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INVESTIGATION OF GEOMORPHOMETRIC PARAMETERS TO SIMPLIFY WATER EROSION MODELLING (A CASE STUDY: EMAMZADEH WATERSHED, IRAN)

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Abstract. In recent decades, water erosion potential has been recognized as a severe threat to soil sustainability and water resources. The present study was conducted to investigate the relation between geomorphometric parameters and soil type to simulate water erosion in the Emamzadeh watershed located in the northeast of Khuzestan Province. The primary and secondary geomorphic parameters, including slope, plan curvature, profile curvature, flow length, flow accumulation, flow direction, and stream power index (SPI) were calculated based on the digital elevation model (DEM). The water erosion was measured using available data and laboratory analyzes, then it was predicted with the water erosion prediction project (WEPP) model. Our results revealed that the measured soil erosion does not show any relation with geomorphic parameters, while some of the geomorphometric parameters depicted a significant relation with WEPP model's predictions. A model with an excellent explanation coefficient was obtained using multivariate linear regression to predict water erosion. The geomorphometric parameters application allows an estimation of erosion based on simple linear models (R^2: 0.934, sig: 0.000). Moreover, for SPI, the total curvature was –0.794, plan curvature was –0.658, and profile curvature was 0.746. Therefore, there was a relation between curvature and SPI. Our results showed no specific relation between sediment transport index (STI) and water erosion. The low amount of STI represents the sedimentation areas in the watershed. Generally, application of geomorphometric parameters simplify the soil erosion prediction.

Keywords: DEM, geomorphometric parameters, regression, soil great group, water erosion

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INTRODUCTION

Water erosion is one form of soil degradation which includes on-site and off-site effects. In recent decades, the potential of water erosion has been recognized as a severe threat to soil sustainability. Also, regarding human activities, accelerated water erosion leads to harmful environmental effects, and transportation of sediments to water bodies is accompanied by loss of nutrients, and eutrophication (Sartori *et al*. 2019, Ding *et al.* 2020). Water erosion includes the linear aspect of the stream system dealing with one-dimensional overland flow lengths (OFL), the river's length, watershed shape, soil properties, and geomorphological parameters (Khademalrasoul and Amerikhah 2020). Generally, variation in topography factor conduces to dramatic changes of water erosion intensity. Therefore, topography in terms of geomorphometric parameters is significant for soil erosion processes. Moreover, morphometric analysis and water erosion modeling are robustly interrelated (Arabameri *et al*. 2020, Khanifar and Khademalrasoul, 2020). Therefore, there is a need to focus on soil erosion outcomes to prevent environmental impacts. The understanding of interactions between land use management and topographical attributes is critical to control water erosion by implementing best management practices (BMPs). Regarding the difficulty of water erosion measurement and monitoring in the watersheds, the application of simulator models to predict soil erosion is required. Some of these models have numerous input parameters (Gholami *et al*. 2018, Borrelli *et al*. 2021). Therefore, it is necessary to simplify those models and provide more simple equations in order to predict soil erosion and ultimately select the BMP in the watersheds. Indeed when the purpose of the simulation is to acquire scientific outputs, the task is to find the simplest model because a more complicated model does not substantially enhance the fitting (Hennrich *et al*. 1999).

The topography is the soil formation factor which influences soil properties. Digital elevation model (DEM) is the best representative of topography conditions in each area. Digital elevation models are the valuable data sources associated with topography, which were widely utilized in soil erosion models (Khanifar and Khademalrasoul 2021). Most field observations have shown that simulator models have predicted soil erosion and the associated depositions affected by geomorphology and land use (Pelacani *et al*. 2008). The measurement and mathematical evaluation of the earth's surface, the shape and dimension of landforms is named "geomorphometry" (Wilson 2018). Geomorphology is an index of geology and represents the erosional behavior (Wilson and Gallant 2000); slope aspect, slope curvature, and other geomorphological parameters determine the factors of the landscape water erosion modeling (Li and Gold 2005, King *et al*. 2005). Also, the hillshading is a technique applied to visualize earth terrain by illustrating its relief with a hypothetical light source. The illumination value for each raster cell is determined by its orientation to the light source which is based on slope and aspect (Wilson and Gallant 2000). Moreover, application of DEM increased as a data source for the visual and mathematical analysis of topography and landform modeling (Martinez and Correa 2016, Tovar-Pescador *et al*. 2006, Martinez-Casasnovasa *et al*. 2004).

As regards the relation between geomorphometric parameters and water erosion, the primary purpose of this study is to find a relation between geomorphometric characteristics and water erosion. Therefore, the main feedback of our paper could be the simplification of water erosion modeling to predict water erosion.

