Effect of environmental policies in combating aeolian desertification over Sejzy Plain of Iran

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ABSTRACT

Wind erosion in arid and semi-arid regions is a serious concern because it can cause land degradation and consequently affect the land use pattern. The aim of this study was to assess the variations of aeolian sediments and gypsum sediment surfaces (ASGSS) during 1992–2017 in Sejzy Plain and to analyze the impact of plans against desertification, as well as human and environmental activities on the variations of these surfaces. In the current study, Landsat satellite images were classified using the multiple layer perceptron (MLP) neural network. Finally, the logistic regression model has been used to study the impact and role of plans against desertification, human and environmental activities on the ASGSS variations in the studied area. The ASGSS decreased from 37.9% in 1992 to 24.3% in 2017 in the study area. Investigation of the effect of aeolian desertification in the region showed that planting stabilizing species and preventive measures taken in controlling gypsum-mining activities and grill areas, especially in the northern parts of the region has prevented further variation in the gypsum sediment cover. The results indicate that the planting of stabilizing species in lands outside the ASGSS has a greater effect on reducing ASGSS, in comparison with the planting of stabilizing species in the interior lands of the and ASGSS. Also, the results show that policies related to plans against desertification have been useful in reducing lands with ASGSS.

1. Introduction

Natural environments are influenced by changes caused by natural and human factors; thus, planning and management of these environments is needed to monitor such changes. In addition, identifying and assessing trends over time and the effects of constructive and destructive activity on the environment can be used as a basis of planning for sustainable development.

Wind erosion in arid and semi-arid regions is a serious concern because it can cause land degradation and consequently affect the land use pattern (Santra et al., 2017; Webb et al., 2006). Wind erosion typically causes problems such as soil fertility degradation (Goudie, 1999), crops production loss and associated economic loss (Hagen et al., 2007), visibility reduction (Blackburn, 2006), and air pollution (Webb et al., 2017). Some studies have shown that most aeolian sediments carried with wind are deposited near the source area (Hagen et al., 2007). The emission and transport of Aeolian sediment causes significant problems for human settlements, transportation networks, vegetation cover, adjacent agricultural land and irrigation networks (Holmes et al., 2012; Webb et al., 2017).

In recent years, remote sensing (RS) and the geographic information system (GIS) technologies have been used to monitor changes in natural environments (Amin and Fazal, 2017; Frohn and Lopez, 2017; Kennedy et al., 2009; Tarolli et al., 2009; Yang and Shi, 2018). Satellite image processing algorithms were used to understand current situation or past trends of surface process (Firozjaei et al., 2018; Milan et al., 2007; Moghaddam et al., 2015; Panah et al., 2017; Telfer et al., 2015; Weng et al., 2018; Willis, 2015; Yao et al., 2011). The use of spatial analysis of the effects of different factors was examined and spatial relationships discussed.

Remote Sensing technology is used to monitor changes in natural environments to decrease time and cost spent. Satellite data offers unique multi-temporal and multi-spectral properties and expands the coverage area providing good facilities with which to study dynamic

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phomena. It provides valuable information for understanding and monitoring patterns and land development in addition to creation of land cover and land use maps (Hu et al., 2016; Were et al., 2013). The use of GIS technology allows comprehensive assessment of the environment accompanied by the risk factors associated with it (Merrett and Chen, 2013; Satapathy et al., 2008).

In recent years, considerable interest has been created in the application of tools related to GIS technology and remote Sensing data to study land cover and land use changes (Butt et al., 2015; Guo et al., 2017; Latifovic et al., 2005). (Anderson et al., 2010; Pacifici et al., 2009; Weng et al., 2017) used neural networks to classify different surfaces. Studies that used remote sensing data to assess desertification include (Symeonakis and Drake, 2004; Tao, 2014; Wang et al., 2017; Weng et al., 2017; Xu et al., 2017). Logistic regression is a statistical model belonging to a group of generalized linear statistic models that provides a powerful device for organizing data analysis. In many environmental studies such as desertification, land degradation and human-caused events, this model has been used to identify influential factors on environmental changes (Djeddaoui et al., 2017; Dubovyk et al., 2013; Huang et al., 2007; Zhang et al., 2010).

