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Original Research Paper

The Use of Remote Sensing Techniques in Detecting and Predicting Forest Vegetation Change Using MODIS Satellite Data, Golestan, Iran

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Abstract: It is so important to be aware of quantitative and qualitative characteristics of changes for the environment, land use planning and sustainable development. Detecting the changes in the condition of an issue is done by time difference observations. Change detection refers to the process of detecting time changes of an object through different time observations. The detection of changes by satellite imageries has come recently to the focus of attention due to their comprehensive and integrated characteristics and their ability to monitor changes during long periods as well as their application to monitoring and controlling changes in the forest ecosystems. The vegetation maps are now used to generate required information for macro and micro planning. This study was done to monitor the changes in the forest of Golestan province in the past and also to investigate the possibility of its future forecast using the Land Change Modeler (LMC). A forest type map was first prepared to monitor changes in forests of Golestan province from 2000 to 2015. The images taken in 12 months during 2000 and 2015 were collected form MODIS satellite imageries to monitor the forest. After pre-processing and preparing the time series in two sections, the forest changes were considered using the Normalized Difference Vegetation Index and Moisture Stress Index (NDVI and MSI). The changes were then classified by indices, including the lands with excellent, very good, medium and poor coverage and compared together. The accuracy of the classification results was assessed using the field maps. The best result was found in the average time series data and the use of the NDVI index was prioritized over other indices. The forecast of changes by 2030 as 0.8629 Kappa and the model results for 2030 indicated a decline of 70000 in the land with high and very high capacities and a further increase in land with a low capacity.

Keywords: Changes of Forest Coverage, Vegetation Index of NDVI, Remote Sensing

Introduction

Ecologists have been always interested in detecting vegetation characteristics and the relationships between plant species and environmental factors (Depew, 2004; Hoersch *et al*., 2002; Magee *et al*., 2008). Vegetation coverage has been changed due to human and natural factors over time. Therefore, detecting and predicting these changes seems to be necessary (Pettorelli *et al*., 2005). The lack of adequate information appears to be one of the main important problems in the study of vegetation changes. The preparation of time series from data bank by using satellite imageries and remote sensing have helped to manage the natural areas (Malimiran, 2004). In recent years, the experts have focused on modeling the changes for land use change prediction and precise planning in future. The monitoring of land use changes has been done in relation to ecology, deforestation, urbanization and sustainable development of natural resources. Determining the changes refers to identifying and clarifying the difference of a subject in two different situations. Determining and predicting natural areas changes have been facilitated by using the remote sensing science due to the possibility of monitoring in different time-periods and employing high-resolution spatial images. Timely monitoring of changes in natural ecosystems has led to a better understanding of human activities related to natural resources. Vegetation indexes have been extensively used for various purposes since the last decade (Panah, 2006). The NDVI index outputs are resulted based on red light absorption by plant chlorophyll and the near-infrared light reflection by mesophyll layer (Adamchuk *et al*., 2004; Pettorelli *et al*., 2005). Climatic effects on vegetation cover and plant phenology have been estimated using NDVI (Pettorelli *et al*., 2005). The MSI Index is also used for vegetation analysis, productivity prediction and modeling, analysis of plant use conditions and ecosystem physiological studies (Arekhi, 2014), to predict the land use change by using the LCM model and predict the variation by 86% with artificial neural network. So far, many studies on monitoring the environmental changes and predicting the long-term remote sensing have been done, some of which are as follows: Used the land-use modeling (LCM) to detect changes in Olomouc in Czech Republic. The results showed that 6% of mixed forests were converted to broadleaved trees and an increase of 3.5% occurred in the residential areas. Used the land-use modeling (LCM) for Nepal's urban development modeling. They used satellite imageries of 1191, 2001 and 2010 for modeling in 2020, 2030 and 2040. Used the land-use modeling (LCM) to model Mexican tropical forests degradation and regeneration. They carried out transmission force modeling using artificial neural network. Karami and Feghhi (2011) studied the process of Zagros forests degradation using Landsat satellite imageries in 1990 and 2000. Their results revealed the capability of remote sensing in detecting forest degradation. They mentioned road construction as the most important factor in forest degradation. Shafiei and Hosseini (2012) investigated the vegetation cover using satellite data in Sistan and Baluchestan since 1990 to 2006. The results showed a decrease of 2600 hectares. Darwish and Faour (2008) investigated rangelands degradation using NDVI index in Lebanon. Their results indicated an increase of 932 hectares of agricultural lands and 4,800 hectares. Kennedy *et al*. (2007) considered forest changes using satellite imageries of TM sensor during a 20-year period and their results showed that changes have occurred in 4% of total area. Most of the studies conducted in this regard have monitored vegetation indexes in the short term. In this study, the images of vegetation indexes were prepared as time series in various statistical data and data standard deviations were compared in the long-term using Level 3 data of MODIS satellite in 2000 and 2015. The process of changes detection was carried out in three distinct steps. Firstly, the indexes were calculated in two-time series using statistical data of mean, minimum, maximum and the median. Secondly, the indexes were classified according to the standard deviation and the selection of the best option to detect vegetation changes. Finally, the changes were predicted using LCM model up to 2030. The accuracy assessment was made based on a comparison of the 2015 projected maps and according to maps of 2000 and 2008 and the use of 2015 earth observation maps. One of the main goals purposes of this study was to assess the MODIS satellite data capabilities in detecting forests changes in Golestan province.