MATERIALS AND METHODS

The study area

The study area is located in the north part of Seydun and is named Emamzadeh Abdollah of Baghmalek city, Khuzestan Province in Iran (Fig. 1). The area of this watershed is approximately 104 km^2 with the geographical coordination of 31º22' to 31º30'N and 50º4' to 50º16'E. In this area, the total annual precipitation is around 712 mm, the minimum temperature is 4.7ºC, and the maximum

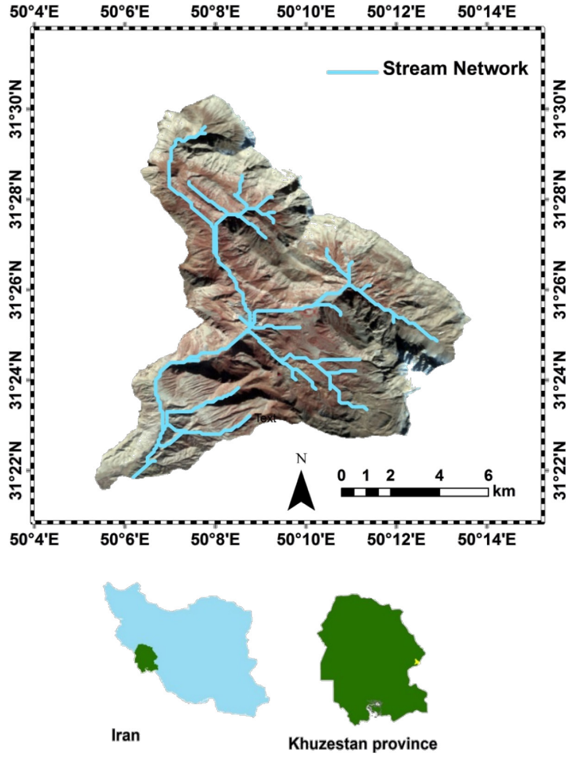

Fig. 1. Location of study area on true color composite of Landsat 7 ETM$^+$ image acquired in March 2000

temperature is 41.7ºC (Data adopted from the synoptic station located in Baghmalek County, 2012–2018.) This watershed includes six hydrological parcels. The main soil great groups in the study area are Lithic Xerorthents, Typic Calcixerepts and Typic Xerofluvents; as the map of soil great groups shows, Typic Calcixerepts occupies the highest area in this watershed (Fig. 2).

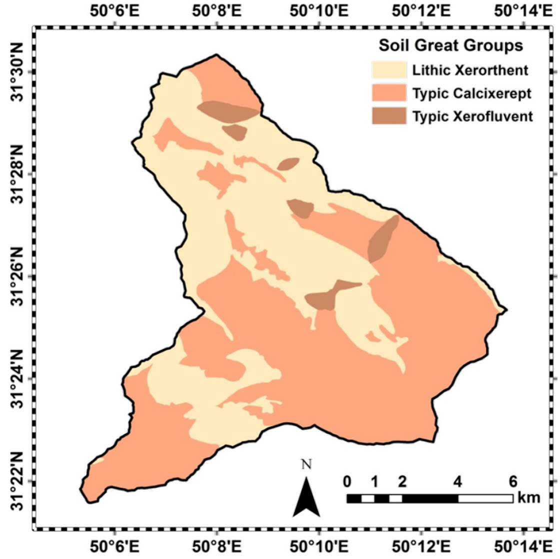

Fig. 2. The map of soil great groups in the study area

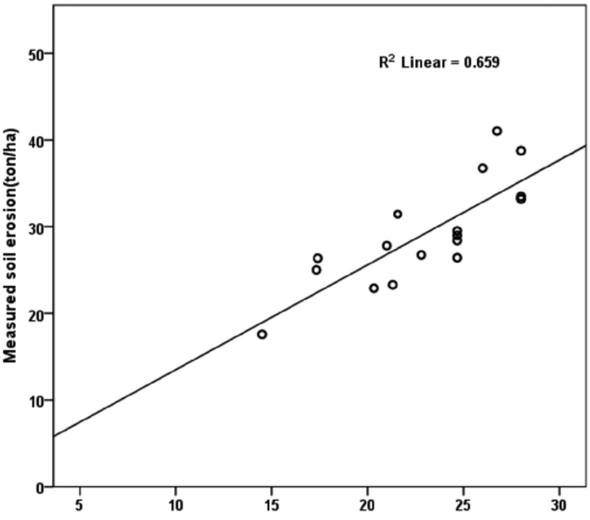

Fig. 3. The scatter plot of measured soil erosion (ton/ha) versus predicted soil erosion (ton/ha)

