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Evaluation of vegetation changes in desertification projects using remote sensing techniques in Bam, Shahdad and Garmsar regions, Iran

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ABSTRACT
The face of the earth is always changing due to human activities and natural phenomena. Therefore, to optimize the management of the natural areas, knowledge of the trend, extent and estimation of land cover / use changes is considered necessary. Reviewing these changes through satellite images and evaluating their potential through modeling can help environmental planners and natural resource managers to make more informed decisions. In the present study, quantitative detection and evaluation of changes in vegetation were performed in the areas with combat desertification projects, Shahdad, Bam and Garmsar in Iran, during a 30-year period within 1987, 2002 and 2017. The Normalized Difference Vegetation Index (NDVI) and land use maps were produced using the Enhanced Thematic Mapper Plus (ETM+), Thematic Mapper (TM) and Operational Land Imager (OLI) satellite images in the three corresponding periods for the vegetation/non-vegetation, and agricultural lands. The Kappa coefficient of 0.83 to 0.86, 0.91 to 0.92, and 0.94 to 0.95 was calculated for 1987, 2002, and 2017 respectively, and the total accuracy was between 88 and 97. After providing the land use maps in different years, the monitoring of land use changes was investigated using the Change Detection method. According to the trend of changes during the periods, the results exhibited that the vegetated lands in these three areas had an increasing trend in average 31.33%, and the non-vegetated lands were turned to vegetated lands over time. In other words, they have declined by an average of 35%. Moreover, an increasing trend was found for the agricultural lands during the periods in average 4%. Eventually, the cost-effectiveness of projects implemented in the studied areas was calculated.

Keywords: Vegetation changes, Remote sensing, Trend determination, Change detection.

INTRODUCTION
The exploitation of nature has been continually carried out since the creation of mankind, and most of the great civilizations have been on the margin of land resources: Makhtoum (2008). In human exploitation of nature, especially in the last century, there have been tensions on nature that have destroyed resources and disrupted the ecological balance (Makhtoum 2008; Khazaee *et al.* 2016).
Knowledge of land cover and human activities in different parts as the basic information for planning is of special importance, and the maps displaying different types of land cover and human activities as the basic information for land planning are called land use maps. In the other words, these maps present the current conditions and geographic distribution of land use in activities such as agriculture, forestry, range management, and public health (Mollalo *et al.* 2018; Mollalo *et al.* 2019). They also represent the area covering the surface of the earth (Anderson 1976; Abtahi & Pakparvar 2002).

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Employing the land use maps is one of the most important information needed by natural resource managers and administrators (Hatami & Shafieardekani 2014). Preparing such maps using traditional methods and interpretation of aerial photographs will take a lot of time and efforts. The satellite data are suitable for this matter because of the wide and integrated view, covering a major part of the electromagnetic spectrum and up-to-date images (Amini 2006; Sparavigna 2013). Previous studies tried to investigate changes in land using over time in different parts of world such as Costa Rica (Carlson & Arthur 1999), New Zealand (Nagendra & Gadgil 1999), China (Frolking *et al*. 2003) , Italy (Fishera 2012), Iran (Sanjari & Boroumand 2013) and Iraq (Al-doski *et al.* 2013) using satellite data. One of the most important problems encountered in the study of vegetation changes is the lack of precise spatial information from the past (Thuiller *et al.* 2008). Satellite imagery and remote sensing (RS) technology provide the opportunity to get better planning for environmental management through the information generated by these technologies (Giriraj *et al.* 2008). Knowledge of the land use ratio and its changes over time is one of the most important issues in planning. Given the ratio of land use changes over time, the changes in land uses could be predicted to perform appropriate measures (Jantz & Goetz 2005; Feizizadeh *et al.* 2007).
At present, remote sensing technology is the best way to monitor the environmental changes and extract vegetation conditions along with mapping at different times, with the highest speed and accuracy. Different land uses could be extracted using the remote sensing multi-temporal data with least time and cost, and then, the ratio of changes could be evaluated by comparing it in different time periods (Fichera *et al.* 1997; Chen *et al.* 2006). Therefore, the effectiveness or ineffectiveness of vegetation on sand dunes fixation and combat desertification over time could be evaluated quantitatively using the remote sensing and geographic information system (GIS) techniques (Malmiran 2001; Fadhil 2018).
The present study was aimed to investigate and evaluate vegetation changes, as well as the effectiveness or ineffectiveness of vegetation cover in combat desertification projects over the past few years using the remote sensing and GIS techniques in Shahdad and Bam in Kerman Province and Garmsar in Semnan Province, Iran during three periods of 1987, 2002, and 2017.

