research topic and their application over large areas is still a challenge due to data availability and quality (Aiello et al., 2015). Current research and development in physical systems modeling is focused on distributed, process based models, often dynamic in three dimensional (3D) spaces. Over the past decades introducing of new cartographic digital techniques (Desmet and Govers, 1996), making more complicated for calculating of the topographic factors in the models.

Among all of theindices in USLE family models, the topographical factor or LS is possibly one of the most questionable one and their determination needs spatial distribution according to the different erosive flows whose consequences should be evaluated (Gisbert Blanquer et al., 2001). In the revised studies different approaches have been used for computing the topographical factor, beginning with classical determination of the slope length and angle on the DEM and ending with the formulas of Moore et al. 1993 (Arghius and Arghius, 2011; Mihaiescu et al., 2004), Mitasova et al. 1996 (Bilasco et al., 2009; Filip S., 2009; Ştefãnescu et al., 2011), Desmet and Govers, 1996 (Anghel et al., 2007; Anghel and Bilasco, 2008; Anghel and Todica, 2008). RUSLE3D model replace slope length by upslope area as a value of water flow. This makes the model applicable to complex topography. It also means that the model captures impact of a wider range of types of flow than the original USLE. It includes the combined, averaged impact of sheet and rill flow on hillslopes as well as concentrated flow erosion and potential for gully formation that has not been covered by traditional USLE (Mitasova, 2000). This paper seeks to account for the amount of LS factor using RUSLE3D model by which soil erosion rates are calculated more precisely. The analysis and quantification of this factor contribute to an understanding of applicability of those empirical models over variable areas. Considering this subject, this study was conducted to assess the effect of various DEM datasets and procedures of LS components (area and slope) and on calculation of LS factor. In addition for calibration RUSLE3d model a spatial values for m parameter were estimated based on the erosion facies. In addition to the above mentioned findings, methods and calibrated RUSLE3D, can be transferred to the other arid and semi-arid mountainous regions of Iran.

1.1. Case Study

The Fashand watershed, in Elburz Province of northern half Iran, has an area of 33100 ha and lies in the longitude of 50° 43′ 40″ –50° 48′ 30″ E and the latitude of 36° 02′ 17″ –36° 06′ 18″ N (fig. 1).

