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Application of IRS-1D Data in Water Erosion Features Detection (Case Study: Nour Roud Catchment, Iran)

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Abstract: The aim of this study was capability of Indian Remote Sensing (IRS) data of 1D to detecting erosion features which were created from run-off. In this study, ability of PAN digital data of IRS-1D satellite was evaluated for extraction of erosion features in Nour-roud catchment located in Mazandaran province, Iran, using GIS techniques. Research method has based on supervised digital classification, using MLC algorithm and also visual interpretation, using PMU analysis and then these were evaluated and compared. Results indicated that opposite of digital classification, with overall accuracy 40.02% and kappa coefficient 31.35%, due to low spectral resolution; visual interpretation and classification, due to high spatial resolution (5.8 m), prepared classifying erosion features from this data, so that these features corresponded with the lithology, slope and hydrograph lines using GIS, so closely that one can consider their boundaries overlapped. Also field control showed that this data is relatively fit for using this method in investigation of erosion features and specially, can be applied to identify large erosion features.

Key words: Erosion features, remote sensing, geographical information systems, classification, PAN, IRS-1D, Nour roud, Mazandaran

INTRODUCTION

Overpopulation, sharp increasing human's requirements to article of food, housing and etc have caused enlargement of eroded area (Cook and Dornkamp, 1993; Toy, 2002; Rafahi, 2006). Soil erosion by water is the most important land degradation problem worldwide which influences the global food security and high economic costs by its effect on life (Eswaran *et al*., 2001; Crosson, 1997; Lal, 1998; Pimentel *et al*., 1995). Global warming in turn is expected to increase erosion rates which are greatly dependent on their environmental and cultural context (Warren, 2002; Nearing *et al*., 2004). In water erosion, detachment of soil material is caused by raindrop impact and drag force of running water (Lal, 2001). To control water erosion, biophysical measures need to be implemented at the field and in this direction, firstly, investigation of erosion features and their density is necessary (Morgan, 2005). An important limitation for this task is data availability and quality such as map preparation (Cook and Dornkamp, 1993). Remote sensing technique provides homogeneous data over large regions with a regular revisit capability and can therefore greatly contribute to regional erosion assessment (Siakeu and Oguchi, 2001) and determination of spatial distribution of eroded area (Cook and Dornkamp, 1993). Surface-sediment dynamics in a dust source from spaceborne multispectral thermal infrared data investigated by Itzhak and Nicholas (2008) and do not allow gully growth analysis with sequential imagery (Dwivedi *et al*., 1997b; Kumar *et al*., 1996; Vrieling *et al*., 2002). The delineation of eroded areas on multi-temporal images allowed an assessment of its increase (Fadul *et al*., 1999; Sujatha *et al*., 2000). Although a clear increase of eroded lands was found, aerial pictures allowed for a better differentiation of ravine types than satellite imagery. An alternative for visual interpretation techniques is the automatic extraction of eroded lands from satellite imagery. Servenay and Prat (2003) applied an unsupervised classification algorithm to multispectral SPOT HRV data to distinguish four stages of erosion. Floras and Sgouras (1999) used the maximum likelihood classifier after principal component analysis of Landsat TM imagery to erosion classification. Dwivedi *et al*. (1997a) also found that SPOT HRV was better in classifying eroded lands than Landsat TM and MSS, but they did not use all TM bands for classification. Metternicht and Zinck (1998) performed a maximum likelihood classification on Landsat

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Tmand on the combination of Landsat TM with JERS-1 SAR data. They achieved highest classification accuracy using the combination of both images. Hajigholizadeh (2005) could provide erosion features map of Tehran province contained badlands, gullies with different intensity and flood plains from ETM^+ image of Landsat 7 satellite. Mousavi *et al.* (2005) used GIS and RS techniques, satellite imagery and aerial photo (1:10000 scale) for monitoring landslide around Imamzadeh Ali located Haraz road in Iran and extracted that IRS satellite imagery with 5.8-m resolution is suitable for extraction of geomorphologic information. Mohammadi-Torkashvand (2007) in a research evaluated ETM^+ image potential for production erosion features map of Jajroud catchment located in Iran and concluded that accuracy of units in rill, gully, channel erosion and mixed units of erosion features were 86.4, 81, 89.8, 88 and 72%, respectively. Soltani *et al.* (2008), in a research evaluated efficiency of Aster data in providing erosion map of Kashkan basin in Lorestan province of Iran and obtained that FCC 123 (with 15 m resolution) is very good present of erosion features and showed geologic formations. This study is aimed to provide investigation of water erosion features detection using IRS-1D satellite remote sensing and focuses only on panchromatic data (PAN) applications.