Geomorphometric maps and data processing

The digital elevation model with a 30 m resolution was generated from the Shuttle Radar Topography Mission (SRTM), using the Earth Explorer website; then, the preprocessing and corrections were performed on the DEM. In preprocessing of DEM, sinks were removed using the Fill subprogram in ArcGIS 10.2 software. The digital elevation model provides geomorphometric characteristics which are effective on landforms, geomorphic levels, and soil erosion processes, i.e. flow length (FL), flow accumulation (FA), and topographical index (TI) in raster-based GIS environment using Spatial Analyst (Fig. 4, Fig. 5). The main parameters discussed in this study were calculated by eleva-

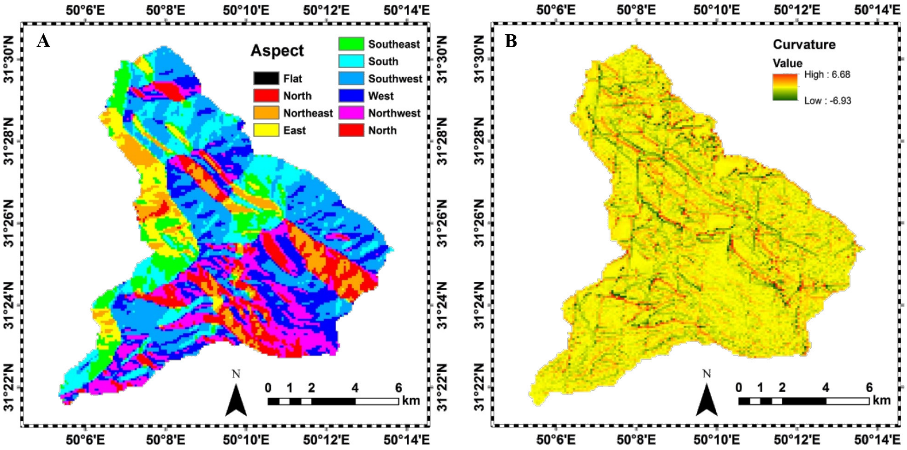

Fig. 4. The aspect map (A) and curvature map (B) of study area

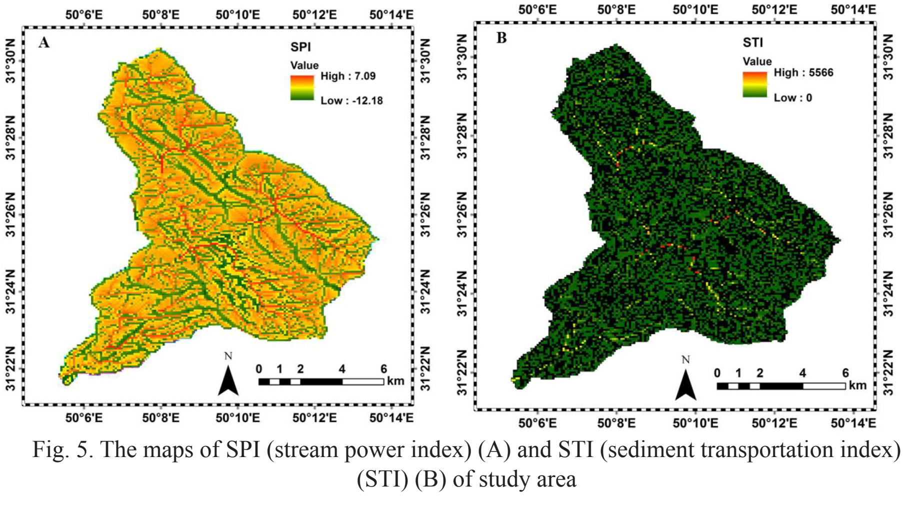

Fig. 5. The maps of SPI (stream power index) (A) and STI (sediment transportation index) (STI) (B) of study area

tion derived data which include slope, plan curvature, profile and, aspect. The secondary attributes are more important because they make an opportunity to describe patterns as a function of the process (Wilson 2018). They include the topographic wetness index, stream power index, and, sediment transport capacity. Flow length is the distance from any point in the watershed to the watershed outlet. The distance is measured along the flow direction; flow accumulation is determined based on the highest decreasing slope steepness.