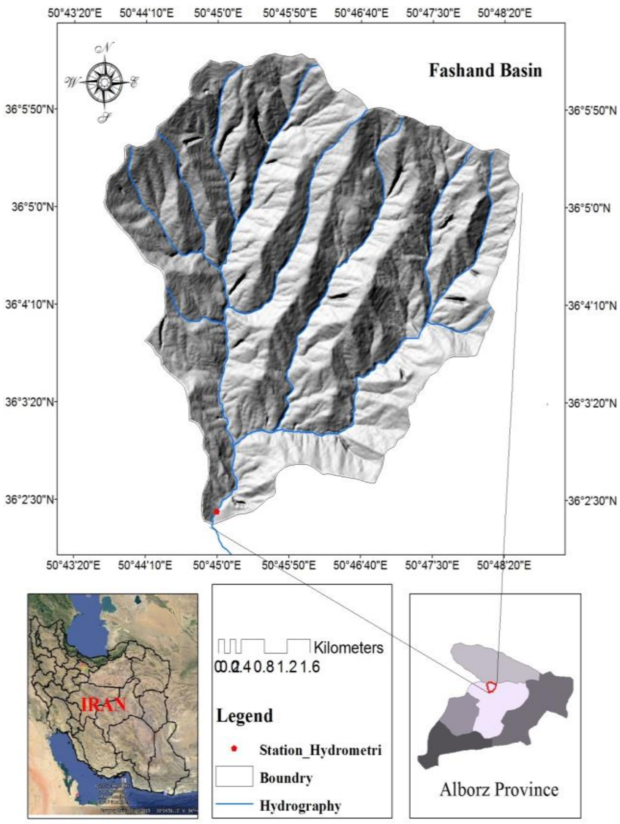

Fig. 1. The study area

In terms of elevation, it is a typical mountainous with high roughness condition and the highest and the lowest elevation respectively 3310 and1600 m asl. The maximum slope gradient is more than 60% and minimum is 5-10% while south is predominant aspect. The study area has Mediterranean climate with average annual rainfall of 427 mm. The type of soil is clay- sandy and lithology and geological structures is sandstone and limestone (dolomitic) mainly. A hydrometric station is located at the outlet and gage the discharge and sediment since 1984. The drainage density of the study is about 2.2 km^{-1} and the permanent channel named Fashand river drainage the watershed overland flow into the Shoor River at the central of Iran.

2. Material and Methods

2.1. RUSLE3D model background

RUSLE3D model uses the same empirical principles as USLE, however it includes numerous improvements, such as monthly factors, incorporation of the influence of profile convexity/concavity using segmentation of irregular slopes, and improved empirical equations for the computation of LS factor (Renard et al., 1997). To incorporate the impact of flow convergence (Fig. 2), the slope length factor, λ, was replaced by upslope contributing area, A (Moore and Burch, 1986). The modified equation for computation of the LS factor in finite difference form in a grid cell representing a hillslope segment was derived by Desmet and Govers (1996). A simpler, continuous form of the equation for computation of the LS factor at a point r = (x, y) on a hillslope, is (Mitasova et al., 1996) (Eq 1):

$$LS(r) = (m+1)\left[\frac{A_s(r)}{22.13}\right]^m \left[\frac{\sin b(r)}{\sin 5.143°}\right]^n \tag{1}$$

Where A_s (m) is the specific catchment area and is the upslope contributing area, A, divided by the contour width which is assumed to equal the width of a grid cell. b (deg) is the slope, m and n are parameters for a specific prevailing type of flow and soil conditions, and 22.13 m (72.6 ft) is the length and 0.09 = 9% = 5.143 (deg) is the slope of the standard USLE plot. The Figure 3 shows the results of the comparison of the estimation of the LS factor using slope length, λ, on the left, and on the right, using the upslope contributing area, A, in each point in particular (Moore & Burch, 1986). We can observe an overestimation in the values of the factor LS, when it is calculated in the traditional way (left figure). LS values decrease when is estimating with A.

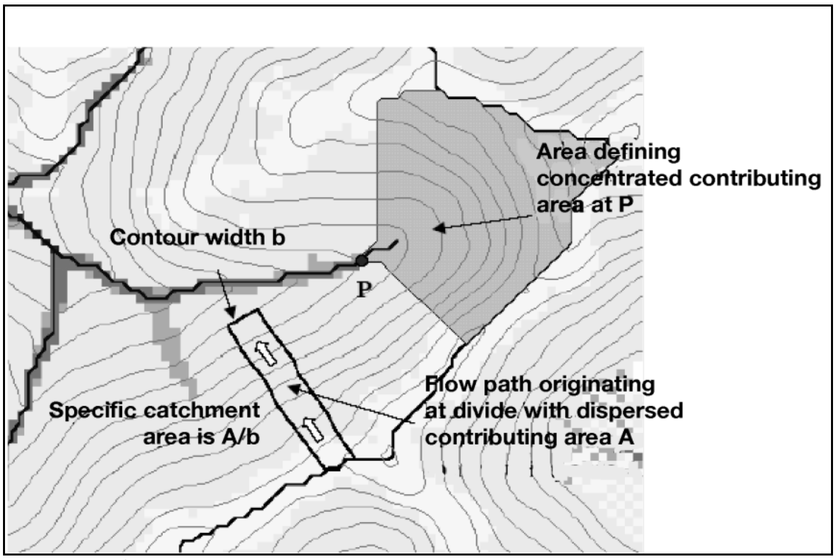

Fig. 2. The concept of upslope contributing area is shown graphically in shady. From Tarboton and Ames, 2001.

