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ORIGINAL ARTICLE

# Modeling the relationship between elevation, aspect and spatial distribution of vegetation in the Darab Mountain, Iran using remote sensing data

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**Abstract** The aim of this paper is to analyze topographic and aspect effects on vegetation indices in the Darab Mountain, Iran. Three commonly used vegetation indices, normalized difference vegetation index (NDVI), enhanced vegetation index (EVI) and difference vegetation index (DVI), were computed from Landsat 8 ETM+ vegetation bands. Based on the results obtained by analyzing the vegetation indices, it was found that vegetation growth and vegetation indices increase with increasing elevation and aspect. The vegetation growth is highest between the elevations of 1500–3000 m, with the NDVI, EVI and DVI values being large. The best vegetation in this zone is distributed towards NW 300°.

**Keywords** Vegetation index · Landsat 8 ETM+ · Elevation · Aspect · Spatial distribution

## Introduction

Vegetation cover in mountain areas is very important as it affects local and regional climate, and reduces erosion. The economies of local communities and millions of people in mountain areas depend on forests and plants. They also effectively protect people against natural hazards such as rock falls, landslides, debris flows and floods (Brang et al. 2001). Settlements and transportation corridors in alpine regions mainly depend on the protective effect of vegetation (Agliardi and Crosta 2003). Therefore, understanding of the distribution and patterns of vegetation growth along with the affecting factors in these areas is important and has been studied by many researchers (Bai et al. 2004; Thomas et al. 2013; Gerlitz et al. 2014; Klinge et al. 2015).

Vegetation indices, defined as the arithmetic combination of two or more bands related to the spectral characteristics of vegetation, has been widely used for the phonologic monitoring, vegetation classification, and biophysical derivation of radiometric and structural vegetation parameters (Huete and Justice 1999). As is well known, the topographic effects in the visible and near infrared parts of a surface's solar spectrum are comparable. Therefore, the topographic effects could be eliminated or weakened when vegetation indices are expressed as band ratios, such as in normalized difference vegetation index (NDVI) and ratio-vegetation-index (RVI) (Lee and Kaufman 1986).

Topography is the principal controlling factor in vegetation growth, while the type of soils and amount of rainfalls play secondary roles at the scale of hill slopes (Dawes and Short 1994). Elevation, aspect and slope are the three main topographic factors that control the distribution and patterns of vegetation in mountain areas. Among these three factors, elevation is the most important (Day and Monk 1974; Busing et al. 1992). Elevation along with aspect and slope in many respects determines the microclimate, and thus, large-scale spatial distribution and patterns of vegetation (Allen and Peet 1990; Busing et al. 1992). Vegetation growth in high mountains is generally restricted by temperature conditions (Jobbagy and Jackson 2000; Klinge et al. 2003; Körner 2012; Dulamsuren et al. 2014; Yospin et al. 2015).

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Matsushita et al. (2007) analyzed differences in the topographic effect on NDVI and enhanced vegetation index (EVI), with two airborne-based images acquired from a mountainous area covered by high-density Japanese cypress plantations used as a case study. The results indicate that the soil adjustment factor $L$ in EVI makes it more sensitive to topographic conditions as compared to NDVI. The results obtained by analyzing NDVI data for 7 years (2000–2006) clearly indicated that elevation is the dominating factor determining the vertical distribution of vegetation in the area. The vegetation growth is at its best between the elevations of 3200 and 3600 m, with the NDVI values being larger than 0.5 and having a peak value of more than 0.56 at 3400 m. Most studies using remote sensing data are concentrated on two-dimensional horizontal patterns, with a few focused on the effect of elevation on the vertical distribution of vegetation in mountain areas (Ustuner et al. 2014; Klinge et al. 2015).

The aim of this paper is to analyze topographic and aspect effects on vegetation indices, taking NDVI, EVI and DVI as three typical examples in Darab Mountain, Iran. We show in this study that readily available NDVI, EVI and DVI data can be used to quantify the spatial distribution of vegetation. The results represent the general conditions of vegetation growth in different elevations and aspects.

## Material and method

### Study area

The study area, with longitude N 29° 52′ and latitude E 52° 48′ east, and with area of 4649 $km^2$, is located in the north of Iran (Fig. 1). The major land use categories of the area is range land mainly and small part of the study area for agriculture, farming and forests. The altitude of the study area ranges from the lowest of 1047 m to the highest of 3003 m. The study area is located in a semi-arid region where the amount of rain in lower than 300 mm for per year (Fig. 2). Given the low amount of rain in the study area, the vegetation in the area needs low amount of water to grow.