Materials and Methods

Study Area

Golestan province is located in the southeast part of Caspian Sea. The total area of the province is 20,387 square kilometers that is about 1.3% of the country's total area. This province is located at 36° 30 'to 38° 08' northern latitude and 53° 51 'and 56° 22' eastern longitude. The area of forests is 379,000 hectares in this province, including 249,000 hectares of commercial, 70,000 hectares of protected and 60,000 hectares of ruined forests.

Methodology

In the first step, the images of mod13q1 of MODIS satellite were prepared for 12 months in 2000 and 2015. Then, two indexes of NDVI, MSI were applied to these images. The time series were developed using IDRISI software to eliminate seasonal and temporary changes. After calculating the medium, average, minimum and maximum data, the images classification was done based on the mean and standard deviation. Followed by comparing the classified images, the best index and statistical data were selected in two times, which were used in the study. The changes were then predicted using the LCM model by 2030. The required layers for this model included classified images in two years of 2000 and 2015 as well as the digital elevation model and the road map. The accuracy assessment was done using map of 2008 so that the map of 2015 was predicted using the LCM model and maps of 2000 and 2008.

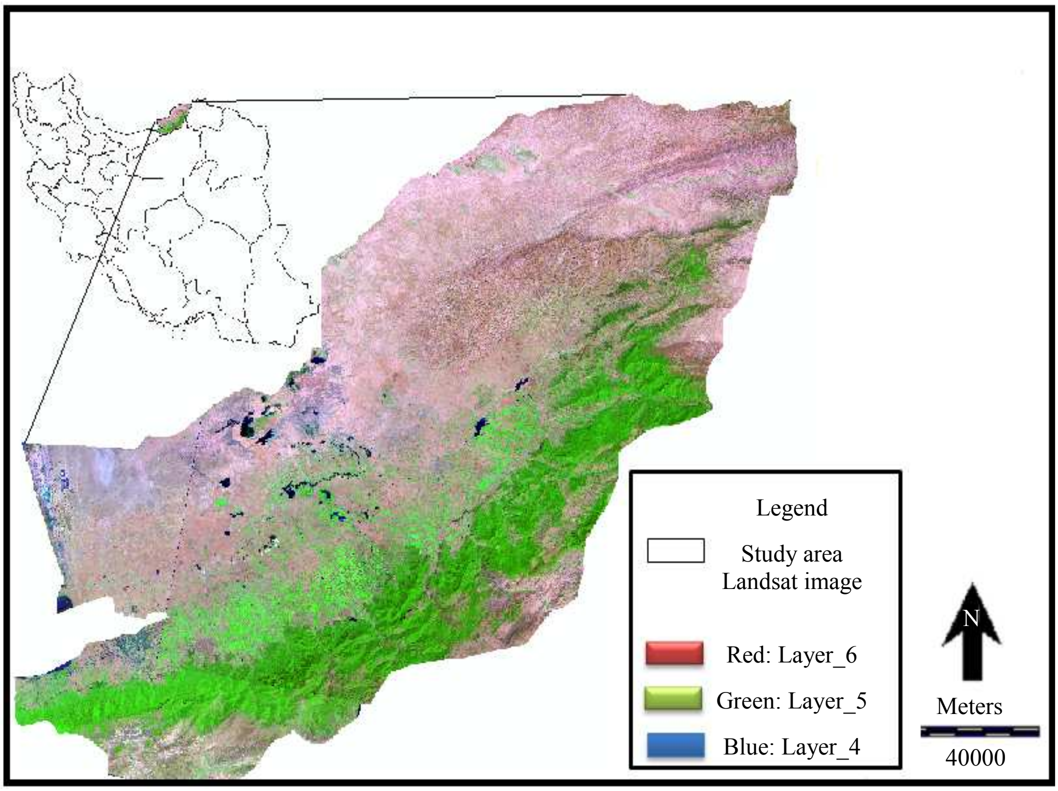

Fig. 1: The geographical location of study area within Iran, Golestan province, Iran

Then, the accuracy of the predicted map was estimated using the ERRORMAT model compared to the ground truth map in 2015. The Kappa with 0.8642 coefficient was calculated to assess the accuracy of prepared maps. Chart 1 shows the overall steps of this study.

Normalized Difference Vegetation Index

NDVI is the most important vegetation index in remote sensing. It is widely used for analyzing land use changes, including vegetation and other factors (1). This index is suitable for areas with moderate and higher vegetation density since it is less susceptible to soil and the effects of atmosphere. However, it is not suitable for areas with less vegetation coverage. The equation of this index (1) is as follows:

$$NDVI = (NIR - RED) / (NIR + RED) \quad (1)$$

"Figure 1" shows the NDVI index based on the greenness index. This index value varies from -1 to +1 and it functions actually based on high reflection of healthy plant in the NIR band and its low reflection in the RED band of electromagnetic spectrum (Pettorelli *et al*., 2005; Wang *et al*., 2003). Accordingly, the healthy plant usually has a high NDVI of 0.5 to 1. This index values show vegetation extent and density. Therefore, the fire extent can be obtained using NDVI, remote sensing and collected information. Chart (3-14) shows the NDVI required data.

