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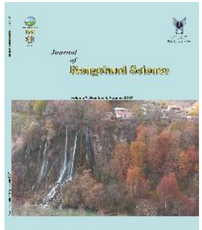

Review and Full Length Article:

Investigating the Effects of Land Use Changes on Trend of Desertification Using Remote Sensing (Case Study: Abarkooh Plain, Yazd, Iran)

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Abstract. More than one-third of the earth is characterized by arid and semi-arid climate and desertification phenomenon in these areas has been intensified in recent decades. This study aims to investigate the trend of desertification using vegetation indices and Iranian Model of Desertification Potential Assessment (IMDPA) in Abarkooh Plain, Yazd province, Iran. The satellite images (Landsat images in May 1987, 2000 and 2013) were used to map the land uses in the region. After the image preprocessing with a supervised classification method (support vector machine) that had the highest accuracy in all years, the map of land use changes was prepared in five kinds of land uses such as residential and industrial lands, agriculture and horticulture lands, arid and desert lands, playa and saline soils, and mountains. Then, the desertification map of Abarkooh Plain was prepared by calculating the Normalized Difference Vegetation Index (NDVI) and Modified Soil Adjusted Vegetation Index (MSAVI) according to IMDPA model. Three criteria, urban and residual lands to agricultural land ratio (Ur/Ag), plant canopy density and vegetation renewal indicators were used in IMDPA model. On the basis of the Ur/Ag ratio, 5.74%, 6.74% and 87.52% of the region were characterized by severe, moderate and low desertification, respectively due to land-use change factors. In the viewpoint of aboveground canopy density indicator, desertification in the area was classified into four classes including very severe, severe, moderate, and low desertification. In this regard, 99.06%, 0.76%, 0.13% and 0.05% of the areas are put in very severe, severe, moderate and low desertification classes, respectively. According to vegetation renewal indicator, 92.51%, 3.21% and 4.28% of the area were characterized as unchanged, low and very severe desertification, respectively.

Key words: Support vector machine, Desertification, Landsat, NDVI, MSAVI

Introduction

More than one-third of the earth is characterized by arid and semiarid climate and in recent decades, desertification phenomena in these areas have been intensified (GEF IFAD, 2002). The desertification phenomenon threatens future living conditions of more than 785 million people (17.7% of the world population) who live in arid and semi-arid areas. Desertification threatens the human life leading to the destruction of natural resources. Therefore, understanding the desertification phenomenon as well as factors intensifying this phenomenon is very important in Iran.

In Iran, 85% of the area are characterized by arid, semiarid and hyper arid climate and also desertification is increased annually. So, here is a vital necessity to find methods of assessing this phenomenon and its causes using models that evaluate the current situation of desertification and predicting its trend. Tueller (1987) suggested that satellite data is a useful approach to evaluate vegetation, compare them in different times and understand the movement of sand dunes in the arid and desert areas. Harasheh and Tateishi (2000) mapped the desertification using remote sensing and GIS in the western Asia and divided desertification into four classes involving low, moderate, high and very high desertification ones.

Akbari *et al.* (2007) studied the assessment and classification in the north of Isfahan using TM and ETM^+ sensors of 1990 and 2001. Their results showed that 35% of the study area was characterized by natural desert while 65% of the area had converted to desert resulted from human interventions. Finally, the most important factors influencing human desertification were found to be conversion of rangelands into agricultural lands, unsuitable agricultural methods, livestock overgrazing, poor economic conditions and inappropriate and excessive use of ground water.

Changes in land use play an important role in the global carbon cycle so that since the industrial revolution had emitted almost 136 Giga ton carbons into the atmosphere as a result of changes in land use (Skutsch *et al.*, 2007). In order to mitigate the desertification phenomena, several studies and scientific researches need to be performed around the world and it is only under such conditions that planning can be made to control and reduce the damages resulted from the desertification phenomena. Different studies have been carried out in Iran and other parts of the world concerning numerous site regional models, criteria and indicators should be evaluated and calibrated again according to the conditions of that region when applying these models in other areas. For this reason, numerous researches had been carried out (Bakhshandeh Mehr, 2009).

To present a suitable desertification model complying with Iranian conditions had been evaluated. Considering the current situation of Iran, some models including Iranian Model of Desertification Potential Assessment (IMDPA) had been proposed by Ahmadi (2004). His study was based on IMDPA method that has been derived from the modified MEDALUS model for Iranian conditions. IMDPA is one of the newest models in case of desertification assessment presented by Iranian Forests, Rangeland and Watershed Management Organization in 2005. It was derived based on methodology of Kosmas *et al.* (1999).