MATERIALS AND METHODS

The study areas

The present study was carried out in Shahdad and Bam (Kerman Province) and Garmsar (Semnan Province) as the field studies, and the technical and operational works were conducted in the Iranian Forests, Range and Watershed Management Organization in Tehran from May 2016 through September 2018.

Shahdad: This area is located in Kerman Province, Kerman city between the latitudes 59.7 28 30 to 30.5 35 30 N and longitudes 17.6 44 57 to 46.8 48 57 E. The minimum and maximum altitudes of the study area are 303 m and 365 m above sea level (a.s.l.) respectively. The minimum and maximum average rainfall are 30.19 mm in downstream and 209.5 mm in upstream, respectively. The maximum absolute temperature is 50.4 ° C while the minimum is -0.4 ° C.

Bam: This area is located 70 km south east of Bam city, Kerman Province between the longitudes 585415 to 590414 E and latitudes 284222 to 285027 N. It is located between the altitude ranges of 788-1633 m a.s.l. The annual rainfall is 54.6 mm (50.4 mm in winter and 4.4 mm in summer).The average annual temperature is 23.62, while the maximum and minimum absolute temperature are 46.6 and 6 ° C, respectively.

Garmsar: This area is located in Semnan Province, 3 km west of Garmsar city. It lays between the latitudes 12 52 to 14 52 E and latitudes 11 35 to 14 35 N. The average annual rainfall is 122.3 mm, with the highest rainfall of 56.5 mm in the winter (46.2%) and the lowest of 3.3 mm in summer (7.2%).The maximum absolute temperature is 47 ° C while the minimum is 11 ° C.

Research Methods

In the present research, the trend of vegetation alterations and also land use changes in the study areas were investigated using the satellite data from Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM +) and Operational Land Imager (OLI) in 1987, 2002, and 2017. At first, images were assessed from geometric aspects. Then, the geometric, radiometric and atmospheric corrections were performed. To detect the vegetation of the study areas, the NDVI vegetation index and land use map were created and the class of vegetation were extracted based on the available samples. Afterward, the land use map was prepared from existing images by

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supervised classification using maximum likelihood methods. Thereafter, the accuracy of the prepared maps was calculated by Kappa index. After preparing the maps, we calculated the land use changes in the study areas during 1987-2017.