MATERIALS AND METHODS

Study area: The catchment area, Nour-roud, is delimited between the coordinate of 51° 26" 13" and 52° 18" 21" longitude and of 36° 00" 58" and 36° 16" 18" latitude, located in southwest Amol, Mazandaran province, Iran, covering approximately 1300.25 km^{-2} (Fig. 1) is a part of central Elborz, full mountainous and with east-westerly elongation. The main part of catchment includes two formations, Shemshak formation, contained shale, marl and sand stone, in north and Karaj formation contained tuff and shale, in south of catchment. The major river flows in the eastern side. Mean annual rainfall and temperature are 504 mm and 7.46°C, respectively. The climate of the region is humid in west, semi arid in centre and east of catchment by using De Martonne method.

In this research, monospectral IRS-1D imagery (PAN), with pixel spacing 5.8 m, was used. 2 sub scenes of a frame (Image acquisition: 9 Aug. 2007; Path: 68 and 69; Row: 45; Zone# 39 north; Datum: WGS 84) were covered study area. Also, topographic map (1:50000), for extraction Digital Elevation Model (DEM), slope and hydrographic layers and geology map (1:100000), for extraction lithology layer and ENVI 3.6 software were used.

Raw taken image (collected from Geographical Organization of Military Forces of Iran), was registered by 13 Ground Control Points (GCPs) in UTM projection, so that these points both have a good dispersion and easily available (3 points were settled on overlay area of 2 sub scenes (contained centre of study area), as Tie Points (TPs) effected in creating orthophotomosaic). Registration accuracy was evaluated by amount of Root Mean Square Error (RMSE) and also, by overlaying hydrographic layer. Then, mosaicing was done and link was effaced by color balancing in ENVI 3.6 software. In order to remove shift error and to obtain elevation geometric correction, DEM was used. In this manner orthophotomosaic was created. Next, filtering and image contrast stretching was done. Steps of remote sensing are in Fig. 2.

Visual interpretation: First, classes of erosion features were determined by field studying. To execute above mentioned method, Photo Morphic Unit (PMU) analysis was used. The important keys of interpretation that have been used were tone, texture, shape and size of features. Due to nonexistence no explicit boundary among erosion features and their gradual changes in this catchment, also, some features are smaller than data resolution

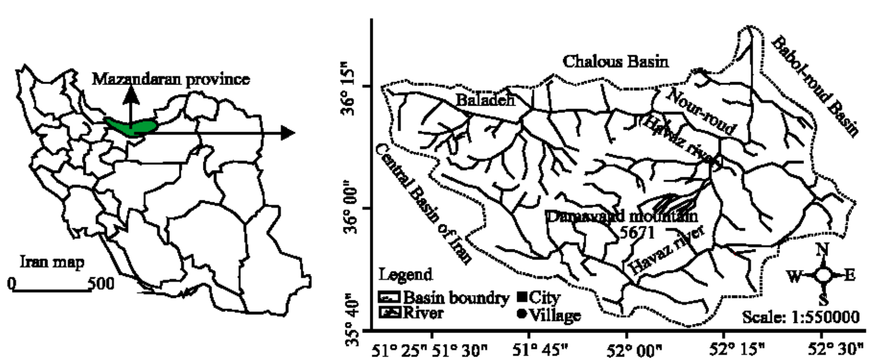

Fig. 1: The map of Haraz River watershed contained Nour-roud river watershed (highlighted lines)

