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Comparing NDVI and RVI for forest density estimation and their relationships with rainfall (Case study: Malekshahi, Ilam Province)

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Abstract
Changes in rainfall have significant effects on vegetation of an area, especially in arid and semi-arid regions. Nowadays, the vegetation can be assessed using indices derived from satellite imagery and remote-sensing techniques. The aim of this study was to evaluate the effect of rainfall on vegetation and to compare NDVI and RVI indices. The study area is Malekshahi, a city with an area of 1165 km^2, located in the northeast of Ilam Province. The statistical data of 10 rain gauge stations in the region were used to investigate the rainfall fluctuations during the years 2000 and 2014. ETM images of Landsat satellite were used for the years 2000, 2007 and 2013. To evaluate the vegetation, NDVI and RVI were assessed using ENVI 4.7 software. The results showed that the highest and lowest rainfalls were 600 and 211 mm in 2000 and 2014, respectively. Comparison of the two vegetation indices showed that the NDVI index with the overall accuracy of above 70% has the highest capacity to separate the semi-dense forests from the dense ones. However, the RVI index showed a greater efficiency to separate the thin forests. The NDVI index had the highest correlation with precipitation compared to RVI index. Thus, NDVI is an appropriate parameter to assess the changing process of precipitation in the study area.

Keywords: Rainfall, Overall Accuracy, RVI, NDVI, Malekshahi

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Introduction

Study of forest cover is one of the important issues as forests directly affect human life and environments. Land covers change constantly due to human activities. Hence, identification of these changes can help managers and planners for appropriate controlling and planning (Shataee and Bagheri, 2010: Braimoh and Vlek, 2003 & Gomez-Mendoza et al., 2006). Many studies have used remote sensing data to assess land cover; and as such, this technique has become known as favorable for this kind of studies (Mokhtari et al., 2000 & Huete, 2004). The studies of vegetation are important in natural resources management. Plants have a special reflection pattern in electromagnetic wave, which is used for making vegetation indexes (Huete, 1988). Vegetation indexes are mathematical conversions defined by different scanner bands, and they are designed for evaluation and assessment of plants in multispectral satellite observations (Kabiri, 2001). Vegetation indexes correlate with vegetation density; however, spectral reflection is affected by height and sun radiation angle, soil, and atmosphere (Sepehri and Motaghi, 2002). Vegetation indexes are used both to calculate the vegetation cover percentage and to assess different types of vegetation cover and greenness condition of the land in different periods of time (Fatemi and Rezaee, 2012). One of the most useful indexes is NDVI. This index is based on the fact that the chlorophyll in the plant structure can absorb the red light and the mesophyll layer of the leaf can reflect the near-infrared (Adamchuk et al., 2004 & Pettorelli et al., 2005). Production potential of many fields and vegetation is limited by water. Hence, the change in precipitation can largely influence the vegetation.

The arid and semiarid lands are more sensitive to precipitation changes; however, seasonal patterns of precipitation influence land cover more than yearly precipitation changes (Ansari et al., 2015). Studies have been implemented to compare vegetation indexes and their relationship with precipitation. Jing et al. (2011), investigated the relationship between vegetation and precipitation in Beijing mountainous region for a 20-year period in China. Using NDVI, they showed that the average vegetation was corresponding well with summer and winter rainfall, but it was different with spring rainfall. The results of a study by Carreiras and Pereiram in 2006 also showed that based on the correlation models between visible and near-infrared bands and vegetation indexes ARVI, NDVI, SAVI, and MSAVI, canopy cover of forest and pasture plants can be relatively well estimated. Liang et al. (2005) also assessed the vegetation changes in response to precipitations in northern China using NOAA images. They found a high correlation between vegetation changes and precipitation in pastures. In another study by Xiao and Moody, (2004) the seasonal and local changes of precipitations and temperatures in the pastures of America were assessed, and the results showed that autumn rainfalls and the average minimum temperatures have increased. In a study of the effects of climate factors on vegetation of the pastures in Zagros using NDVI, the effect of seven monthly climate factors, temperatures, and partial humidity (minimum, average, and maximum) on monthly NDVI were assessed. The results showed that vegetation responds well to the precipitation of two months and the partial humidity of the one-month period (Farajzadeh et al., 2011). In another study, the satellite images of vegetation were used to assess and classify vegetation. The results showed that NDVI, GVI, and LWI are more efficient in determination of vegetation in comparison with other indexes (Sanaenejad et al., 2008). In a study, the relationship between vegetation and the percentage of non-vegetated lands in a watershed area was assessed using NDVI, PVI, and RVI (Mokhtari et al., 2000). The results showed that NDVI is very efficient as it has a high correlation with vegetation. The results of the assessment of precipitation variability and vegetation in the period from 1996 to 2008 in the pastures of Yazd revealed a significant relationship between forbs and grasses and precipitation variability, while no relationship was found between tree and shrubs and precipitation variability (Hosseini et al., 2011).