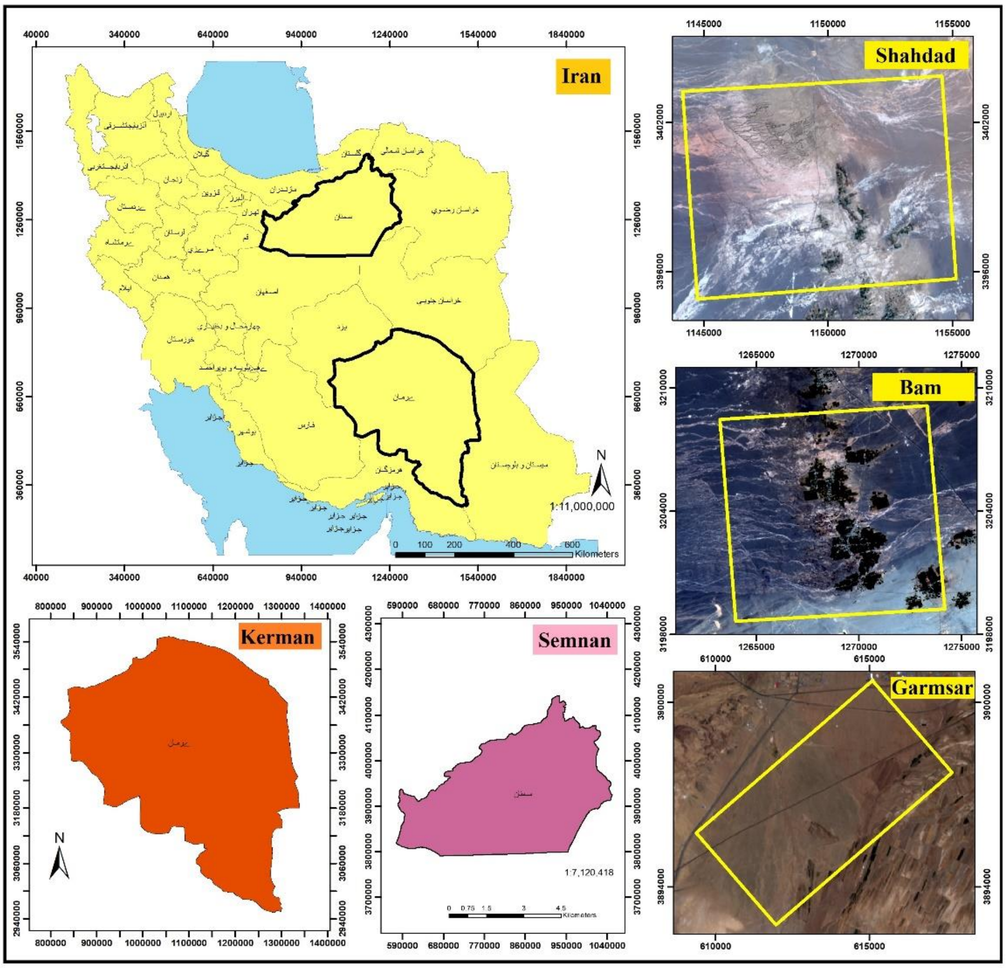

Fig. 1. Geographical location of the study areas.

Image processing

Satellite image processing is a three-step process including pre-processing, processing, and post-processing. The present study also follows satellite imagery processing in the same way.

Pre-processing operation

In this step, the pre-processing of radiometric and atmospheric corrections was carried out on Landsat satellite images in 1987 and 2002. Re-georeferencing of maps was not carried out due to the acceptable georeferencing of those produced. Then, the normalized difference vegetation index (NDVI) maps were prepared and the land use maps were classified. Due to the high importance of the extraction accuracy of land use classes in assessing the changes in time series, the supervised pixel-based classification was applied using maximum likelihood method based on the review of literature previously performed in similar works in these areas.

Satellite images were composed of a series of spectrum bands, and each of image elements or pixels had a digital number (DN). In unprocessed images, the DN of pixel has a linear relationship with recorded radiance by sensor. Therefore, the DN values can be easily converted to the recorded radiance by a linear conversion. Equations using for these types of conversion are different based on the physical features of various sensors. The linear conversion for the Landsat series satellites is as following (Science Data Users Landsat 7 Handbook):

$$L = (Gain \times DN) + Bias$$

So that, by applying the linear conversion, the radiance values of pixels were converted to Reflectance using ENVI software. For atmospheric corrections, the recorded signals for phenomena like water and shadow were

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removed because they have near zero reflection percentage in satellite images. Therefore, the effects of atmospheric scattering were removed using Dark subtraction method in ENVI software.
Then, NDVI index was produced for images using red near infrared band based on the following equation:
$NDVI = \frac{NIR-RED}{NIR+Red}$
In the next step, the accuracy of the classification images was evaluated and other necessary post-processing operations were performed. The detailed description of each of these steps and the results of the processes carried out are described below.
Radiometric and atmospheric corrections were made on the Landsat image series by entering the calibration parameters available in metadata accompanying images. Each DN was converted to the radiance. Due to the absence of atmospheric errors, the atmospheric correction of images was performed by selecting the darkest pixels using the Dark subtraction method.

Processing operation
At first, the NDVI index was produced using red near infrared bands. The threshold was applied based on field observations and recognition from the study areas. Therefore, the NDVI value is zero in those pixels that do not have vegetation cover but exhibit a numerical value in the NDVI map. In order to assess vegetation changes in the study areas, the NDVI values were not classified into equal classes. However, according to the histograms obtained from the application of the NDVI index, they were classified into vegetation and non-vegetated lands. Then, supervised classification was performed on the Landsat images in 1987, 2002, and 2017 using maximum likelihood method as well as the field and training points in agricultural lands along with the vegetation and non-vegetated lands as a sample. Figs. 2-4 illustrate the mixture classification map derived from the maximum likelihood method and also the vegetation classification resulted from NDVI vegetation index in Bam region.

