

Full Length Research Paper

The possibility in providing soil surface erosion map by the supervised classification of ETM⁺ satellite images in a mountainous basin (Roodbar sub-basin, Guilan, Iran)

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Soil surface erosion is a serious environmental problem which caused decrease in the lands agriculture value and increase in sediment and water pollution. In this research, the aim is to evaluate the supervised classification of ETM⁺ satellite images producing surface erosion map. The Roodbar sub-basin; downstream Sefidrood dam, Guilan province, Iran, was considered as studying basin in a mountainous land type. Results showed that the overall accuracy of surface erosion classification is 69.2%, but accuracy differentiates in different intensities of surface erosion. The greatest accuracy is related to very high intensity and the lowest accuracy is for the low intensity of surface erosion.

Key words: Surface erosion, erosion mapping, supervised classification, ETM⁺ images.

INTRODUCTION

Soil erosion phenomena are the result of a complex interaction between natural (e.g. soil properties and climate conditions) and human factors (e.g. over-grazing, over-cultivation and deforestation). During the last few decades, unsustainable land management and extreme meteorological events have accelerated the effects of exiting erosion/degradation phenomena, incrementing the risk of their occurrence in regions with vulnerable soils (den Biggelaar et al., 2004). The erosion features map is one of the most important and basic method in erosion and sediment yield studies to determine suitable soil conservation programs (Mohammadi, 2006). The possibility using aerial photographs for soil mapping has been recognized for a long time. Commonly, photographs were used to support conventional geomorphological methods, and also for direct identification of sheet, rill and gully erosion. But field survey and photo interpretation for erosion mapping at the national scale is time consuming and expensive.

The extension of the use of modern spatial information technologies, such as geographical information systems (GIS), digital elevation modeling and remote sensing, have created new possibilities for research as a key for erosion mapping that is economical due to low costs as well as quickness. Most erosion and sediment studies have been carried out to provide a quantitative erosion map (Singh et al., 1992; Martinez-Casanovas, 2003; Ygarden, 2003; Essa, 2004; Mohamed, 2005) rather than

to preparing erosion features map. A digital classification using Landsat TM and JERS-1 SAR data covering the visible, infrared, thermal and microwave regions of the spectrum was implemented to detect and map soil erosion features in the Sacaba Valley (Bolivia) by Metternicht and Zinck (1998). The synergy of Landsat TM and JERS-1 data provided a unique combination that allowed more accurate identification of badlands, slightly eroded areas, miscellaneous land, fallow land and moderately eroded areas, as compared to the results obtained by Landsat TM alone.

Sidorchuk et al. (2003) mapped erosion type, its degree and extent, as well as the density of its features, based on 1996 aerial photographs of scale 1:30,000 in order to classify the features and subsequently delineate the erosion units in the Mbuluzi basin, southern Africa. For carrying out the analyses the adapted method of Van Zuidam (1985) was applied. By applying airborne digital camera orthomosaics and GIS for small-scale studies and field measurements for large-scale studies, Sirvio et al. (2004) have studied gully erosion hazard assessments in the Taita Hills, south east Kenya. Detection of distribution and intensity of gully erosion and the main factors affecting gully erosion and its changes during the last 50 years were investigated. Raoofi et al. (2004) attempted to recognize and map erosion in the Taleghan basin in Tehran Province by using image processing techniques. Erosion was categorized into rill, gully and no erosion

