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Prediction of the desertification variation trend in Haj Ali Gholi desert basin for 2030 and 2045

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Abstract

Nowadays, prediction of the desertification variation trend used to explain the drought status for the next decades. In this study, using Landsat time series images, desertification variation trend in Haj Ali Gholi basin predicted using indicators like (drought, soil salinity, vegetation) and other information like (erosion, slope, climate, land surface temperature, evaporation and transpiration), while the desertification trend predicted for 2030 and 2045 using the Artificial Network. Results showed that the average soil salinity is increasing, and the spatial distribution of soil salinity has extended and intensified in the period of 30 years, starting from 1987, when only a small area around the Salt Lake exposed to weak saltification. Soil drought indices also showed an increasing trend. Vegetation indices showed a decreasing trend, leading to increased saltification and desertification. Therefore, developing the vegetation is proved to be the best way for combating desertification. Prediction of the desertification variation trend for 2030 and 2045 conducted using neural network model and results showed that if the current desertification trend continues in the basin, large areas of the basin will be subjected to the risk of desertification in the next two decades. Among the factors used in this model, geomorphology and slope erosion classes, and among the climatic factors, land surface temperature and evaporation and transpiration have the greatest impact on the area desertification trend. The results signified the worsening of desertification in Haj Ali Gholi basin. If this continues, large areas of the basin will be converted to deserted and saltified areas.

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Introduction

Today, dry areas occupy about 41 percent of the Earth's surface and these areas are the shelter for 38 percent of 6.5 billion populations of the Earth (Reynold, 2007). 10 to 20 percent of these areas have subjected to some severe forms of land degradation and it is estimated that as a result of it, the life of 250 million people in developing countries has been affected, while the number of this affected population is permanently increasing due to the population growth and climate change (Reynold, 2007; Okin *et al*, 2008]. So today, with the current global situation and human interventions, desert areas are extended each year. Desertification can be defined as land degradation in arid, semi-arid, arid and semi-humid lands.

Desertification is originated from several factors such as climate change and human activities (Danfeng, 2006), or in other words, it is the destruction of the land and reduction of soil subsistence production capabilities in arid, semi-arid and dry sub-humid lands that occurs in the result of various factors including human activities and climate change (Oi *et al*, 2012). Therefore, desertification leads to a decrease in the ecological and biological potency of the ecosystem, occurring both naturally and artificially (Akbari *et al*, 2011).

Hence, effective factors of desertification can be divided into two categories: natural and human-made. Natural factors originate from the Earth's history and have changed the nature inherently from the time of creation; successive droughts and climatic factors also reinforce this issue.

In recent decades, desertification has been accelerated by massive human intervention in nature, not only in arid and semi-arid lands, but also in other biomes, and has affected biological communities. Poor management of land-use and population growth are human-made factors that have been led to an increase in the irrigating areas, incorrect or too much harvesting and increase in the number of livestock. These events transform the land and soil, reduce the resources and increase the possibility of desertification (Wu *et al*. 2002; Luo, 2003; Mahmoodi, 2006; Zehtabian *et al*, 2007; Oi *et al*, 2012). Desertification has been raised as one of the most striking aspects of environmental degradation and the destruction of natural resources in the world, and many international efforts have been made in order to counter the spread of this phenomenon and to modify its harmful effects during the past few decades, the most important of which is the establishment of United Nations Convention to combat desertification and to mitigate the effects of drought (UNCCD, 2002).

Recognition of criteria and indices of desertification, evaluation of a regional model, and determination of the most important factors in desertification are crucial in preventing its expansion.

The effective criteria and indices of the desertification should be identified and evaluated in order to understand the status and severity of desertification and to protect the vulnerable areas against degradation factors. In such case, desert greening projects can be successfully implemented and desertification can be prevented through optimal land use and by taking into account the effective criteria and indices (Zehtabian *et al,* 2007).

There are various methods for modeling the desertification trends and its prediction, among which Artificial Neural Network can be noted. Artificial Neural Network (ANN) is one of the achievements that can evaluate complex and complicated phenomenon by modeling the human brain.

A new perspective of Neural Network was introduced by adding betting action as an education rule, which was then that developed with the same name by the emergence of single-layer perceptron network and learning rule. Later, significant changes occurred in the world of Artificial Neural Network (Menhaji, 2005), by the development of propagation algorithm plan (BP) and microprocessors.