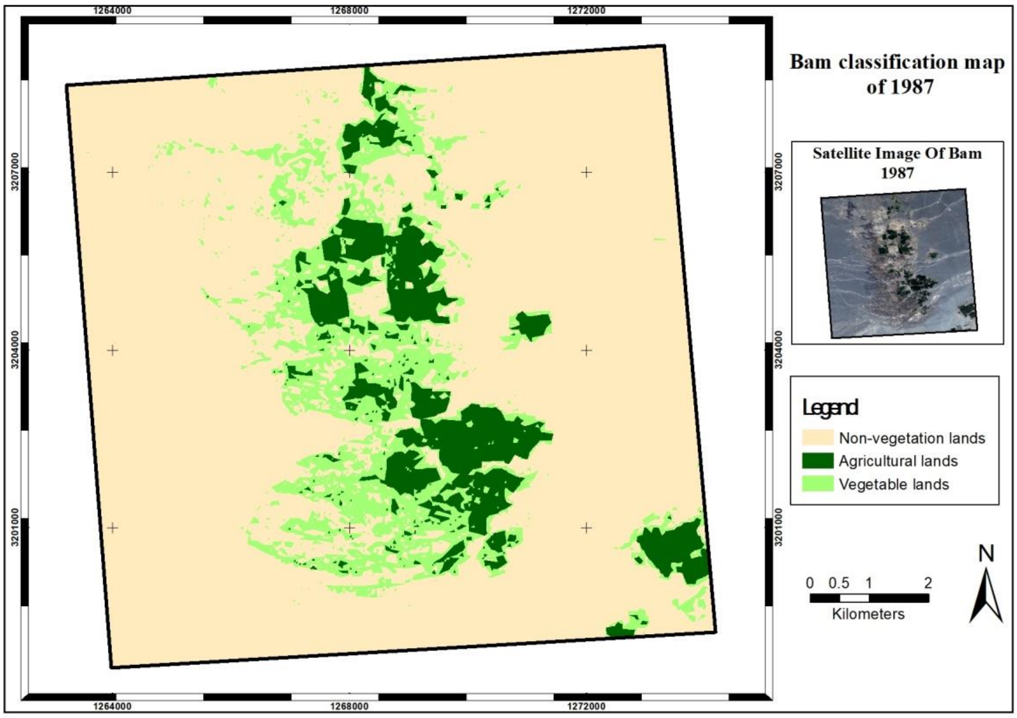

Fig. 2.Land use map extracted from the Landsat image in 1987 for Bam by maximum likelihood classification.

Post-processing operation
To calculate the classification accuracy, the images classified with maximum likelihood methods were compared using previous vegetation maps of the Iranian Forests, Range and Watershed Management Organization and the images with high spatial resolution on the Google Earth site. It was controlled by field study as well.

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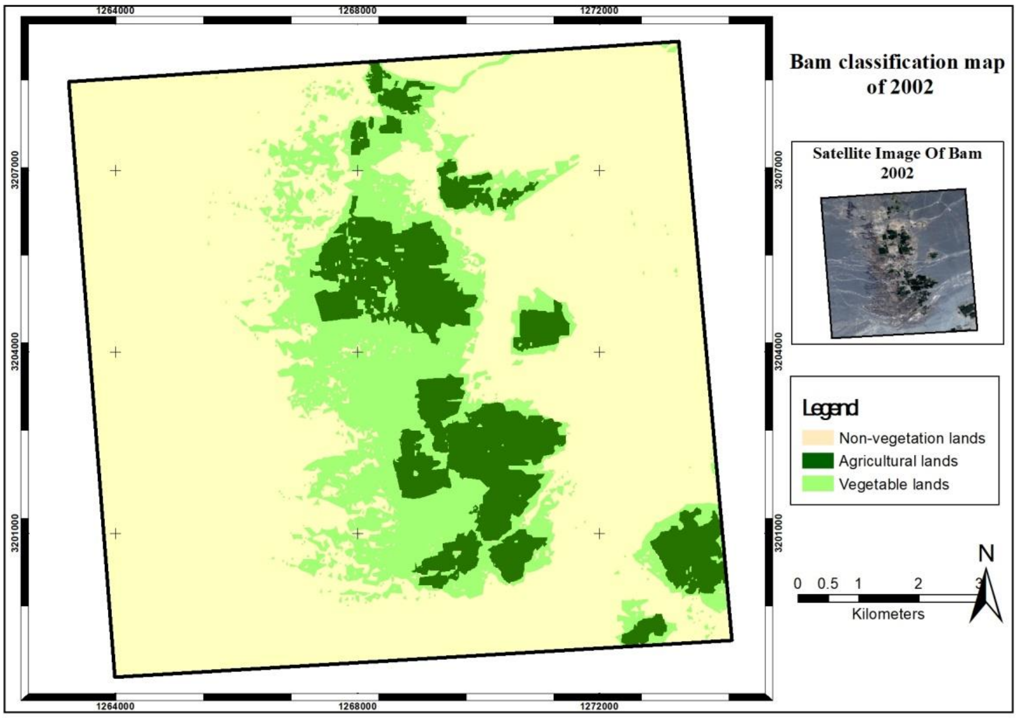

Fig. 3. Land use map extracted from the Landsat image of 2002 for Bam by maximum likelihood classification.