Moisture Stress Index

This index is sensitive to the increase of leaf water content. It is used for analyzing vegetation coverage, predicting the productivity and modeling, analyzing the plant use conditions and studying the ecosystem physiology. The calculated number of this index is in the range of 0 to 3 and the usual number representing the vegetation coverage is in the range of 0.4 to 2:

$$MSI = MIR / NIR \quad (2)$$

Discussion

Studying Time Series of Vegetation Coverage

The images were aggregated to eliminate the effects of season on the indexes used and obtain the normal data. In the next step, the maps were divided into four vegetation classes based on mean and standard deviation to investigate the vegetation coverage changes during 15 years. Then, the percentage area of each class was calculated for each period and the resulting numbers were compared together in Table 1.

Table 1: Images classification based on average and standard deviation data

Class	Description	Formula
Very low	Values smaller than the mean minus standard deviation	(X+SD<)
Low	Mean minus standard deviation minus average	(X−SD, X)
High	Average to averaging more than standard deviation	(X, X+SD)
Very high	Larger values beyond the average over standard deviation	(X+SD<)

Results

Select the Best Index

The maps prepared from images classification were compared with ground control points. These points were collected from Forest, Rangelands and Watershed Management Organization (FRWO) and rangelands of Golestan Province, which include 37 points of vegetation coverage data in 2015. The images of average NDVI index have more accuracy. "Table 2" was used to continue the changes monitoring.

Forecast class changes in 2030 and accuracy assessment.

In this study, changes were predicted using LCM model and classified maps in two periods by 2030. The road map and digital elevation model were used in this model and the amounts of changes were compared together in two 15-year periods in Fig. 2 and 3.

The accuracy assessment was done using the map of 2008 so that the map of 2015 was predicted by using the LCM model and the maps of 2000 and 2008. Then, the accuracy of the predicted map was estimated using the ERRORMAT model compared to the ground truth map in 2015. The Kappa with 0.8642 coefficient was calculated to assess the accuracy of prepared maps. Therefore, it can be inferred that the prediction level in 2030 is equally accurate in Fig. 4, 5 and 6.

Discussion

The most important destructive factors in forest areas are land use change from forest to agricultural and residential areas, high population growth rate, forest dependent livelihoods in the deprived areas causing reduced forest areas and the environment non-sustainability. These factors are very important to identify and monitor qualitative and quantitative changes of the forest areas (Rezaei *et al*., 2008). Remote sensing images were used to prepare the required maps due to the cost and onerousness of fieldworks in the forest areas. Access to statistics and information at the time of available capacity is essential for proper management of the forest arenas. One of the sources of natural resource management is information on land change (Ghorbani *et al*., 2010). In the present research, the MODIS satellite was used to detect changes in the forest of Golestan province. Vegetation indexes are the most common instances to calculate vegetation percentage of an area during different periods. Changes in the use of an area of 2,000,000 ha in two periods from 2000 to 2008 and 2008 to 2015 were examined using MOSID satellite imagery and also based on the ability to predict landslide changes according to the Lcm approach by 2030 Fig. 7, 8 and Table 3.

Table 2: Accuracy assessment of various techniques using ground truth map

Index	Kappa	Accuracy (%)
Maximum NDVI index	0.5508	61.94
Minimum NDVI index	0.4280	58.76
Median NDVI index	0.7100	83.00
Mean NDVI index	0.8400	88.00
Maximum MSI index	0.1914	30.28
Minimum MSI index	0.2705	41.85
Median MSI index	0.3504	45.00
Mean MSI index	0.2403	51.36

Table 3: Classes assigned to each category in 2000- 2030

	2000	2015	2030
Class	Area (h)	Area (h)	Area (h)
Very low	70,938	104,411	192,258
Low	120,078	148,159	199,979
High	1,434,390	1,416,778	1,305,105
Very high	488,129	390,995	325,002

Table 4: The amount of changes in each class

Area (hectare)

Class number	2015 to 2030	2000 to 2015	Type of change
1	142258	64967	Change very low to very low
2	-	16257	Change low to very low
3	-	73999	Change high to low
4	-	16665	Change very high to very low
5	-	1622	Change Very low to high
6	95701	41919	Change low to low
7	32247	30212	Change high to low
8	5219	7346	Change VERY HIGH TO LOW
9	142258	12427	Change very low to low
10	-	79644	Change low to high
11	1415105	1137362	Change high to high
12	-	218098	Change very high to high
13	-	460	Change low to very high
14	-	107	Change low to high
15	-	105618	Change high to very high
16	325002	223066	Change very high to very high

The above-mentioned images were prepared using the main components analysis method and NDVI subtraction method, where the numbers of 0 and near 0 indicated no changes (yellow class) and the positive number (green class) and negative number (red class) indicated changes in two aspects. The highest increase occurred in poor vegetation coverage and the most decrease occurred in the excellent vegetation coverage Fig. 9, 10, 11 and Table 4.