Artificial Neural Network is among those dynamical systems that by processing the experimental data, transfer the knowledge and the latent rule beyond them to the network structure.

That's why they are called intelligent systems, as they learn the general rules based on the calculations on numerical data or examples. These systems are based on computational intelligence and are trying to model the neuro-synaptic structure of the human brain (Mahmoodi, 2006).

Yanli *et al* (2012), examined the environmental changes of northern parts of the Shaanksy province in China using ETM and TM satellite images and remote sensing and GIS methods and stated that the study area, with 28.4 percent severe environmental changes, 34.2 percent average environmental changes and 37.4 percent low environmental changes, is subject to high-risk environmental changes (Yanli *et al*, 2012). Alrawashdeh (2012), conducted an environmental study in East Jordan by monitoring the variations based on normalized vegetation index using Landsat satellite imagery in the period of 1983-2004. He stated that the efficiency of this method in identifying the variations of degraded areas is appropriate due to the increased salinity of groundwater as a result of excessive extraction (Al Rawashdeh, 2012).

Harashh and Tatashy (2000) prepared the map of desertification intensity in a study at West Asia by taking into account the factors of vegetation deterioration, water and wind erosion and soil salinity (as the main causes of desertification) (Harashe & Tatashi, 2000).Abrisham and FeizNia (2013) used Iranian method of assessing the potential desertification area (IMDPA) to assess the potential desertification in Derakht Senjed area and after an initial review and assessment, introduced four criteria of climate, vegetation, soil, geology and geomorphology as the most important contributing factors in the desertification of Khorasan Razavi province (Abrisham & Feiznia, 2013).

Mousavi *et al* (2013) examined the desertification status in Haj Ali Gholi for the 1987- 2006 time interval using TM satellite data of Lands at 5 and ETM + of Landsat 7 and stated that desertification status suggests that broad changes have occurred in the eco-geomorphologic characteristics of the study area, so that 748.099 square kilometers of the area is unusable and subject to the ecological and biological potential drop (Mosavi *et al*, 2013).

Materials and methods

Study area

This area is located in Semnan province, between longitudes of 53° 15' - 56° E and latitudes of 35° 15' - 37° N. The general slope of this desert is towards southwest. The maximum height of the area is 1094 meters and the minimum height is 1050 meters above the sea level. This desert is confined to Dolat Yar, Kooh Khers and Torkman Gozar mountains to the south, Kooh Panj and Kooh Sorkh mountains to the southwest, Forat village to the west, Dameghan desert to the north and Kooh Ahvand Mountain to the east. Its location at the south of the Alborz Mountains, its proximity to the dry plains of central Iran and distance from moisture centers, the lack of rain-producing air masses, the direction and length of the nearby mountain ranges and the local dry winds have resulted in dry climatic condition for this area. Haj Ali Gholi desert with 2391 km² area is located in the southeastern part of Damghan city.

The used data

Accurate and reliable information layers can be prepared by remote sensing technology, field surveys and aerial photos, while Geographic Information System (GIS) manages and integrates them with each other to achieve the above-mentioned objectives. In this study, the occurrence of desertification is affected by multiple natural and human-made parameters, while the importance of each factor varies depending on the characteristics of the area.

