

INVESTIGATION OF FOREST CANOPY DENSITY CHANGES IN HYRCANIAN FOREST RESOURCES DURING 1987 TO 2002 USING REMOTE SENSING TECHNOLOGY

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ABSTRACT:

Forest canopy density (FCD) of seventeen protected areas of the Caspian Hyrcanian mixed forest are studied here. A modified version of FCD mapper based on spectral band fusion and customized threshold calibration that is optimized for Hyrcanian forests is used for this purpose. In this project, the results of applying the FCD model on three time series of satellite images have been analysed. This classification is based on the FAO standard and consist of four categories such as no-forest, thin, semi-dense and dense. These images, taken with TM and ETM sensors, belong to three-time series between 1987 and 2002. The results of this study indicate that the rate of growth or destruction of forests has been investigated in the regions. Then, using tables and diagrams of variations, the rate of growth or destruction of forest lands in the corresponding period in each class is determined. The FCD model has the ability to study the canopy loading classes in the annual time series.

1. INTRODUCTION

Assessment of forest density and its evaluation is one of the important aspects of management and long-term monitoring of protected area for meaningful biodiversity conservation (Rikimaru, 1997). It is also an important tool for sustainable management of natural resources. Forest canopy density can be detected by either ground survey or using remote sensing method. Ground survey cannot be easily carried out for the large area. Satellite remote sensing has played a pivotal role in generating information about forest cover, vegetation type and landuse changes.

One of the methods to assess the forest density through remote sensing application is through the use of the Forest Canopy Density (FCD) model. This model, which was first introduced by Rikimaru in 1996, is a method to detect and estimate the canopy density over large area in a time and cost-effective manner (Rikimaru, Utsuki, & Yamashita, 1999). FCD model is based on the growth phenomenon of forests and it can indicate the degree of degradation.

The great advantage of the FCD model is the lack of training data compared to other models such as classification. Indeed, use of the FCD Mapper eliminates the need to undertake much of the usual field validation process which is necessary with conventional remote sensing technology. This advantage has made the FCD model a popular model for assess the forest density.

To date, many studies done on monitoring forest canopy using FCD model. Panta and Kim (2006) studied spatio-temporal change in canopy cover with site-associated biophysical factors and human interferences in Nepal using the FCD model (Panta & Kim, 2006). Using the FCD model, Deka, Tripathi and Khan (2013) monitored tropical deforestation and degradation of forest

stands in Assam, north east India (Deka, Tripathi, & Khan, 2013). The FCD model has also been used to assess old growth forests in India with high accuracy (Banerjee, Panda, Bandyopadhyay, & Jain, 2014). Therefore, FCD estimates have been widely adopted in monitoring tropical mixed deciduous vegetation and assessing deforestation and forest degradation over time (Chandrashekhar, Saran, Raju, & Roy, 2005; Joshi, De Leeuw, Skidmore, Van Duren, & Van Oosten, 2006; Mon, Kajisa, Mizoue, & Yoshida, 2010; Panta, Kim, & Joshi, 2008; Su Mon, Mizoue, Htun, Kajisa, & Yoshida, 2012).

Hyrcanian forest, located in north of Iran, contain the most important and significant natural habitats. There are 17 forest protected areas located in the Hyrcanian forest. The main objective of this paper is to evaluate the FCD model of these areas using multi-temporal satellite data. In this study, the FCD model were implemented on three time series consist of 1987, 1999 and 2002. Afterward, the amount of forest growth and degradation, and the FCD changes have been calculated.

2. METHODOLOGY

2.1 Study Area and Datasets

The study areas located in the north of Iran (Fig. 1). To support this study, three sets of TM & ETM+ of 1987, 1999 and 2002 were used.

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Figure 1. Distribution of studied areas.

2.2 Methods and background

FCD model is a combination of four biophysical indices. These indices are Advance Vegetation Index, Bare Soil Index, Shadow Index and Thermal Index. Figure 2 shows the relationship between forest condition and these indices.

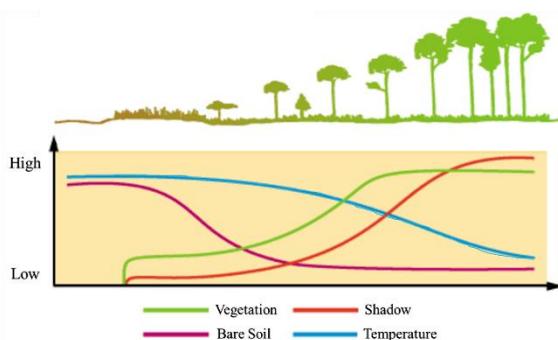


Figure 2. The Characteristics of four indices for forest condition.

Shadow and vegetation parameters of forest are strongly correlation whit each other. Similarity, temperature and bare soil are also correlated as shown in Table 1. Shadow index increases when the forest density increases. Thermal index increases as the vegetation quantity decreases. Bare soil index increases as the bare soil exposure degrees of ground increase (Rikimaru, Roy, & Miyatake, 2002).

Index	Hi-FCD	Low-FCD	Grass-Land	Bare Land
AVI	Hi	Mid	Hi	Low
BI	Low	Low	Low	Hi
SI	Hi	Mid	Low	Low
TI	Low	Mid	Mid	Hi

Table 1: Combination Characteristics between Four Indices.