Sejzy Plain is located 20 km east of the city of Isfahan in central Iran. In recent years, it has become the source of first-grade wind erosion. Natural and human factors are involved in the development of aeolian desertification in the region. Aeolian desertification is a type of land degradation because of wind erosion resulted from the extreme human activities in arid and semi-arid regions (Tao, 2014). Low rainfall, high evaporation and severe wind are among the natural factors. Uncontrolled exploitation of groundwater and surface water leading to groundwater salinization, unprincipled exploitation of gypsum mines, loss of protective soil surfaces (crusts) caused by mining activity, the movement of heavy vehicles, expansion of gypsum furnaces and intensification of land degradation are human factors. Only more than 5000 ha of Sejzy Plain lands have been destroyed because intensive exploitation of gypsum and other building materials (Department of Natural Resources and Watershed of Isfahan Province, 1995).

Eastern Isfahan, with its industrial, logistical and military facilities, enjoys a strategic location. However, aeolian desertification and land degradation, followed by sandstorms and the suspension of dust in the air has damaged the ecological, economic and social aspects of the environment. An example of this includes damage to the facilities of Shahid Beheshti International Airport and Shahid Babaei air base, industrial and economic damage to factories and railways in the region, accidents leading to loss of life and property on the Isfahan-Bandar Abbas route, damage to agricultural land and orchards in the region and creation of dust and air pollution in Isfahan and its environs. On some occasions, relatively dense dust covers the city of Isfahan (Department of Natural Resources and Watershed of Isfahan Province, 2015). Studies on fine particulates in Isfahan confirm that dust mainly originates from deposits east of Isfahan (Mahmoudi and Khademi, 2014; Norozi, 2015).

The Iranian government signed the United Nations Convention on Combating Desertification (UNCCD) (UN, 1995), and based on the national action plan against desertification promulgated in 1996. The national action plan to combat desertification is programs for the Convention implementation at country level (Wang et al., 2013). The basic objectives of the national action plan on combating desertification are prevention of land degradation, rehabilitation of degraded land and reclamation of desertified land (UN, 1995). The Iranian national action plan includes sub-regional and regional action plans to combat desertification in different part of country (Range, 2005). The Combat to Desertification department of Natural Resources and Watershed organization has taken action against aeolian desertification in Sejzy Plain by planting Haloxylon ammodendron (C.A.Mey.) in different periods, prevention of mining, shutting down 38 furnaces and, in recent years, implementing a 10-thousand ha action plan to plant stabilizing species against desertification. These include planting stabilizing species (such as Tamarix, Nitraria and Calotropis procera), irrigation and protection (Department of Natural Resources and Watershed of Isfahan Province, 2015).

The present study was undertaken to monitor variations in the aeolian sediments and gypsum sediment surfaces (ASGSS) to discover the effects of action plans against desertification implemented in eastern Isfahan. The modelling of spatial patterns of variation in ASGSS gives valuable information for better understanding of the process of change and to determine the effect of the plans. The importance of recognizing environmental changes can be understood when integration of data revealed the availability of the objectives envisaged by the plans implemented against desertification. Also, the impact and success rate of policies and plans against desertification implemented by the local government is to be assessed. The results of this study could be a useful for making optimal decisions by planners and decision-makers. This study has prepared some references for the plans and projects implemented by local governments and for researchers who studied about aeolian variations that affect cities.

2. Study area

Sejzy Plain east of the city of Isfahan in central Iran is located between 51°57' and 52°9' E longitude and 32°34' and 32°50' N latitude (Fig. 1). This region is an area of approximately 433 km² and is divided by the Isfahan-Nain road into two parts (north and south). A major feature of the Sejzy Plain is the fine-grained material of the region. The prevailing wind direction in Sejzy Plain transports the fine-grained colloidal material from the fields and meadows surrounding the plain towards the plain. Gypsum and sand mining in the area has severely damaged the surrounding plains and the chalky sediment has been spread by the wind, burying fertile soil and natural vegetation (Fig. 2). There are about 220 furnaces in this area which produce bricks and gypsum (Department of Natural Resources and Watershed of Isfahan Province, 2015).

3. Methods

The methods applied in this study consist of four steps (Fig. 3). The first step is to apply atmospheric correction on satellite images. The second step is to classify satellite images. The training data set and the neural network classification algorithm are used in this step. In the third step carried out the assessment of ASGSS variations using the Cross-Tab model. Finally, the logistic regression model was considered to assess the effect of environmental policies on ASGSS variations and in combating desertification.