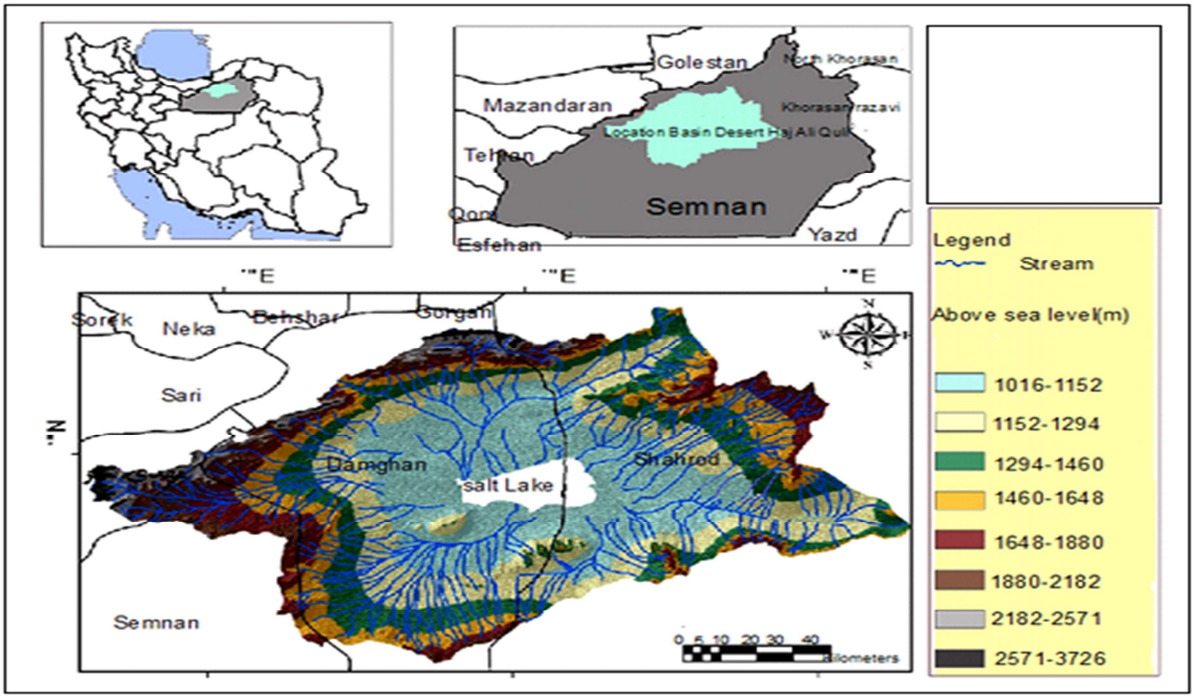

Fig. 1. Location Basin Desert Haj Ali Qoli in Iran.