Materials and methods

Study area

The location of the study area is the forest of MalekShahi County with an area of 1165Km^2 located in the Northeast og Ilam province between 46° 40′-46°20′E and 33°20′-33°N. Temperature and average precipitation of the area is 16.4 and 750 mm respectively (Figure 1).

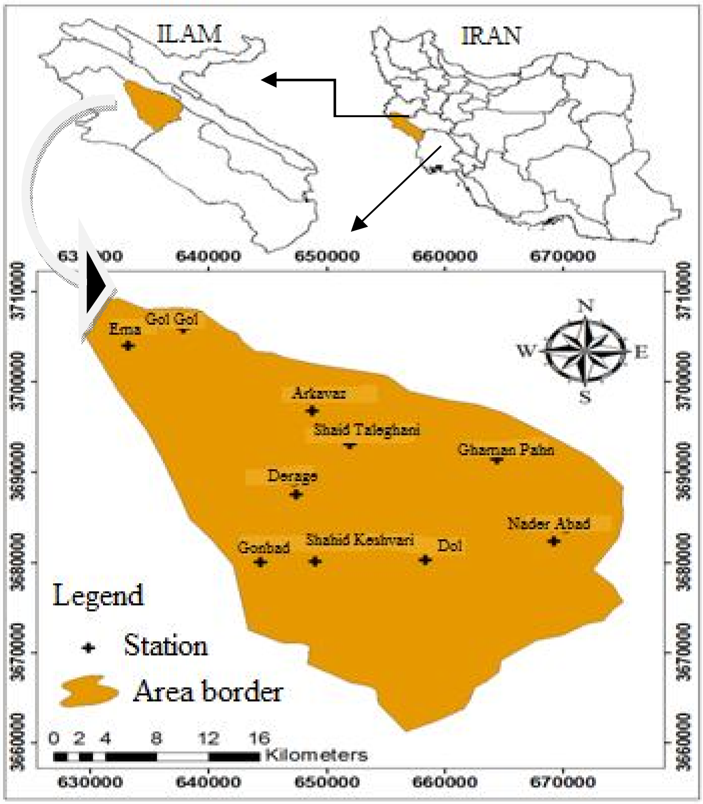

Figure 1. The geographical location of the study area in Ilam and Iran

Data

Topographical maps at a scale of 1:50000 from geography organization of Iran and aerial images at a scale of 1:50000 and TM and ETM+ data of Landsat satellite dated August 3 and June 16 of the years 2000, 2007, and 2014 were used in ENVI 4.7 software. Google earth and the previous vegetation map of the province were used to assess the accuracy of vegetation mapping, and ArcGIS9.3 software was used to calculate areas and create output map. The data needed to assess the precipitation of the area from 2000 to 2014 were collected from 10 stations located in the area.