3.1. Data and preprocessing

The three satellite images used in this study were acquired by the thematic mapper (TM), enhanced thematic mapper plus (ETM +) and operational land imager (OLI) sensors from Landsat satellites for January 1992, 2002 and 2017 (path/row 164/37). The image from 1992 reflects the situation in the region before implementation of the plan against desertification, the image from 2002 reflects the situation 7 years after implementation and image from 2017 represents the situation after implementation of major plans against desertification. These satellite images were used to examine changes in the area over time. The accuracy of the classification results and extraction land surface variations are directly related to the spectral properties of the various surfaces. In addition to the effect of surface biophysical properties on spectral properties, the climatic factors and seasonal changes also affect the spectral properties of land surfaces. This study uses images for 1992, 2002 and 2017 correspond to the same month of the year (January) so that changes in climate and seasonal conditions do not affect the results of the study. Also, for selected dates, climate conditions such as air temperature, relative humidity and precipitation
have also been studied. Climate conditions for the selected images should be minimal. Considering the two limitations of seasonal and climatic conditions, the Landsat images collection for the studied area in the period 1985–2017 were investigated and the most suitable images were selected for different years. All images employed in this study are level 1 products of USGS, georeferenced in World Geodetic System (WGS84) datum and are projected using the Universal Transverse Mercator system (zone 39 north). The Root Mean Square Error (RMSE) of the geo registration process has been achieved as less than 12 m. Also, the FLAASH (Cooley et al., 2002) atmosphere correction algorithm was used owing to the importance of radiometric and atmospheric effects on the final processing results.

Data from basic studies conducted by Natural Resources and Watershed organization of Isfahan Province such as maps of soil types, geomorphology, erosion, vegetation, mines and roads network also were used. Field observations were carried out to detect the destruction or improvement of Sejzy Plain. It should be noted that additional datasets for 2017 were obtained through field observations. Also, data for 1992 and 2002 have been extracted from previous maps and studies of the Natural Resources and Watershed organization of Isfahan Province.

3.2. Image classification

Images were taken using pattern comparison in order to identify regional variations in terms of contamination from spreading Aeolians and were classified in order to separate the two classes of areas covered and not covered with gypsum. The use of many different images classification methods for extracting the various terrestrial features and land cover and land use maps has advantages and disadvantages. Amongst all the methods, artificial neural networks (ANNs) have been widely applied because of its advantages over other classification method, such as no assumption about the distribution model of data (Atkinson and Tatnall, 1997), the ability to learn complex patterns (Ji, 2000) and efficient in noisy environments classification (Hu and Weng, 2009). The classification using Multiple Layer Perceptron (MLP) neural networks is a common method of classifying images that offers high quality segregation of different classes of land cover, especially mixed pixels (Di Gregorio, 2005; Myint et al., 2011). MLP neural networks classify remote sensing data based on the certain relationships during the training phase. Other types of artificial neural networks also exist for land cover classification (Wijaya, 2005).

The MLP model is a feed-forward network with one or more hidden layers among the input and output layers. The supervised learning algorithm of the MLP is a propagation algorithm which is learning based
Fig. 2. Photos of current conditions in study area.

Fig. 3. The analytical procedures in this study.
on calculations in the training data. The basic steps of the learning algorithm are forward propagation and backward propagation. These processes are repeated frequently as long as the errors of network are minimized or until they reach an acceptable value. The aim of network learning is to achieve the proper weights for both relationships between the input layer and hidden layer and the hidden layer and output layer (Eastman, 2009).

Prior to the application of the MLP classifier, training datasets for each class were carefully chosen by visual interpretation and based on local information about the study area. The quality and size of the training datasets have the greatest effect on the interoperability of classification results and accuracy. The number of input layer nodes in this study equalled the number of spectral bands. The training dataset size should increase in proportion to the increase in the number of input nodes or spectral bands, the variability of the spectral class and the accuracy of classification (Omo-Irabor and Oduyemi, 2007). Another important factor to be carefully determined in a neural network is momentum factor, which operates similarly to a low-pass filter and allows the network to ignore small effects at the error level (Yuan et al., 2005). The momentum factor must be chosen by experimentation. The number of iterations in the classification of neural network is important and should be large enough to train the network, but not so high as to over-teach the network (Sugumaran, 2001). More detail about MLP neural networks can be found in (Samarasinghe, 2016; Zhang et al., 2017).