A Shuttle Radar Topography Mission (SRTM) DEM of the study area, with spatial resolution of 30 m was used. In addition, in order to compute the vegetation indices, bands 1, 3 and 4 of Landsat 8 ETM+ images for the year 2015 were used. Using ENVI v.5, preprocessing, including geometric and atmospheric corrections, were performed, and then, the vegetation indices for the study area were calculated.

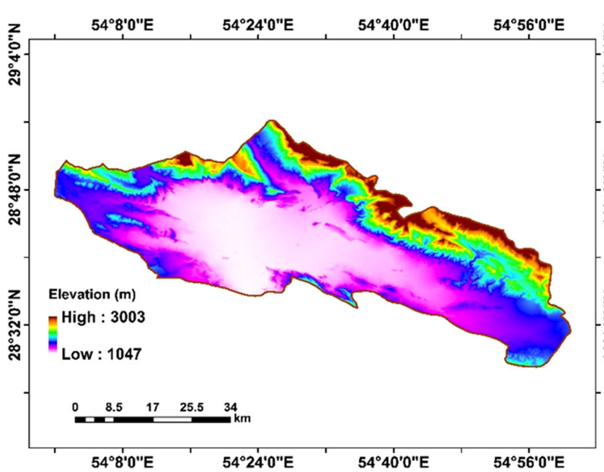


**Fig. 1** Digital elevation model (DEM) of the study area

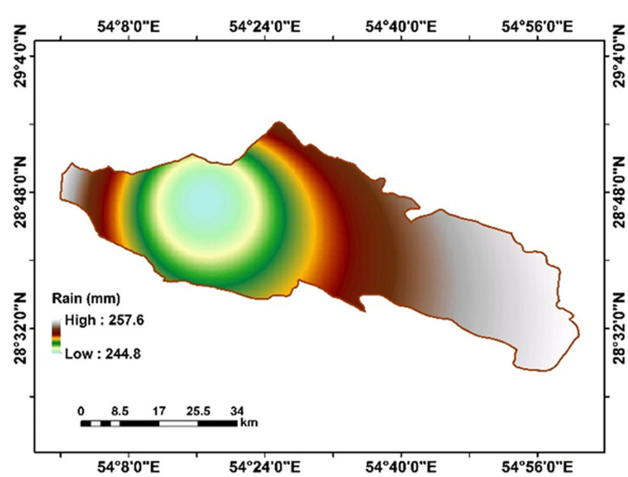


**Fig. 2** Rain map of the study area (Fars Meteorological Bureau) (http://www.farsmet.ir/Default.aspx)

### Vegetation indices

#### *Normalized difference vegetation index (NDVI)*

The one of most important vegetation indices is NDVI, which can be used as a basis for determining other parameters of vegetation index. The values of this index are between −1 to +1, with higher values indicating increase in vegetation density. NDVI is calculated as follows (Rahmani et al. 2011):

$$(TM4 - TM3)/(TM4 + TM3) \quad (1)$$

where *TM4* and *TM3* respectively are near infra-red (band 4) and red (band 3) bands of the ETM sensor.

#### *Enhanced vegetation index (EVI)*

EVI was developed to optimize the vegetation signal with improved sensitivity in high biomass regions and improved