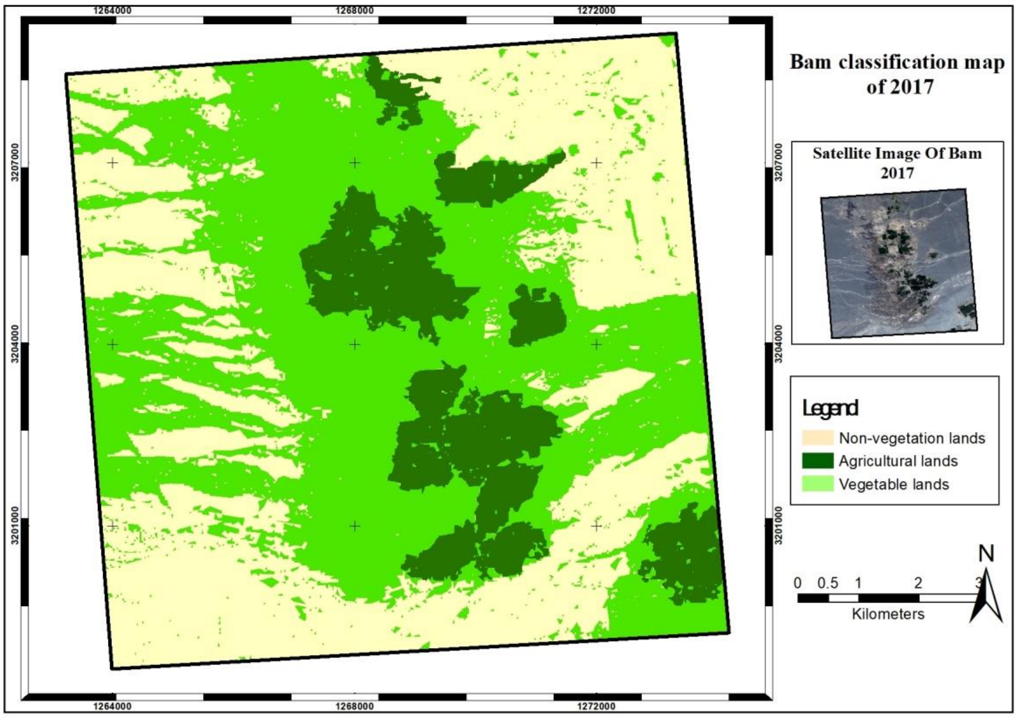

Fig. 4. Land use map extracted from the Landsat image in 2017 for Bam by maximum likelihood classification.

RESULTS

The classification accuracy was calculated for the classified images using total accuracy and Kappa index. The total classification accuracy of 87-96 and the Kappa index of 0.83-0.95, whose highest and lowest accuracies are related to those in 2017 and 1987 respectively, indicate that the radiometric power of the Landsat series satellite has gradually been improved (Tables 1-3).

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Table 1. Classification accuracy and Kappa index of Bam in 1987.

	Classification of Bam in 1987				Commission error
landuse	Vegetated lands	Non-vegetated lands	Agriculture lands	Total	User's accuracy
Vegetated lands	50	2	2	54	92.59259259
Non-vegetated lands	2	42	3	47	89.36170213
Agricultural lands	4	2	40	46	86.95652174
Total	56	46	45	147	
Producer's accuracy	89.28571429%	91.30434783%	88.88888889%		
accuracy	89.79591837%				
Kappa	0.865567634				

Table 2-classification accuracy and Kappa index of Bam in 2002.

	Classification of Bam in 2002				Commission error
landuse	**Vegetated lands**	**Non-vegetated lands**	**Agriculture lands**	**Total**	**User's accuracy**
Vegetated lands	55	1	1	57	96.49122807
Non-vegetated lands	2	46	3	51	90.19607843
Agricultural lands	2	2	48	52	92.30769231
Total	59	49	52	160	
Producer's accuracy	93.22033898%	93.87755102%	92.30769231%		
accuracy	93.125%				
Kappa	0.910709575				

Table 3-classification accuracy and Kappa index of Bam in 2017.

	Classification of Bam in 2017				Commission erro
landuse	**Vegetated lands**	**Non-vegetated lands**	**Agriculture lands**	**Total**	**User's accuracy**
Vegetated land	63	0	1	64	98.4375
Non-vegetated lands	1	58	1	60	96.66666667
Agricultural lands	3	1	52	56	92.85714286
Total	67	59	54	180	
Producer's accuracy	94.02985075%	98.30508475%	96.2962963%		
accuracy	96.11111111%				
Kappa	0.948658939				

Vegetation changes in Bam between 1987 and 2017

The non-vegetated lands exhibited the most changes during the study period. The surface area of this class decreased from 80% of the total study area in 1987 to 40%, indicating a reduction over 3887 ha. Moreover, the area of vegetated lands (by conducting projects to combat desertification) and agricultural lands elevated from 12% and 8% to 46% and 14%, respectively. Fig. 5 illustrates the land use alteration map. The values of these changes during 1987-2017 in Bam region as the sample are presented in Table 4.

