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Investigation of Some Models Derived from Data Layers Integration in Geographic Information System with Slope Layer for Providing Water-Soil Erosion Types Maps

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Abstract: The aim of this study is to investigate some models of data layers integration and slope layer (GIS) for providing erosion types maps in Roodbar sub-basin, downstream Sefidrood dam. From topographic layer, DEM was provided and then from that, four slope layers with different categories of slope were prepared. Nine working units' maps were provided from the integration of the land use, rocks erodibility, land unit and different slope layers. In basin, 652 ground control points were investigated with the view of erosion features (surface, rill and gully erosions) and the point's position were recorded by GPS. Homogenous points percent with the view of the surface erosion, rill erosion, gully erosion and erosion features were computed to derive the accuracy of working units. Mean accuracy of these working units has been considered as the accuracy of working units maps. Results indicated in providing erosion features, using slope layer is led to the high numbers of small area working units that in addition to increase in field controls expenses and executive limitations, it is also accompanied with cartographic limitations. Overall accuracy and precision of the model derived from the integration of land use, land units and rocks erodibility layers was investigated as compared with truth maps of surface, rill and gully erosions and erosion features map. Results indicated that this model can be used in providing erosion types maps with accepting error, but without forest land use, it is not proposed.

Key words: Roodbar sub-basin, DEM, soil erosion types, GIS

INTRODUCTION

Soils are eroded as different features. Erosion features mapping determine the preference of soil conservation practices that this is important in watersheds management (Mohammadi-Torkashvand *et al*., 2005). Watershed studies office of Iran (2000) prepared a design for providing erosion types map at the national level (scale-1:250000). They integrated data layers of soil, slope, lithology, land type and land use for providing working units map, but field investigations had indicated that this way is impossible for the total area of Iran because of time and costs. With regards to the high expenses of ground mapping and aerial photogrammetry in providing erosion features map (Raoofi *et al*., 2004), 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 mapping (Martinez-Casasnovas, 2003). One of these possibilities is different data layers integration for providing working units as homogenous units with the view of erosion features in the environment of Geographic Information Systems (GIS) and investigation of executive regards.

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In different studies, one of the important data layers in layers integration is slope layer. Ceredan *et al*. (2002) believed the slope is an important factor on appearing surface and rill erosions. Busoni *et al*. (1995) in mass movement mapping introduced the slope as an effective factor. For providing quantitative erosion maps, slope layer is used as a basic layer (Singh *et al*., 1992; Feoli *et al*., 2002; Essa, 2004) and also, in providing qualitative erosion maps such as land slide map (Bayramin *et al*., 2003; Esmali and Ahmadi, 2003) and erosion risk map (Khawlie *et al*., 2002).

Noble and Fletcher (1984) provided a New Zealand erosion features map of scale 1:250,000. They integrated different layers including lithology, soil, erosion, vegetation cover, climate and land use with slope layer for providing working units map. Then these units regarding erosion intensities of sheet, rill, gully, tunnel gully, stream bank and massive were investigated and labelled by field observations.

Mohammadi-Torkashvand (2005) studies in Kan-Sologhan basin indicated using slope layer in integration with land use and geology layers and also with geology and land cover layers in providing erosion features map caused to establish uniform units with the view of erosion features intensity, but the high numbers of units and its field control need a great costs and time. They proposed to use land units layer instead of slope layer in integration with land use and rocks erodibility in another basin to differentiate geology and land use of its. Also, the possibility using slope layer with different classes of slope in integration with other data layers is investigated in providing accurate and economical maps. Therefore, the aim of this study regarding economical regards and also necessity in preparing accurate map is to investigate the possibility using slope layer with other data layers in preparing erosion features map.

MATERIALS AND METHODS

This study was conducted during 2007-2008 years in Islamic Azad University, Rasht Branch, Rasht, Iran. The Roodbar sub-basin with 102898 ha located between 49°15' E and 49°15' E, 36°43' N and 37°02' N was considered as studying basin. It extends in south of Guilan province, Iran, in central part of Alborz mountains. Sefidrood river after exit of Sefidrood dam to go through basin width and move to Caspian sea. Land units of basin are 1.11, 1.14, 1.2, 1.21, 1.23, 1.7, 2.13 and 3.22. Land covers are poor and moderate rangeland, orchards, dense and sparse forest, agriculture land and urban regions. Within the basin, different lithic units include sand stone, shale, conglomerate, mud stone, silt stone, diorite, limestone and alluvial deposits (Quaternary deposits). Climate according to the Demartonne method is sub-humid and humid in the southern and northern regions, respectively.