Mashayekhan and Honardoust (2011) introduced multi-criteria evaluation method for investigating the desertification process in Golestan Province, Iran; the major desertification factors were determined by doing field surveys. Their results showed that 36.55, 15.21, 40.17 and 8.07 % of the study area were classified as severe, high, moderate and slow affected by desertification, respectively. Toranjzar and Poormoridi (2012) prepared the desertification map of the Taraz Nahid, Saveh by IMDPA model that found moderate and severe classes of desertification process in the region. According to the performed evaluations, the soil texture index with the average value of 3.75 (very severe class) and vegetation conditions with the average value of 2.9 were more effective indices in the region desertification.

Mesbah Zadeh *et al*. (2013) calibrated the IMDPA model in Abozeydabad, Kashan, Iran considering land criteria in order to present a regional model for estimating the desertification severity. Three key criteria including geological desertification, soil and wind erosion were considered. In addition, many researchers have studied the desertification trend using satellite images and remote sensing techniques by applying vegetation indices. Esfandiari and Hakimzadeh (2011) studied the desertification potential conditions in Abadeh-Tashk, Fars province, Iran using IMDPA model to recognize the effective factors in land degradation. Their results showed that 47, 43 and 10% of the study area were classified as low, moderate and sever affected by desertification, respectively.

Fathizad *et al*. (2013) showed that land use change was one of the factors contributing to desertification using satellite images in the desert region of Mehran, Ilam province, Iran. They used change detection techniques, Principal Components Analysis (PCA), Normalized Difference Vegetation Index (NDVI), Conventional Component Analysis (CCA), Tasseled cap differencing (KT), and comparison after classification method. Based on results, they found that infrared band difference method (with overall accuracy and kappa coefficients of 95.66 and 0.94% respectively) had the highest accuracy while CCA_2 difference method (with overall accuracy and kappa coefficients of 29 and 0.16% respectively) and showed the lowest accuracy in land use changes detected in the study area.

Arami *et al*. (2013) assessed the risk of desertification in semiarid region of Aghband of Golestan Province, Iran according to a nine criteria model of IMDPA. Their results showed that 17.7% of the total studied area occurred in severe desertification class while 51% occurred in the moderate desertification class. Further analyses showed that the criteria of vegetation and soil conditions in the region are among the most important factors causing desertification in the Aghband region.

Assessment of desertification sensitivity in central part of Iran was performed by Hakimzadeh Ardakani *et al.* (2014). They showed trend of desertification using IMDPA model with emphasis on climate criteria. Their results indicated 68.42% of the study area located in moderate desertification class, and 31.58% of the study area located in high desertification class.

The qualitative values of desertification indices were studied by Hakimzadeh (2014) in south of Iran. According to his results, among the evaluated indices, the Irrigation system and level of groundwater had the most effects on desertification.

Callado and Camarasa (2002) using remote sensing analysis in desertification monitoring of central San Luis Province (Argentina) showed that as a result of changing rainfall and land use patterns, the re-vegetation trends and variations in water bodies were changed.

HabibiPour *et al*. (2014) evaluated the desertification conditions of Bahabad, Yazd province, Iran using IMDPA model with an emphasis on criteria of water and wind erosion. Their results indicated that the criterion of wind erosion was more effective than water erosion in desertification. In addition, vegetation cover plays an important role in desertification phenomenon of the study area based on both water and wind erosion criterion.

Mahmoud Adel *et al*. (2016) used two Landsat (ETM^+) satellite images (in September 2006 and 2014) to map, monitor and assess the patterns of changes in vegetation cover. Three enclosures (fenced areas) with moderately to severely degraded soil and vegetation were selected along a strong north-south rainfall gradient. Landscape Function Analysis (LFA) technique was used to calculate Total Patch Area (TPA) for a comparison purpose.

Most of the Abarkooh regions represent favorable conditions for wind erosion and the emergence of different wind shapes due to its specific climatic and geomorphological conditions. According to the research, NDVI and MSAVI were used as a consistent and comparatively simple tool in management and assessment of desertification processes in the Mediterranean rangelands.

This study aimed to investigate desertification trend in the Abarkooh using remote sensing techniques, applying vegetation indices and also emphasizing the criteria of the IMDPA model.