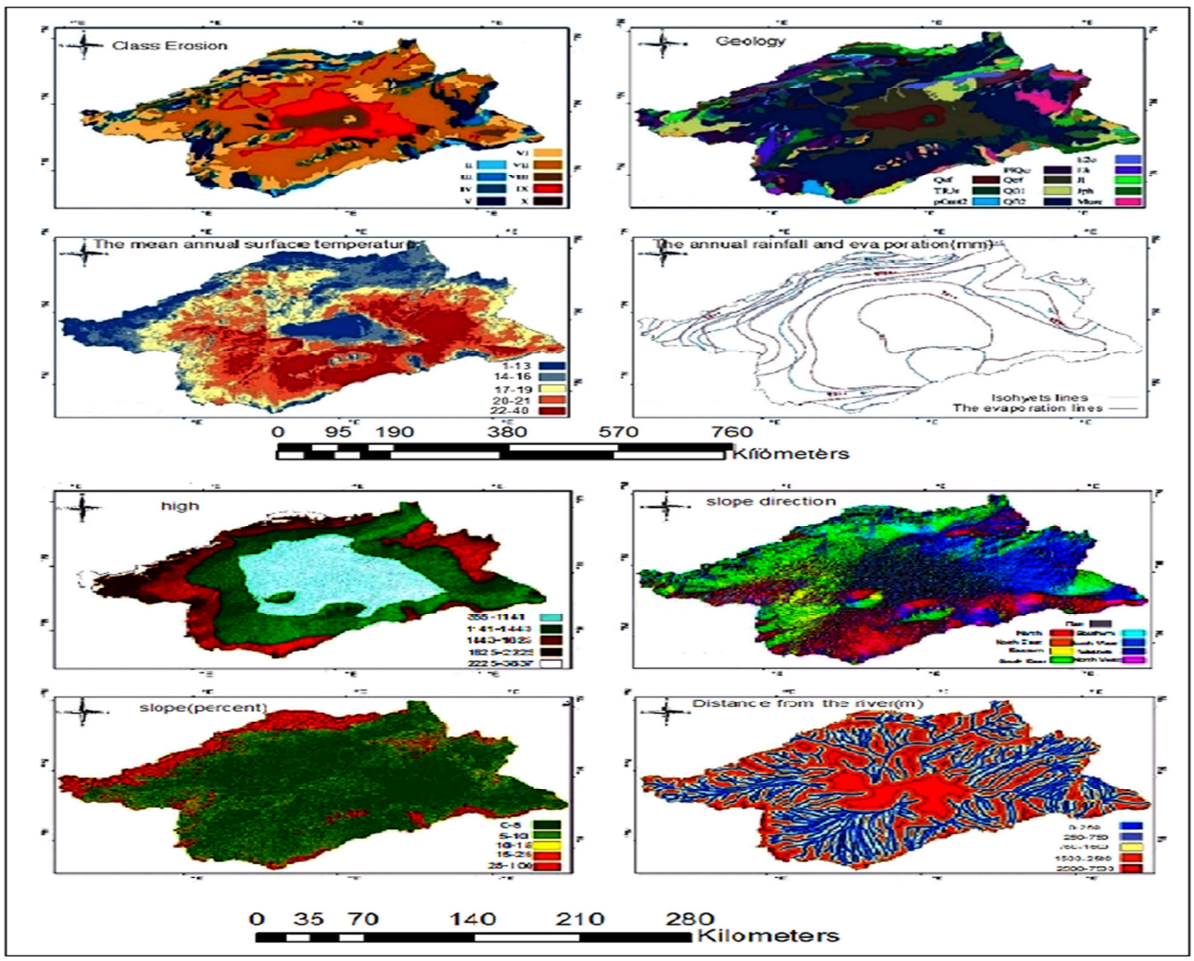

Fig. 2. The input layers status in the Neural Network.

The more accurate the selection of effective factors and their classification, the more realistic the obtained results are. Natural factors affecting on the occurrence of land degradation can be divided into several major categories such as geomorphological, geological, climatic, hydrological and soil criteria. In this study, the geomorphological and also the hydrological parameters have been evaluated according to their importance in the Haj Ali Gholi desert basin. Neural Network input data layers include: elevation, slope and its direction. These three layers were achieved from 30 m digital elevation layers (DEM) of ASTER sensor provided by the Geological Survey of America (USGS). Geological layer with 1:100.000 scale was obtained from Geological Survey of Iran. Layers of erosion classes were provided by the Ministry of Agriculture.

Research methodology

After obtaining satellite data, images were first geometrically corrected based on the 1: 5000 topographic maps in order to prepare them for processing and extracting useful information. Then images were matched geometrically with each other. Atmospheric corrections were applied on the images using dark object subtraction technique (DOS) to eliminate the atmosphere effect. Then, color combination was created using the correlation between bands for the years of 1985 and 2015 and the supervised classification of artificial neural network was performed. Considering the importance of geomorphological, as well as hydrological parameters (drought, soil salinity, vegetation, erosion, slope, climate, land surface temperature, evaporation and transpiration), they were evaluated for the Haj Ali Gholi desert basin and finally, the future desertification status was predicted using Artificial Neural Network and considering the effective parameters.

Results

Classification of the images and preparation of the desert variation map for this study was carried out by Kohonen Neural Network method, which is a supervised classification method. For this, the variation map of desertification classes was used as the input base map of the neural network to prepare the potential variation map. Fig. 2 shows the input layers status in Neural Network for the study area.

Table 1. Layers used in artificial neural network.

Variable10	Variable9	Variable8	Variable7	Variable6	Variable5	Variable4	Variable3	Variable2	Variable1
Maximum likelihood evaporate layer	Slope direction	The mean annual surface temperature	Slope	Distance from the river	Annual rainfall	Geology	High	Class erosion	The annual evapotranspiration

Table 2. Fixed a parameter and scores other parameters.

Forcing all variables constant except one											
Variable10	Variable9	Variable8	Variable7	Variable6	Variable5	Variable4	Variable3	Variable2	Variable1	Total variable	Model
50.08	50.08	47.20	50.08	50.08	50.08	50.08	54.08	54.70	58.46	95.15	Accuracy(%)
0.0016	0.0016	0.0559	0.0016	0.0016	0.0016	0.0016	0.0016	0.0940	0.1691	0.9030	Trade Skills

The general trend of the network used in this study is also showed in Fig. 3, along with the input and hidden layers and also the desired output. After preparing the data and putting them into the Neural Network, the model was implemented and stopped with the accuracy of 95.15%, skill size of 0.9030, experimental and education RMS 0.125 and 0.13, respectively.

Table 3. The verification and validation of variables.