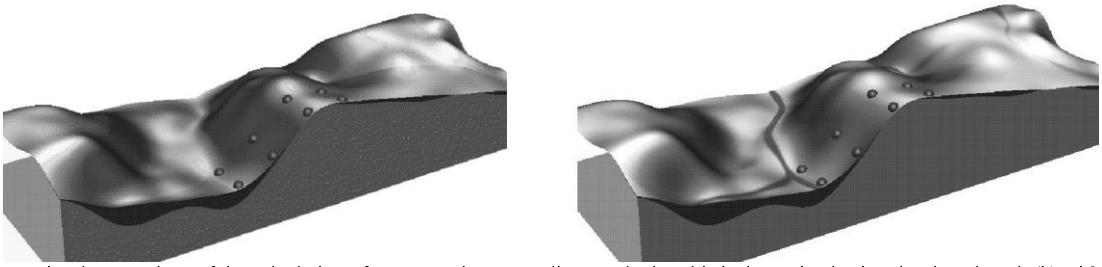

Fig. 3. Visual comparison of the calculation of water erosion, according to whether this is determined using the slope length (λ) with the RUSLE model (Left Fig.) or the upslope contributing area, A, with RUSLE3D model (right Fig.). From Mitasova et al., 2010 (on-line).

The aim of this study is to develop methods for computation of topographic factors both for the RUSLE3D and for the unit stream power based model suitable for complex terrain and applicable to large areas. Special attention is given to the proper representation of terrain and computation of topographic parameters significant for erosion/deposition modeling. The methodology presented in this paper for estimating the LS-factor has the following items: (a) uses two different-resolution DEM at 10 & 30 m, (b) applies three different methods to calculate specific catchment area, and (c) the calibration m parameters for each erosion facies.

2.2. Cell optimum size for DEM

This study was supported by GIS software, ArcGIS 10.3. In this study, we used the best interpolation algorithm for DEM construction was the method included in ArcGIS, Topo to Raster. This algorithm also permits an advanced hydrological correction (Nigel and Rughooputh, 2010). We chose cell size of 10 and 30-m to create DEM from 10-m interval contours, elevation points and hydrographic network of basin. Then, using digital elevation model, slope map was prepared using the Four cell algorithm () and to determine the flow accumulation, the single flow direction (D8) (O'Callaghan and Mark, 1984) algorithm were used resolution and accuracy of available DEMs makes the flow tracing difficult because of insufficient vertical resolution and the incidence of numerous pits that trap the flow lines (Jenson and Domingue, 1988; Martz and Garbrecht, 1992).

2.3. Specific catchment area

Upslope contributing area is the area from which the water flows into a given grid cell. Upslope contributing area per unit contour width A_j for the given grid cell j is computed from the sum of grid cells from which the water flows into the cell j (Moore et al. 1992). Where a_i is the area of grid cell, n_j is the number of cells draining into the grid cell j, i is the weight depending on the runoff generation mechanism and in infiltration rates, and b is the contour width approximated by the cell resolution. This approximation is acceptable if the DEM is interpolated with the adequate resolution which depends on the curvature of terrain surface.

In this study, we used three different method to derive specific catchment area map from the upslope contribution area:

1. Total contribution area: specific catchment area which is assumed as equal the upslope contribution area multiplied by pixel area and afterward specific catchment area map was calculated by divided it into local separation power of digital elevation model.

3. Contribution area per unit contour line and maxium of 120 m run off length: in this method, first accumulation raster map is multiplied by pixel area and afterward obtained map was categorized from1 to 12 (in the range of 10 to 120) and finally: specific catchment area map (A_s) was calculated.