Vegetation changes in Shahdad during 1987 - 2017

The non-vegetated lands exhibited the most changes during the study period. The area of this class (non-vegetated lands) decreased from 93% of the total study area in 1987 to 53% in 2017, indicating a reduction over 3384 ha. Moreover, the area of vegetated (by conducting projects to combat desertification) and agricultural lands increased from 6% and 1% to 40% and 6%, respectively.

Vegetation changes in Garmsar during 1987 - 2017

The non-vegetated lands exhibited the most changes in surface area reducing during the study period same as Shahdad and Bam. The area of this class decreased from 85% of the total study area in 1987 to 59%, indicating a reduction over 791 ha. Moreover, the area of vegetated (by conducting projects to combat desertification) and agricultural lands increased from 4% and 11% to 29% and 12%, respectively.

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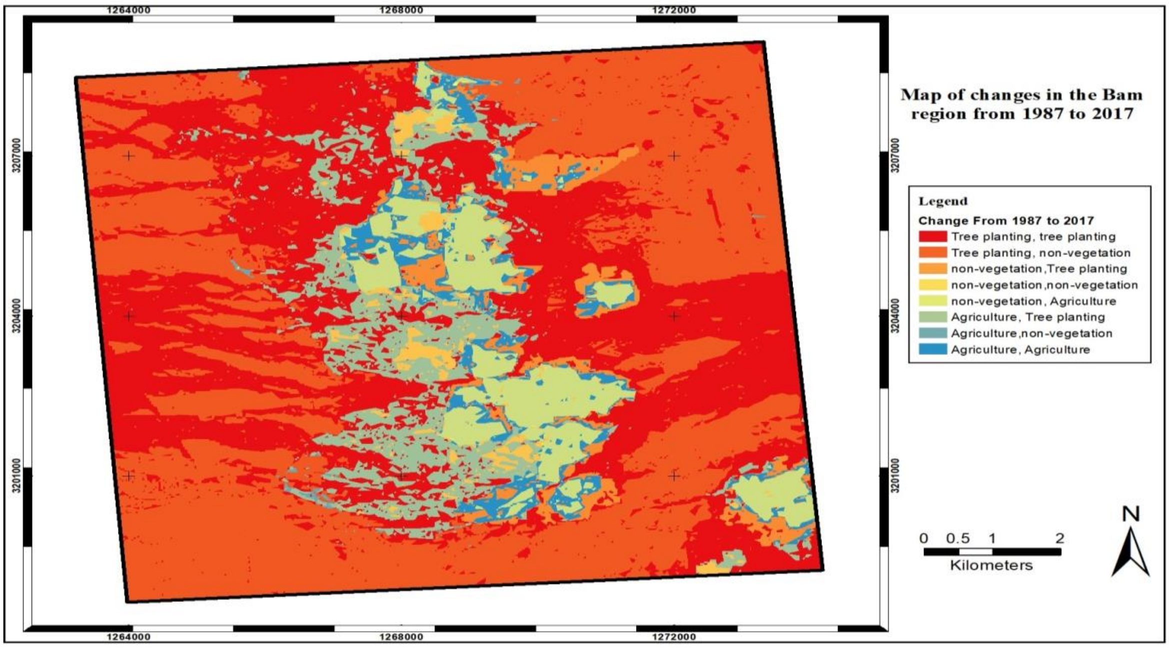

Fig. 5. The land use alteration map in Bam during 1987-2017.

Table 4. The rate of each land use alteration in Bam during 1987-2017.

		Land uses in 2017 (ha)			
		Vegetated lands	**Non-vegetated lands**	**Agricultural lands**	**Total land uses 1987**
Land uses in 1987 (ha)	Vegetated lands	850	21	334	1205
	Non-vegetated lands	3555	3997	355	7907
	Agricultural lands	160	2	660	821
	Total land uses 2017	4565	4019	1349	9933