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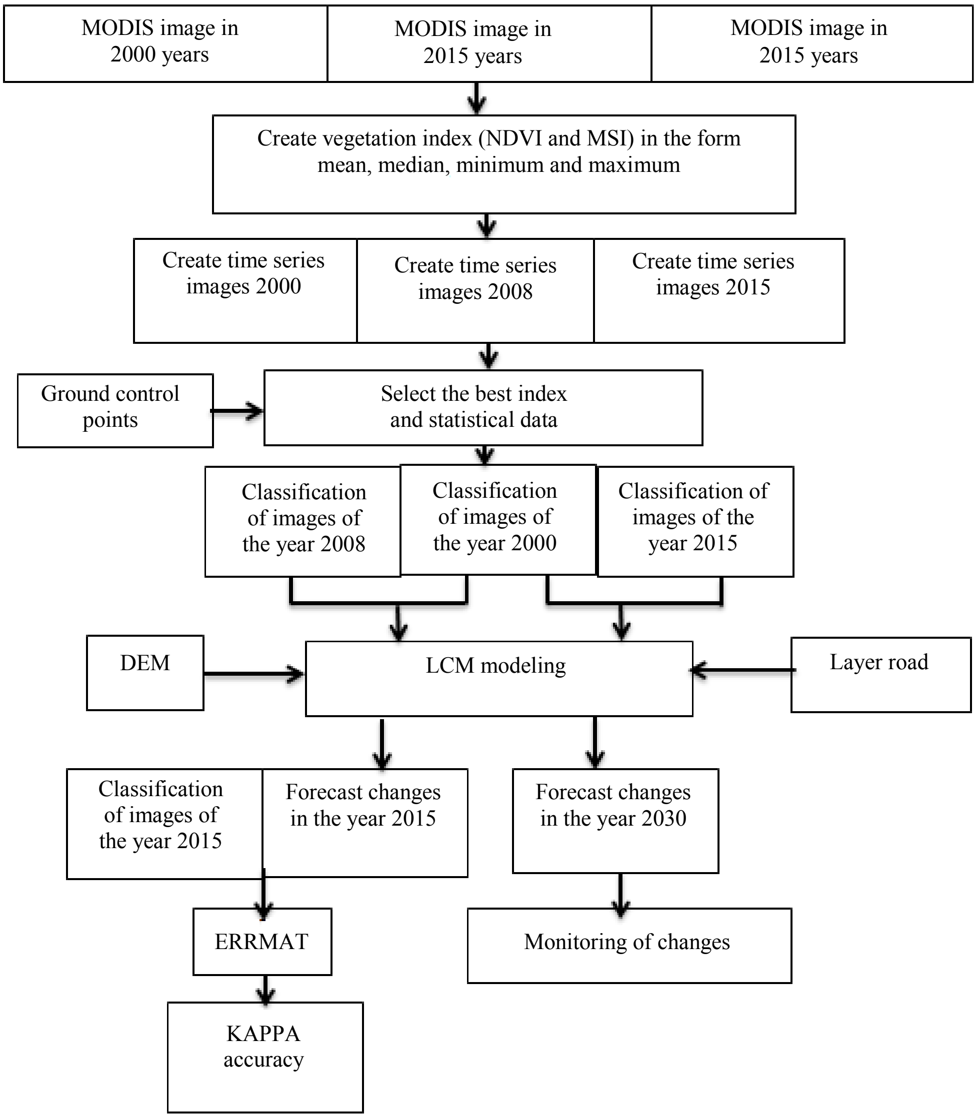