2.4. Exponent m

Exponents for water and slope terms in the sediment transport and detachment equations reflect the interaction between different types of flow and soil detachment and transport. Generally, in most studies, m parameter is considered to be 0.5 constant value. While the value of this parameter is different in each various erosion facies. So, in this study, we have decided the m parameter value to be calibrated for each erosion facies. For this purpose, at first, proposed values by Mitasova (2000) were used for the m parameter for each various erosion facies and map variability of m parameter was prepared. For example in the sheet flow, detachment and sediment transport increases relatively slowly with the amount of water. Geometric properties of topography (slope, curvatures) play a more important role in the evolution of the pattern of soil detachment and net erosion/deposition than the pattern of water flow. This type of flow is typical for areas with good vegetation cover but also for a severely compacted, smooth soil cover where compaction prevents soil detachment and formation of rills. This type of flow is reflected by the lower value of exponent m (m=0.1) for the water term represented by the upslope area. For rill and stream flows are present in the given area, which is usually the case due to spatial variability in land cover and soil properties, the value m=0.4 provides reasonable (Mitasova, 2000). Also, we have used the exponents m=0.2 for rocky areas, m=0.3 for agriculture and m=0.09 for residential areas. The value of the parameter n was considered the constant 1.3 too. Then, due to the erosion and sedimentation rates in the region less value was considered for m parameter.

3. Results and discussion

3.1. Start with erodibility map and describe the spatial variability in a small paragraph

The descriptive statistics results for the LS factor are stated in Table 1. The data show differences in the value of LS factor according to the two DEM and applied methodology for computing specific catchment area and values of exponent m proposed by Mitasova et al. (1996). In this study, the basis of select the most appropriate method of calculating the LS factor is Fashand hydrometric station that it is located at the basin outlet. The amount of observed sediment in the station is 2.21 (ton/ha/yr). Also, considering that high significant correlation coefficient (R=0.93) between LS factor and erosion rate it is postulated that LS factor can impact the model out put remarkably. Consequently in one side more precise method should be used for LS estimation and on the other side the coefficients and exponents of LS equation can be used as suitable parameters for model calibration. Results show that using of 30*30m DEM and area per contour line showed a closer estimation of erosion in study area. Because the area is representative if runoff and represents a true cross section of the crossed stream. This method has the dimensions closer relationship between ups and downs and also gives us the current level. The Fig. 4 shows topography factor local variability in Fashand basin. As its being observed, the variability of topography factor is very high that it is especial mountainous areas and in accordance with slope map variability, it has the least amount is in the north, southeast and south gradually and its value increase in the central parts, waterways, channels and dimples. So that highest amount of topography factor is in the main waterways. Actually, by replacing the area upstream slope instead of the slope length, values of topography factor increases from the ridge (the ridge) to channels (dimples), gradually. That reflects the effective use of current density. In other words, use of index flow accumulation hydrological causes estimated factor topography at the a true three-dimensional perspective and its application composite and complex slopes. The method is not limited to express the sediment transport capacity by the runoff, but it also considers the surface flow, the ramp geometry - if concave or convex - and the erosion way (Silva, 2003). In other words, enjoying of flow accumulation hydrological index leading to an estimate of topography factor in a real three-dimensional perspective and its application in compound and complex slopes. Also, change range of ups and downs at the 30-meter digital elevation model is less but with more average. The grid size change affected the steepness values, compromising the L and S factor values, since the L factor depends on the grid size and the steepness and the S factor only on the steepness. When affecting the L and S factors, the resolution also affected the sediment transport ratio. The best sediment production estimates were observed in DEM with resolution of 30 m. A fundamental observation who highlight that the better results of the 30 m resolution compared to the 10 m using the RUSLE3D methodology, is probably due to fact this resolution is closer to the 22.4 m slope length, the length used in the derivation of the USLE relationships.