DISCUSSION

During the 30-year period, there were three sets of satellite images in the studied regions during 1987, 2002 and 2017. Hence, in order to evaluate the land use changes, the years were divided into two periods, i.e., 1987-2002 and 2017-2002 and then analysed. As shown in the tables 5-7, the vegetated lands increased in the afforementioned periods, while non-vegetated ones reduced. In addition, a low increasing trend was found for agricultural lands (Tables 5-7). Shahdad, Bam and Garmsar all are located in the warm and arid regions and free from vegetation. Hence, the combating desertification projects have been performed by the Iranian Forests, Range and Watershed Management Organization on a large scale due to the wind erosion and dust. Thus, the increased vegetated lands in the regions where were previously free of vegetation, may be related to these projects. Notably, these projects not only reduced the dust and erosion in the areas, but also contributed to the increased vegetated and agricultural lands (Engelstaedtr *et al*. 2007). According to the Desert Affairs Office in the Iranian Forests, Range and Watershed Management Organization, the cost of administrative activities based on work units per hectare and also the total administrative costs for each area (Shahdad, Bam and Garmsar) are presented in Table 8. According to the area calculated for the vegetated land (by conducting projects to combat desertification) using RS and GIS techniques and the benefits of planting through conducting these projects by the Desert Affairs Office in the Iranian Forests, Range and Watershed Management Organization, the economic benefits for Shahdad, Bam, and Garmasar were calculated to be 1.097, 1.180, and 1.108, respectively (Table 9). Benefits of planting presented in Table 9, were calculated based on: 1- direct and indirect benefits created in agriculture lands. The direct benefits include the employment of natives for agriculture, and the indirect benefits due to the settlement of farmers witn no need to immigrate to cities. 2- Benefits of preventing damage caused by wind erosion.

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Table 5. Changes in the land uses in Shahdad during 1987-2002 and 2002-2017.

Land uses	1987 (ha)	2002 (ha)	change rate during 1987-2002 (ha)	2002 (ha)	2017 (ha)	change rate during 2002-2017 (ha)
Vegetated lands	491	1909	1418	1909	3457	1548
Non vegetated lands	7959	6247	-1712	6247	4583	-1663
Total land uses	121	415	294	415	532	116

Table 6. Changes in the land uses in Bam during 1987-2002 and 2002-2017.

Land uses	1987 (ha)	2002 (ha)	change rate during 1987-2002 (ha)	2002 (ha)	2017 (ha)	change rate during 2002-2017 (ha)
Vegetated lands	1205	1614	409	1614	4565	2951
Non vegetated lands	7907	7223	-685	7223	4020	-3203
Total land uses	821	1096	275	1096	1348	252

Table 7. Changes in the land uses of Garmsar during 1987-2002 and 2002-2017.

Land use	1987 (ha)	2002 (ha)	change rate during 1987-2002 (ha)	2002 (ha)	2017 (ha)	change rate during 2002-2017 (ha)
Vegetated lands	111	557	446	557	863	307
Non vegetated lands	2561	2088	-473	2088	1770	-318
Total land uses	331	358	27	358	370	11

Table 8. The cost of a work unit per hectare and total administrative cost in the study areas (Desert Office Affairs, Iranian Forests, Range and Watershed Management Organization, 2017).

Study area	Activities implemented	Area of implementation (Study area) (ha)	cost of a work unit (ha) (USD)	cost in the study areas (milion USD)
Shahdad	Mulching, planting and taking care	3457	3,900	13.482
Bam	Mulching, planting and taking care	4565	3,900	17.803
Garmsar	Planting and taking care	863	1,150	0 .992
		Total		32.277

Table 9. The economic benefit of the implemented projects regarding to benefits and cost (Desert Office Affairs, Forests, Range and Watershed Management Organization of Iran, 2017).

Study areas	The land area (ha) in this study	Project benefits (Million USD)	Project costs (Million USD)	BENEFIT/COST
Shahdad	3457	14.79	13.482	1.097
Bam	4565	21.01	17.803	1.180
Garmsar	863	1.10	0 .992	1.108
Total	8885	36.90	32.277	-

Our results clearly exhibited that conducting projects to combat desertification in all three regions was cost-effective, indicating the project success rates in these areas. Preventing immigration, employment creation, preservation of agricultural lands and gardens, maintaining facilities and routes, strengthening groundwater aquifers, fresh air, as well as erosion and dust reduction are among the remarkable effects of these projects (Iranian Forests, Range and Watershed Management Organization 2017; Ministry of Cooperative Labor and Social Welfare 2015). The highest economic benefit was obtained in Bam, indicating the effects of the type of activities such as mulching, planting and taking care as well as the compatibility of most species such as *Tamarix gallica*, *Calligonum persicum*, *Prosopis cineraria*, and *Holoxylon ammodemdrom* planted in this area (Iranian Forests, Range and Watershed Management Organization, 2017).