Necessary maps such as topographic, geology, land use 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 four methods:

- Classes 0-2, 2-5, 5-8, 8-12, 12-20, 20-40, 40-70 and >70% (Mahler, 1979)
- Classes 0-3, 3-5, 5-15, 15-25, 25-33, 33-100 and >100% (Shrimail, 2001)
- Classes 0-5, 5-10, 10-20, 20-50 and >50%
- Classes 0-5, 5-10, 10-20 and >20%

After this, above slope maps are called maps A, B, C and D. Rocks erodibility layer based on Feiznia (1995) was prepared from geology map that regarding their sensitivity to erosion, the rocks were categorized in to the following five classes: sensitive, moderately sensitive, nearly resistant and resistant. Nine methods were used to prepare working units' maps by the integration of different data layers including:

- Land use, rocks erodibility and slope (Map A)
- Land use, rocks erodibility and slope (Map B)
- Land use, rocks erodibility and slope (Map C)
- Land use, rocks erodibility and slope (Map D)
- Land use, rocks erodibility and land units
- Land use, rocks erodibility, land units and slope (Map A)
- Land use, rocks erodibility, land units and slope (Map B)
- Land use, rocks erodibility, land units and slope (Map C)
- Land use, rocks erodibility, land units and slope (Map D)

Selection of the data layers was carried out having made exploratory studies in Kan-Sologhan basin (Mohammadi Torkashvand *et al*., 2005). Slope, land use, geology and land unit are the important factors in the appearing of the soil-water erosion features.

In this study, erosion features are soil-water erosion types including surface, rill and gully erosions. Different methods were incorporated for classification of surface, rill and gully erosion severity such as Flugel *et al*. (2003), Refahi (2000), Boardman *et al*. (2003) and Sirvio *et al*. (2004) and the series of changes are based on experience and expertise considerations (Mohammadi-Torkashvand *et al*., 2005). A total of 652 points has been considered on color composite images (for field investigation) by classified randomized sampling and were controlled in field. Ground control points map was prepared to overlay on nine working units maps 1-9. In every working unit, uniform point's percent with the view of surface erosion to all points in that working unit was computed to obtain conformity percent of every working unit. Map conformity percent as map accuracy of surface erosion obtained from mean conformity percent of working units. This method also applied for obtaining maps accuracy of rill and gully erosions and erosion features.

Investigations of data layers integration methods caused to select the better method until its overall accuracy and precision is evaluated in providing surface, rill and gully erosions maps; and erosion features map base on Eq. 1 and 2. For each ground control point, therefore, a polygon was determined with due attention to the field views for every one of the surface, rill, gully and channel erosions. 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, gully and channel erosions were prepared. The erosion features map obtained from integration of the surface, rill, gully and channel 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 model overall accuracy.

$$A = \frac{\sum_{i=1}^{n} Z_{(x_i)} c_i}{\sum_{i=1}^{n} Z_{(x_i)}} \tag{1}$$

where, A is the overall accuracy of model or map conformity with actual condition (percent), $Z_{(x_i)}$ is working units' area (ha) and C_i is maximum area of each working unit that is uniform compared to actual conditions (percent).

The precision of model was investigated by applying the working units' accuracy coefficient of variation (Eq. 2).

$$CV = \frac{S}{A} \times 100 = \frac{\sqrt{(A - c_i)/n}}{A} \times 100 \tag{2}$$

where, S is working units' accuracy standard deviation and A is the overall accuracy of model.

RESULTS

Table 1 indicates the created working units' numbers due to the integration of data layers and their area in Roodbar basin. The highest working units' number is related to the integration of rocks erodibility, land use, land units and slope layers; of course using slope layers A and B has been led to more working units. The least working units are also related to the integration of land use, rocks erodibility and land units layers.

The greatest accuracy, in providing surface erosion map, is related to maps 6 and 2 those are 80.4 and 78.1%, respectively (Table 2). For this map, the lowest accuracy is related to Map 4 with 54.6%. In providing rill erosion map, also, the greatest accuracy is related to Maps 6, 7 and 3. Map 5 (integration of land use, rocks erodibility and land units layers) and Map 1 indicate the greatest uniformity with the view of gully erosion map.