Table 1. Statistical values of topography factor

Digital elevation model resolution (m)	method	min	max	mean	Standard deviation
10	total upland area	0	2285	19.67	31.2
	Per unit contour width	0	909.78	11.69	12.67
	Per unit contour and max 120 m length	0	155.81	18.59	15.18
30	Free	0	1528	26.67	47.5
	Per unit contour width	0	392	11.57	12.33
	Per unit 120 m width	0	221.54	24.82	25.97

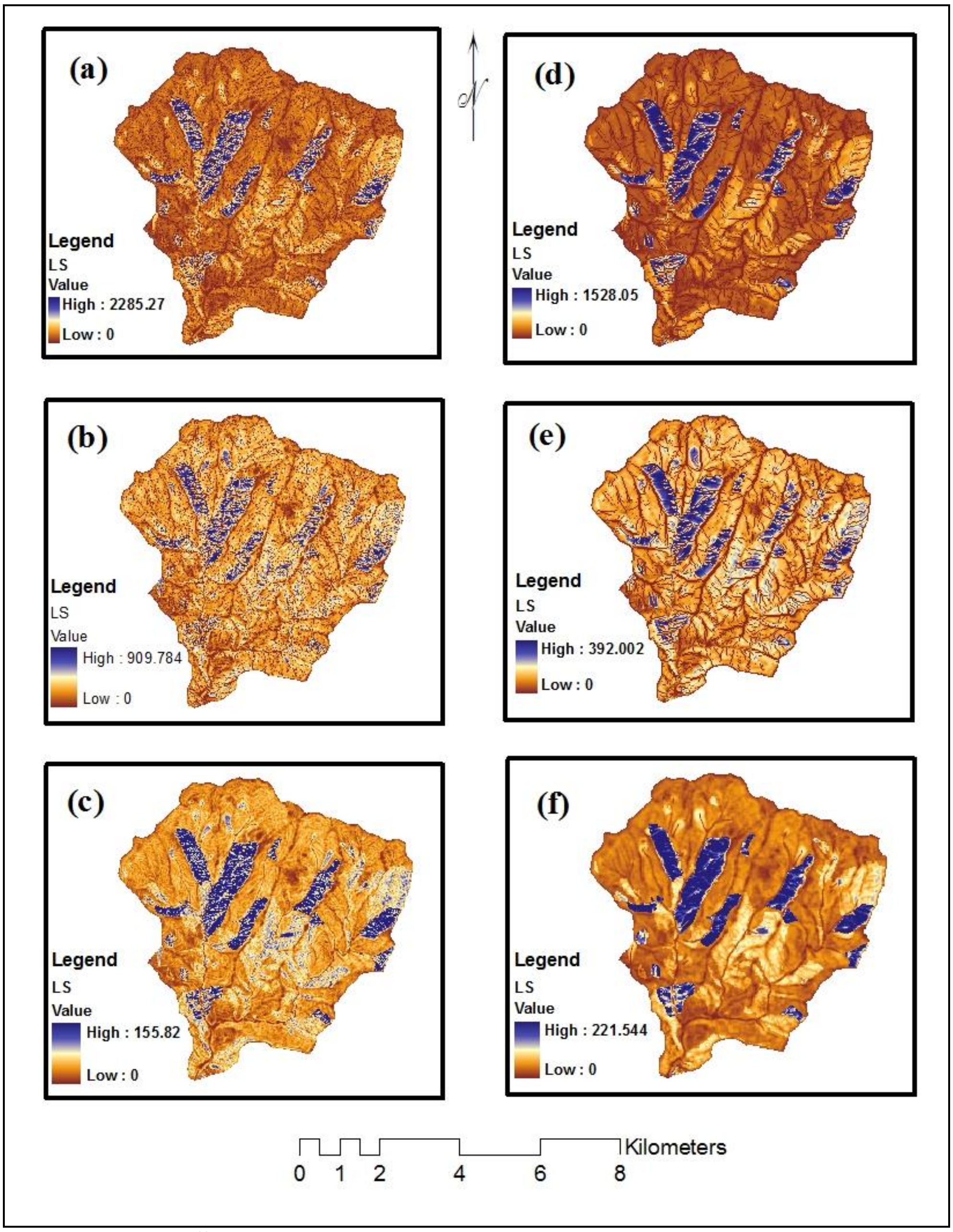

Fig. 4. LS factor maps based on different methods. The open method, area per unit contour length method & area per unit 120 m length method with 10 (m) DEM respectively at (a), (b) & (c) and open method, area per unit contour length method & area per unit 120 m length method with 30 (m) DEM respectively at (d), (e) & (f).