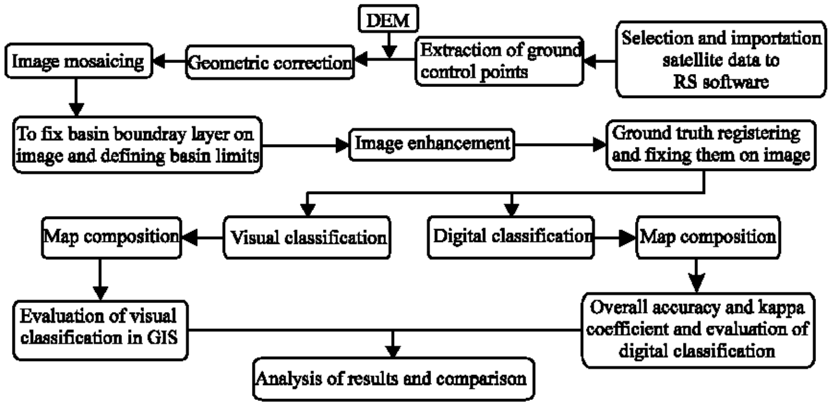

Fig. 2: The process of using remote sensing

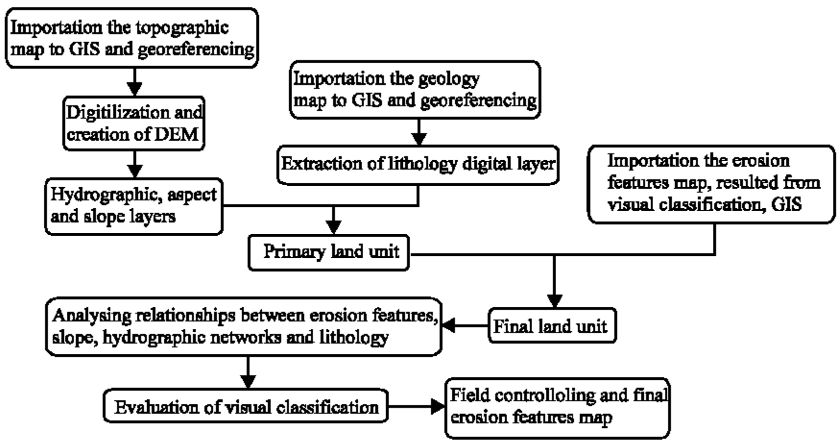

Fig. 3: The process of evaluation of visual classification

(<5.8 m), so, two or three features were mixed in one class. Then, PMUs of erosion features based on keys of interpretation were distinguished and demarcated. To evaluate of visual classification accuracy, GIS (ArcGIS 9.2 software) was used according to Fig. 3. Also, field controlling was done by GPS.

Digital classification: First, based on field studying, 455 ground truth samples contained 280 training and 170 controlling samples, based on number of samples for each classes = 10 N where, N is number of band (Alavipanah, 2006), were collected in random by GPS and partly visual interpretation. These points transport to computer and then point map modeling was provided. Next, Maximum Likelihood Classification (MLC) algorithm based on gray level and Digital Number (DN) was executed. Due to use monospectral data, band selection could not been done. Finally, in order to evaluate digital classification, error matrix was created by intersecting digital classification map and ground truth points map. Based on this cross, overall accuracy and kappa coefficient (Foody *et al*., 1992) computed. Also, omission error and producer accuracy for each column and commission error and user's accuracy for each row were computed (Lillesand and Kiefer, 2000). For investigating spectral characters of erosion features, spatial profile of these phenomenons was extracted.

RESULTS

In registration process, one of the GCPs due to have RMSE>1 (= 1.21), was deleted. Final orthophotomosaic overlaid with hydrographic layer (Fig. 4) with combination to the slope and lithology maps, resulted to the final map of erosion types.

Visual interpretation: Gully erosion was seeing as single channel (without drainage network) in low slope area, generally in east of watershed (Fig. 5a). Badland distinguished by light area with high drainage density, was seeing as limited area in east and centre of watershed. This feature changes into channel erosion in lower elevation (Fig. 5b). Bank erosion was seeing clearly along the main river, after Razan village, toward outlet of basin

