

# GIS: Some Models for Preparing Erosion Features Map

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## 1. Abstract

Soil erosion is a serious geo-environmental issue causing land degradation in sub-humid to arid mediterranean countries including parts of Iran. This study in Jajrood sub-basin, north-east Tehran, was conducted to investigate some methods for water-soil erosion types mapping by GIS. Four models were used for providing working units' maps by integration of data layers including A. plant cover, geology and slope B. land use, geology and slope C. land use, rocks sensitivity to erosion and slope and D. land use, rocks sensitivity to erosion and land units. The surface, rill, gully erosion Intensity in the 314 spot was controlled to provide ground truth map from each of these erosion features. Soil erosion type's map obtained from integration of these truth maps, and then this map was crossed by the maps A to D. Results indicated that the integration of land use, rocks erodibility and land units layers is a better model for providing erosion types map than other models from an economic and executive regards. The cross of the map D with the ground truth maps of surface, rill and gully erosions showed the greatest and least accuracy are related to providing gully erosion and erosion features maps, respectively. The greatest precision of model was related to providing gully erosion map (with coefficient of variation 17.8%), and the least precision (with 40.5% coefficient of variations) was related to providing erosion features map. In conclusion, model D is suitable for preparation of gully erosion map no erosion features map.

## 2. Introduction

Soil erosion as a serious geo-environmental has both direct and indirect negative impacts: loss of soil, loss of green cover, deterioration of agriculture, desertification and, of course, economic reverberations (Khwlie et al., 2002). The implementation of effective soil conservation measures has to be preceded by a spatially distributed erosion risk assessment (Moussa et al., 2002; Souchere et al., 2005), and erosion features assessment and its intensities (Mohammadi Torkashvand, 2005). Most of erosion and sediment studies have been carried out to provide a quantitative erosion map (Singh et al., 1992; Martinez-Casanovas, 2003; and Ygarden, 2003) and less to preparing an erosion features map. Qualitative erosion mapping approaches are adapted to regional characteristics and data availability. Resulting maps usually depict classes ranging from very low to very high erosion or erosion risk. There is no standard method for qualitative data integration, and consequently many different methods exist (Vrieling, 2006).

Khwlie et al. (2002) for providing a risk map of soil erosion in eastern Mediterranean rugged mountainous areas, Lebanon, applied remote sensing and GIS. With steep slopes, torrential rain, improper human interference, run-off is high and water-soil erosion is continuously deteriorating the land cover. Remote sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Digital elevation models created from SAR imagery contribute significantly to assessing vulnerability of hydric-soil erosion over such a difficult terrain. GIS layers of the above factors are integrated with erosional criteria to produce a risk map of soil erosion. Results indicated that 36% of the Lebanese terrain is under threat of high-level erosion, and 52% of that is concentrated in the rugged mountainous regions. Bou Kheir et al. (2006) integrated two data layers including erodibility of rocks and soil and potential sensitivity to erosion as a model for providing risk map of soil erosion. The risk map corresponds well to field observations on the occurrence of rills and gullies. In recent researches, integration of data layers has been used in erosion and sediment different studies (Feoli et al. 2002; Navas & Machin, 1997; Bayramin et al. 2003). Shrimali et al. (2001) prioritized erosion-prone areas in hills using remote sensing and GIS as a case study of the sukhna lake catchment, northern India. The study indicated that 1. IRS ID LISSIII data can be used for land use/land cover mapping with a reasonably good (83 percent) classification accuracy for hydrological and erosion assessment applications, and 2. That a simple index-based approach using three main causative factors, i.e., slope, soil and land use/land cover, can give fairly good delineation of erosion-prone areas for prioritizing.

In Isfahan province, Rahnama (2003) also concluded similar results in providing erosion types map by aerial photograph interpretation. He recommended satellite imagery and GIS for this aim. The extension of the use of modern spatial information technologies, such as geographical information systems (GIS), digital

elevation modeling (DEM) and remote sensing, have created new possibilities for research as a key for erosion types mapping (Martinez Casanovas, 2003) that is economical due to low costs as well as quickness (Raofi et al. 2004). But it should be regarded that the field survey and photo-interpretation for erosion types mapping at the national scale is time consuming and expensive (Raofi et al. 2004). The aim of this paper is to develop a methodology based on data layers integration in GIS for providing water-soil erosion types map and its intensities at the national scale (1:250000).

### 3. Methods

The Jajrood sub-basin with 162,558 ha located between 51°34'E and 52°6'E, 35°13'N and 35°48'N was considered for the investigation of erosion features. It extends from northeast to southeast Tehran Province, Iran. The highest and the lowest height of basin are 3000 and 867 m, respectively. Land covers were rangeland, badland, sand borrow, agriculture land and urban regions. Within the basin, different lithic units include pyroclastic stones, tuffs, andesite, shale, conglomerate, gypsum and limestone. Also, Quaternary deposits have covered in the major part of the southern basin particularly in the Varamin plain (47.8% of area basin). Necessary maps such as topographic, geology, plant cover type and land units were scanned and georeferenced. Digital Elevation Model (DEM) was prepared by 1:50,000 topographic digital data, classified slope map-the DEM- derived slope map was classified into eight slope (percent) classes 0-2, 2-5, 5-8, 8-12, 12-20, 20-40, 40-70 and >70 based on Mahler (1979) classification, land use was derived using ETM<sup>+</sup> satellite image and rocks erodibility layer based on Feiznia (1995). According to their sensitivity to erosion, the rocks were categorized in to the five classes. Four models applied for preparation of working unit's maps that derived from integration of data layers including: A. plants cover, lithology and slope layers, B. land use, lithology and slope layers, C. land use, rocks erodibility and slope layers, and D. land use, rocks erodibility and land units layers. Selection of data layers was regarding exploratory studies in Kan sub-basin (Mohammadi Torkashvand, et al. 2005). After this, these models are called models "a", "b", "c" and "d".

