RELATIONSHIP BETWEEN GEOMORPHOLOGIC UNITS AND EROSION AND SEDIMENT YIELD IN KASHIDAR WATERSHED, GOLESTAN PROVINCE, IRAN

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Abstract
Soil erosion is a complex process and pervasive geomorphological hazard "earth cancer" and its rate is counted as a comprehensive index for assessing degree of development and sustainability of land management programs of the countries. Due to the strong dependence of pedogenesis on geomorphic systems, there is a close relationship between geomorphic units and erosion rate at different spatial levels. In this research, the potential erosion rate of watershed was estimated by MPSIAC model within geomorphologic facies (as work unit) that differentiated on the homogeneity of topography, lithology and erosion reaction at semi-detailed level and 1:50000 scale. Based on obtained results, this watershed contains three erosion intensity classes' II, III and IV with completely different area frequency and its mean specific erosion rate is 1105m^3 km^{-2} y^{-1}. A regression equation with R^2=0.981 was established between specific erosion rate and effective factors of model in each geomorphic facies that significant at 5% level. Also, in multiple regression analysis (backward) all of the nine effective factors remained in the equation with R^2=0.95478 at significant level. Differences of erosion rate in geomorphologic units (unit, type, subtype, and facies (76 polygons with repeat) and also differences in number and area of polygons of units maps and erosion intensity map was compared by Chi-square test. Beside differences in polygon number of unit map, the other differences are significant at 0.01 to 0.05 ($.01<p<0.05$) level. These relationships indicate to geomorphologic diversity of type and rate or erosion in Kashidar watershed. Therefore geomorphologic units with spatial hierarchy and close genetic relation to each other, can be used as suitable for estimation of erosion and sediment yield and erosion hazard management in watersheds at different level.

Additional Keywords: geomorphologic units, erosion, MPSIAC

Introduction
Soil erosion as ″soil cancer ″ (CSIRO, 2003) is a complex process and pervasive geomorphic hazard due to its self-induced and multiple obvious and hidden social and environmental impacts (Ownegh, 2003). Soil erosion rate is key index for the assessment of land management strategies and sustainability of development programs of the countries .synergetic effect of environmental susceptibility and land misuse can easily cause to land degradation and syndrome such as California in USA (Cangir *et al.*, 2000) and Maraveh loess province in Iran (Ownegh, 2003). Determination of soil erosion key factors and intensity in the framework of homogenous spatial units, is the first stage of conducting a benefit single or integrated program of erosion control and management in a watershed (Hariston, 2002).

The intense dependency of pedogenesis on morphogenetic in morphosystem of different spatial dimension, degree of homogeneity and different erosion behavior, permits the selection of ″ geomorphic units ″ as ″ work unit ″ for all stage of soil survey, assessment and management of erosion and sediment hazard (Ownegh, 1996). Among the units ″ geomorphic facies ″ can be used as a suitable work unit for detailed studies of planning and management of natural resources and geohazards (Ownegh, 1996; 2003, Memarian *et al.*, 2003). The main aim of the present study is the determination of relationship between geomorphologic units and erosion and sediment yield in Kashidar watershed (one of the third order sub-basins of the Gorgan -Rud River) using MPSIAC model.

Materials and Methods
The study area located in northern slopes of the Alborz range, Golestan province, south east Caspian Sea region, Iran, and encountered with severe soil erosion hazard in recent years (Nohtani, 1996).

Results and Discussion
The results of this research were presented in separation of geomorphic units, erosion and sediment map, and statistical relationships.

Geomorphologic units

Geomorphologic unit map of Kashidar watershed contains 3 distinctive units (Mountain, Hill and plateau-terrace) in 3 polygons (7 types as rock group) in 29 polygons, 18 subtypes as ″ rock formation ″ in 29 polygons, and 12 well-identified facies in 55 polygons (76 with repeating) (Figure 2).