Methods

Climate data processing

The changes in annual precipitation of the area were obtained using precipitation data of 10 stations (Table 2). The reason for using precipitation data is to show the impact of precipitation on the vegetation changes in the area. After classification and restructuring the statistical data, the chart of precipitation changes from 2000 to 2014 was created using Excel 2007 software. After making a database for climate factors using ArcGIS9.3 software, interpolation of the data was completed using Kriging method.

Geometric and radiometric corrections of the images

NDVI and RVI are compared to assess the vegetation and forest of the area. Geometric and radiometric corrections were applied to the primary satellite images. Each image in this process was geo-referenced using UTM-WGS94 coordinates. Then, the internal area of the watershed borders was cut by its vector layer and the final subset of each image was used as the base layer for classification. The main process in geometric correction is making positions on images match with the reality on earth (Jahani, 1996). Radiometric corrections are applied to remove errors in the images. These errors are the result of incorrect data (Zobeiri et al., 1996). For geometric correction, the maximum acceptable error (RMS3) was set at 0.5 pixel, and to attain it 36 sample points were used (Figure 2). To classify images, we used prior knowledge and histogram of the images helped understand the difference between cell distributions in different classes. Thus, the clusters with maximum number of cells were determined by assessment of the histogram (Salmanmahiny and Kamyab, 2009).

As a result, three classes were considered for the area. Then, the correlation between each index with the precipitation of the area was determined, and the best method was selected based on the highest correlation and general accuracy.

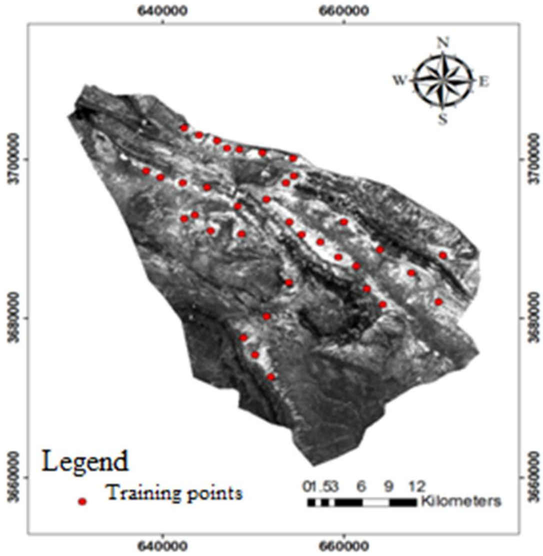

Figure 2. Ground truth points used for the study area

Table 1. Geographical features of the stations

Station name	Longitude	Latitude
Arakvaz	648794.67	3696776.2
Ama	633191.93	3703942.4
Cheshmeh Pahn	664390.08	3691482.6
Darageh	647385.01	3687512.3
Shahid Taleqani	651952.89	3693128.3
Shahid Keshvari	649049.91	3680143.8
Gol Gol	637812.18	3705855.7
NaderAbad	669204.19	3682322
Dul	658366.61	3680290.9
Gonbad	644391.63	3680073.5

Vegetation indexes

The normalized difference vegetation index (NDVI)

One of the important indices used for determination of change in vegetation is the normalized difference vegetation index (NDVI). This index is related to Rouse's work (Rouse et al). However, the concept was expressed for the first time by Kriegler et al. (1969). This index is calculated via the following formula:

$$\text{NDVI} = \frac{(\text{NIR} - \text{R})}{(\text{NIR} + \text{R})} \quad (1)$$

In this formula NIR is the reflectivity in near-infrared band and R is reflectivity in red band. NDVI ranges from -1 to +1.

When the vegetation has high density, this index is closer to +1 and in case of destruction of vegetation, it decreases towards -1. The common variation range for vegetation is 0.2 - 0.8.

Ratio vegetation index (RVI)

RVI is the simplest vegetation index proposed for the first time by Jordan in 1969. Rouse et al. (1974) suggested RVI to separate vegetation from background soil using MSS images. RVI is a linear gradient that attaches the beginning and the end of the vegetation in red to infrared space. This index is calculated by formula 2:

$$\mathrm{RVI} = \frac{\mathrm{NIR}}{\mathrm{R}} \quad (2)$$

NIR and R are reflectance of pixel in near-infrared and red bands respectively. This index ranges from 0 to infinity. The common variation range for vegetation is from 2 to 8.