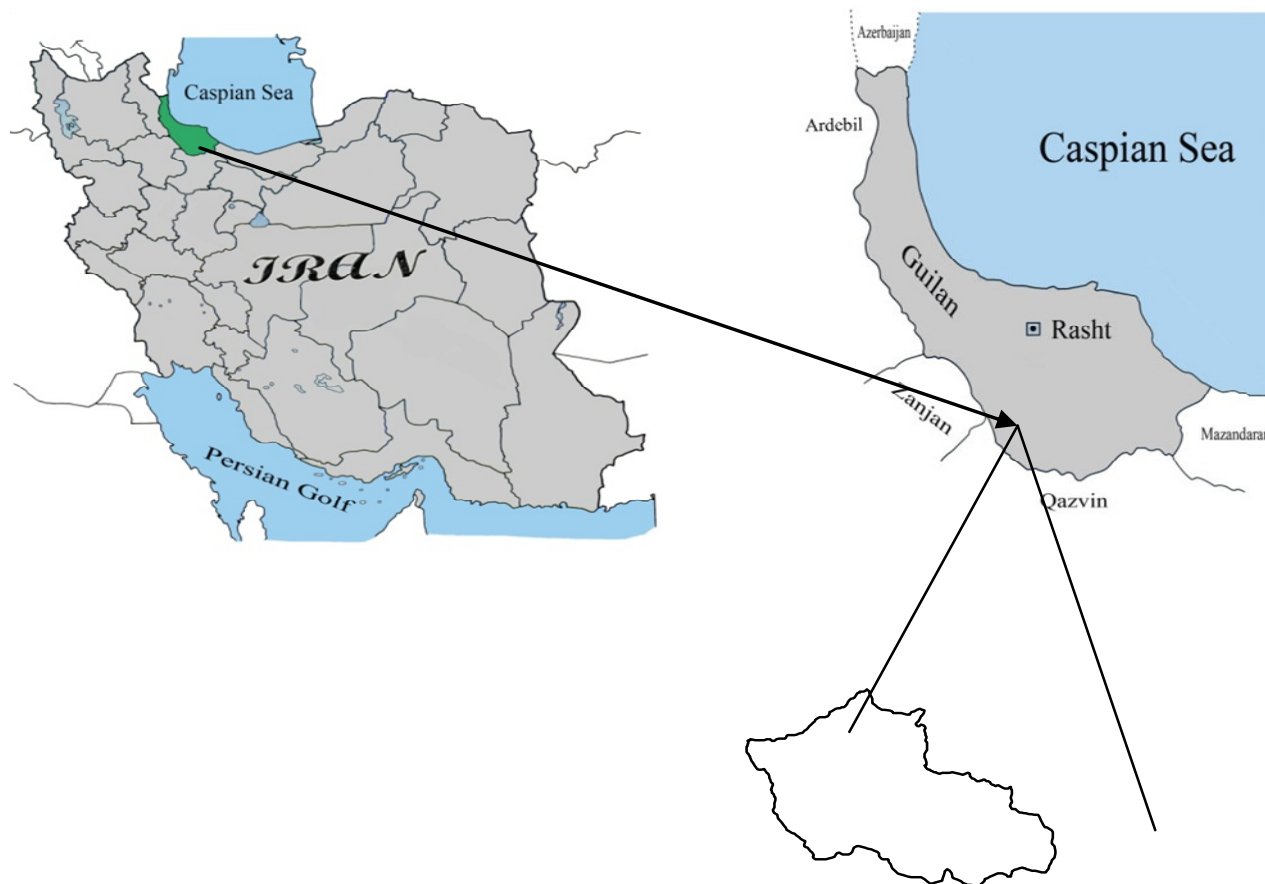


Figure 1. site of study (Roodbar sub-basin, Guilan, Iran).

regions by using images from the fusion of ETM⁺ bands and Cosmos images. Also, a map of ground truth from eroded regions was produced from field observations. Measurements indicated an approximate 80% accuracy for the categorization. Hajigholizadeh (2005) used the ETM⁺ satellite images interpretation method for providing erosion features maps of five basins in Tehran province, Iran. Results of this research showed that the recognition of surface and rill erosions is very difficult due to image resolution. Therefore, they differentiated gully erosion polygons with low, moderate and high intensity on images and polygons were controlled and corrected by field studies.