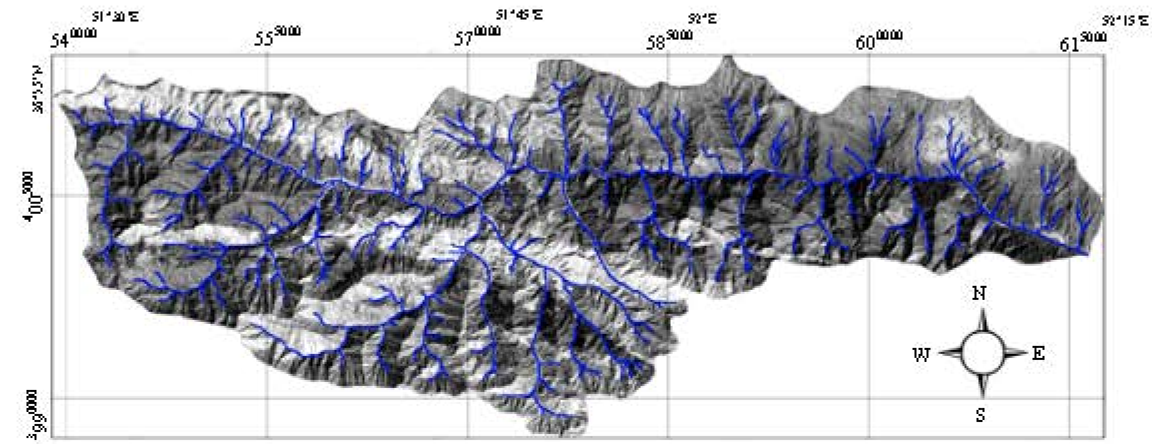

Fig. 4: Orthophotomosaic of study area

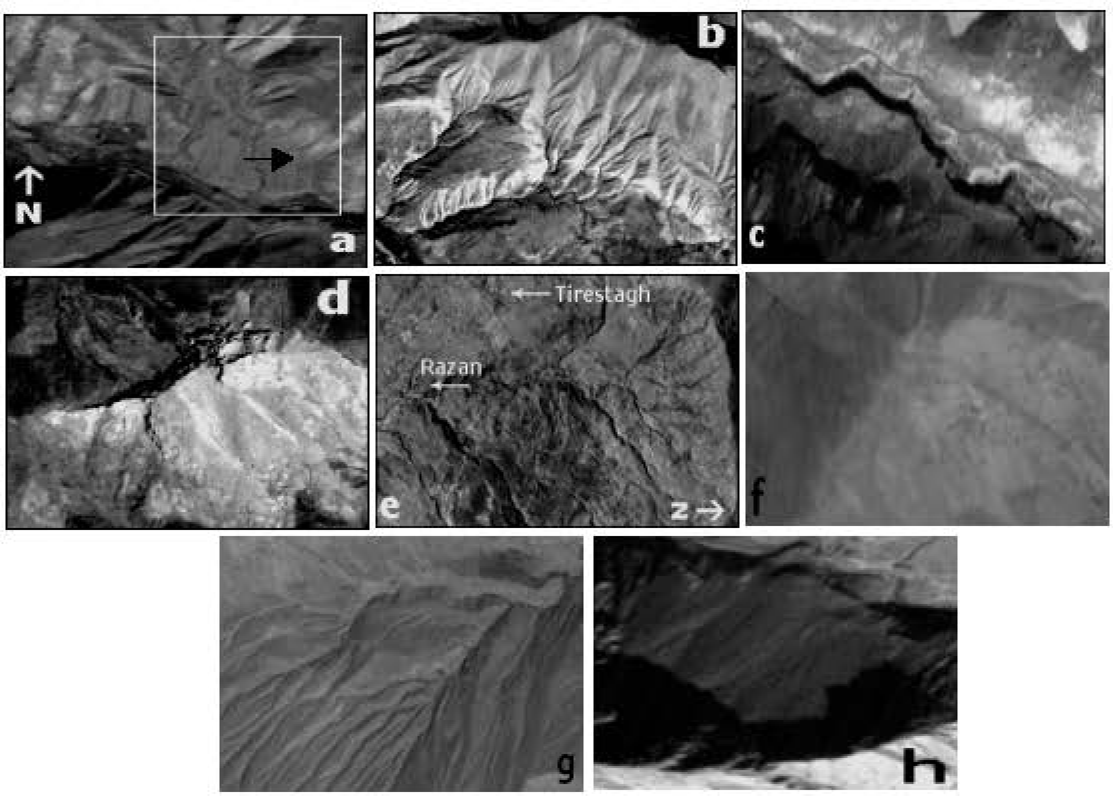

Fig. 5: Gully erosion (a), badland (b), Bank river erosion (c), out craft (d), landslide affected on village (e), surface erosion (f), Channel erosion (g) and fall (h)

(Fig. 5c). Fall (rock fall and debris flow) and out craft are in main part of watershed (Fig. 5d, h). Due to intense land disruption, the effects of landslide were seeing around Razan and Tirestagh villages (Fig. 5e). The effects of sheet erosion were seeing as light area (Fig. 5f). Figure 5g shows channel erosion. Big rills are detected hardly and small rills were not recognized. Figure 6 shows map resulted by using visual interpretation.