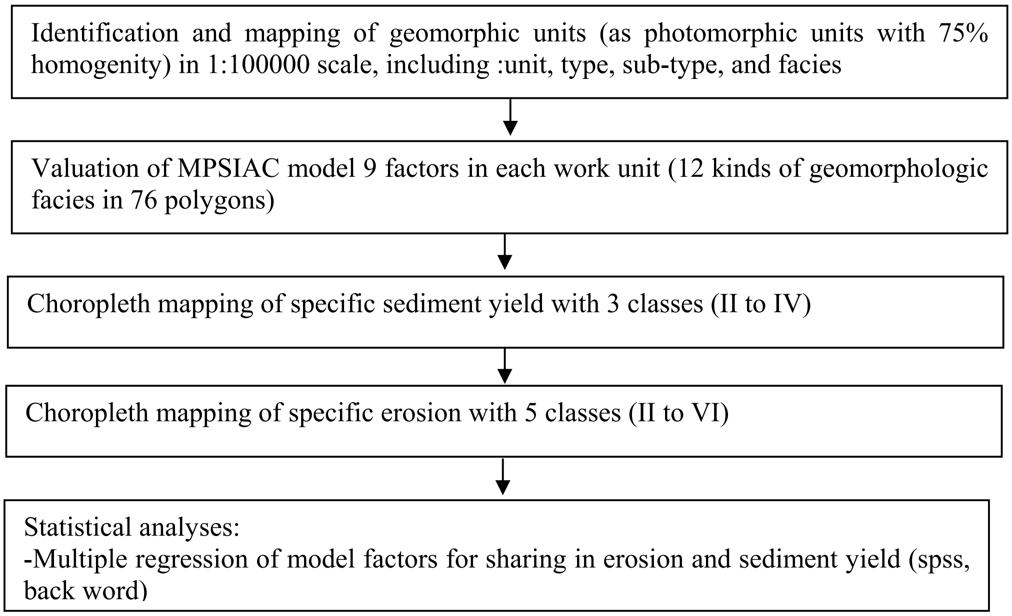

Figure1. Stages, materials and methods of research

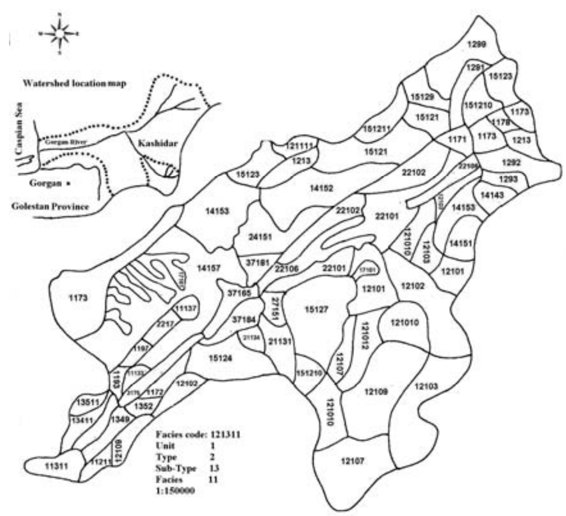

Figure 2. Geomorphic unit map (Facies) of Kashidar watershed

In the facies map, area of polygons ranges from 40 to 400 ha, with average area of 217 ha, that are equivalent to cell size of 1.26, 4, and 2.94 cm in 1:50000 scale respectively (Table 4 and Figure 2). This spatial resolution of facies map is appropriate for identification of critical points and implementation of erosion hazard management and control programs. This result corresponds completely for reduction of soil loss in Belgium with 1:10000 scale map, 56 work unit (sub basins), polygon area range from 20 to 260 and average area 80 ha (Verstertian, 2002).

Sediment yield map

Comparing sediment delivery value by MPSIC standard model, in each geomorphic facies, a choropleth specific sediment map of the watershed was prepared with 3 categories of potential sediment yield hazard classes including II, III and IV. This map contains 20 polygons that distributed with different spatial repitition (from 2 to 11 polygons for each class) (Figure 3 and Table 1)

Erosion map

The erosion choropleth map contains 5 erosion hazard class including II to VI, and 32 polygons with more different spatial repeating pattern (from 2 to 13) (Figure 4 and Table 2). A high difference of specific erosion between geomorphic facies (from 756 t/ha/y in eroded slope facies with dense forest cover to 2586 in channel erosion facies shows completely the effect and nature of erosional facies of the watershed (Memarian *et al*., 2003).

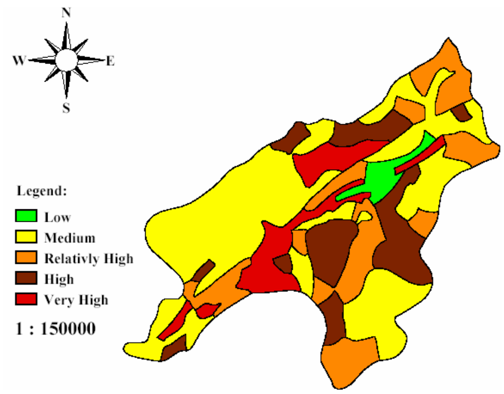

Figure 3. Potential sediment yield map of Kashidar watershed

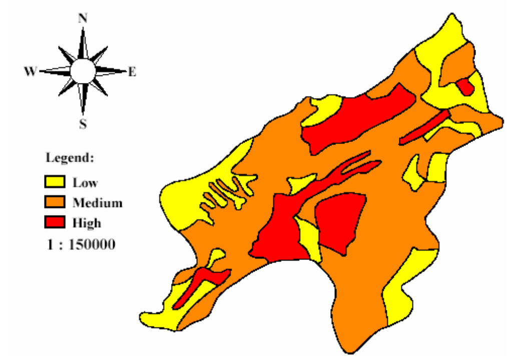

Figure 4. Potential erosion map of Kashidar watershed

Table 1. Number and area of polygons of sediment yield map classes in Kashidar Watershed

Class	Area Km^2	Polygon number	Polygon average area	Facies number by code												Sum	Facies average area
				1	2	3	4	5	6	7	8	9	10	11	12		
II	50	11	4.55	13		11						3		3		30	1.67
III	78	3	26	5	6	3		1		6		2	5	3	1	32	2.44
IV	85.36	6	6.14		3	2	3	2	2	1	1					14	2.63
	85.164	20	8.24	18	9	16	3	3	2	7	1	5	5	6	1	76	2.17