Materials and Methods

Study area

The present study was performed in Abarkooh, southwest of Taft County, Yazd province, Iran with an area of about 5480.5 km^2. Abarkooh is located at 52º 58' E and 30º 46' N. Elevation of the study area above sea level is 1550 m and climate has been characterized by desert (hot and dry) climatic classifications. In general, the climate of this county is similar to that of desert plateau of the country, characterized by low rainfall, high temperature fluctuations and high dryness. Mean annual rainfall of this county is 111.2 mm with the highest mean monthly temperatures occurring in June, July, August and September, and these four months are relatively different from other months in terms of temperature. The highest (39.1°C) and the lowest (0.4 °C) temperatures have been recorded in August and February or March, respectively (Fig. 1).

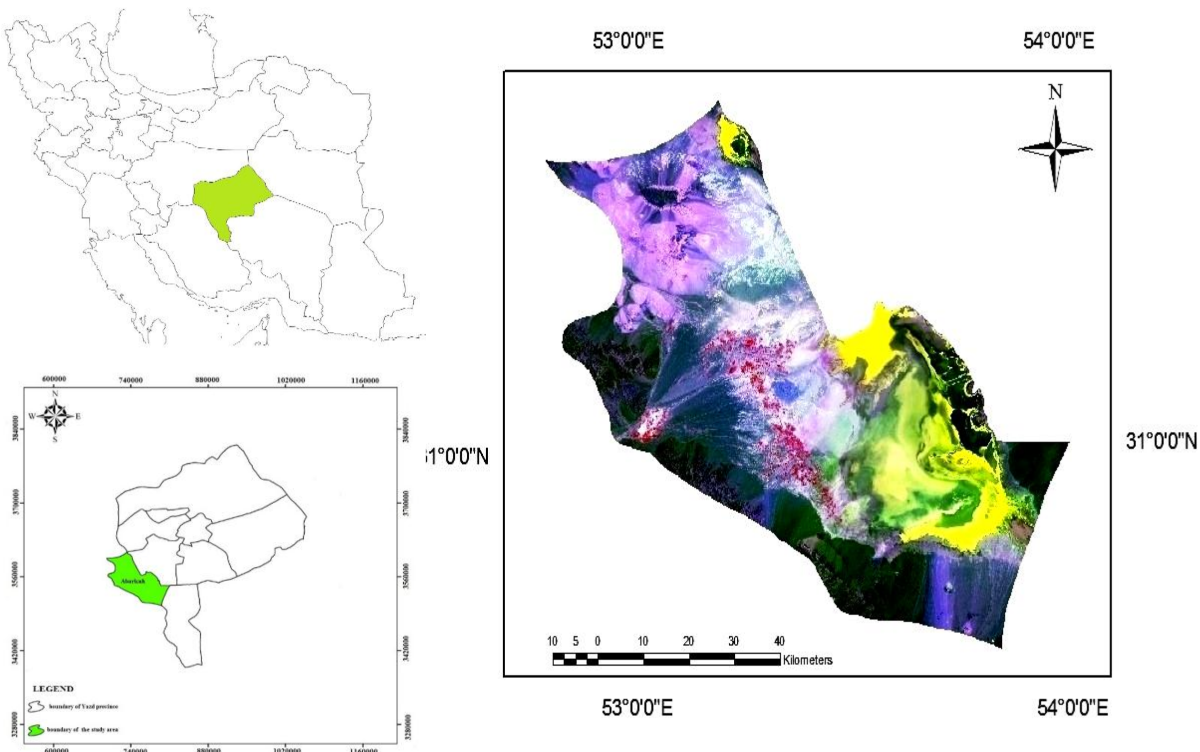

Fig. 1. Geographical location of Abarkooh plain, located in Yazd province, central part of Iran

Methodology

Landsat images of May in 1987, 2000 and 2013 were used in this study for preparing land use maps. The reason for using the images of this date lies in the fact that the highest vegetation cover on the land occurs in May. Geometric correction and geo-referencing of images were conducted using vector maps of road networks and aerial photos. Resampling was conducted using the nearest neighbor interpolation method. Radiometric correction of the image was performed on the images to reconstruct phenomena and enhance the quality of the images as well as to remove the unfavorable effects of light and atmosphere.

In this study, images in related years were classified before applying different vegetation indices on images. First, related classes were defined and determined using false color images (135, 157 367 as the best combination band for 1987, 2000 and 2013, respectively) while evaluating the histogram of spectral bands based on different features such as color, tone, texture, shape and size of the image. Then, using different algorithms of image processing, classes were separated from each other in different steps using support vector machine or supervised classification method (Sabin, 1996).