In the present study, training data sets have been used for classifying satellite imagery. For each class more than 300 samples have been used. Training samples are randomly selected in different locations from each land surface (as an average 600 training samples for the entire region in different years). Also, to evaluate the results, at least 400 test samples were used for each land surface (as an average 900 test samples for the entire area in different years) (Table 1). The training and test data sets have been provided from field observations in 2017 and Natural Resources and Watershed organization of Isfahan Province data sets for 1992 and 2002. To achieve the highest accuracy of classification in this method, different values for network parameters such as learning rate, momentum factor and iteration were considered, their accuracy was tested to identify the most appropriate values for the study. The number of hidden layer nodes were automatically determined with the help of software based on the number of bands introduced into the input layer. Table 1 shows the values used in the MLP neural network.

After the images classification was applied, the assessment accuracy of classification was examined using field data and a topographic map (1:25000). Finally, the areas belonging to classes were extracted. The overall accuracy and kappa coefficient (Otukei and Blaschke, 2010) were calculated to assess the accuracy of the classification results. To recognize changes during the studied period, classified images were compared. Overall accuracy is the simplest and most popular of the accuracy measures, which consider only the diagonal elements of confusion matrix, in contrast to the overall accuracy measures, which consider only the diagonal elements of the matrix (Otukei and Blaschke, 2010).

Among the important applications and uses of satellite imagery processing is change detection. Detection of changes in land use and cover is an essential tool for environmental analysis, planning and management (Lillesand et al., 2014). Images classified in different years are compared using crosstab model (Shalaby and Tateishi, 2007). The advantage of this method is that it reveals environmental changes for each pixel on the different dates. In this model, both calculating the number of pixels that are changes between two imaging dates and changing the nature of the lands are feasible. The disadvantage of this method is that it is affected by errors in multi-temporal image classification (Jensen, 2005). In this stage, classified maps from 1992 to 2002 and 2002 to 2017 were evaluated to analyse and detect changes in the study area. To focus more on the study objectives, the classes in the region were classified into two classes: non-ASGSS (Gypsum-uncovered areas) and ASGSS class (Gypsum-covered areas). Therefore, the non-ASGSS class includes all lands except aeolian sediments and gypsum sediment surfaces.

Using classified images, environmental changes were mapped individually for period of time (1992–2017). For better visualization, the 2017 satellite image has been used as a background for the map of changes and all types of land use in the area were placed on it.

3.3. Analyzing the effect of different factors on ASGSS variations

Factors affecting the ASGSS variations in the region were identified based on thematic literature, field studies and observations, as well as interviews with local experts and planners. These additional data which used to modelling have been provided by the Natural Resources and Watershed organization of Isfahan Province. The logistic regression model has been used to discover the relationships between effective factors, the area of ASGSS variations. The effective parameters used in modeling include: agricultural lands, lands with high erosion, lands with low erosion, mines, wastewater discharge area, industrial areas, planting of stabilizing species inside ASGSS, planting of stabilizing species outside the ASGSS and roads. The erosion map of the study area prepared by the department of Natural Resources and Watershed of Isfahan Province is used to extract lands with high and low erosion. During implementing action plans, the organization has had two approaches to planting stabilizing species as part of the action plan. Planting stabilizing species in areas where is the origin and source of ASGSS (planting of stabilizing species outside the ASGSS) and the other approach is planting stabilizing species in areas where ASGSS are deposits (planting of stabilizing species inside the ASGSS). Since these two approaches are different, two distinct factors are considered in the analysis.

Logistic regression is a statistical model belonging to a group of generalized linear statistic models that provides a powerful device for organizing data analysis. It explains a dependent variable (ASGSS) as a function of multiple independent variables (effective factors) (Menard, 2002). Logistic regression is used to determine the probability of occurrence of each of the two-state qualitative variable levels based on independent variables. The main point behind the binary logistic regression model is that the dependent variable is a two-state variable, meaning that it can be zero, indicating the non-occurrence of the event, or one indicating the occurrence of the event (Hosmer et al., 2013). Logistic regression uses the maximum probability estimation method to find the best set of parameters which better fit the model. Logistic regression uses the maximum probability estimation method to find the best set of parameters which better fit the model. Logistic regression is a logarithmic model that estimates the probability of event occurrence by Eq. (1) (Press et al., 1986; Yu et al., 2012).