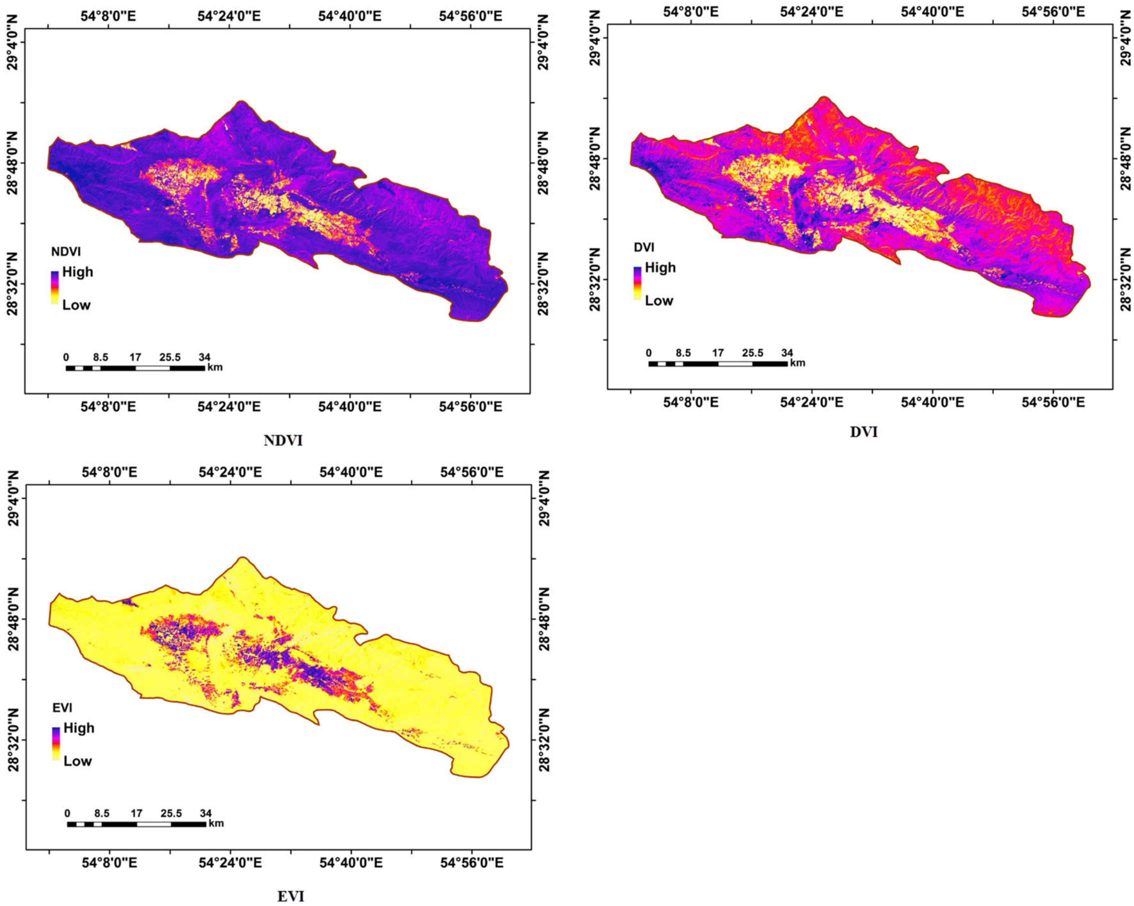


**Fig. 3** Vegetation indices of the study area

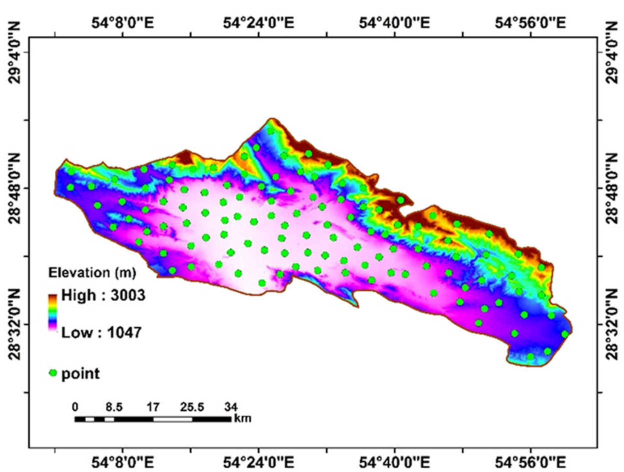


**Fig. 4** Positions of randomly selected sample points in the study area

vegetation monitoring through de-coupling of the canopy background signal and reduction in atmosphere influences (Rahmani et al. 2011):

$$EVI = G \cdot (P_{NIR} - P_{RED})/L + P_{NIR} + c_1 \cdot P_{RED} - c_2 \cdot P_{BLUE} \tag{2}$$

where NIR, RED, and BLUE are atmospherically-corrected (or partially atmospherically-corrected) surface reflectances, and $C_1$, $C_2$, and $L$ are coefficients to correct for atmospheric condition (i.e., aerosol resistance). For the standard EVI products, $L = 1$, $C_1 = 6$, and $C_2 = 7.5$.

### *Difference vegetation index (DVI)*

DVI is probably the simplest vegetation index, and is calculated as follows (Tucker 1979):

$$DVI = NIR - Red \tag{3}$$

DVI is sensitive to the amount of vegetation, distinguishes between soil and vegetation, and does not deal with the difference between reflectance and radiance caused by the atmosphere or shadows.