CONCLUSION

The overall purpose of the evaluation and monitoring is to obtain a continuous set of information and compare the extent of access to goals at different levels of the study. Changing the surface characteristics is the process taking place to combat desertification. In the other words, combat desertification confronts land degradation through implementing applied projects at regional levels and beyond. Therefore, evaluating the quantitative and qualitative extent of land degradation and desertification is one of the requirements for planning managers.

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Changing detection-based methods are those currently available for the land degradation assessment using degradation estimating models (LASOD-LADA, etc.) as well as methods based on remote sensing techniques (including assessment of vegetation indices, soil, water), which were introduced briefly. In fact, by examining these changes in spatial, temporal, spectral and radiometric dimensions, it is possible to determine the extent of degradation and desertification in areas where projects to combat desertification have been carried out.
Studies have exhibited that in order to combat wind erosion (consisting of three sites including origin, transporting and sedimentation), the origin site is the best place albeit by strengthening rangeland vegetation. Combating wind erosion in the origin site, in addition to ease and speed and less cost, will be much more successful than in the other two sites (transport and sedimentation). Because of the ecological and morphological conditions, governing the region, are in such a way that combating with wind erosion, especially biological control, are conceivable with more ease due to the establishment of plants in such areas. By fixing the sand source area and increasing vegetation, it would be expected that the wind erosion and its consequent damage would be greatly reduced. The results of this research, conducted only in part of the critical regions of the study areas, indicate the success of the implementation of these projects to strengthen vegetation and rangelands. Noteworthy, conducting projects to combat desertification not only increase the vegetation cover of the study areas, but also lead to a positive impact on the agricultural development. All three study areas show an increasing trend in terms of agriculture which is effective in employment of inhabitants and preventing immigration (Iranian Forests, Range and Watershed Management Organization 2017).

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ارزیابی روند تغییرات پوشش گیاهی در طرح‌های بیابان زدایی با استفاده از تکنیک‌های -RS GIS در مناطق بم، شهداد و گرمسار

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چکیده

بر اثر فعالیت‌های انسانی و پدیده‌های طبیعی چهره زمین همواره دستخوش تغییر می‌شود. از این‌رو برای مدیریت بهینه مناطق طبیعی آگاهی از روند و میزان تغییرات پوششی و کاربری اراضی از ضروریات محسوب می‌شود و برآورد این تغییرات از اهمیت بسزائی برخوردار است. بازبینی این تغییرات از طریق تصاویر ماهواره‌ای و پیش‌بینی و ارزیابی پتانسیل آنها از طریق مدلسازی می‌تواند به برنامه‌ریزان محیط زیست و مدیران منابع طبیعی برای تصمیمات آگاهانه‌تر کمک کند. در این پژوهش آشکارسازی و ارزیابی کمی روند تغییرات پوشش گیاهی در مناطق با طرح های بیابان زدایی شده، شهداد و بم در استان کرمان و گرمسار در استان سمنان در طول یک دوره زمانی ۳۰ ساله طی سه بازه زمانی ۱۹۸۷، ۲۰۰۲ و ۲۰۱۷ میلادی انجام گرفت. بدین منظور نقشه‌های شاخص پوشش گیاهیNDVI و کاربری اراضی با استفاده از تصاویر سنجنده های +ETM و TM و OLI ماهواره لندست به ترتیب در سه دوره زمانی مربوطه در کلاسهای اراضی با پوشش گیاهی، فاقد پوشش گیاهی و اراضی کشاورزی بترتیب با ضریب کاپای ۰/۸۳ تا ۰/۸۶ برای سال ۱۹۸۷ و ظریب کاپای ۰/۹۱ تا ۰/۹۲ برای سال ۲۰۰۲ و ضریب کاپای ۰/۹۴ تا ۰/۹۵ و همچنین دقت کل بین ۸۸ تا ۹۷ بدست آمد. پس از تهیه ی نقشه های کاربری اراضی در سالهای مختلف، پایش تغییرات کاربری با روش Change Detection بررسی گردید. نتایج نشان داد با بررسی روند تغییرات صورت گرفته در طی دوره‌های مورد مطالعه، اراضی دارای پوشش گیاهی در این سه منطقه روند افزایشی داشته و در مقابل اراضی بدون پوشش به مرور به اراضی با پوشش تبدیل گشته‌اند. همچنین اراضی کشاورزی در این مناطق در طی این سه دوره روند افزایشی داشته اند. درنهایت صرفه طرح‌های اجرا شده در مناطق مورد مطالعه محاسبه و مورد ارزیابی قرار گرفت.

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