Soil surface erosion is a serious environmental problem in land degradation that has on site and off site effects such as decreasing the lands agriculture value and increasing the sediment and water pollution. Soil surface erosion mapping is one of the most important and basic methods in erosion and sediment yield studies to determine suitable soil conservation programs. Few studies have been done for providing surface erosion map particularly by the classification of satellite images in Iran; therefore, the aim of this study is to evaluate the supervised classification of ETM⁺ satellite images for providing

surface erosion map.

MATERIALS AND METHODS

The Roodbar sub-basin; downstream Sefidrood dam, Guilan province, Iran, with 102898 ha between 49°15'E and 49°51'E, 36°43'N and 37°02'N was considered as studying basin in a mountainous physiography. Figure 1 shows the location of this basin. It extends to the south of Guilan Province, Iran, in central part of Alborz mountains. Sefidrood River after exit from Sefidrood dam passes 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; therefore, land types were mountains, hills and upper terraces. 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 De Martonne method is sub-humid and humid in the southern and northern regions, respectively.

In order to evaluate the capability of mapping surface eroded areas from ETM⁺ data on July 2004 (166 paths and 34 rows), Software ILWIS 3.2 Academic was used for processing data. Image processing included georeferencing, radiometric correction and selecting the best bands for making color composites was done. With regard to optimum index factor, bands 5, 3 and 1 were

Table 1. The classification of soil surface erosion intensity.

Extent in field intensity class	< 5	5 - 25	25 - 50	50 - 75	> 75
1	No	Low	Moderate	Sever	Sever
2	No	Low	Moderate	Sever	Very sever
3	Low	Moderate	Sever	Very sever	Very sever

Intensity classes 1-3 with regard to 1 or more of below characteristics: 1: Good plants cover than region potential, no detectable deposition or erosion. 2: Moderate plants cover than region potential, deposited soil around plant with thickness less than 10 cm, crust with thickness less than 1 cm. 3: Weak plants cover than region potential, deposited soil around plants with thickness higher than 10 cm or roots exposed to air, crust with thickness higher than 1 cm.

Table 2. Results of the supervised classification of soil surface erosion and other surface covers including forest, plant cover and river.

Category	Classified pixels	Classified correct pixels	Accuracy (%)
Low surface erosion	952	596	62.6
Moderate surface erosion	1656	1136	68.6
Sever surface erosion	802	568	70.8
Very sever surface erosion	1072	804	75.0
River	520	492	94.6
Forest	3838	3824	99.6
Plant cover	1408	1340	95.2
Overall accuracy = 80.9%			

incorporated to obtain a color composite 531RGB. A total of 652 points on the color composite images has been considered for field investigation by classified randomized sampling and the geographic position of these points were recorded by GPS in field investigations. Selection of this method was because of different surface covers so that lower ground points were controlled in dense forest and more points in rangelands and bare lands

In ground control points, surface erosion intensity and land cover kind (forest, plant cover and other surface features) were investigated. Since there was other plant covers such as orchards and afforestation in basin that their DN was different with forest lands, therefore, they were considered as a separate category. Surface erosion intensity base on plant cover compression, transferred soil depth, crust thickness, root situation was divided into 5 categories: no erosion, low, moderate, severe and very severe surface erosion (Table 1).

With regard to the ground control points and auxiliary points, training pixels were introduced to software to classify surface erosion intensity as supervised by maximum likelihood method. It was selected as a most common supervised per-pixel classification useful for obtaining thematic maps from multispectral satellite data (Richards and Jia, 2006). Figure 2 shows the supervised map of soil surface erosion. This map was crossed by introduced pixels map to calculate accuracy for each of land uses and surface erosion severity classes and their accuracies were also evaluated. The classification accuracy was assessed on the entire study area by estimating the overall accuracy (Congalton and Green, 1999) derived from the error matrix that is the core of accuracy assessment of a classified map (Foody, 2002):

$$A = \frac{1}{N} \sum_{i=1}^r n_{ii}$$

Where n_{ii} is the number of pixels correctly classified in a category and N is the total number of pixels in the confusion matrix.