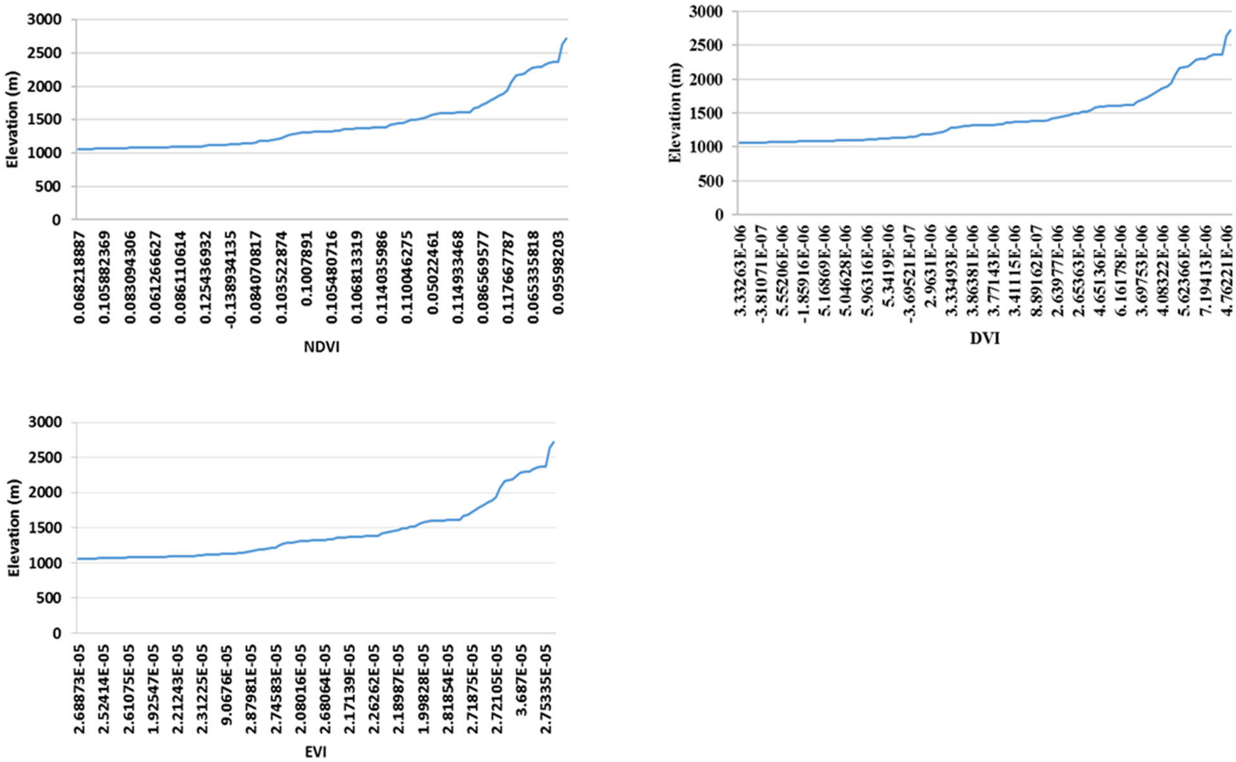


**Fig. 5** The change of the vegetation indices values with elevation in the study area

## Results and discussion

Based on Fig. 3, vegetation in the Darab Mountain area is distributed between the elevations of 1047 and 3003 m. Several observations can be made regarding the effects of elevation on vegetation growth in the mountain area. First of all, it is clearly seen that elevation is the main controlling factor for vegetation growth. The NDVI, EVI, DVI values increase with increasing elevation and reaches its maximum value at 3003 m, which is the highest elevation in the region. The NDVI, EVI and DVI values are mostly larger than 0.30 when the elevation is 3000 m, which is the best vertical zone in terms of vegetation growth. The NDVI, EVI and DVI values are <0.30, and vegetation growth is poorer when the elevation is lower than 3000 m.

For determination of the relationship between indices and elevation, 117 randomly selected sample points were used (Fig. 4). Figure 5 confirms that with increasing elevation, vegetation indices (EVI, NDVI and DVI) increases. Most vegetation in the northern part of Darab mountain area is distributed between the elevations of 1500 and 3003 m, indicating that this is the best elevation range for vegetation growth in the study area. In the elevation, the rain is more and the condition is good for growing the vegetation. These results demonstrate that readily available elevation data can be used for the prediction of vegetation indices and to quantify the spatial distribution of vegetation.