3.2. Calibration of m parameter

According to the results, considering the magnitude m per erosion facies causes to determine the spatial distribution of ups and downs more precisely in this study and caused this model to be able to consider the impact of facies on the soil erosion. Actually, m parameter is runoff representative and is a main factor in the determining the amount of erosion due to geomorphology erosion which is preferred Revised Universal Soil Erosion three-dimensional model than the older versions of this model and also many soil erosion models. It has also a theoretical foundation (Moore and Burch, 1986) and is being used, for example, by Engel. (1999) this exponent balances the impact of turbulent and sheet overland flow. The result increases the negative impact of disturbed areas and reduces the impact of vegetated areas. So, considering the variability of the parameter m that has different values in different erosion forms and land uses, the parameter m in GIS maps to be and instead of using a fixed amount, a map of the spatial variation of the parameter m, were used. Also the variability of these parameters is defined by Mitasova. (1996) in the range 0.1 for sheet erosion to 0.6 for gully erosion, according to Iran arid and semi arid climates requires to calibration for each used facies. Therefore, for this purpose and also based on model results, calibration and in other words determining the optimum values for the parameters m was attempted, so that it can provide more appropriate results for arid and semi arid climates such as Iran. In this regard, suggested values for parameter m are provided for Fashand basin erosion facies and also values of ups and downs and consequently the amount of soil erosion in Tables (2) and (3). Thus, as it can be observed, by reducing the m parameter values of ups and downs and consequently the rate of soil erosion and sediment dropped from 0.4 to 0.2 for erosion table (2) and as well as surface erosion from 0.1 to 0.07 Table (3), agriculture from 0.3 to 0.06, rock mass of 0.2 to 0.05 and residential from 0.09 to 0.03 and became closer to the observed values.

Table 2. The optimum parameter values & the amount of erosion and sediment

Facies of Erosion	**m Parameter**	**Digital elevation model (m)**	**LS Factor**	**Soil Erosion Rates (ton/ha/yr)**	**Deposition Rate (ton/ha/yr)**
Stream	0.2	10	9.27	77.45	25.19
Sheet	0.07				
Agriculture	0.06			38.07	12.54
Rock mass	0.05				
Residential	0.03				
Stream	0.2	30	8.48	71.49	12.45
Sheet	0.07				
Agriculture	0.06			35.19	6.19
Rock mass	0.05				
Residential	0.03				

Table 3. The optimum parameter values & the amount of erosion and sediment

Facies of Erosion	**m Parameter**	**Digital elevation model (m)**	**LS Factor**	**Soil Erosion Rates (ton/ha/yr)**	**Deposition Rate (ton/ha/yr)**
Stream	0.1	10	8.88	73.21	20.63
Sheet	0.07				
Agriculture	0.06			36.01	10.30
Rock mass	0.05				
Residential	0.03				
Stream	0.1	30	8.01	66.39	8.82
Sheet	0.07				
Agriculture	0.06			32.70	4.4
Rock mass	0.05				
Residential	0.03				