RESULTS AND DISCUSSION

The areas most likely to contribute to a large volume of sediment, and which are susceptible to a high degree of erosion, get higher priority in treatment (Shrimali et al., 2004). Soil erosion hazard maps can be an essential tool in erosion prone areas as they explain and display the distribution of hazards and areas likely to be affected to different magnitudes (Rejaur et al., 2009). Table 2 shows the supervised classification of soil surface erosion and other surface covers. Results showed that the greatest accuracy was related to forest and then plant cover. Forest classification accuracy was approximately 100% (99.6%). Accuracy decreased in the classification of surface erosion severities. Overall accuracy was 80.9%, but it decreases without considering forest, plant cover and river.

Overall accuracy of supervised map was 80.9%, which decreased to 69.2% without considering forest, plant cover and river and only the classification of surface erosion (Table 3). Nejabat (2003) also provides indirect detection of surface erosion on ETM+ satellite images in part of Fars Province, Iran and calculated 68% accuracy when the ground truth map of surface erosion was compared with the photomorphic units map. In the

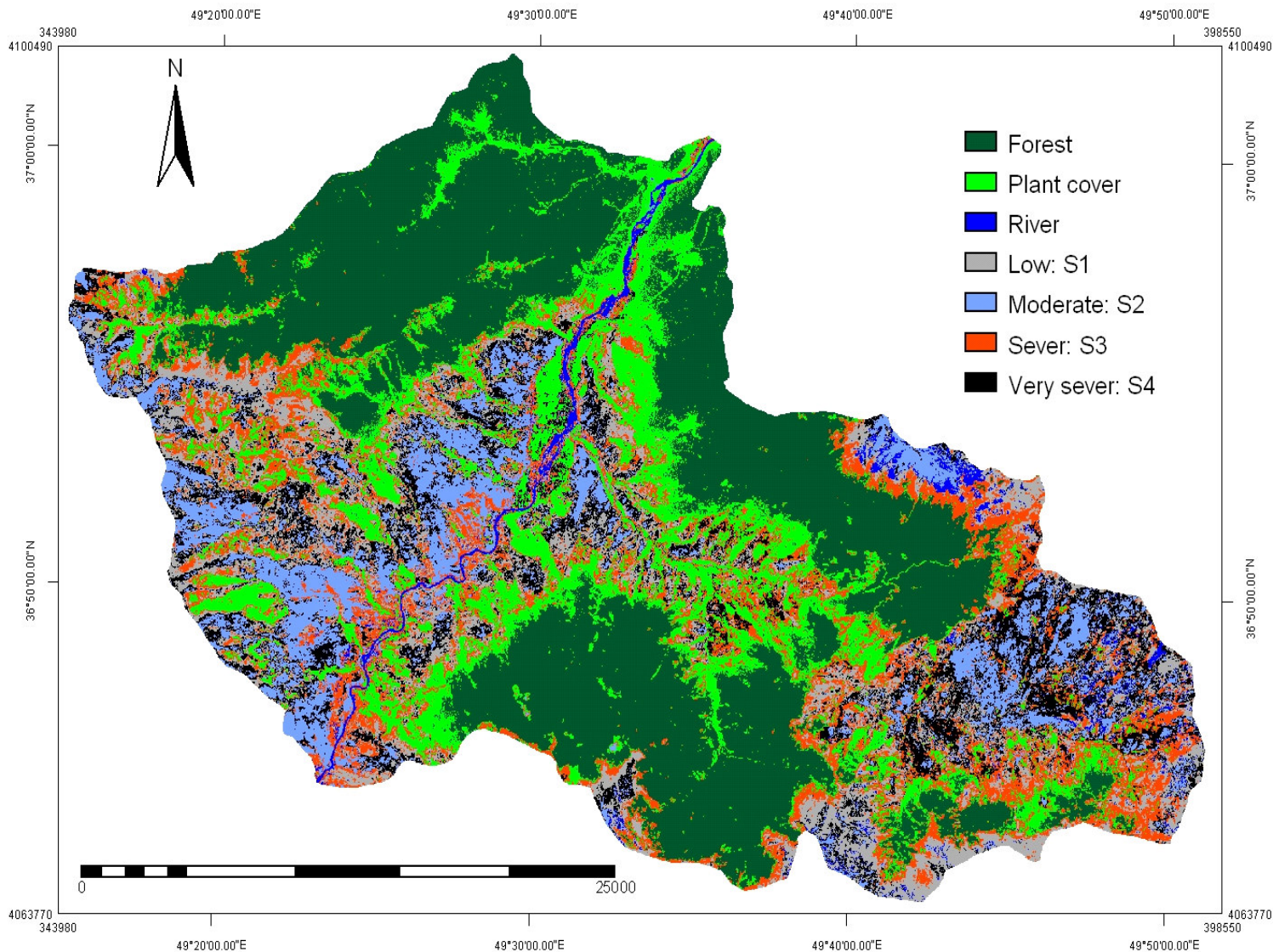


Figure 2. The supervised map of soil surface erosion in Roodbar sub-basin.

Table 3. Results of the supervised classification of only soil surface erosion intensity classes.

Surface erosion Intensity class	Classified pixels	Classified correct pixels	Accuracy (%)
Low	952	596	62.6
Moderate	1656	1136	68.6
Sever	802	568	70.8
Very sever	1072	804	75.0
Overall accuracy = 69.2%			

Taleghan basin in Tehran Province, Iran, a gully erosion map (direct image obtained from the fusion of ETM+ bands and Cosmos image) with a ground truth map indicated approximately 80% accuracy (Raofii et al., 2004). Results obtained from Liberti et al. (2009) in the use of

spectral bands (with and without thermal channel) and principal components for the classification of badland showed an overall accuracy ranging from 53% (for classification on first three components) to 72% (for classification on all bands from TM).

Table 4. Accuracy evaluation of the surface erosion intensity classification.

Soil surface intensity	The number of ground control points	Classified correct points	Accuracy evaluation
Low	325	265	81.5
Moderate	520	441	84.8
Sever	285	274	96.1
Very sever	480	467	97.3

Mean accuracy evaluation = 89.94%.