Finally, five classes of lands including residential and industrial lands, agriculture and horticulture lands, arid and desert lands, Playa, saline soils and mountainous areas were recognized.

Vegetation indices

Vegetation indices were calculated using a number of appropriate and useful bands (Boyd *et al.*, 1996). These indices are significantly correlated with leaf density, but they are sensitive to three factors namely solar elevation and angle of the sunlight, soil, and atmospheric effects (Sepher and Mottaghi, 2002). Sensors of satellites receive different information from vegetation and the vegetation can be characterized relatively by analyzing the information. Normalized Difference Vegetation Index (NDVI) and Modified Soil Adjusted Vegetation Index (MSAVI) were used.

In this study, the Supervisor Vector Machine (SVM) method with the highest accuracy in all years was selected for classification. After preparing land-use map and also applying the calculated NDVI and MSAVI indices, desertification map of the region was prepared by IMDPA model using three criteria including urban development criterion (urban and residual lands to agricultural land ratio (Ur/Ag) indicator), wind erosion criterion (plant canopy density indicator) and vegetation criterion (vegetation renewal indicator).

The determination of NDVI and MSAVI indices was as follows (Equations 1 & 2):

NDVI= NIR-red/ NIR+ red (Rouse *et al.*, 1973) (Equation 1)

MSAVI= [(NIR-red/NIR+ red+ L)(1+L)] (Qi *et al.*, 1994) (Equation 2)

Where:

L= 1-2S × (NDVI) (WDVI)

S= the slope of the soil line

NDVI= Normalized Difference Vegetation Index

MSAVI= Modified Soil Adjusted Vegetation Index

NDVI is the best-known vegetation index. This index shows that the solar energy is reflected from the earth surface that suggests different types of vegetation. NDVI fluctuates between -1 and +1 and when the measured spectral response of Normalized Difference Vegetation Index of the earth's surface is very similar to both bands, NDVI values approach to zero. Healthy vegetation (with photosynthetic activity) in the Near Infrared (NIR) spectral band (band 4 of ETM^+) shows higher reflection as compared to visible spectral band (red, band 3 of ETM^+). Therefore, NDVI values for green vegetation will be positive. Areas with little or no vegetation cover such as urban areas and arid lands commonly represent

NDVI values ranging from -0.1 to +0.1 while clouds and water resources show negative or zero values. NDVI has used to calculate ground spectral data and the results have shown that this index is highly correlated with the aboveground biomass (Lin, 1997). MSAVI vegetation index calculates aboveground living vegetation density index.

Iranian Model of Desertification Potential Assessment (IMDPA)

Some researches in Iran attempted to assess the desertification and their studies led to Iranian Model of Desertification Potential Assessment (IMDPA); this model is a modified model of ESAs or MEDALUS by which preliminary studies were conducted in 2004 (Ahmadi, 2005a; Ahmadi, 2005b)**;** then, the model was calibrated in the east of Isfahan province and northern Hableh-Roud catchment in 2005. IMDPA model comprises nine different criteria including climate, geology-geomorphology, soil, vegetation, agriculture, water, and erosion, socioeconomic, technological and urban development.

Results

NDVI map

In order to calculate the indicator, NDVI index was first calculated for the years of 1987, 2000 and 2013. NDVI values varied from -0.13 to -0.52 for 1987, 0.12 to 0.56 for 2000, and 0.15 to 0.49 for 2013. The results showed that positive values (vegetation) in 2013 were lower than that for 1987 and 2000. Then, the values lower than zero were excluded from the prepared maps.

Then, the images were subtracted from each other and the obtained map was classified (Fig. 2). According to Fig. 2, the obtained difference values of NDVI between 1987, 2000 and 2013 ranged from +0.56 to -0.81. Positive values indicate the renewal of vegetation in the area, negative values represent the destruction of vegetation and zero value shows unchanged vegetated areas.

After classification of NDVI difference map, desertification intensity of vegetation renewal indicator was obtained (Fig. 3). In this map, positive points show the renewal of vegetation that occurs in low desertification class. Negative points indicate destruction of vegetation that occurs in severe desertification class and points with values equal to zero occur in the unchanged class that are not influenced by this index. Finally, the areas of different classes and their percentages were calculated and compared. In case of this index, 4.28% (23487 ha) of the region may occur in very severe desertification class, 3.21% (17553 ha) occur in low class and 92.51% (507039 ha) occur in without change.