Table 1

<table>
<thead>
<tr>
<th>Value of parameters used in MLP network.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average of training pixels</strong></td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>600</td>
</tr>
</tbody>
</table>

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For this purpose, the receiver operating characteristic (ROC) and tions. The results of the logistic regression model should be assessed. will be as a continuous spatial map of the probability of ASGSS varia-

tions in the ASGSS showed in Fig. 5. The area of each class, along

different years and a decreasing trend

4. Results and discussion

4.1. Data classification with MLP neural networks

After the introduction of training samples, the MLP neural network was implemented on satellite images from 1992, 2002 and 2017 to obtain land cover maps of the region for the different years (Fig. 4). According to Fig. 4, the industrial areas were significantly increased from 2002 to 2017. These changes of industrial areas were more obvious in the center of study area. The development of industrial areas is part of the local government’s plans to prevent rising unemployment rate due to limiting mineral activities. In contrast, the area of mines and furnaces has been decreased over different years and a decreasing trend can clearly be observed. Also, the wastewater discharge area has been developed in the northwest of the study area from 1992 to 2002.

The training samples originating from field observation were used to evaluate the accuracy of classification. After the formation of the error matrix, overall accuracy for 2017 image classification was 93.22% and the Kappa coefficient was 0.91. The further results of the classification accuracy assessment have been shown in Table 2. In this table, the overall accuracy and Kappa coefficient of each year for the entire study area, the user’s and producer’s accuracy for the ASGSS class are listed. The MLP algorithm needs a suitable training dataset for training phase. Due to access to the complete training dataset for the study area, the use of the neural network algorithm has been appropriate for land cover classification of Sejzy region. The results of accuracy assessment indicate the efficiency of the MLP algorithm.

4.2. Identify changes in study area over period of study

After change detection for period of time (1992–2017), regional variations in the ASGSS showed in Fig. 5. The area of each class, along with the percentage of area assigned to each class in different years are listed in Table 3. An analysis of the results found that ASGSS in the Sejzy Plain had decreased over the term of the study. For 1992–2002, the gypsum sediment class had decreased approximately 6% and almost 8% from period 2002–2017.

4.3. Logistic regression analysis

The output of the model is a function that provides the probability of occurrence of ASGSS to Non-ASGSS for each point with specific features of considered factors. Also, based on the coefficients of this function, which is specified for each parameter, the amount and direction of the effect of that independent variable on the dependent variable is determined. Therefore, the coefficients of variables in the regression equation are of great importance. The logistic regression equation related to the assessment of the effect of factors set of government plans, human and environmental parameters is obtained as Eq. (3). In this study, the ROC value was 0.81 while the statistic value of pseudo R-square was 0.172.

$$\logit(\text{ASGSS to Non-ASGSS}) = -1.99 + 2.46 \times \text{planting outside the ASGSS}$$
$$+ 2.14 \times \text{industrial areas}$$
$$+ 0.97 \times \text{agricultural lands}$$
$$+ 0.84 \times \text{roads}$$
$$+ 0.35 \times \text{planting inside the ASGSS}$$
$$+ 0.12 \times \text{wastewater discharge area}$$
$$- 0.65 \times \text{land with low erosion}$$
$$- 0.85 \times \text{land with high erosion}$$
$$- 0.96 \times \text{mineral areas}$$

Logistic regression takes into account the impact of a set of factors simultaneously (Eq. (3)). Many of the factors considered are related to land use changes, such as increasing industrial areas and reducing mines. The results show that in the studied area, factors such as the planting of stabilizing species outside of ASGSS and industrial areas development have respectively the most positive effect, while factors such as mineral areas and lands with high erosion have respectively the most negative effect on variations of ASGSS to Non-ASGSS. This demonstrates that human activities are the most influential factor that affects aeolian desertification processes. Sajzi Plain is a complex natural environment which all factors affecting its conditions. Therefore, the results suggest that an action plan to combat aeolian desertification over Sejzy Plain should be considered all influential factors and the extent of the impact of each factor. Fig. 6 shows the map of the probability of conversion of ASGSS to Non-ASGSS. The continuous spatial map of the probability of ASGSS variations over years indicates how surfaces affected by aeolian desertification processes. Areas with a high probability are areas that have been less affected by the aeolian desertification processes over the years. The change possibility of these areas from ASGSS to Non-ASGSS has been high. Industrial areas and wastewater discharge area are among high probability areas. While areas with a low probability are areas that have been most affected by the aeolian desertification processes over the past years. The change possibility of these areas from ASGSS to Non-ASGSS has been low. The more southern regions of the study area are low probability areas.