Slope and curvatures

The slope is one of the most critical factors in soil erosion studies, therefore, a reliable assessment of slope is required for accurate estimation by erosion models. DEM derived slope map is more accurate than those obtained from topographic maps in general soil surveys (Munar-Vivas and Martínez 2014). Curvature from a practical point of view on the earth's surface is the degree of surface deviation from the flat plate. As for the profile curvature, the values of less than zero indicate the least risk of soil erosion; in general, the convex slopes have the highest potential for erosion concerning the profile curvature. The profile curvature affects the rate of erosion and sedimentation, as well as facilitates the flow on the slope (Wilson and Gallant 2000, Neteler and Mitasova 2008, Kennelly 2008). The topographical index, which was proposed by Beven and Kirkby (1979), predicts the flow accumulation in the lowest part of a landscape and is calculatedusing the following formula:

$$\lambda = \mathrm{Ln}\,(\alpha/\tan\beta)$$

where: λ is the topographical index, α is effective upslope area, and β is slope degree for each cell.

The TI is based on the assumption that the hydraulic slope can be proximate by the topographic slope (Ballerine 2017). The topographical index was calculated by assessing the flow direction, flow accumulation, and slope factors derived using ArcGIS 10.2 software.

Stream power index is the erodibility power of streamflow as a function of local slope and upslope drainage area (Fig. 5a); therefore, SPI takes into account the two parameters of gradient and location of the site on the landscape by integrating the area of the catchment and the slope geometry (Florinsky 2016).

$$\mathrm{SPI} = \mathrm{Ln}\,(CA.\tan G)$$

where: CA is catchment area, and G is the slope gradient.

Because of the parameters used in calculating SPIs, the SPI is used to show the potential for erosion on topographic surfaces (Florinsky 2016). The higher amount of SPI on the landscape indicates the higher erosion potential and overland flow during a runoff event (Danielson 2013).

The WEPP model

The USDA water erosion prediction project model (WEPP) is a new erosion estimation technology based on erosion mechanics, infiltration theory, stochastic weather generation, soil physics, and hydrology. The most notable advantage of this model is the capability for predicting spatial and temporal distributions of net soil loss for an entire hillslope, or each point on a slope profile based on daily, monthly or average annual time scales. Since the WEPP model is process-based, it can be extrapolated to a broad range of conditions that may not be practical or economical to field test (Flanagan and Livingston 1995).

Simulation and statistical analysis

In this study, the statistical analysis and Pearson's correlation were performed using SPSS software (IBM SPSS Statistics 19), and the modeling was accomplished based on multivariable regression using the ENTER technique. Moreover, the amount of all pixels for each polygon of land use is calculated with Zonal statistics subroutine in ArcGIS software. Based on all available data and field observations, the input data for WEPP running was prepared. These data included soil, topography, management, crop cover, and climate for each hillslope. After the hillslopes were defined as projects, these projects were defined in terms of channels and impoundments as a watershed. Therefore, regarding the WEPP simulation, each watershed consisted of hillslopes, channels and impoundments. Finally, for 17 hydrological units, which represented the whole watershed, the WEPP model was run, and the amount of water erosion was measured with the WEPP model with the data extracted from maps of geomorphic parameters. The measured data were analyzed using SPSS software. In this study, in 17 hydrological units, the sediment load was converted to soil erosion values in ton/ha using the relationship between sediment load, sediment delivery ratio (SDR), and soil erosion described in PSIAC (1968) and modifications applied on PSIAC (MPSIAC) by Jonson and Gebhardt (1982). Sediment delivery ratio (SDR) for each hydrological unit was calculated based on the unit area (in m^2) as above-mentioned references (Table 1). Hydrological unit sediment production was obtained from the ministry of agriculture's hydrometric/sediment gauging stations (2009).

Table 1. The measured erosion, WEPP predicted and measured SDR for hydrological units

Hydrological unit	Area (km^2)	SDR	WEPP predicted	Measured erosion
H1	7.76	43.82	21.57	31.44
H2	0.15	83.27	17.33	25.01
H3	0.28	78.11	14.50	17.57
H4	0.47	72.30	24.67	28.40
H5	0.92	64.26	28.01	33.47
H6	6.36	48.11	26.00	36.75
H7	0.40	71.10	28.02	38.75
H8	31.9	38.20	21.01	27.80
H9	38.7	36.25	21.31	23.29
H10	0.20	81.10	17.40	26.35
H11	0.18	80.36	24.67	26.42
H12	3.78	58.20	24.67	29.51
H13	0.85	63.88	28.12	33.19
H14	7.10	46.80	26.75	41.03
H15	0.32	73.50	24.67	28.99
H16	3.26	58.70	20.33	22.90
H17	1.81	55.70	22.80	26.74