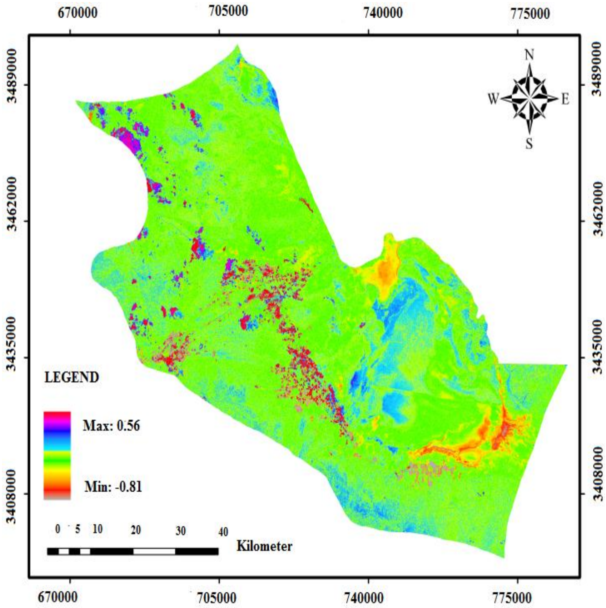

Fig. 2. NDVI difference map among three years of 1987, 2000, 2013

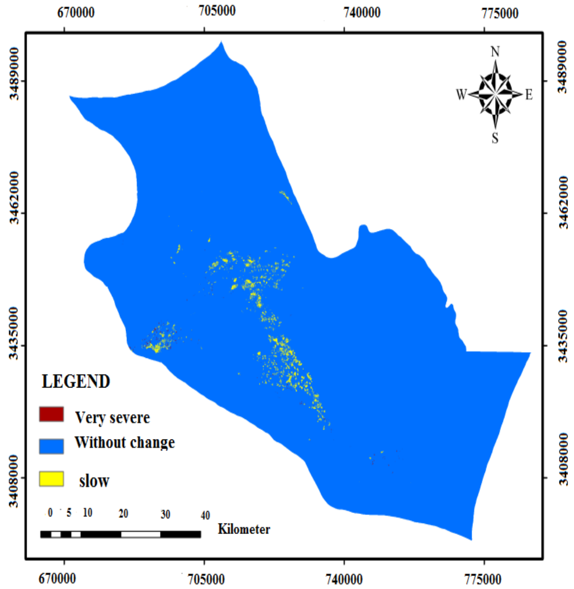

Fig. 3. Desertification intensity map in terms of vegetation renewal in the study area

Map of vegetation

To calculate aboveground plant canopy density indicator, MSAVI map of the study area was prepared. MSAVI values range from 0 to -0.27 for 1987, 0 to -0.30 for 2000 and 0 to -0.86 for 2013.

After preparing the MSAVI map with values higher than zero, Vegetation Fraction (F.V.) map was generated. The equation (F.V. =0.973 MSAVI + 0.06), (Darvish Zadeh, 2012) was applied to the image (Fig. 4).

Then, F.V. map was classified (Fig. 5). In this regard, desertification severity in the region was classified into four classes of very severe, severe, moderate and low (Table 1). On the basis of this index, 99.06% (543495 ha), 0.76 % (4194.6 ha), 0.13% (747.4 ha) and 0.05 % (259.7 ha) of the region occur in very severe, severe, moderate, and low desertification classes, respectively.

Table 1. Scoring range of vegetation density and its role in the classification of desertification caused by wind erosion (Ekhtesasi and Sepehr, 2011)

Score range	0-1(low)	1-2(moderate)	2-3(severe)	3-4(very severe)
Vegetation density	40>%	40-20%	10-2%	10<%