Accuracy of methods in preparing erosion features map has decreased. In providing erosion features map, in addition to the integration of land use, rocks erodibility and land units layers (Map 5), integration of these layers with slope layer A and B had the greatest accuracy. In general, the highest accuracies of different methods are related to providing gully erosion map than other maps of erosion type's.

Table 1: Results of the data layers integration in different working units' maps

Working units map	Area (ha) <6.25	Area (km^2) 0-0.1	0.1-1	1-10	10-100	>100	Total No. of working units
1	10	34	107	80	22	1	244
2	10	22	63	57	25	1	168
3	18	20	53	43	21	1	138
4	10	29	97	62	26	1	215
5	10	17	28	47	25	1	118
6	172	228	294	147	21	-	690
7	95	130	201	124	20	1	476
8	71	97	157	92	22	1	369
9	129	183	252	143	18	1	597

Table 2: Accuracy of working units maps base on homogenous ground control points percent with the view of the erosion to all controlled ground points

Kind of erosion	Working units map 1	2	3	4	5	6	7	8	9
Surface	75.4	78.1	65.2	54.6	76.3	80.4	77.9	66.1	69.2
Rill	72.4	73.1	71.7	63.5	72.2	77.5	75.2	71.4	63.4
Gully	81.8	85.2	80.6	75.8	86.2	82.6	85.4	83.2	78.4
Erosion features	61.8	64.6	49.8	50.2	68.2	67.7	67.2	57.3	56.8

Table 3: Accuracy and precision of model (derived from the integration of the land use, land units and rocks erodibility) in providing erosion types maps with considering forest land use

Index	Kind of map: Surface	Rill	Gully	Erosion features
Accuracy	84.2	76.6	78.8	71.2
Precision	29.6	31.5	28.7	42.2

Table 4: Accuracy and precision of model (derived from the integration of the land use, land units and rocks erodibility) in providing erosion types maps without considering forest land use

Index	Kind of map: Surface	Rill	Gully	Erosion features
Accuracy	68.0	54.5	57.2	41.8
Precision	36.4	55.5	50.5	85.6

Regarding conformity percent of controlled ground points with the view of erosion types and also economical, executive and cartographic regards, Map 5 has been distinguished as a better model in providing erosion types map. This model has obtained from the integration of land use, land units and rocks erodibility layers. Accuracy and precision (base on Eq. 1 and 2) of this model in providing erosion types map is observed in Table 3. The greatest accuracy of model is related to providing surface erosion map that is 84.1%. Accuracy in providing gully and rill erosion maps and erosion features map is 78.8, 76.6 and 71.2%, respectively. The greatest precision is related to providing gully erosion map because its coefficient of variation is 28.7%.

Since the great part of basin area has been covered by dense forest, therefore, the accuracy and precision of model without forest land use has also been computed and its results is observed in Table 4. The difference accuracy between two models (with and without forest land use) in providing surface, rill and gully erosion maps respectively is 16.2, 22.1 and 21.6%. This difference for preparation of erosion features map is 29.4%. The precision of model in preparing surface, rill and gully erosions maps is approximately 30%, but without forest land use, the precision severely reduce so that the coefficient of variation of model in providing rill and gully erosion maps decrease from 31.5 to 55.5 and from 28.7 to 55.5%, respectively. This decrease in coefficient of variation in providing erosion features map is more (from 42.2 to 85.6%).

DISCUSSION

Slope is an effective factor on appearing soil erosion features with different intensities. In providing quantitative and qualitative erosion maps, slope layer is used as a basic layer (Rahmani *et al*., 2005). When the aim is to provide quantities maps of sediment and erosion, different classes of slope layer are weighted to use in data layers integration and map calculation, but when the aim of data layers integration is to establish homogenous units with the view of erosion features intensity, three subjects are important:

- Accuracy and precision of models (derived from data layers integration) in providing erosion types maps
- Cartographic regards and limitations
- Economical and executive regards

When the slope layer is used for providing erosion features map; it established the high No. of units with the small area. A slope class (for example 2-5%) has been formed from the high No. of small area sub-units (many of sub-units have an area less than 1 ha) replicated in different regions of basin, but all these sub-units are principally an unit. When this unit is integrated with a great area unit (for example a unit with moderate rocks erodibility), it is led to creating a working unit that this unit has been formed from many sub-units replicated in different regions of basin. These sub-units have a small area and it is not possible their representation in maps at the 1:250000 scales. In data layers integration with slope layers A and D, this problem is more than use of slope layers B and C. Increase in data layers numbers is led to increase in numbers of working units; in turn it decreases the working units' area. On the other hand, small units usually have a more uniformity as compared with large ones causing more accuracy in maps 6 and 7 than maps 1-5 excluding gully erosion map. It appears categories of slope in maps A and B have better been selected than maps C and D, because accuracy of the integrated layers with slope layers A and B in providing surface, rill and gully erosion maps (excluding map 8) and erosion features map is more than the use of slope layers C and D.