N	Overall SDR	Mean of predicted erosion (ton/ha)	Mean of predicted erosion (ton/ha)	Mean hydrological units SDR	Mean hydrological units area
17	30.68	23.04	29.27	61.98	6.15

RESULTS AND DISCUSSION

Statistical analysis of geomorphometric characteristics and erosion

The statistical analysis of geomorphometric characteristics is shown in Table 2. Evaluation of these indices was helpful to understand the geomorphic characteristic of the Emamzadeh Abdollah watershed. The lowest elevation in this area is 931 m, and the highest is 3,189 m; therefore, the variation of elevation is significant, showing complex topography with high mountains in this watershed. The wide range of hillshade (0–254) depicts the high variation of the topographical conditions in the study area (Table 2).

Table 2. Statistical analyses of geomorphometric characteristics in the study area

Geomorphometry parameter	Min	Max	Mean	Std. dev.
Aspect	0.0000	359.8900	198.7800	95.6100
Curvature	–6.9300	6.6700	–0.0020	0.6260
Plan curvature	–2.8190	2.4020	0.0030	0.3190
Profile curvature	–4.6320	4.2710	0.0060	0.3930
Flow accumulation	0.0000	3116.0000	29.7850	166.9360
Flow direction	1.0000	128.0000	24.8630	33.4800
Flow length	0.0000	9429.6600	2996.0000	2028.1600
Topographical index (TI)	–5.3580	13.8880	2.2490	4.2140
Hillshade	0.0000	254.0000	166.3290	50.7430
Sediment transport index (STI)	0.0004	5566.8960	119.3830	355.3250
Stream power index (SPI)	–12.0950	7.0900	-1.9580	4.2510
DEM stat	931.0000	3189.0000	2041.3750	475.1040

Also, the high amounts of topographical index (higher than zero) confirm the concentrated flow in most parts of the watershed, therefore, indicate high risk of water erosion occurrence (Cavazzi *et al*. 2013). Our results demonstrated that topographical indices were useful in water erosion processes, and their spatial distribution. The digital elevation model, as a representative of topography in the studied watershed, illustrated the high variations of slope characteristics, and was based on the DEM product, location and type of application. The error that originates from DEM alters, and is effective on the prediction of soil characteristics, especially the topographical properties and flow parameters (Chaplot *et al*. 2000, Khanifar *et al*. 2020). The relation between predicted water erosion using the WEPP and geomorphic parameters were presented in Table 3.

Table 3. The Pearson's correlation coefficients of geomorphometric characteristics with water erosion

Predicted SE[a]	Curvature	FA[b]	FD[c]	FL[d]	Hillshade	Plan C.[e]	Profile C.[f]	SPI	TI	STI
WEPP	0.512*	–0.466	–0.359	–0.010	–0.524*	0.230	–0.539*	0.572	–0.523*	–0.044
Measured	0.108	–0.310	0.071	0.11	0.377	0.123	–0.086	–0.191	–0.252	–0.211

a: soil erosion, b: flow accumulation, c: flow direction, d: flow length, e: plan curvature, f: profile curvature

According to the results, there was no significant correlation between measured outputs and geomorphic parameters. In contrast, our results showed the relation between WEPP outputs and geomorphometric parameters (mostly for curvature, FA, and TI), because the WEPP model as a mathematical model uses a DEM for water erosion prediction and LS that originate from DEM which has a significant impact on water erosion (Moore *et al*. 1991, Wilson and Gallant 2000). For some geomorphic parameters such as TI and profile curvature, there was a significant correlation (5%). Indeed the smaller values of TI depict low potential for the development of ponding in the watershed, whereas larger values indicate that the local slope is gentle (Wolock and McCabe 1995). As regards our results and the relation between WEPP outputs and geomorphic parameters, there is a possibility to apply the WEPP model as a tool to predict geomorphometric characteristics, especially curvature. Curvature is a geomorphometric parameter and includes negative values that present convex slopes, positive values that illustrate concave slopes and zero values that are representative of flat areas. Therefore, this geomorphometric parameter is an index of slope shape, and topography (Wilson 2018). As our results showed, the topography factor was influential on soil erosional responses in the study area. To study the relation between geomorphic parameters, and the predicted water erosion with the WEPP model, linear multivariable regression was performed. Regarding the obtained R-square and adjusted R, there was a high linear relation between predicted soil erosion with the WEPP model and geomorphic parameters (R^2: 0.987, Std. Error: 4.213). A milestone in the WEPP model is using a DEM as a map in order to simulate slope characteristics (Zhang and Liu 2005). As for the relation between WEPP outputs and geomorphometric parameters and the difficulty of input preparation for the WEPP model, our results confirm the capability of multivariable regression to predict water erosion. Using soil erosion modeling could cover selecting and applying the best management practices to mitigate soil erosion. In summary, the application of these linear regressions, simplify the complicated process of water erosion modeling.