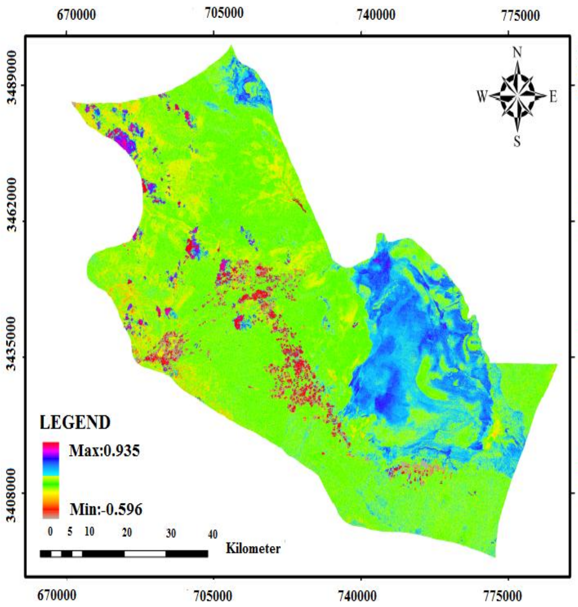

Fig. 4. Vegetation percentage

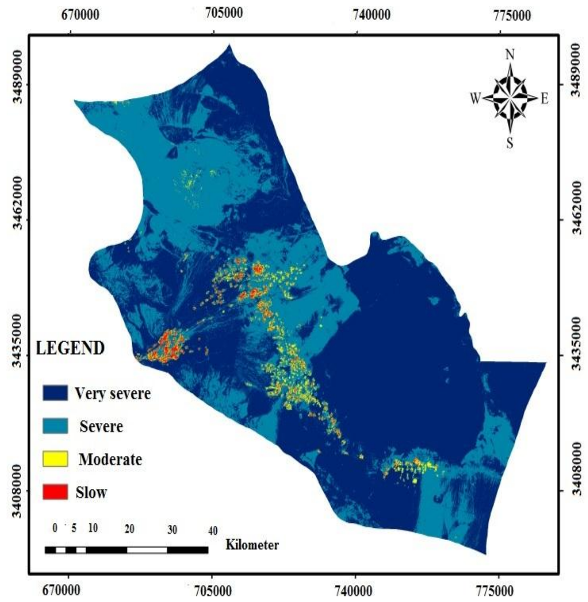

Fig. 5. Desertification intensity map in terms of vegetation density index

Land use maps

To calculate the index of residential and urban lands to agricultural and horticultural land ratio using satellite images, land-use map of 1987, 2000 and 2013 was prepared using support vector machine classification method with kappa coefficient of 0.99, 0.96 and 0.98, respectively (Figs. 6 to 8). Five classes of land use including residential and industrial, agricultural and horticultural, arid and desert, Playa and saline soil and mountainous areas were identified and classified in the study area. Statistical parameters of overall accuracy and kappa coefficient were used to determine the accuracy of image classification and the results are shown in Table (2).

Table 2. Overall accuracy in different land uses

Years	Coefficient kappa (%)	Overall accuracy (%)
1987	0.9956	99.68
2000	0.9622	97.18
2013	0.9801	98.59