Forcing all variables constant except one											
Variable10	Variable9	Variable8	Variable7	Variable6	Variable5	Variable4	Variable3	Variable2	Variable1	Total variable	Model
50.08	50.08	47.20	50.08	50.08	50.08	50.08	54.08	54.70	58.46	95.15	Accuracy(%)
0.0016	0.0016	0.0559	0.0016	0.0016	0.0016	0.0016	0.0016	0.0940	0.1691	0.9030	Trade Skills

General specifications of the model is shown in the Table 1. Then, prediction was done for the years 2030 and 2045 using the created model, results of which are shown in Fig.5. According to the figure, if the current desertification trend continues in the basin, large areas of the Haj Ali Gholi basin will be at the risk of desertification in the next decades. Although the model itself acquires an assessment of the model validity, but in spatial issues for validation of predictive models, the model should be implemented using the previously available data and compared with the recent data to calculate the accuracy of model in prediction. For this, Neural Network model was created using variation layer of 1987-2000 and then, it was run to predict the desertification areas for 2015. Comparison of the model result with desertification status in 2015, with the kappa coefficient of 94%, the standard Kappa of 91% and class kappa of 93% for desertified areas and 92% for regions prone to desertification shows acceptable results. Fig.6 illustrates the desertification status in 2015, along with the prediction results for 2015.

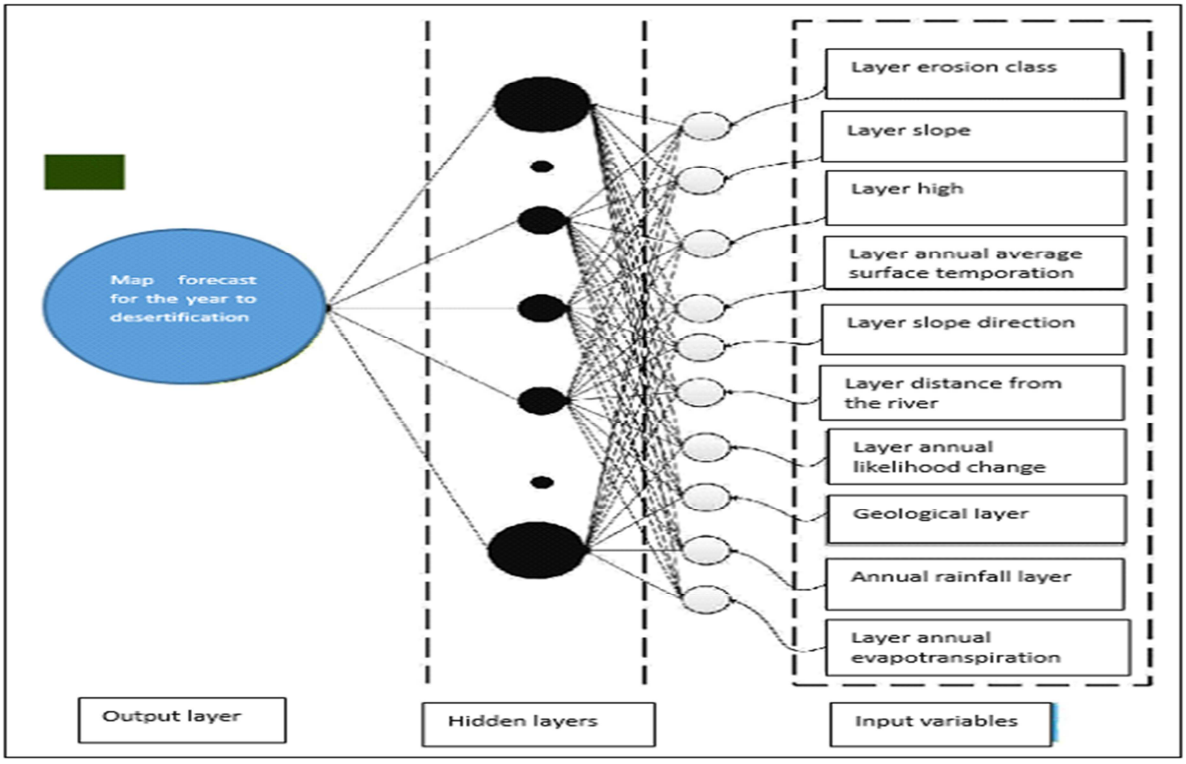

Fig. 3. An overall view of the network used in this study.

The results revealed the worsening of desertification in the Haj Ali Gholi basin and showed that in case of continuation of this trend, large areas of the basin will be desertified and saltified. Moreover, the results showed the efficiency of time series satellite images in monitoring the environmental variations of watershed basins and that in issues with high complexity, including natural issues, Artificial Neural Networks can model the existing complexities in the best way and obtain optimal results.