4. Conclusion

RUSLE3D calculates a higher value of the LS factor on streams and therefore, when it is calculated in the traditional way (RUSLE), the problem of an overestimation of the erosive power is solved in the highest areas or at the beginning of the hillslopes. In fact, the model includes irregular hillsides integrating a wide spectrum of hillside convexities and concavities and it incorporates the contribution area A for the determination of the LS factor. The topographic factor is the most sensitive parameter of RUSLE3D in the soil loss predictions, where a higher relative effect of the steepness factor is observed in a simple analysis of sensitivity. The high-resolution DEM and taking advantage of the variability m parameters and erosion faces and users helps to capture the geomorphological changes with greater precision and thereby estimate soil erosion with greater accuracy compared to past assessments. In fact, the flexibility of parameter m for different user erosion faces and soil erosion in the global model being revised three-dimensional, states the ability of calibrating the model under different climatic conditions states. However, considering the interplay undulating flow pattern and ups and downs pattern different values of parameter m can be considered in different climate. For example, in northern Iran, where humid climate is dominant, m parameter values can be more different from to the central regions of Iran, which has a relatively dry climate.

References

Aiello, A., Adamo, M. & Canora, F., 2015. Remote sensing and GIS to assess soil erosion with RUSLE3D and USPED at river basin scale in southern Italy, *Journal of Catana*, 174-185.

Anghel, T. & Bilaşco, S., 2008. The Motru mining basin – GIS application on sheet erosion. *Geographia Napocensis*, 2(1),90-108.

Anghel, T. & Sandu, T., 2008. Quantitative assessment of soil erosion using GIS empirical methods. A comparative study between the Motru mining area and the Sucevita catchment. Analele Universităţii din Oradea, seria Geografie. 18, 95-102.

Anghel, T., Bilasco, S. & Oncu, M., 2007. Estimarea cantitativă a pierderilor de sol din bazinul Motru ca urmare a eroziunii de suprafaţă (aplicaţie GIS a modelului ROMSEM de tip USLE). Analele Universităţii Spiru Haret, seria Geografie, 10, 78-94.

Arghius, C. & Arghius, V., 2011. The quantitative estimation of the soil erosion using USLE type ROMSEM model. Case-study- the Codrului Ridge and Piedmont (Romania). *Carpathian Journal of Earth and Environmental Sciences*, 6(2), 59-66.

Bilasco, S., Horvath, C., Cocean, P., Sorocovschi, V. & Oncu, M., 2009. Implementation of the USLE model using GIS techniques. Case study the Someşean Plateau. Carpathian *Journal of Earth and Environmental Sciences*, 4(2), 123-132.

Desmet, P.J.J. & Govers, G., 1996. A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *J. Soil Water Conserv*, 51, 427-433.

Engel, B., 1999. Estimating Soil Erosion Using RUSLE (Revised Universal Soil Loss Equation) Using ArcView. http://danpatch.ecn.purdue.edu/~engelb/abe526/gisrusle/gisrusle.html.

Filip, S., 2009. Starea morfodinamica, hazardele si vulnerabilitatea geomorfologica in depresiunea si munceii Baii Mari. Riscuri şi catastrophe, 8, 139-147.

Foster, G.R. & Meyer, L.D., 1977. Soil erosion and sedimentation by water an overview. Procs. National Symposium on Soil Erosion and Sedimentation by Water, Am. Soc. Of. Agr. Eng., St. Joseph, Mechigan, 1-13.

Gisbert Blanquer, J.M., Ibáñez Asensio, G., Andrés Aznar, A. & Marqués Mateu, A., 2001. Estudio comparative de diferentes métodos de cálculo del factor "LS" para la estimación de pérdidas de suelo por erosión hídrica. Edafología, 8, 57-66.

Hill, T.M., Christen, S.D. & Davis-Dentici, K., 1995. Effect of supplementing late gestation and lactating ewes receiving low protein grass hay with barley or soybean meal. J. Sustainable Agriculture, 7(2-3), 41-51.

Imbrenda, V., D'Emilio, M., Lanfredi, M., Macchiato, M., Ragosta, M. & Simoniello, T., 2014. Indicators for the estimation of vulnera- bility to land degradation derived from soil compaction and veg etation cover, Eur. J. Soil Sci., 65, 907-923.