The results of Figs. 5 and 6 indicate that the planting of stabilizing species by the Natural Resources Department has prevented the spread of gypsum sediments in the northern regions. However, plans on the planting of stabilizing species have encountered with proper success and development in some places, and in some places with inappropriate development and failure. Generally, the planting of stabilizing species inside ASGSS has not been very successful in comparison with the planting of stabilizing species outside ASGSS. The images are shown in Fig. 7 illustrate an example of field observations on the status of the planting of stabilizing species inside and outside of ASGSS.}

Fig. 7 shows that in some places, the stabilizing species are covered
Fig. 4. Land cover maps for Sejzy region for: (a) 1992; (b) 2002; (c) 2017.
with gypsum sediments. As a result, the implementation of these projects has not been successful in these areas.

According to the 1994 plan of the Natural Resources Organization, it should be noted that the starting place for the planting of areas northwest toward the center of the plain and perpendicular to the region with dominant wind. Based on information extracted from the satellite images of different times, which generally indicate the decrease in ASGSS, in general, these policies have had a positive impact on the area, such that the planting of stabilizing species and the entrance of wastewater into the region, as well as increasing the industrial activities of the center of the region, which are entirely located in the previous ASGSS, and the control of mines exploitation, have reduced the ASGSS in the center of the region.

### 5. Conclusions

Aeolian desertification is a type of land degradation because of wind erosion resulted from the extreme human activities in arid and semi-arid regions. The present study was undertaken to monitor variations in the ASGSS to discover the effects of action plans to combat aeolian desertification implemented in eastern Isfahan. Natural conditions and human activity has degraded the environment in Sejzy Plain. Using multi-temporal remote sensing data, ASGSS variations of Sejzy Plain from 1992 to 2017 were evaluated. A decrease in the ASGSS from 37.9% in 1992 to 24.3% in 2017 was seen in the study area. The implementation of plans to combat aeolian desertification and banning of expansion of gypsum furnaces and mines has prevented the increase in destruction of ASGSS in the northern study area; however, no significant variations occurred in southern and south-eastern parts of the region. With caution, it can be concluded that implementation of projects in the region have been a successful solution to sediment stabilization to combat aeolian desertification. Sajzi Plain is a complex natural environment which all factors affecting its conditions. Therefore, the results suggest that an action plan to combat aeolian desertification over Sejzy Plain should be considered all influential factors and the extent of the impact of each factor. It is recommended that with the completion of the planting of 10 thousand ha in one project, non-issuance of gypsum and sand mining licenses and the non-renewal of existing licenses, variations the operation of remaining gypsum furnaces and focusing erosion control on reconstruction of existing surfaces will continue the process of consolidation of the sediment. The results suggest the effectiveness of remote sensing technology and GIS for understanding natural environments. Therefore, it is recommended that local governments should use these technologies to manage and monitor different plans and policies. The methods and results of the study can be considered as a reference for developing standards and

### Table 2

The results of the accuracy assessment for classified images of the Sejzy region.

<table>
<thead>
<tr>
<th>Year</th>
<th>1992</th>
<th>2002</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa coefficient</td>
<td>0.92</td>
<td>0.93</td>
<td>0.91</td>
</tr>
<tr>
<td>Overall accuracy (%)</td>
<td>94.1</td>
<td>93.9</td>
<td>93.2</td>
</tr>
<tr>
<td>Producer's accuracy (%)</td>
<td>91.5</td>
<td>92.8</td>
<td>91.5</td>
</tr>
<tr>
<td>User's accuracy (%)</td>
<td>92.2</td>
<td>93.1</td>
<td>91.8</td>
</tr>
</tbody>
</table>

### Table 3

Percentage and hectare of each class during period of study.

<table>
<thead>
<tr>
<th>Year</th>
<th>1992</th>
<th>2002</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hectare</td>
<td>Percent</td>
<td>Hectare</td>
<td>Percent</td>
</tr>
<tr>
<td>Gypsum-covered areas</td>
<td>16346.3</td>
<td>37.9</td>
<td>14101.5</td>
</tr>
<tr>
<td>Gypsum uncovered areas</td>
<td>27243.3</td>
<td>61.1</td>
<td>29488.1</td>
</tr>
</tbody>
</table>

### Fig. 5

Map of change in Sejzy for 1992–2017 (The red areas represent the aeolian desertified areas which converted to Non-ASGSS. The blue areas represent the surfaces which converted to Non-ASGSS). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

### Fig. 6

The map of the probability of the conversion of ASGSS to Non-ASGSS in Sejzy region.
principles of sustainable development in regions with similar conditions in arid and semi-arid zones.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aelonia.2018.09.001.

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