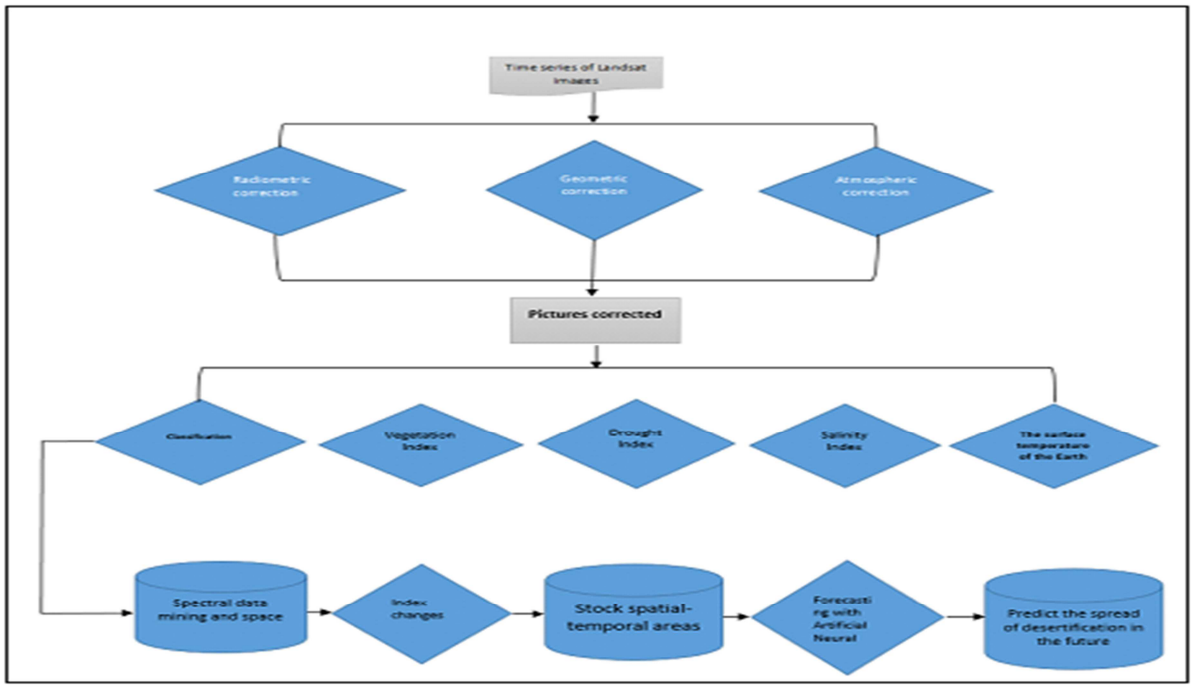

Fig. 4. The general trend of the research.

Discussion

Desertification and a reduction in biological and ecological processes can be affected by two types of factors: human and natural ecosystems. Parameters such as geomorphic agents, soil, hydrological, geological and climatic factors that can be considered the most important natural factors of land degradation. Desert areas are component of the ecosystem in tropical and subtropical countries.

These areas have always been interested to scientists and the majority of researchers are trying to find new methods to study these areas. Restriction of Iran by the High Mountain and desert strips has led to the phenomenon of drought and desertification problem, the characteristics of two-thirds of the Iran areas.

Therefore, according to sensitivity of these environments, identify and evaluate in the scientific and applied community is quite important. Mean while, the emergence of new techniques such as remote sensing and geographic information systems in recent decades has brought a lot of potential in monitoring environmental change and desertification.

These techniques, due to time series data the possibility of space-time research such as monitoring desertification changes, desertification trend analysis, modeling and predicting the spread of desertification and etc. has created. As well as the increasing development capabilities of spectral, spatial, temporal, and radiometric satellite imagery and telemetry instruments and spectroscopy, the performance of this method in such studies more and more increased.

According to the complexity of the dynamics of desertification processes, defined a mathematical model to describe this process is very difficult.

The desertification modeling during the past two decades developed. Many models developed the use of artificial intelligence, neural networks (NN) and fuzzy logic systems automated cells in simulated desertification.

Unlike many multivariates modeling techniques, artificial neural network input data are independent of relations and no need any assumptions about the spatial and multiple linear spatial correlation of data.