Table 2. Number and area of polygons of specifci erosion map classes in Kashidar Watershed

Class	Area Km^2	Polygon number	Polygon average area	Facies number by code												Sum	Facies average area
				1	2	3	4	5	6	7	8	9	10	11	12		
II	1.92	1	1.92	1												1	1.92
III	82.48	8	10.31	13		12				3		4		5		37	2.23
IV	38.45	10	3.85	4	2	3				3		1	2		1	16	2.41
V	25	8	3.13		4	1	1	1		1	1		3	1		13	1.92
VI	17	5	3.4		3		2	2	2							9	1.89
	164.85	32	6.09	18	9	16	3	3	2	7	1	5	5	6	1	76	2.17

Statistical relation of data

In multiple regression analysis (Backward) all of the 9 factors of model remained in the equation (R^2=0.95). factors according to relative importance or contribution share in specific erosion lay as 9, 7, 5, 1, 8, 6, 2, 3 and 4 respectively. In each geomorphic facies, between specific erosion and model factors establish a regression equation with R=0.98 (R^2 =0.96) and F=125.3 that significant at 5% level ($P<0.05$) as follows:

$$Y = -1767.8 + 57.39W_9 + 39.22W_7 + 36.88W_5 + 46.01W_1 + 27.38W_8 + 59.82W_6 + 32.5W_2 + 50.35W_3 + 408.43W_4$$

The contribution of all model parameters in regression equation can be well explained by proportion of number and area of geomorphic facies and spatial distribution and intensity effect of 9 factors in erosion and sediment yield of the watershed from this regression equation point of view, the Kashidar watershed can be considered as a unique watershed in regional scale. From 17 cases of Chi-square test between number, area and sediment and erosion class between and within geomorphic units, and sediment and erosion map polygons, 12 cases are significant at 1 to 5 % level ($0.01<P<0.05$). These relationships can be explained by the diverse erosion morphogenetic systems and lithology and different spatial pattern of erosion and sediment yield factors in the watershed.

Table 3. Comparison of number and areas of erosion and sediment yield map polygons by geomorphic facies in Kashidar.

Code	Facies	Polygon number with repeat	Average area	Area	Area percent	Specific erosion	Specific sediment	SDR
1	Regular slope	18	172.11	30.98	18.79	780	238	0.305
2	Surface and rill erosion	9	237.22	21.35	12.95	1516	465	0.306
3	Eroded ridges	16	210.68	33.71	20.45	756	218	0.288
4	Gully erosion	3	204	6.12	3.71	2302	682	0.296
5	Wide bed valley	3	128	3.84	2.33	1968	572	0.290
6	Channel erosion	2	169.5	3.39	2.05	2586	750	0.290
7	Bad land	7	421.57	29.51	17.9	1135	330	0.290
8	Mass erosion(Scree)	1	74	0.74	0.45	1650	329	0.199
9	Irregular slope	5	300.2	15.01	9.1	875	236	0.269
10	Rock outcrop	5	195.6	9.78	5.93	1279	334	0.261
11	Rock ridge	6	111.83	6.71	4.07	820	238	0.290
12	Rock mass	1	373	3.73	2.26	1035	300	0.289
Sum		76	216.90	16.85	100	1105	322	0.291

Table 4. Comparison of number and areas of map polygons and geomorphic units ratio

Geomorphic unit	Main criteria	Unit number	No. of map polygons	No. of map polys.(repeated)	Average area	Ratio to facies	Ratio to type	Ratio to Sub-type
Unit	Physiography	3	3	3	5494	25.32	9.66	12.99
Type	Erosion sensitivity	7	7	29	569	2.62	1	1.35
Sub type	Rock formation	18	18	39	423	1.95	0.74	1
Facies	Erosion reaction	55	55	76	217	1	0.38	0.51

Conclusions

Most of the MPSIAC model factors have geomorphic nature. Range of four main geomorphic factors including channel erosion relief, surfucegeology and surface erosion is 1, 3, 4 and 5 respectively. Also, other factors of MPSIAC model controlled somewhat different with geomorphic processes. Thus, according to this strong genetic relation, estimation and mapping of erosion and sediment rate is not only acceptable, but also unavoidable. It seemed that erosion and sediment rate estimation based on geomorphic facies is much practical than based on homogenous work unit obtained from model factors layer overlay. Variety in number area, rate of erosion and sediment, and irregular spatial distribution of erosion classes polygons, will cause to variety and scattering of erosion hazard control and management projects in Kashidar watershed. The area of erosion classes III and higher that cover more than 70% of the watershed indicater to acritical condition for soil conservation practices.the medium specific sediment rate (II, III and IV classes) and high specific erosion rate (II toVI) can be explaind more with the triggering effects of channel erosion, land use, relief, surface geology and surface erosion, and nearly with decreasive effects of other 4 remained factors of the model. This finding is completely corresponded to the work of Memarian *et al.* (2003) in a urban and more arid watershed in Kashmer.

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