Different methods were incorporated for classification of soil erosion type's severities (Flugel et al., 1999; Refahi, 2000; Boardman et al., 2003 and Sirvio et al., 2004) and experiences and expertise considerations (Mohammadi Torkashvand et al. 2005). A total of 314 points has been considered on color composite images (for field investigation) by classified randomized sampling. A primary polygon was determined for each control point regarding image characteristics. The magnitude of erosion in each erosion feature was investigated in these ground control points and then frontiers of each primary polygon were corrected with due attention to the field views for every one of the surface, rill and gully erosions. Modified polygons with regard to the intensity of each erosion features in the field, were marked. Polygons with same the intensity were combined together and ground truth maps of surface, rill and gully erosions were prepared. The erosion features map obtained from integration of the surface, rill and gully erosions maps. Erosion features maps were crossed with working units' maps to investigate the ability of each method on separating erosion features. Equation 1 was used for investigating method's accuracy.

$$A = \frac{\sum_{i=1}^n Z^*_{(x_i)} c_i}{\sum_{i=1}^n Z^*_{(x_i)}} \quad (1)$$

That  $A$  is map accuracy or map conformity with actual conditions (percent),  $Z^*_{(x_i)}$  is working units' area (ha)

and  $C_i$  is maximum area of each working unit that is uniform in compared to actual conditions (percent). Root mean squared error of working units' accuracy was computed by equation (2).

$$RMSE = \sqrt{\frac{\sum_{i=1}^n [Z_{(x_i)} - Z^*_{(x_i)}]^2}{n}} \quad (2)$$

That  $Z_{(x_i)}$  is working units' area (ha) that is uniform in actual conditions. The precision each of method by equation 3 was obtained.  $CV = \frac{S}{\bar{X}} \cdot 100$ . That CV and S are coefficient of variation and standard deviation of working units' accuracy, respectively, and  $\bar{X}$  is method accuracy ( $A$  in equation 1).

### 4. Results

Table 1 indicates the numbers of units' in the working units' maps. In layers integration models, the most and least numbers of working units are related to models "a" and "d", respectively. Most polygons of

models "a", "b" and "c" have small area which is not possible to be presented in the maps 1:250,000 maps due to cartographic limitations. Table 1 presents the accuracy and error of data layers integration models in distinguishing soil erosion type's intensities. According to this table, the highest and the least accuracy belong to models "a" and "c" that is 68.3 and 53.4 percent, respectively. The accuracy difference between models "a", "b" and "d" is not considerable, but it is significant with model "c". It should be regarded that model "c" has the greatest precision (high coefficient of variation).

With regards to the results of data layers integration, model "d" has suitable been distinguished than models "a", "b" and "c" Totally, regarding results and economic and executive regards, integration of land use, rocks sensitivity to erosion and land units as a method as working units map applied for preparing of surface, rill and gully erosion features maps. Table 2 shows the accuracy of model "d" in preparing erosion features maps. The greatest and the lowest accuracy are related to preparation of gully erosion map that working units have 89% conformity with field actual conditions. Accuracy is approximately similar for providing surface and rill erosions map. The least accuracy is related to providing erosion features map.

Areas of working units' in compared to the basin area (%) in different accuracies are seen in table 3. It can approximately tell that working units had not the accuracy less than 50% for preparing rill erosion map, but the greatest area is related to providing erosion features map (39.9%). In providing gully erosion map, 72.3% area of working units had the accuracy more than 90%. Least area of working units in accuracy more than 90% is related to providing erosion features map. Results that are related to root mean squared error of model "d" are observed in table 2. This index also shows that model has the least error for preparing gully erosion map as compared with other erosions. RMSE trend for providing different erosions map is following: Gully < rill < surface < Erosion features. Therefore, model has the greatest error in preparing erosion features map that RMSE is 1732.5 ha.

Table 2 indicates the precision of model "d" for preparing different erosions map and erosion features map. The greatest precision of model is related to providing gully erosion map, because have the least coefficient of variations. Least precision of model with 40.5% coefficient of variations is related to providing erosion features map. Precision trend approximately is same with accuracy trend, with this difference that providing rill erosion map has a few more precision as compared with surface erosion map preparation.

**Table 1 Accuracy and error of crossed layers as the working units' maps in the Jajrood sub-basin**

Working Units' Map	Crossed Data Layers	Accuracy (%)	Coefficient of Variation (%)	Root Mean Squared Error (ha)	Total Number of Working Units
A	Slope, Plant cover and Lithology	68.3	34.8	1686.8	902
B	Slope, Land use and Lithology	67.4	40.1	716	436
C	Slope, Land use and Rocks sensitivity	53.4	30.9	1933.8	149
D	Land use, Rock Sensitivity and Land units	66.6	36.5	1732.5	86

**Table 2 Results related to accuracy, coefficient of variation (precision) and root mean squared error of model D in providing different erosions maps**

Index	Kind of erosion map	Surface	Rill	Gully	Erosion Features
Accuracy (%)		78.9	78.4	89.0	66.0
Coefficient of Variation (%)		26.2	24.1	17.8	40.5
RMSE* (ha)		1185.3	1013.1	507.5	1732.5

\* Root Mean Squared Error

**Table 3 Working units area (in terms of percent as compared with basin area) in different accuracies for providing different erosions maps**

Kind of Erosion Map	Accuracy (%)	> 50	50 - 70	70 - 90	< 90
Surface		15.9	18.6	20.6	44.8
Rill		0.9	37.6	21.9	39.6
Gully		5.7	6.1	15.9	72.3
Erosion Features		39.9	15.5	6.0	38.6

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