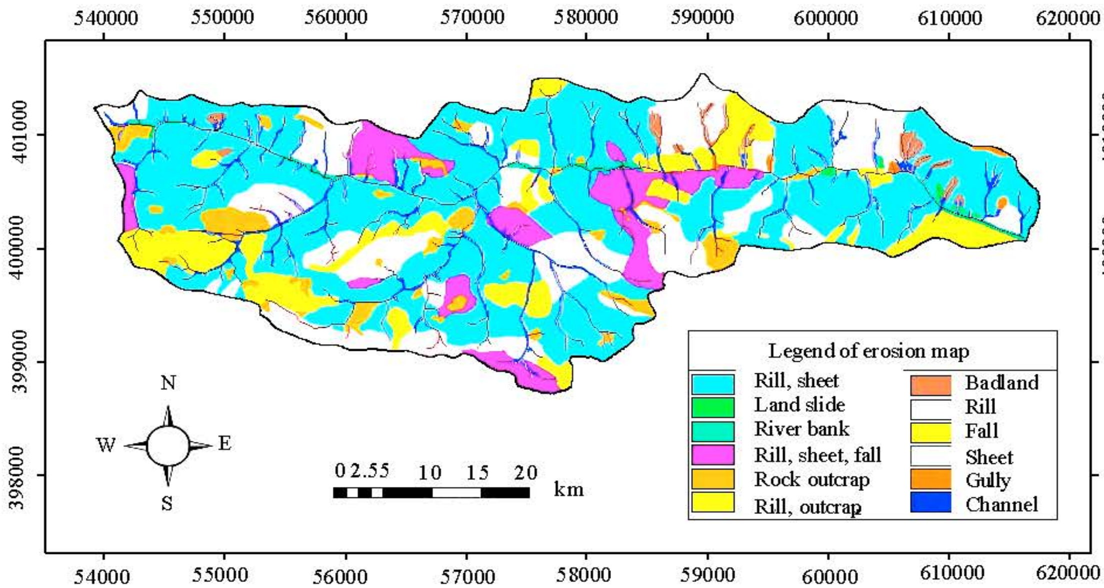

Fig. 6: The map resulted from visual interpretation

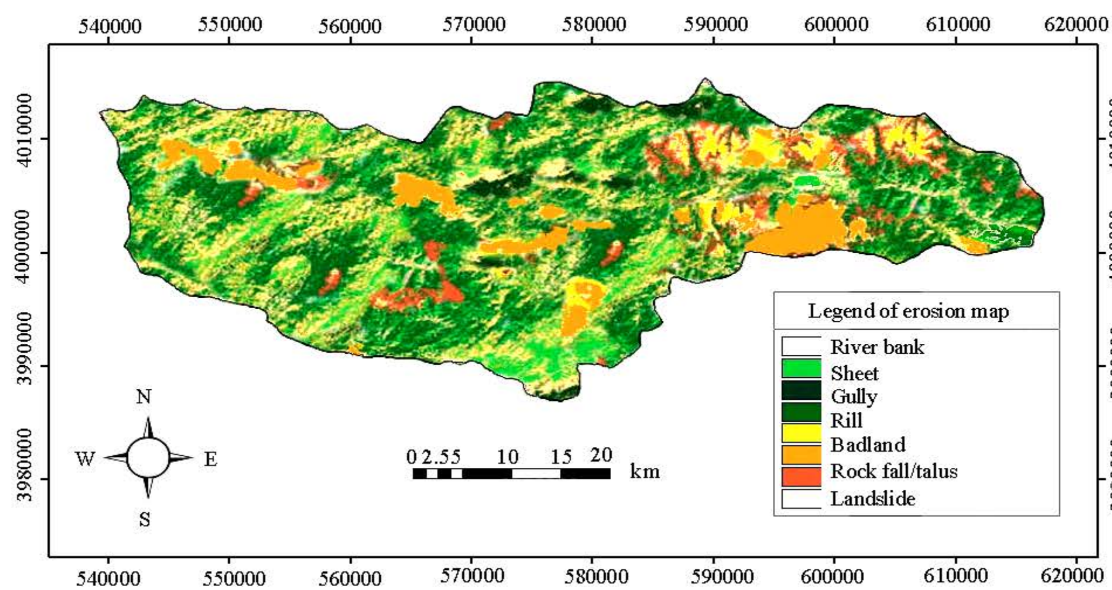

Fig. 7: The map resulted from digital classification

Results of evaluation of visual interpretation (using GIS) are as follows: Bank erosion conformed to alluvial deposit. Debris flow and rock fall confirmed to speed slope area, sandstone and limestone. Big rill erosion almost confirmed to susceptible formations, special to Shemshak and Karaj formation. Gully erosion confirmed to less than 14° slopes as Morgan (2005) concluded, except in some points and to shale and siltstone. Badland confirmed to clay, marl and shale. Sheet erosion is in most formation and any slope. Channel erosion confirmed to hydrographic lines. Landslide confirmed to same feature marked in geology map, completely.