Another basic factor in preparing soil erosion types maps is economical regards that nowadays is a criterion in executive works (Nikkami, 2006). High numbers of working units' and their small area increase the expenses of map preparation due to increase in field views numbers. In addition to this, at the national scales, representation of small working units is difficult and results in map confusion, color eating piecemeal and low quality (Mohammadi-Torkashvand *et al*., 2005). Above limitations is more in integration of data layers with slope layers A, B and D. These limitations in integration of four data layers with slope layers are enhanced than the integration of three data layers with slope layers. Therefore, this is correct that the Map 6-7 have a more accuracy, but regarding executive and cartographic regards is not proposed in providing soil erosion types maps.

In all models, accuracy of models in preparing surface, rill and gully erosion maps alone is more than providing erosion features map. This is natural to decrease the accuracy of models in preparing erosion features map, because the diversity of erosion features increase to decrease accuracy. In providing erosion features map, off course, cartographic limitations is more than providing map of each erosion type's alone e.g., gully erosion. In this state, since we can to show erosion intensity on map from low to sever by colors, therefore, it is not necessity to leg map units led to less limitation in providing map. We cannot represent areas less than 6.25 ha at the scales 1:250000 even though color (Mohammadi-Torkashvand, 2008).

Integration of the land use, land units and rocks erodibility layers more or less have accuracy similar Map 6 or 7, but its working units numbers is very less than these maps. In Map 5, accuracy in providing gully erosion map and erosion features map is even more than maps 6-7. Therefore, the overall accuracy and precision of this model that had derived from the integration of the land use, land units and rocks erodibility layers was investigated. Bou Kheir *et al*. (2006), also for providing risk map of soil erosion in Lebanon applied two data layers including erodibility of rock and soil and potential sensitivity to erosion. Shrimali *et al*. (2001), for prioritizing erosion-prone areas in hills, a cumulative erosion index computed from the rating given to the some main causative factors among them soil erodibility and land cover.

Regarding results of Table 3 and 4, the greatest accuracy of model was related to the preparation of surface erosion. This probable be due to more conformity of surface erosion with integrated layers i.e., these layers are more effective factors on appearing surface erosion than rill and gully erosions. Mohammadi-Torkashvand (2008) reported that the accuracy of this model in providing gully erosion map was 89.0% in Jajrood basin, but now is 78.8% and without forest land use is 57.2%. This decrease in accuracy of gully erosion map preparation can be due to increase in the diversity of gully erosion intensity in a mountainous basin, because the great part of Jajrood basin is level plain with homogenous erosion.

Investigations indicated that in the great part of basin covered by dense forest, obvious erosion is not observed unless as point. Working units with forest land use have a full conformity with the view of erosion features intensity than actual conditions. This increases model accuracy and since in the great parts of mountainous regions of Iran don't exist dense forest land use; therefore, accuracy and precision of model without dense forest land use was investigated. In this state, accuracy and precision of model in providing all erosion types maps and erosion features map severely decreased. In this state, this model can to apply only for preparing surface erosion map.

CONCLUSION

Regarding results, using slope layer is led to creating the high numbers of small area working units. In addition to cartographic limitations, this increases field control expenses and executive limitations of map preparation. Integration of land use, rocks erodibility and land units layers was a better method in providing erosion features map. Above model not only had a similar accuracy in compare with the layers integration with slope layers A and B, but also was a more suitable model with the view of economical and executive regards. Overall accuracy and precision of recent model indicated that this can be used in providing erosion types maps with accepting error, but without forest land use, it is not proposed.

Some diversity of erosion features intensities can be due to the kind of soil and its depth and properties. Regarding lack soil map of Iran at the scales 1:250000, it is proposed to investigate the preparation of erosion features map for regions having soil map as a data layer.

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