Results

Precipitation changes

Assessment of changes in annual precipitation from 2000 to 2014 showed that in 2000 the average precipitation of the stations was 600 mm that represents a wet year in the area of the study. In 2007 the average precipitation of the stations was 213 mm which is less than the previous years. From 2004 to 2007, the precipitation decreased. In 2014, the average precipitation was 211.8 mm which is the least amount of rainfall in the period of the study (Figure 3).The variability of precipitations was shown using Kriging interpolation map. The highest rainfall belonged to stations Cheshmeh Pahn, NaderAbad, Arakvaz, Darageh, Shahid Keshvari, Shahid Taleqani, and Gonbad. These areas are greener in comparison with others (Figure 4).

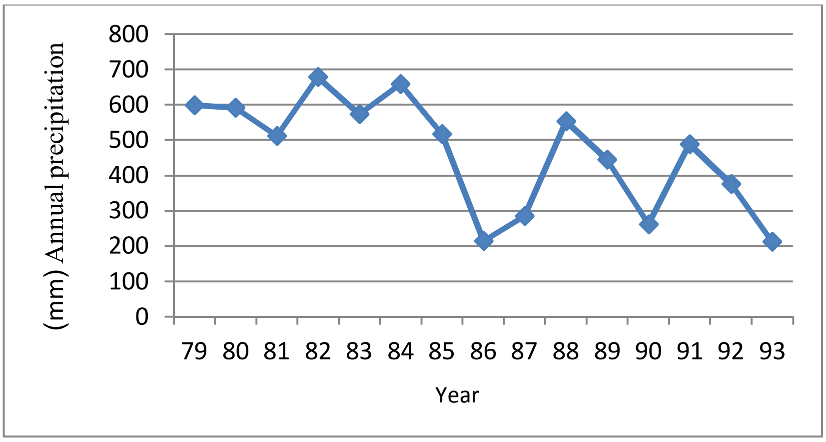

Figure 3. Annual precipitation changes between 2000 and 2014

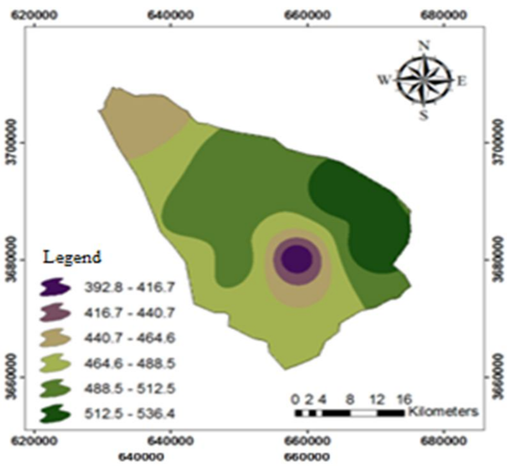

Figure 4. Kriging map of the average precipitation of the stations (2000 to 2014)

NDVI maps

After preparing the maps using NDVI, density of the forest cover in the area was classified based on the numerical value of this index. This index ranges from -1 to +1 and the ranges of NDVI in 2000, 2007 and 2014 were between 0.3 to 0.2, 0.3 to -0.4 and 0.2 to -0.6 respectively. Therefore, the cover of the land was classified into three categories of thin, semi-dense and dense forest. The numerical value for thin area was less than 0.05, for semi-dense areas it ranged from 0.05 to 0.5, and for dense forests it was more than 0.5. The maps obtained from NDVI form 2000, 2007 and 2014 are shown in Figures 5, 6, and 7 respectively.