Digital classification: Figure 7 shows digital classification using MLC algorithm. Matrix error table and result of evaluation of digital classification is in Table 1. According to Table 1 overall accuracy and kappa coefficient was computed 40.02 and 31.35%, respectively.

Table 1: Matrix error table for evaluation of digital classification

Erosion features	Gully	Badland	Rill	Rock fall	Land side	Sheet	Bank	Channel	Total	Users error accuracy (%)	Commission error (%)
Classification											
Gully	81	21	19	26	15	17	23	24	226	35.85	64.15
Badland	21	127	35	29	16	32	20	31	311	40.84	59.16
Rill	14	35	106	25	22	38	17	32	289	36.68	63.32
Rock fall	27	21	24	123	20	22	25	27	289	42.56	57.44
Land side	18	27	31	21	168	24	21	25	286	41.61	58.39
Sheet	12	32	33	18	22	144	18	16	295	48.81	51.19
Bank	34	18	22	29	23	14	77	20	237	32.49	67.51
Channel	25	27	29	27	27	23	18	112	288	38.89	61.11
Total	232	308	299	298	264	314	219	287	2221		
Producers accuracy (%)	34.91	41.12	34.45	41.28	45.03	45.86	35.16	39.02			
Commission error (%)	65.09	58.88	64.55	58.72	54.97	54.14	64.84	60.98			

DISCUSSION

Visual interpretation: Results show that visual interpretation of this high-resolution satellite (5.8 m) provides similar possibilities in detecting almost all erosion features (except medium or small size rills), so that these features correspond with the lithology, slope and hydrograph lines using GIS, so closely that one can consider their boundaries overlapped. Also field control shows that this data is relatively fit for using this method in extraction of erosion features and specially, can be applied to identify large erosion features. This is in agreement results obtained later (e.g., Pickup and Nelson, 1984; Pickup and Chewings, 1988; Hajigholizadeh, 2005; Soltani *et al*., 2008).

Pickup and Nelson (1984), Lee and Liu (2001), Liu *et al.* (2001, 2004) and Ahmadi and Feiznia (2006) obtained that in semi-arid environment, such study area in this research (Nour-roud Watershed), detection of erosion features are simpler than humid environments. In other words, remote sensing technique will only work under specific conditions and cannot be transferred to any conditions, such as very humid environment. But, there are some difficulties, especially in extracting of rock falls and debris flows, such shadows and limitation in image contrast.

Digital classification: The kappa coefficient k varies from 0 (full disagreement) to 1 (full agreement)and if $k<0.4$, $0.4< K<0.75$ and $K>0.75$, it will be classified as poor, fair and power, respectively (Foody, 1992). Kappa coefficient, in this research shows the poor digital classification.

Experiences showed that many phenomenons on earth surface can be recognized by their spectral characteristics and some cannot (Alavipanah, 2006). Limitation in spectral sensibilities of satellite imagery and the spectral similarities between classes of features is an important cause of very low accuracy in classification (Taherkia, 2004; Alavipanah, 2006).

According to date and season of taking image (9 Aug. 2007-summer), there was no snow cover in study area. So, this parameter had no effect on spectral character of features.

Evaluation of visual interpretation shows each kind of erosion features occurred in various formations (rocky units) and also, a rocky unit was contained kinds of erosion features. Details of this same result were explained later by Ahmadi and Feiznia (2006) and Rafahi (2006). Also, due to the gradual changes among erosion features in study area, gray level of pixels among classes of erosion is mixed and similar, so that these pixels is classified incorrectly. This is in agreement results explained later (Alavipanah, 2006). So, the similar spectral reflectance from the surface of erosion features is clear, so that the analysis of these features will be hard and the computer will be confused in auto classification.

Generally, although the visual mapping of erosion features is an important application of IRS-1D, the limited spatial extent of the features often inhibits its detection using other methods or satellite imagery.

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