Fig. 2: The first step is to provide forest map and fire points

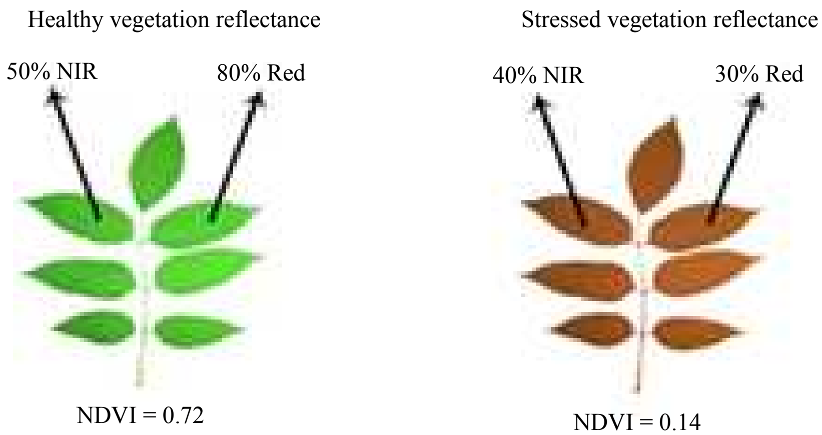

Fig. 3: NDVI index based on greenness index

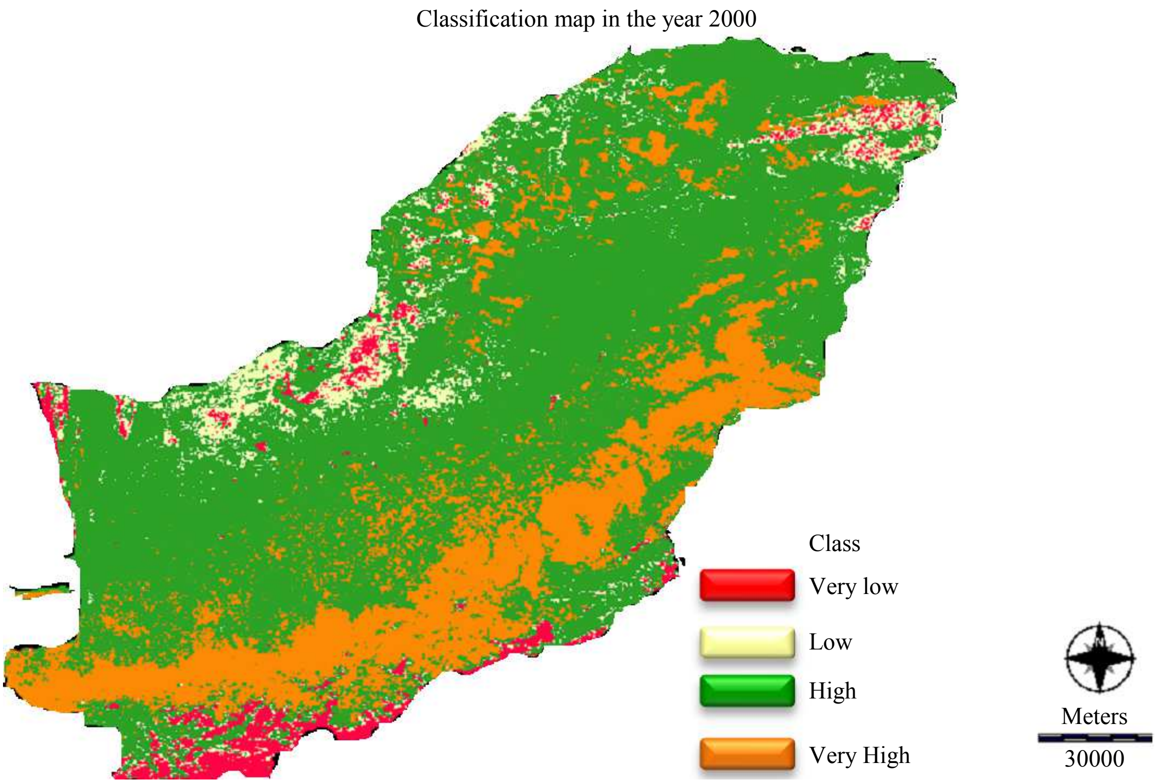

Fig. 4: Map of changes in average NDVI in 2000

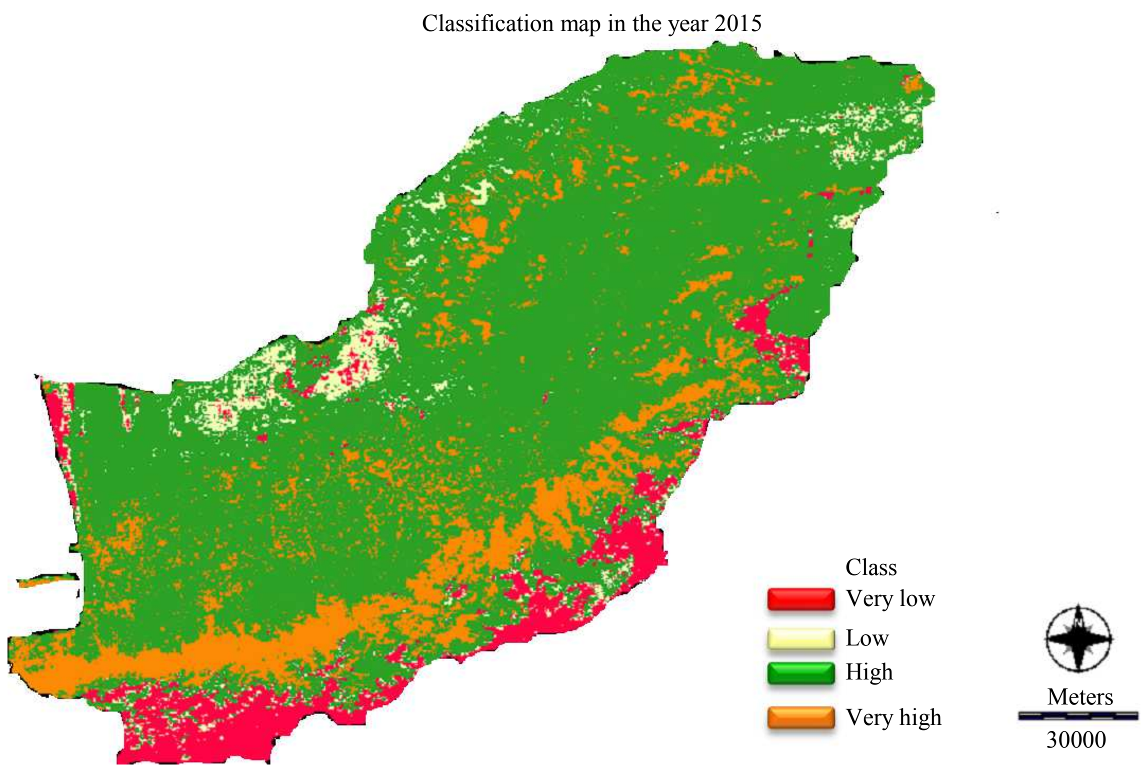

Fig. 5: Map of changes in average NDVI in 2015