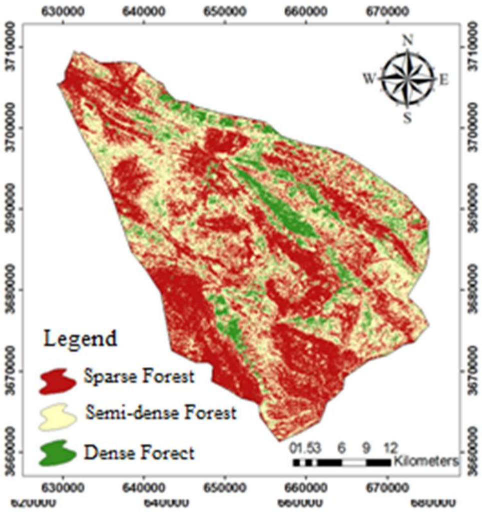

Figure 5. NDVI classification for the year 2000

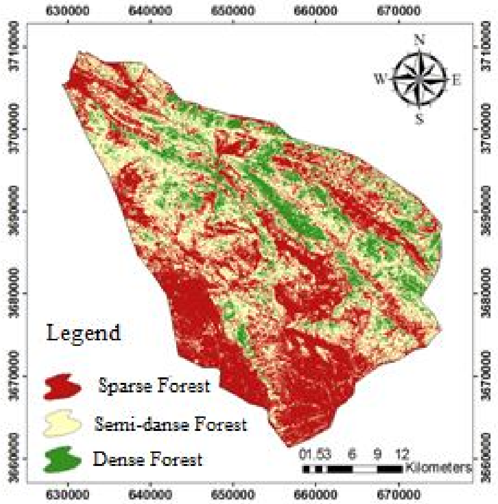

Figure 6. NDVI classification for the year 2007

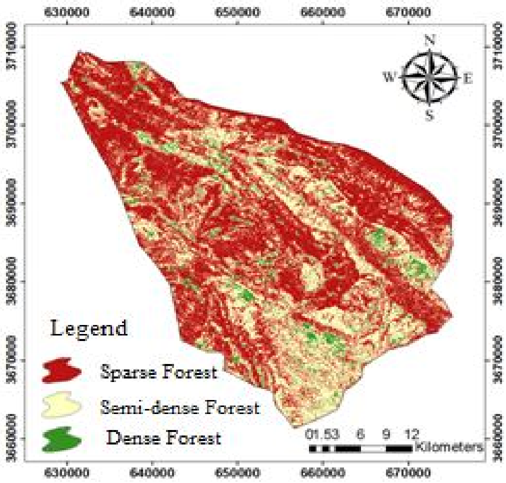

Figure 7. NDVI classification for the year 2014

RVI maps

After preparing the maps using RVI, the forest cover density of the area was classified based on the numerical value of this index. The variation range of this index was from 2 to 8, and its variation for the years 2000, 2007 and 2014 were from 0.2 to 2.3, 0.5 to 2.1, and 0.53 to 5.5 respectively. The numerical value for thin forest was set at less than 0.5, for semi-dense forest between 0.5 and 5 and for dense forests it was set at more than 5. The maps obtained from RVI for the years 2000, 2007 and 2014 are shown in Figures 8, 9, and 10 respectively.