The relationship between vegetation indices and aspect in the study area is also studied, as shown in Fig. 6, which indicates increasing vegetation with increasing aspect. The best vegetation in this zone is distributed more than North West (NW) 300°. It is also found that the best vegetation growth is on the shady side of the mountain where much less evapotranspiration (ET) is expected. The reduced ET in the shaded side is important for vegetation growth in the Darab Mountain area since it is located in a semi-arid region.

## Conclusion

The aim of this paper was to analyze topographic and aspect effects on vegetation indices in Darab Mountain, Iran. Three commonly used vegetation indices, NDVI, EVI and DVI, were computed from Landsat 8 ETM+ vegetation bands.

Based on the results obtained by analyzing the vegetation indices, it was found that vegetation growth and vegetation indices increase with increasing elevation and

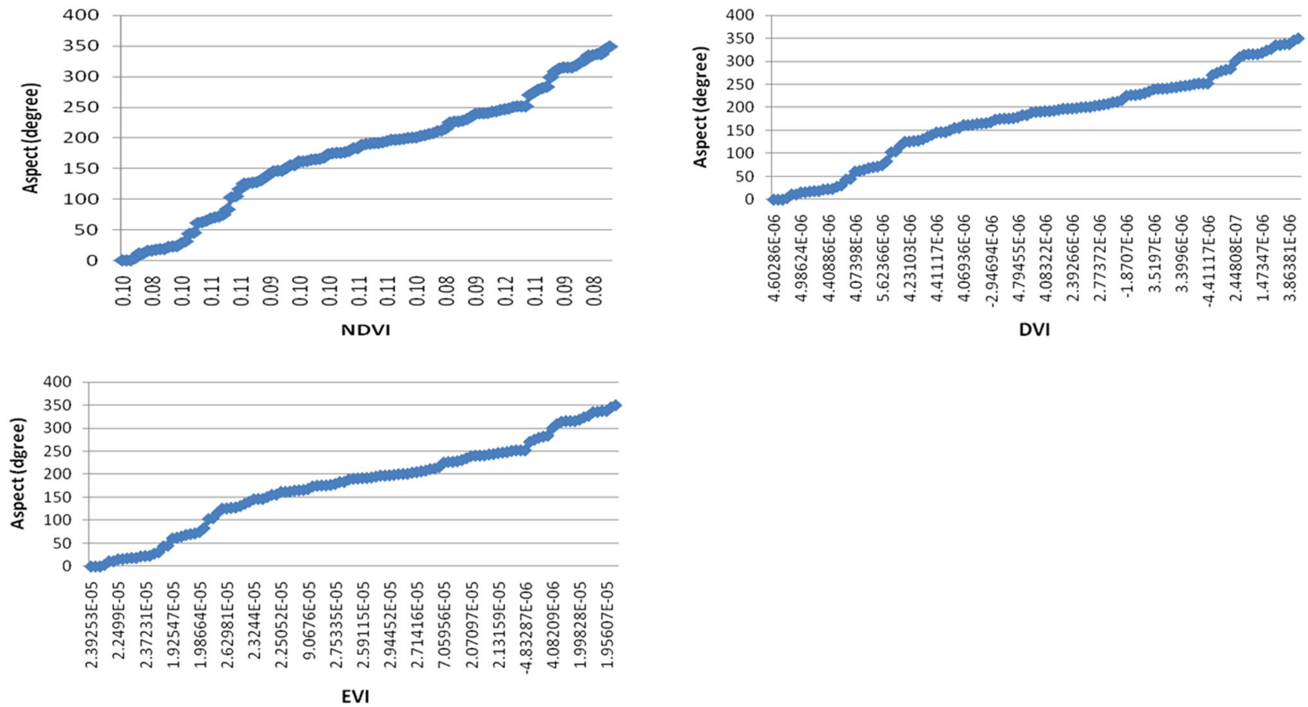


**Fig. 6** The change of the vegetation indices values with aspect in the study area

aspect. The vegetation growth is highest between the elevations of 1500 to 3000 m, with the NDVI, EVI and DVI values being large. In addition, the best vegetation in this zone is distributed towards NW 300°.

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