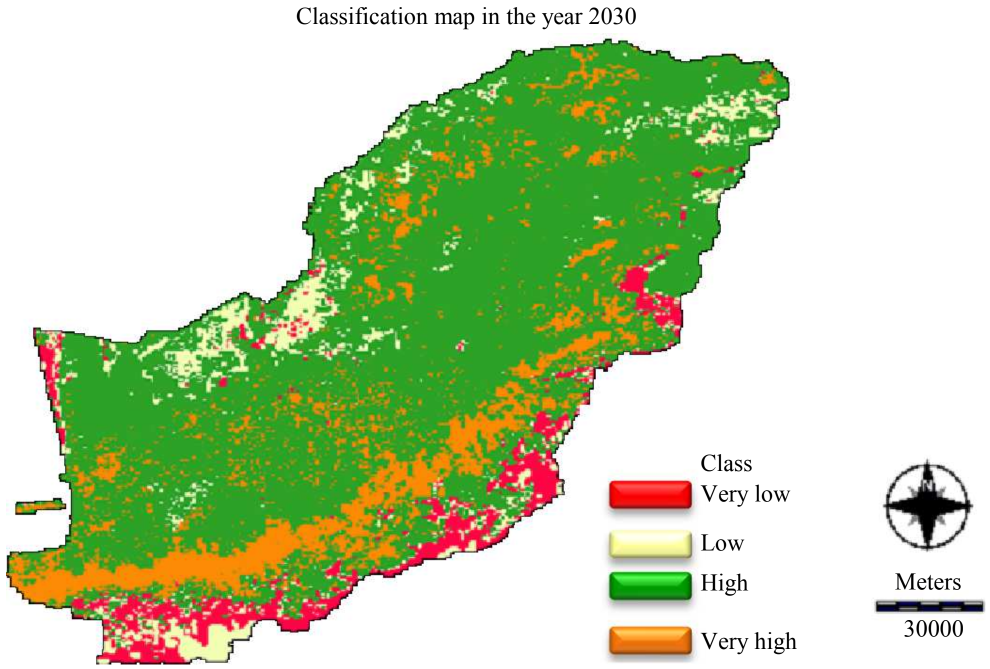

Fig. 6: Map of changes detection average NDVI in 2003

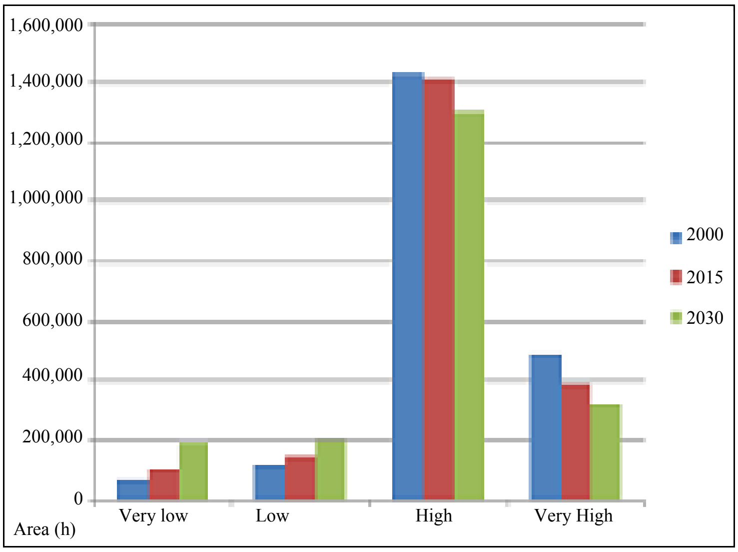

Fig. 7: Classes assigned to each category in 2000- 2030

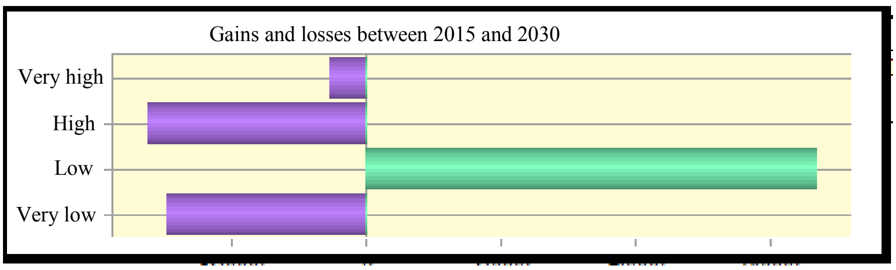

Fig. 8: The amount of decrease and increase in the area of vegetation coverage classes from 2015 to 2030 per hectare