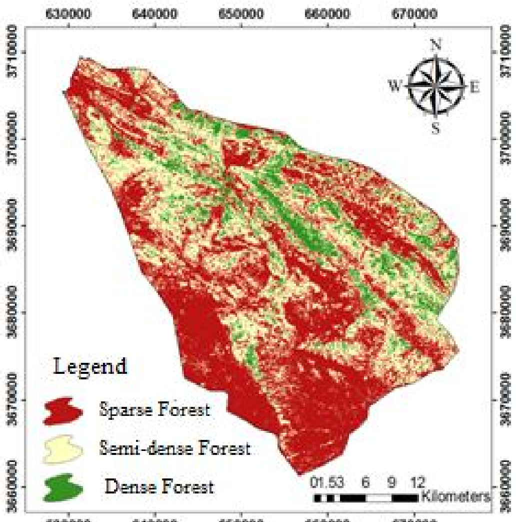

Figure 8. RVI classification for the year 2000

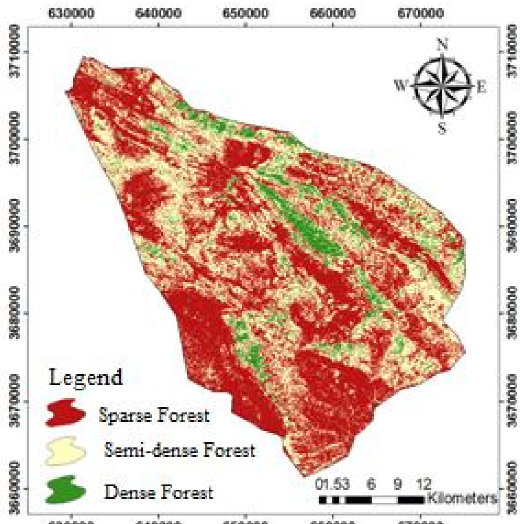

Figure 9. RVI classification for the year 2007

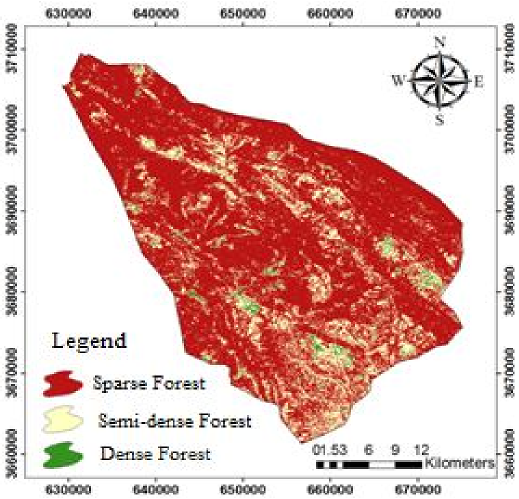

Figure 10. RVI classification for the year 2014

The area of the different classes of forest covers

Table 2 shows the area of forest cover classes obtained from NDVI and RVI. In RVI thin forests had the largest area in comparison with NDVI. NDVI showed more area for semi-dense and dense forests in comparison to RVI. As a result, RVI is efficient in demonstrating thin forest area, and NDVI is efficient in showing the area of semi-dense and dense forests. Figures 11 and 12 show the area of different classes in 2000, 2007 and 2014.

Table 2. The area of forest cover classes (in square kilometers) using NDVI and RVI in 2000, 2007 and 2014

2014	2007	2000	index
			RVI
892.3 (76.53%)	634.04 (54.38%)	573.9 (49.33%)	Sparse
251.52 (21.53%)	451.31 (38.71%)	454.2 (38.98%)	Semi-dense
22.2 (1.90%)	80.51 (6.90%)	137.41 (11.78%)	Dense
			NDVI
684.79 (58.73%)	558.16 (47.87%)	526.82 (45.18%)	Sparse
452.16 (36.86%)	490.55 (42.07%)	475.2 (40.75%)	Semi-dense
55.91 (4.79%)	117.15 (10.04%)	163.84 (14.05%)	Dense

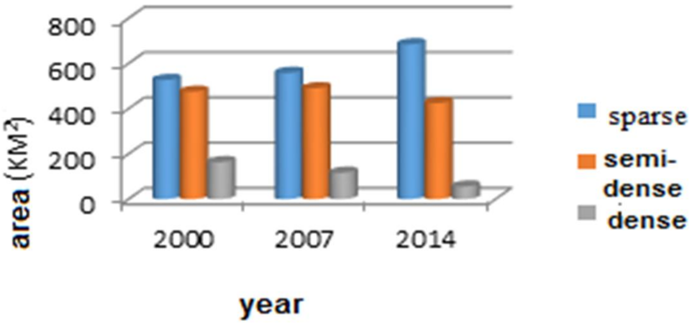

Figure 11. The changes in area of classes of forest cover via NDVI in 2000, 2007 and 2014