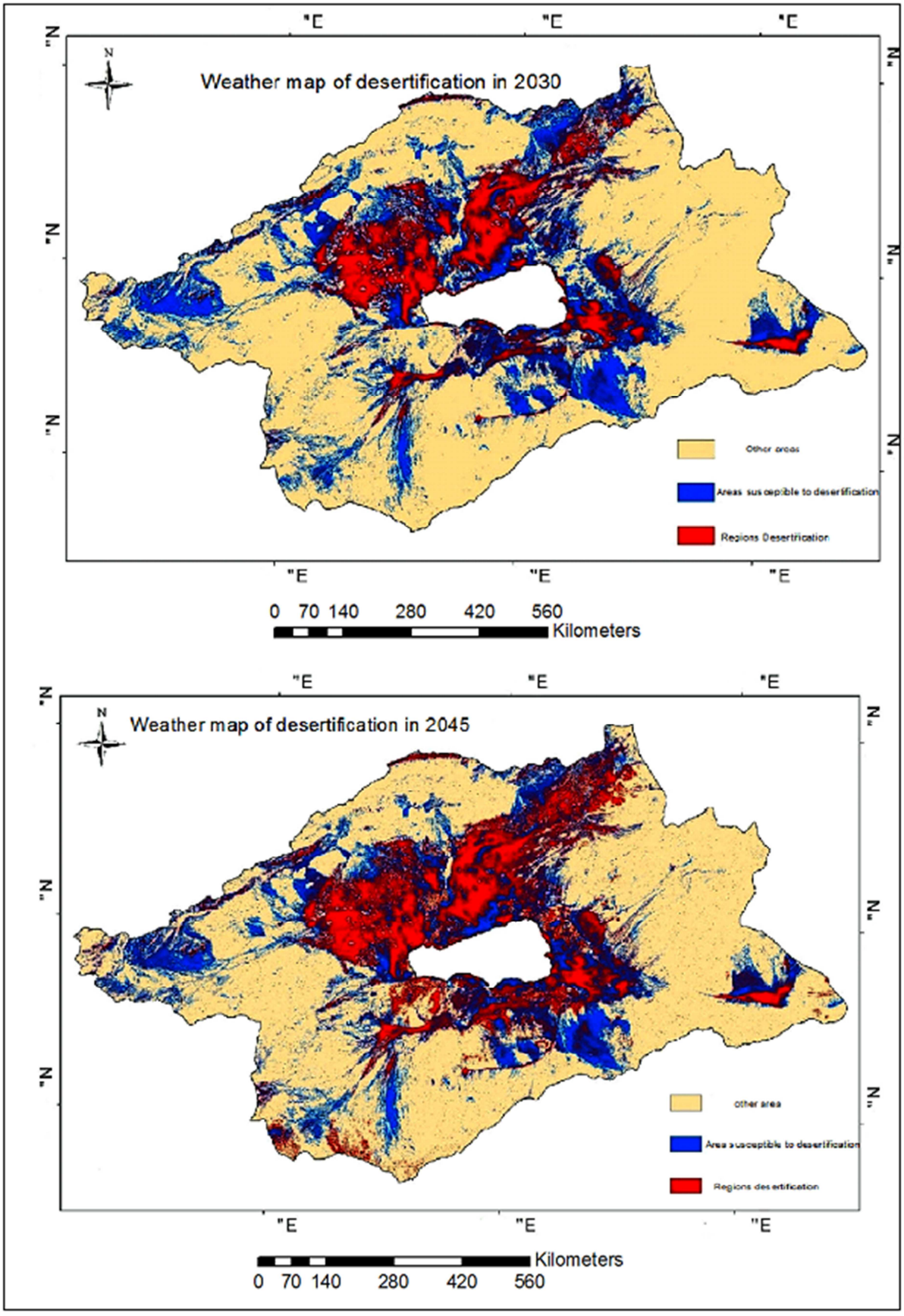

Fig. 5. Results of desertification status prediction for 2030 and 2045 with Neural Network in the Haj Ali Gholi basin.