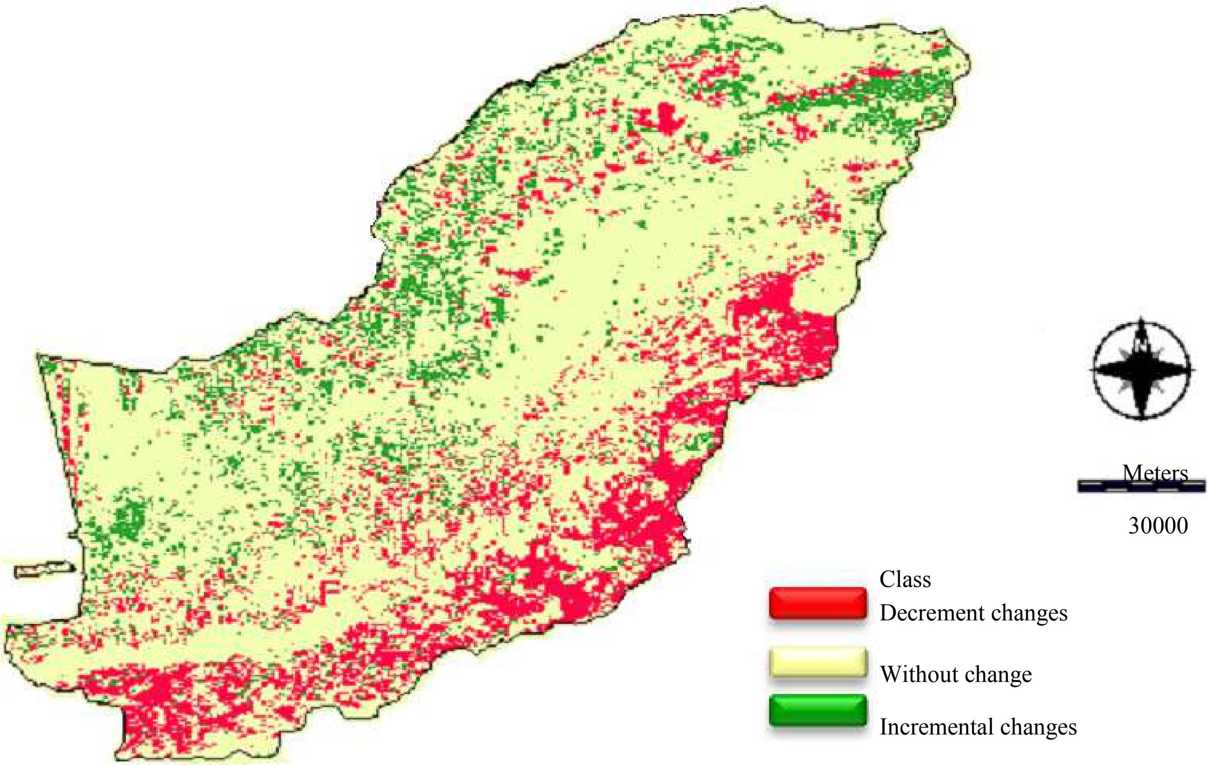

Fig. 9: Map of changes ratio in classe 2015- 2030

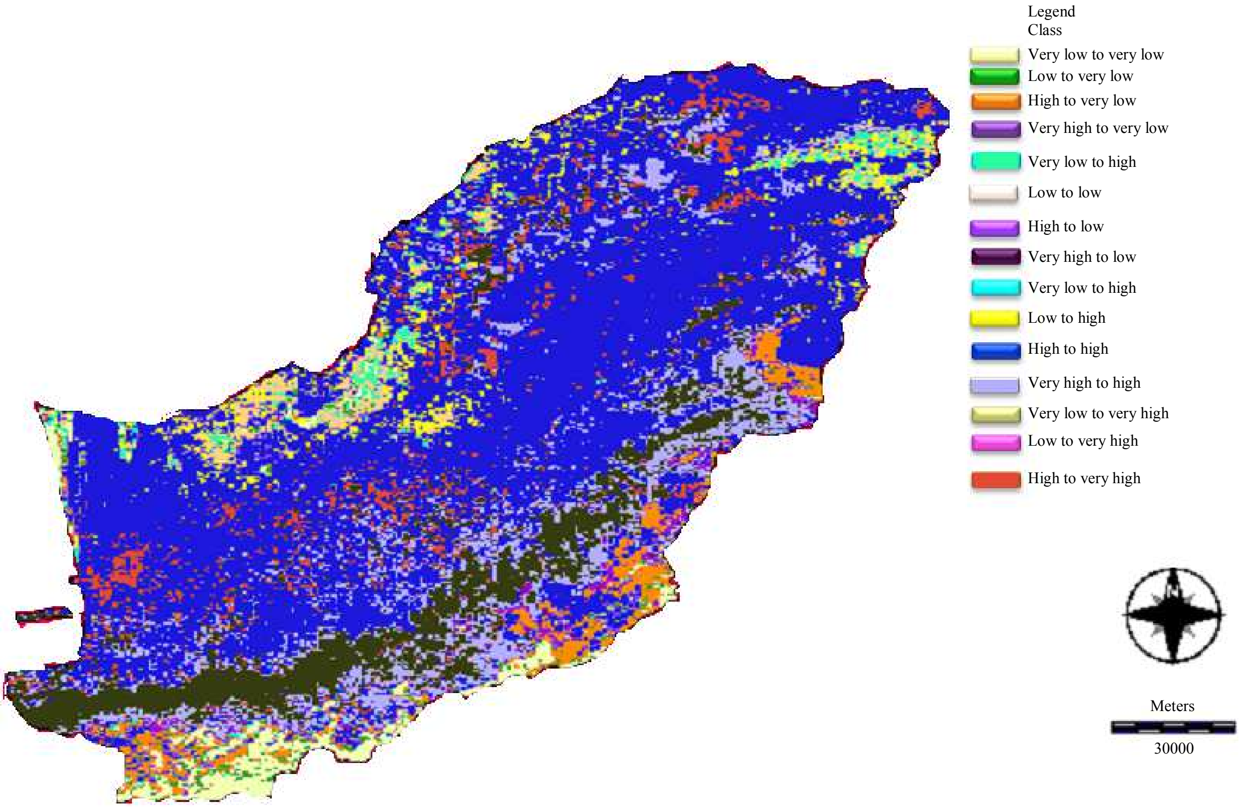

Fig. 10: Map of changes between classes 2000-2015

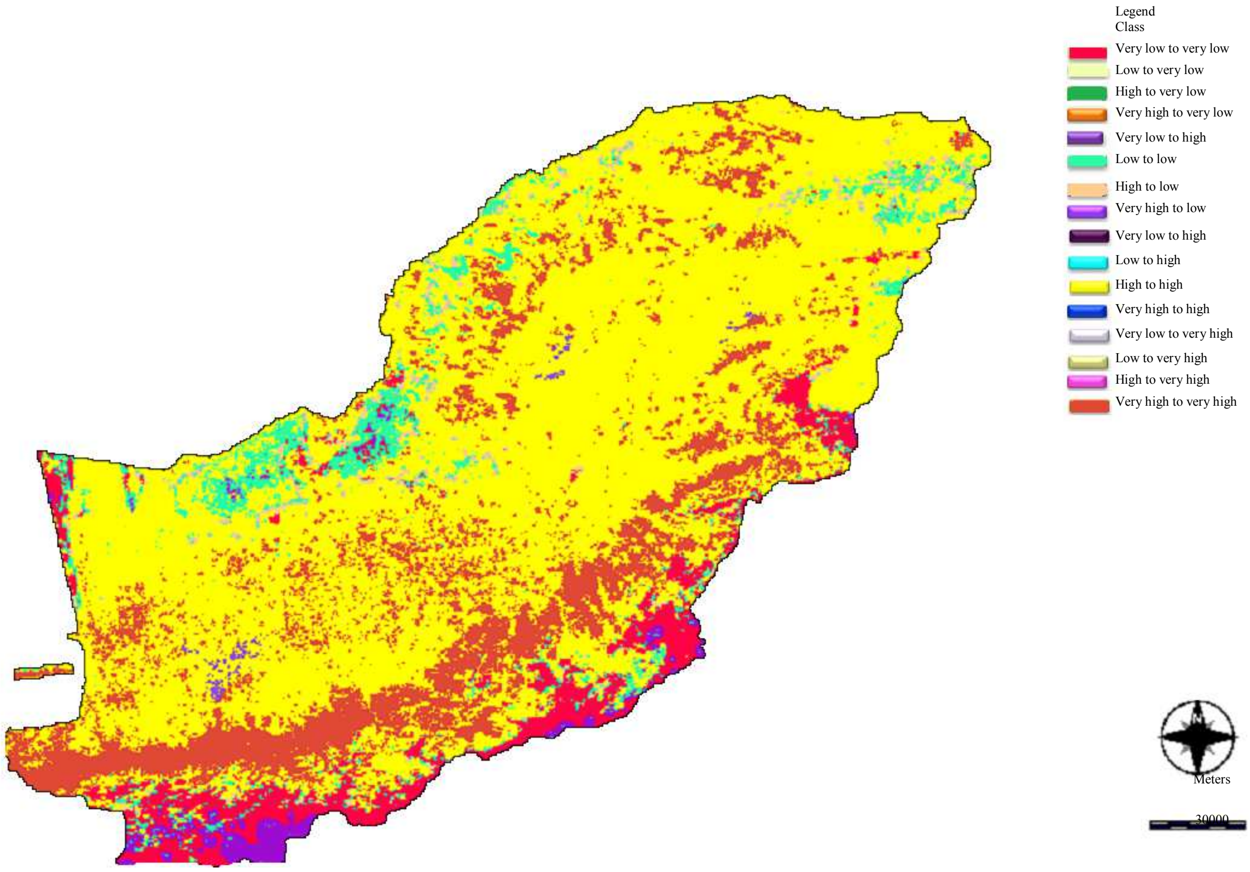

Fig. 11: Map of changes between classes 2015-2030

Then, two classified maps in 2015 and 2030 were compared together and the type of changes in each class was determined from 2015 to 2030. The amount of vegetation changes was determined by comparing vegetation indexes calculated based on two-time images. The results of detecting changes indicated a reduction in 2000 when we have 488129 hectares of very high forests, down from 390,995 in 2015, to 325,002 by 2030.

Conclusion

Today, sustainable management in areas and minimizing the environmental damage caused by land use change may require forecasting the land use change in the long term based on possible changes, sustainable management and appropriate management in such areas. In this research, the modeling of user LCM in the area of Golestan province, northern Iran, was used to improve the natural ecosystems by 2030 based on NDVI and MSI indexes. In this regard, both of these indicators were measured as the average and minimum mines in 2000, 2008 and 2015. Validity assessment was performed using 37 points with cover information. The results of this stage indicated that the maps classified by using the average NDVI index with a correctness of 83% are better than the other best case of conditional conditions in the region. In the next step, considering that previous changes can predict future changes based on the historical scenario, the change was predicted by 2030 with Kappa's 0.8629 margin using the LCM model. The results of this study can provide a good prospect for forestry planners in the past, present and future due to the changes in the forest cover.

Due to the rapid growth of urban areas and land use change, the study of vegetation changes indicates the inappropriate use of forest areas. The results of this study indicated a decrease in very suitable lands and an increase in the poor lands. These changes have been predicted using LCM model with an accuracy of 83% by 2030. The previous changes can predict future changes based on the historical scenario. The results of this study can provide a good prospect for forestry planners based on the past, present and future changes in the forest. The results of this study can be used for projects related to the reduction of deforestation, forest degradation and biodiversity protection.

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Author's Contributions

Akram Karimi, Sara Abdollahi, Hamid Reza Kabiri Balajadeh, Saeid Eslamian and Vijay P. Singh: Write manuscript.

Kaveh Ostad-Ali-Askari: Write manuscript and revise it.

Ethics

In this article, all ethical principles related to scientific-research articles such as validity and authenticity, originality, data collection in a standard manner, integrity and accuracy of research, etc. are observed.

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