Jenson, S.K. & Domingue, J.O., 1988. Extracting topographic structure from digital elevation data for geographic information system analysis. Photogrammetric Engineering and Remote Sensing, 54(11), 1593-1600.

JULIEN, P.Y., 1998. Erosion and Sedimentation. First paperback edition; first published 1994. xvii+280 pp. Cambridge, New York, Melbourne, 9-16.

Martz, L.W. & Garbrecht, J., 1992. Numerical definition of drainage network and subcatchment areas from digital elevation models. Computers & Geosciences, 18, 747-761.

Mihăiescu, P., Man, T. & Oncu, M., 2004. Evaluarea riscului de eroziune a solului în bazinul Someşului Mic prin aplicarea modelării GIS. Riscuri şi catastrofe. III, 251-261.

Mitasova, 2000. Terrain Modeling and Soil Erosion Simulation Final Report.

Mitasova, H., Brown, W.M., Hohmann, M. & Warren, S., 2010. [on line]. Using soil erosion modelling for im - proved conservation planning: A GIS-based Tutorial Geographic Modelling Systems Lab. UIUC., http:// skagit.meas.ncsu.edu.

Mitasova, H., Hofierka, J., Zlocha, M. & Iverson, L.R., 1996a. Modeling topographic potential for erosion and deposition using GIS. International Journal of GIS, 10, 629-641.

Moore, I.D., Turner, A.K., Wilson, J.P., Jenson, S.K. & Band, L.E., 1993. GIS and land-surfacesubsurface process modeling. In: Goodchild, M.FR., Parks, B.O. & Steyaert, L.T. (eds): Environmental modeling with GIS, 196-230.

Moore, I. & Burch, G., 1986b. Physical basis of the length–slope factor in the Universal Soil Loss Equation. Soil Science Society of America Journal, 50, 1294-1298.

Moore, I.D. & Wilson, J.P, 1992. Length–slope factors for the Revised Universal Soil Loss Equation: simplified method of estimation. Journal of Soil and Water Conservation, 47, 423-428.

Moore, I.D. & Burch, G.J., 1986a. Modeling erosion and deposition: topographic effects. Transactions of ASAE 29, 1624-1640.

O'Callaghan, J.F. & Mark, D.M., 1984. The extraction of drainage networks from digital elevation data. Computer Graphics and Image Processing, 28, 323-344.

R Nigel, SDDV Rughooputh, 2010. Soil erosion risk mapping with new datasets: An improved identification and prioritisation of high erosion risk areas, Catena, 82(3), 191-205.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. & Yoder, D.C., 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Dept. of Agriculture, Washington, DC.

Rendell, H.M., 1986. Soil erosion and land degradation in Southern Italy. In: Fantechi, R., Margaris, N.S. (Eds.), Desertification in Europe. Springer, Netherlands, 184-193.

Salvati, L., et al., 2013. Map of long-term changes in land sensitivity to degradation of Italy. J. Maps, 10, 65-72.
Silva, A.M., 2003. Erosividade, erodibilidade e perdas por erosão em Cambissolo e Latossolo sob chuva natural. M.Sc. Thesis, Universidade Federal de Lavras.
Stefanescu, L., Constantin, V., Surd, V., Ozunu, A. & Vlad, S.N., 2011. Assesment of soil erosion potential by the USLE method in Roșia Montană mining area and associated NATECH events. Carpathian Journal of Earth and Environmental Sciences, 6(1), 35-42.
Tarboton, D.G. & Ames, D.P., 2001. Advances in the mapping of flow networks from digital elevation data, in World Water and Environmental Resources Congress, Orlando, Florida, May 20-24, ASCE.
Wischmeier, W.H. & Smith, D.D., 1978. Predicting rainfall erosion losses. A guide to conservation planning. USDA Agriculture Handbook no, 537, 58 p