The variance analysis of the linear regression equation with geomorphic parameters is shown in Table 3. As can be seen, this model is significant (1%) with a low residual error. Besides, the amount of soil erosion is dependent on geomorphological factors that are effective in controlling flow velocity and flow concentration. As regards the amount of R for this equation, it is feasible to use geomorphometric parameters from DEM, instead of the WEPP as a complicated model. However, to apply this model to estimate water erosion, an equation using linear modeling with stepwise technique should be provided. Equation 1 contains simple and readily available parameters to predict soil erosion in tonnes per hectares (ton/ha), therefore, it is precipitant to use this model for water erosion prediction.

$$\text{Erosion (ton/ha)} = 0.09\ \text{hillshade} - 3.129\ \text{SP}\ (R^2 = 0.934,\ \text{sig. } 0.000) \qquad (1)$$

In this equation, SPI is a stream power index that is effective in sediment transportation. Another parameter in this equation is hillshade; a hillshade is a grayscale 3D representation of the earth's surface, in which the sun's relative position is taken into account for creating a shading raster (Fig. 3). Raster image was created based on the altitude and azimuth properties to specify the sun's position. The primary input for this function is DEM and the quality of DEM is adequate to the results (Deng *et al*. 2007). The high R^2 of this equation confirms the possibility of geomorphometric parameters for water erosion prediction. With regard to the importance of economic factors in any project, using readily available parameters in order to estimate complicated parameters is profitable. Moreover, based on the above equation, the continuous soil erosion map was provided (Fig. 6), which shows the spatial distribution of soil loss in the watershed.

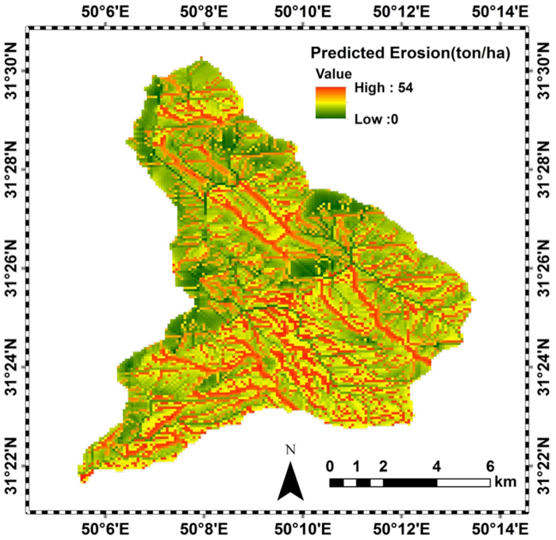

Fig. 6. The continuous soil erosion map (CSEM) based on WEPP simulations

Also, using the ENTER technique we found another equation (eq. 2) with a higher R-square (R^2: 0.987) when compared to the first equation, including numerous geomorphometric parameters (Table 4).

$$\text{Erosion (ton/ha)} = 1028.353\ k - 0.145\ FA - 1030.754\ kp + 1028.580\ \text{profile curvature} - 5.296\ SPI + 3.626\ TI \tag{2}$$

Table 4. Variance of analysis of linear regression equation for water erosion prediction

Model	Sum of square	Df	Mean square	F	Sig.
Regression	9160.623	10	916.062	51.612	0.000
Residual	124.244	7	17.749		
Total	9284.867	17			

Also, the Pearson's correlation coefficients of geomorphometric parameters are shown (Table 5).

Table 5. Coefficients of linear equation between water erosion and geomorphic parameters (ENTER method)

Geomorphic factor	Std. Error	B	Sig.
Curvature	380.441	1028.353	0.031
Flow accumulation	0.047	-0.145	0.017
Flow direction	0.121	0.107	0.409
Flow length	0.002	0.000	0.907
Hillshade	0.041	0.005	0.899
Plan curvature	377.843	-1030.754	0.029
Profile curvature	379.465	1028.580	0.030
SPI	1.108	-5.296	0.002
TI	1.697	3.626	0.070
STI	0.022	0.043	0.088

The WEPP model showed a good correlation with some of the geomorphometric parameters. Suriyaprasit (2008) used the land shape (geomorphometric) parameters in order to separate the prone lands to gully erosion and applied simple equations based on the Morgan-Finny model using geomorphometric parameters, and found the relation between water erosion and geomorphometric characteristics. The highest amount for soil erosion was achieved in the agricultural land and the lowest was in the forest (Table 6), hence land use is effective on water erosion and the main reason for highest amount of soil erosion in the agricultural land is the application of inconvenient management strategies. Land use reflects the type of management and operations in the field; therefore, with altering land use, the amount of soil erosion changed. One of the most critical points in watershed management is the selection, and application of management practices to conserve the soil against erosive forces.