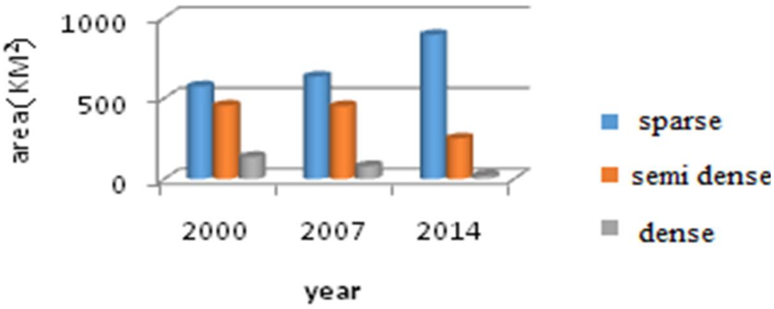

Figure 12. The changes in area of classes of forest cover via RVI in 2000, 2007 and 2014

Results of accuracy assessment and correlation of the indices

To assess the accuracy of the forest cover density classes obtained via NDVI and RVI, a ground truth map was created using the previous vegetation map and aerial photos. Then, the total accuracy, Kappa coefficient, user and producer accuracy for each image was calculated using error matrix table (Table 3). A correlation graph between NDVI and RVI, and the average precipitation of the stations from 2000 to 2014 were prepared to show the relationship between precipitation and vegetation density. The results showed 90% correlation between precipitation and NDVI (Figures 13 and 14).

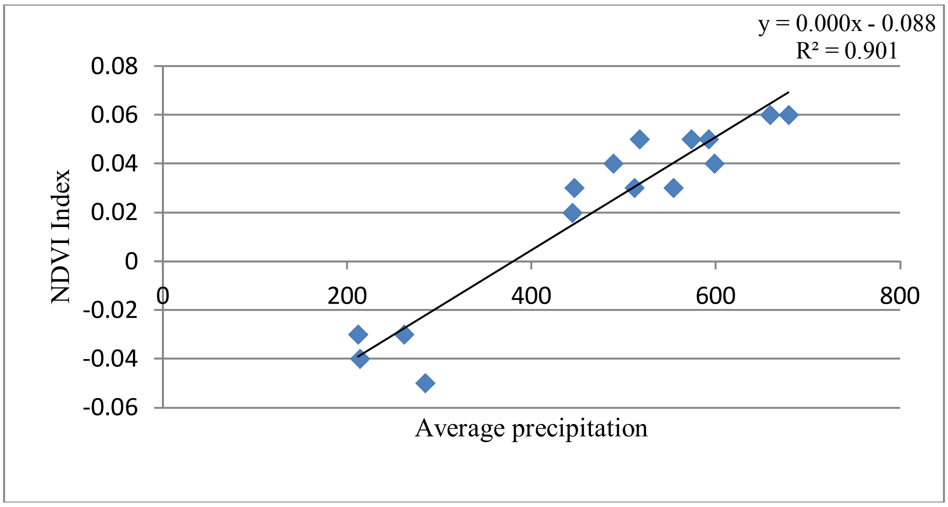

Figure 13. The relationship between NDVI and average precipitation

Table 3. Results of total accuracy of the classified images based on NDVI and RVI in 2000, 2007 and 2014

RVI	NDVI	year	Total accuracy %
68.6	30.5	2000	
64.6	21.4	2007	Total accuracy of sparse forests
86.3	49.9	2014	
47.6	71.4	2000	
48.4	89.5	2007	Total accuracy of semi-dense forests
24.2	78.5	2014	
15.5	76.7	2000	
10.4	81.8	2007	Total accuracy of dense forests
21.1	72.8	2014	