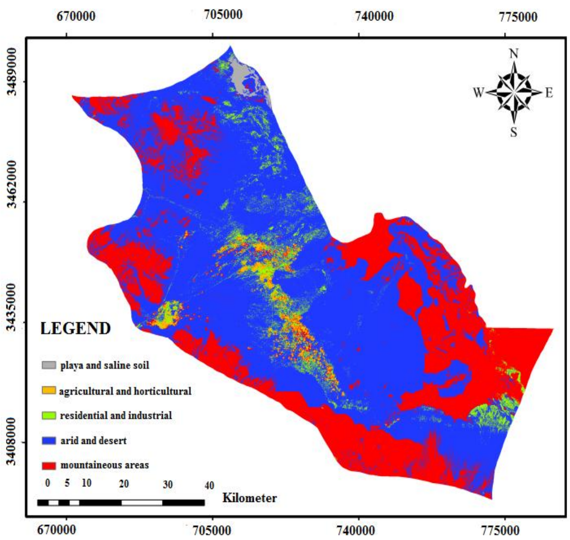

Fig. 6. Land use map in 1987

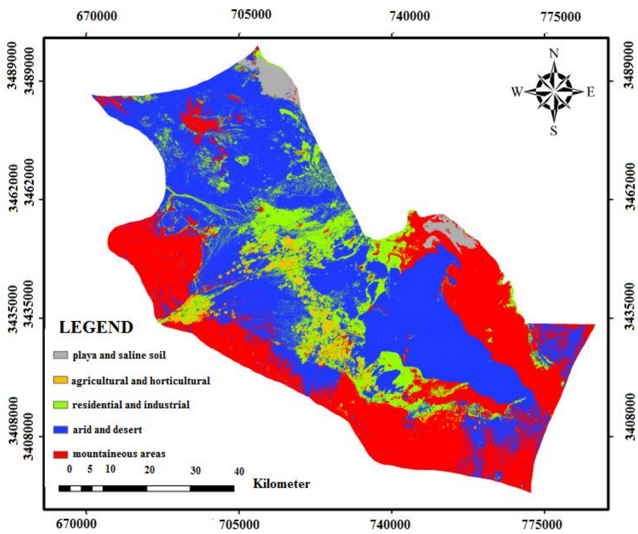

Fig. 7. Land use map in 2000

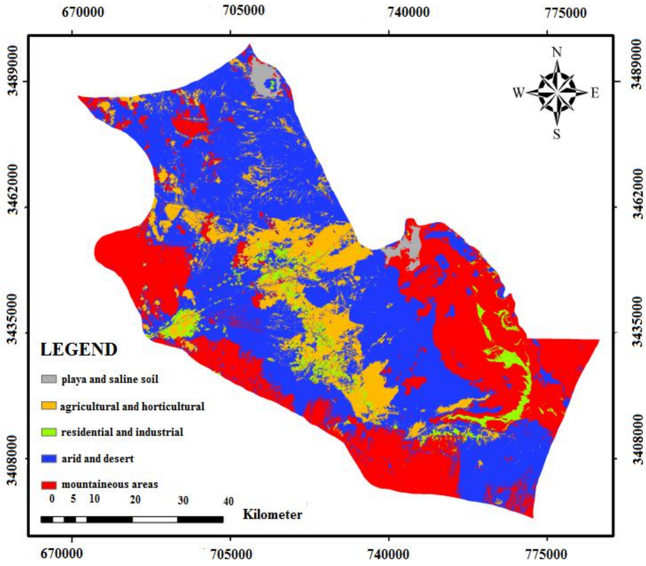

Fig. 8. Land use map in 2013

After calculating the area differences of residential and industrial lands in 1987, 2000 and 2013, the result showed that residential and industrial land occurs in severe desertification classes. Agricultural and horticultural lands occurred in the moderate desertification while other lands occurred in slow desertification class because they had no influence on this index.

The map of desertification severity based on the index of residential and urban lands to agricultural, horticultural lands ratio has been shown (Fig. 9). According to the Ur/Ag ratio (Ekhtesasi and Sepehr, 2011), 87.5% (479612 ha), 6.74% (36978 ha), 5.74% (31459 ha) of area occurred in low, moderate and sever desertification classes, respectively.

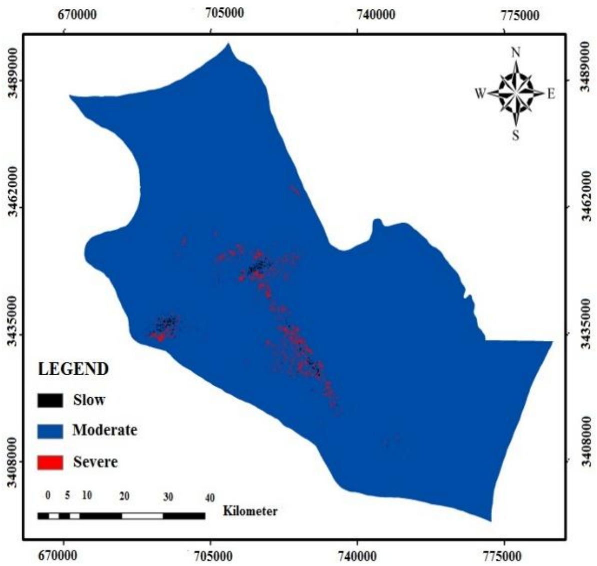

Fig. 9. Map of desertification severity based on index of residential and urban lands to agricultural and horticultural lands ratio (Ur/Ag)

Discussion

Desertification is an important environmental problem. This problem occurs not only in arid and semi-arid region but also in some parts of sub humid region. Many methods have been developed for the assessment and mapping of desertification hazards in recent years and it was found that the desertification models are the best method for the assessment of effective factors in land degradation and desertification severity from the views of experts.

Desertification trend in the Abarkooh region was evaluated using the satellite images of 1987, 2000 and 2013 as well as IMDPA model and vegetation density index. Results obtained from this index demonstrated that four classes of desertification such as very severe, severe, moderate and slow were observed.

The vegetation renewal index was used in vegetation criterion. According to vegetation renewal indicator, 92.52%, 4.28%, and 3.20% were characterized by unchanged, severe and slow desertification classes, respectively.

Concerning urban and industrial development criterion, the index of residential and urban lands to agricultural and horticultural lands ratio was applied. With respect to this index, three classes of desertification including slow, moderate and severe were investigated in which the destruction intensity of agricultural lands and converting these lands into residential and industrial lands were 5.74%. In addition, 6.74 % and 87.52 % of lands occur in moderate and slow desertification classes, respectively.