Table 6. Pearson’s correlation coefficients of geomorphometric parameters

Parameter	Index	Curvature	Flow acc.	Flow dir.	FL	Hillshade	Plan cur.	Profile cur.	SPI	TI	STI
Curvature	0.195	1	–0.337	0.249	0.074	– 0.076	0.770 **	– 0.963	–0.794**	– 0.757	– 0.488*
Flow acc.	0.400	–0.337	1	0.355	– 0.275	0.437	–0.259	0.318	0.083	0.629**	0.536*
Flow dir.	*0.497	0.249	0.355	1	– 0.005	0.555*	0.402	–0.160	–0.042	0.100	–0.006
FL	0.049	0.074	–0.275	– 0.005	1	0.242	–0.128	–0.150	0.306	0.019	0.179
Hillshade	0.604	0.076	0.437	0.555*	0.242	1	0.062	0.117	0.188	0.380	0.380
Plan cur.	0.167	0.770 **	–0.259	0.402	– 0.128	0.062	1	–0.570*	–0.658**	–0.704**	–0.477
Profile cur.	0.311	–0.96**	–0.318	–0.160	– 0.150	0.117	–0.570*	1	0.746**	0.671**	0.422
SPI	0.145	–0.794**	0.083	–0.042	0.306	0.188	–0.658**	0.746**	1	0.717**	0.391
TI	0.314	–0.757**	0.629**	0.100	0.019	0.380	–0.704**	0.671**	0.717**	1	0.604*
STI	0.101	– 0.488*	*0.536	–0.006	0.179	0.380	–0.477	0.422	0.391	0.604*	1
Erosion	0.650 **	0.502	–0.466	–0.359	–0.010	–0.324	0.230	–0.539*	–0.372	–0.523*	–0.044
Total erosion	0.257	0.108	–0.310	0.071	0.110	0.377	0.123	–0.086	–0.191	–0.252	–0.211
Index	1	0.195	–0.400	–0.497*	0.049	– 0.604*	– 0.167	– 0.311	– 0.145	– 0.314	– 0.101

Geomorphometry and soil great groups

For the Aspect parameter, the highest mean variations were for Typic Xerofluvents (Table 7), which shows that the slope aspect has the highest effect on Typic Xerofluvents. Therefore, the slope aspect affects the formation and properties of this great group. For curvature parameter, the highest mean variation was for Lithic Xerorthents. This result illustrates that the range of elevation variations in areas with Lithic Xerorthents has the greatest value. In areas with complex topography, soil formation factors and soil erosion processes do not operate uniformly but alter with the location and situation of landforms (Kumhálová *et al*. 2008). Moreover, for water flow parameters, including accumulation, direction and length, the highest amount of mean variation was in Typic Calcixerepts. This result confirms that these soils (representative of some area in the watershed with Typic Calcixerepts soils) were significantly affected by water flow and flow characteristics (Table 7); therefore, in these areas, with regard to the watershed management, it is essential to mention flow characteristics. Also, for TI, the highest mean variations were for Typic Xerofluvents. These results present the effectiveness of topography indices. The differences in hillslope orientations can have a significant effect on microclimate and conduce to a discrepancy in soil characteristics, therefore, they influence soil erosion potential in the hillslopes (Iqbal *et al*. 2004). From the perspective of geomorphology, the effect of topography and land use on the development of hillshade is known, and the gradient and shape of slopes can be used to specify the age of the landscape. Also, geomorphometry is the best tool for visual and mathematical analysis of topography, landform, land shape, and modeling (Florinsky 2016, Wilson 2018). As regards the importance and role of topography in terms of soil erosion occurrence, especially in areas with complicated topography and high variability in elevation factor, the topography factor is very useful (Schaetzl and Anderson 2005).