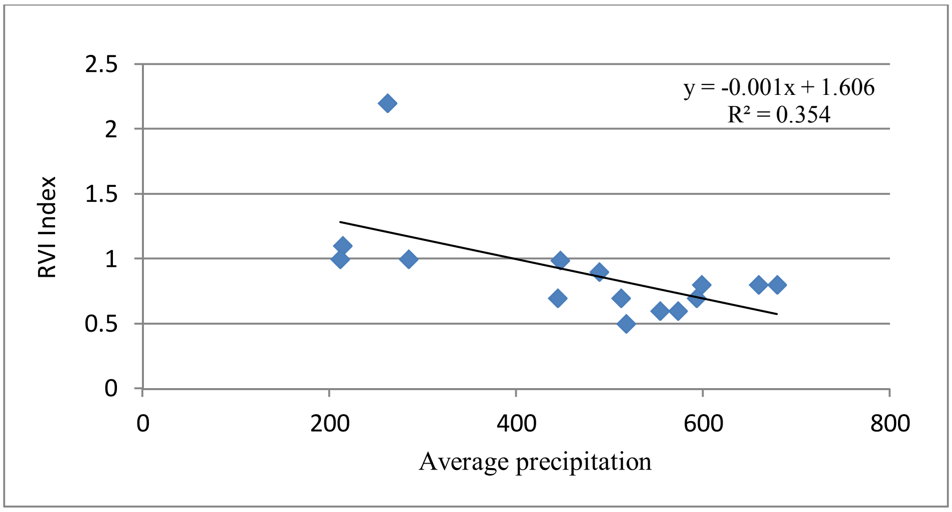

Figure 14. The relationship between RVI and average rainfall

Discussion and conclusion

One of the most important factors that affect vegetation and forest cover is precipitation. A decrease in precipitation leads to a decrease in photosynthetic activities and reflectivity of the plants (Scanlon et al., 2002). The reflectivity of the plants in visible and infrared bands differs in different seasons, and it leads to the changes of NDVI and RVI. A single vegetation index cannot be used for accurate assessment of vegetation density and determination of vegetation type, hence the need to various indices and more information of the area. Different indices have pros and cons in different areas (Khajedin, 1996, Khaninzadeh, 1999, Motaghi, 2000). The present study compared NDVI and RVI, and the best index with the highest correlation with precipitation in the area of the study was chosen. On the one hand, the relationship between vegetation and vegetation indices showed that NDVI is more valid in classifying dense forests in comparison with RVI. On the other hand, RVI can identify thin forests better than NDVI. In the present study RVI had lower accuracy in classifying dense forests. Comparing different vegetation indices in the assessment of the vegetation of Silakhor Plain showed that NDVI and SAVI are the most efficient indexes but OSAVI and ARVI could not identify areas with dense vegetation (Godarzi and Zandieh, 2014). Assessment and comparison of the vegetation indices using ETM satellite images in Neyshabur Plain also showed that NDVI is very efficient in classifying area with dense vegetation (Ghaemi et al., 2010). In the present study, precipitation in 2007 was 211 mm which decreased in comparison with the precipitation in 2000; however, the vegetation did not have significant difference from 2000 to 2007. It was because of the increase in precipitation from 2000 to 2007 that compensated the decreased precipitations in 2007.

The correlations between precipitation and NDVI and RVI showed that NDVI with a correlation coefficient R2=0.90 could better exhibit the relationship between the annual precipitation and vegetation of the study area. Thus, NDVI was found to be an appropriate index to assess the changing process of precipitation in the study area. We found a strong positive correlation between NDVI and precipitation, and the least correlation has reported to be between NDVI and temperature (Li and Yan, 2005). NDVI is a function of location variability of precipitation, and it also shows the fertility of the soil (Firmino et al., 2009). Assessment of the vegetation variability using precipitation data in Kermanshah shows that there is no relationship between precipitation and vegetation in urban areas. The highest correlation was identified between pastures and spring rainfall, and between farms and Spring and March rainfalls. On the contrary, in forest areas the highest correlation was between forest cover and average precipitation (Hadian et al., 2011).

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