Based on the obtained results, human factors were the most important factors in land use changes. Contribution of human factor not as vegetation destruction by overgrazing has been considered as the main factor of desertification in many studies (Hill *et al.*, 1998). In Abarkooh, raising livestock in the area is not economic due to negligence to conserve rangelands by mine-owners because of developmental activities that cause destruction of pastures and insecure proration of fodder for livestock. In fact, the main cause of land degradation in Abarkooh region is the uncontrolled development of urbanization and conversion of agricultural and horticultural land-use to residential ones, confirming the reported results (Khresat and Mohammad, 1998) in Jordan.

IMDPA model was used in present study that allows the severity estimation of desertification condition. Therefore, understanding factors influencing the desertification in the region can provide information for macro-scale decision-making on conserving soil and water resources and presenting plans and applied projects based on the effect of different indicators on the severity of desertification. Implementation of this research could be effective in improving land management, preventing desertification extension, conserving soil and water resources and optimal utilization of resources and planning the desert areas.

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بررسی تاثیر تغییرات کاربری اراضی در روند بیابان‌زایی با استفاده از سنجش از دور (مطالعه موردی: دشت ابرکوه، یزد، ایران)

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چکیده. بیش از یک سوم اراضی کره زمین دارای اقلیم خشک و نیمه‌خشک بوده و پدیده بیابان‌زایی در این مناطق در دهه‌های اخیر شدت یافته است. تحقیق حاضر به منظور بررسی روند بیابان‌زایی با استفاده از شاخص‌های گیاهی و با استفاده از مدل IMDPA در دشت ابرکوه واقع در استان یزد صورت گرفته است. تصاویر مورد استفاده در این پژوهش جهت تهیه نقشه کاربری اراضی منطقه، تصاویر لندست سال‌های ۱۹۸۷، ۲۰۰۰ و ۲۰۱۳ مربوط به اردیبهشت ماه می‌باشند. پس از انجام اقدامات مورد نیاز در مرحله پیش پردازش، با روش طبقه‌بندی نظارت شده (ماشین بردار پشتیبان)، که در بین روش‌های مورد استفاده بالاترین دقت را در همه سال‌ها نشان داد؛ نقشه آشکارسازی تغییرات در پنج کاربری مورد استفاده: اراضی مسکونی و صنعتی، کشاورزی و باغی، بایر و بیابانی، خاک‌های شور و کویری و مناطق کوهستانی تهیه گردید. در مرحله بعد با محاسبه شاخص‌های NDVI و MSAVI و استفاده از مدل IMDPA نقشه بیابان‌زایی دشت ابرکوه تهیه شد. در این مدل از سه شاخص نسبت اراضی مسکونی و شهری به زراعی و باغی شاخص تراکم پوشش گیاهی زنده سطح خاک و معیار پوشش گیاهی شاخص تجدید پوشش گیاهی استفاده شد. از نظر شاخص نسبت اراضی مسکونی و شهری به زراعی در ۵/۷۴ درصد از منطقه تحت تاثیر بیابان‌زایی شدید، ۶/۷۴ درصد در کلاس بیابان‌زایی متوسط و ۸۷/۵۲ درصد در کلاس بیابان‌زایی آرام ناشی از عوامل تغییر کاربری قرار گرفت. از نظر شاخص تراکم پوشش گیاهی زنده سطح خاک شدت بیابان‌زایی منطقه در چهار کلاس خیلی شدید، شدید، متوسط و آرام قرار گرفت. از نظر این شاخص ۹۹/۰۶ درصد در کلاس بیابان‌زایی خیلی شدید، ۰/۷۶ درصد در کلاس بیابان‌زایی شدید، ۰/۱۳ درصد در کلاس بیابان‌زایی متوسط و تنها ۰/۰۵ درصد در کلاس بیابان‌زایی آرام قرار گرفت. از نظر شاخص تجدید پوشش گیاهی نیز ۹۲/۵۱ درصد از سطح منطقه بدون تغییر، ۳/۲۱ درصد در کلاس بیابان‌زایی آرام و ۴/۲۸ درصد تحت تاثیر بیابان‌زایی شدید قرار دارند.

کلمات کلیدی: طبقه‌بندی ماشین‌بردار پشتیبان، بیابان‌زایی، لندست، NDVI، MSAVI