Table 7. Statistical analysis of geomorphometric parameters based on soil great groups

Geomorphological parameter	Soil Type	Min	Max	Mean	Std. dev.
Aspect	Lithic Xerorthents	0.455	359.790	182.400	85.580
	Typic Calcixerept	0.000	359.890	208.500	100.800
	Typic Xerofluvents	0.000	359.160	232.000	88.700
Curvature	Lithic Xerorthents	–6.930	6.670	–0.046	0.728
	Typic Calcixerept	–5.450	4.320	–0.033	0.535
	Typic Xerofluvents	–4.840	4.910	–0.067	0.668
Plan curvature	Lithic Xerorthents	–2.820	2.240	0.020	0.367
	Typic Calcixerept	–2.390	2.360	–0.007	0.277
	Typic Xerofluvents	–2.310	2.400	–0.007	0.339

Geomorphological parameter	Soil Type	Min	Max	Mean	Std. dev.
Profile curvature	Lithic Xerorthents	–4.630	4.270	–0.026	0.459
	Typic Calcixerept	–2.630	3.220	0.026	0.335
	Typic Xerofluvents	–2.500	2.530	0.059	0.410
Flow accumulation	Lithic Xerorthents	0.000	2599.000	23.518	155.450
	Typic Calcixerept	0.000	2430.000	32.350	156.350
	Typic Xerofluvents	0.000	3116.000	61.500	357.650
Flow direction	Lithic Xerorthents	1.000	128.000	8.000	–
	Typic Calcixerept	1.000	128.000	16.000	–
	Typic Xerofluvents	1.000	128.000	16.000	–
Flow length	Lithic Xerorthents	0.000	7205.870	2595.760	1517.290
	Typic Calcixerept	0.000	9429.660	3327.120	2291.040
	Typic Xerofluvents	0.000	6114.890	2211.180	1524.380
Topographical index (TI)	Lithic Xerorthents	–5.360	12.770	1.780	4.080
	Typic Calcixerept	–5.030	13.880	2.540	4.260
	Typic Xerofluvents	–4.830	13.430	2.890	4.310
Hillshade	Lithic Xerorthents	0.000	254.000	151.660	54.180
	Typic Calcixerept	9.000	254.000	175.750	45.520
	Typic Xerofluvents	9.000	254.000	179.350	50.830
Sediment transport index (STI)	Lithic Xerorthents	0.001	5566.890	96.780	308.140
	Typic Calcixerept	0.0004	5117.630	133.600	379.390
	Typic Xerofluvents	0.023	5207.070	155.130	445.980
Stream power index (SPI)	Lithic Xerorthents	–12.090	7.090	–2.010	4.190
	Typic Calcixerept	–11.800	6.540	–1.950	4.290
	Typic Xerofluvents	–11.210	6.140	–1.330	4.160
DEM stat	Lithic Xerorthents	1084.000	3189.000	2103.270	414.000
	Typic Calcixerept	931.000	3179.000	1980.190	505.630
	Typic Xerofluvents	1694.000	3135.000	2328.590	425.670

CONCLUSIONS

The agricultural land covered just a small part of this watershed, while the amount of soil loss that originates from farmlands was meaningful. Topography and slope parameters showed high variations in the study area. Furthermore, there was high correlation between slope parameters and distribution of crop cover. Therefore, the amount of water erosion was disparate. The curvature, plan curvature, and profile curvature in this area depicted the uniformity of slopes in most areas, but in some areas, the convex slopes enhance the flow accumulation; therefore, the amount of water erosion increased. Also, there was no correlation between plan curvature and the predicted soil erosion using the WEPP. The main reason is the lack of this type of curvature in WEPP principles. The low amount of soil STI represents the sedimentation areas in the watershed. The amount of soil erosion in the geomorphic units (based on the landscape, mountain, hill, piedmont and valley) was different. There was a significant difference between sub-watersheds (hydrological units), and the main reason for these discriminations was land use. The results showed a good relation between geomorphologic parameters and WEPP outputs. Based on the high R^2, it was possible to apply the linear regression equation instead of complicated soil erosion models. However, using regression modeling with stepwise method resulted in the high R^2 and only two significant parameters on water erosion; therefore, it is possible to utilize geomorphologic parameters in order to predict water erosion.

Generally, the evaluation of these indices depicts that it is possible to use these parameters in order to predict soil erosion and prepare soil erosion and deposition maps to visualize spatial distribution of soils. Moreover, the cost of this method is significantly lower than traditional methods (Borough 1991). For topographic index values, the cells with higher values indicate the areas with enhanced accumulated runoff potential. Regarding the relationship between geology, topography and water erosion, there is a possibility to use geomorphometry and pedometery to predict and estimate water erosion. Management of soil resources is important and the evaluated techniques in this study help to cover the purposes of soil management resources. Indeed one of the primary purposes of soil management resources is diminishing soil degradation and water erosion because water erosion is a dynamic and widespread process and can threaten the soil quality, soil health, water health, and, finally, the human health.

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