Overall accuracy of surface erosion classification was 69.2%, but the accuracy differentiated in different intensities of surface erosion. Accuracy increased proportional with surface erosion intensity, so that the greatest and lowest accuracy was related to very high and low intensity, respectively. Mohammadi (2009) showed that the use of images satellite is a suitable method in providing erosion features map and concluded that a photomorphic units map produced from processed satellite images of ETM⁺ sensor had a great conformity than truth ground map of erosion types. Photomorphic units had been differentiated base on image properties such as color, tone, drainage pattern; so that some homogenous units had a very large area that caused an increase in accuracy, but in this study, the total pixels of image were classified taking into consideration surface erosion intensity. Of course, classification accuracy increased for further intensity of soil surface erosion.

Taking into consideration results obtained, there is a relationship between DN and soil surface erosion intensity. When there is a greater intensity of surface erosion, texture, color, crusting and plant cover tends to differ around lands which leads to a difference in spectral reflections (DN) to be more than land experiencing lesser intensity, consequently, a decrease in spectral reflections interference increases classification accuracy. Accuracy evaluation (Table 4) showed that the ground control points have correctly been classified in more than 95% with the view of high and very high intensity of surface erosion. This is 81.5 and 84.8% for low and moderate intensities, respectively. Therefore, Investigations showed that supervised classification of surface erosion maps had good conformity compared with greater intensity of surface erosion.

Conclusion

The study indicates that ETM⁺ data can be used for surface erosion mapping, but with a reasonably weak (69.2% in this study) classification accuracy. Results indicated that there is a relationship between DN and soil surface intensity; so that spectral reflections had a large difference around land which increases the accuracy. In general, supervised classification of surface erosion maps had good conformity compared with greater inten-

sity of surface erosion. It is proposed to investigate the supervised classification of erosion features in other regions with different characteristics such as land type, geology, plant cover etc.

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