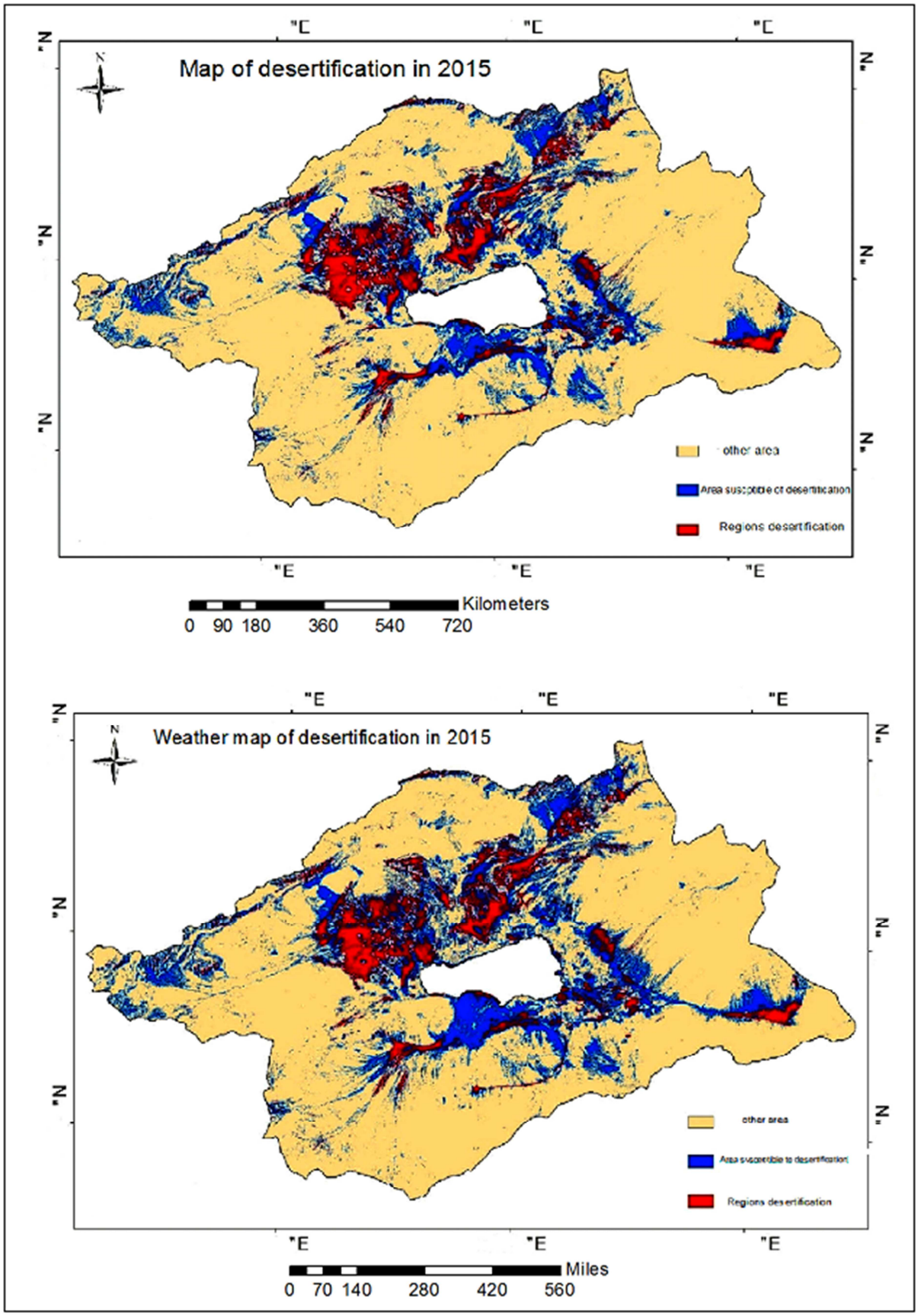

Fig. 6. The existing desertification status in 2015, along with the results of prediction for 2015 in order to verify the model.

Conclusion

In this study, by using Land sat time series images and biophysical and environmental indicators, the trend of desertification variation for the Haj Ali Gholi basin was investigated for a 30 year period. Statistical analysis of soil salinity indicators showed that the average soil salinity is increasing. Saltification causes soil degradation and in some cases, leads to irreversible loss of soil fertility so that, fertile farmlands with great production potency eventually become wastelands. Spatial distribution of soil salinity showed that in 1987, only a small land area around the Salt Lake was weakly saltified, while in a 30 year period, more areas have been exposed to saltification and its severity have also increased. Studying the soil drought indicators also showed an increasing trend for the area. Statistical analysis of vegetation indices revealed a decreasing trend for vegetation in the area, which led to increased saltification and desertification in the region. It is while the expansion of vegetation is known as the best way to combat desertification.

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