2.2.1 Advanced vegetation index: Advanced Vegetation Index (AVI) is a one of the essential parameters to determine the vegetation density based on the red and near-infrared spectral band [2]. It is similar to NDVI (Normalized Difference Vegetation Index). NDVI is used to identify the high and low vegetation area. It is unable to high-light delicately balanced amount in cover relation between mass and size. For this reason, it has been getting better by using power degree of the infrared response. This index is calculated using Equation 1 (Rikimaru et al., 1999):

$$B4 - B3 < 0 \Rightarrow AVI = 0$$

$$B4 - B3 > 0 \Rightarrow \quad (1)$$

$$AVI = [(B4 + 1)(256 - B3)(B4 - B3)]^{\frac{1}{3}}$$

wherein, B3 is red band and B4 is near infra-red band.

2.2.2 Bar Soil Index: The Bar Soil index (BI) helps to give clear idea of vegetation from the surrounding environment. Similar to the concept of AVI, this is formulated whit medium infrared information. So Bare soil Index has been calculated using Equation 2 (Rikimaru et al., 1999):

$$BI = \frac{(B5 + B3) - (B4 + B1)}{(B5 + B3) + (B4 + B1)} \times 100 + 100 \quad (2)$$

where B1 corresponds to blue band and B5 refer to short-wave infrared.

2.2.3 Canopy Shadow Index: Canopy shadow provides essential information about trees and plants arrangement which are defined by spectral information and thermal information of the forest shadow. In the field of Remote sensing forest shadow is characterized by Canopy shadow Index (SI). SI has been calculated using Equation 3 (Rikimaru et al., 1999), where B2 corresponds to green band.

$$SI = [(256 - B1)(256 - B2)(256 - B3)]^{\frac{1}{3}} \quad (3)$$

2.2.4 Thermal Index: The temperature of the forest and non-forest area is different. Because forests are cooler due to the shadow effect and transpiration from leaves. Therefore, the Thermal Index (TI) is used to differentiate bare soil from grassland and forest. The infrared band of data is the source of thermal information. The temperature calibration of the thermal infrared band into the value of ground temperature has been done as following:

$$L = L_{min} + \left(\frac{L_{max} - L_{min}}{255} \right) * Q$$

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)} \quad (4)$$

where L: value of radiance in thermal infrared, T: ground temperature (k), Q: pixel DN value and K₁, K₂: calibration coefficients.

$$K_1 = 666.09 \frac{\text{watts}}{\text{m}^2 \times \text{ster} \times \mu\text{m}}$$

$$K_2 = 1282.71(\text{kelvin})$$

$$L_{min} = 0.1238 \frac{\text{watts}}{\text{m}^2 \times \text{ster} \times \mu\text{m}} \quad (5)$$

$$L_{max} = 1.500 \frac{\text{watts}}{\text{m}^2 \times \text{ster} \times \mu\text{m}}$$

2.2.5 The Procedure of FCD Model: As mention, the components of FCD model are four indices; vegetation, bare soil, thermal and shadow. The FCD combines data from the four indices to calculate the canopy density in percentage for each pixel. Figure 3 illustrates the flow chart of the procedure.

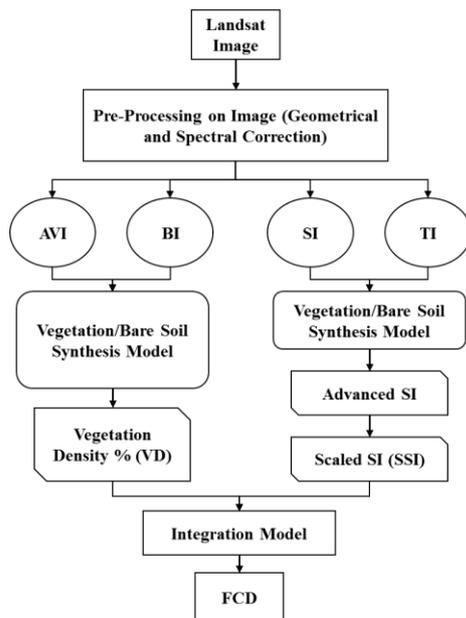


Figure 3. Methodological flow chart demonstrating different stages of the forest canopy density (FCD) model.

2.2.6 Vegetation Density: The FCD Model determines vegetation density (VD) by using principal component analysis based on two input parameters AVI and BI. Since AVI and BI have high reciprocity of bare soil status and vegetation status, it is useful to assess land as a continuum ranging from dense forest to exposed soil (Rikimaru, 1997). Thereafter, the result is scaled from 0 to 100 to form Scaled Vegetation Density (SVD).

2.2.7 Scaled Shadow Index: The shadow index (SI) is a relative parameter which was developed in order to integrate VI values and SI values. Maximum value of SSI (i.e.100%) corresponds the highest possible shadow whilst minimum (i.e.0%) represents the lowest shadow value.

2.2.8 Integration process to achieve FCD model: Finally, the FCD is obtained for each pixel of forested land by integrating the values of SSI and SVD. Both parameters are scaled from 0 to 100. Forest Canopy Density (%) for each pixel is calculated by using the Equation 6 (Rikimaru et al., 1999).

$$FCD = \sqrt{VD \times SSI + 1} - 1 \quad (6)$$

3. RESULTS

surface area of 17 forest protected areas are ~195,356 hectares. The forest canopy density was calculated over three time periods for each of these areas, and the results were compared. The analysis was applied on imageries from 1987 to 1989 (T2), 2000 to 2001 (T3), and 2002 (T4).

The FCD model results show over of 17 forest areas based on the FAO standard (Fig. 4). According to fig. 4, it was concluded that the degradation and rehabilitation of the forest are similar trends. The forest degradation and rehabilitation have been occurred in T2 to T3, and T3 to T4, respectively.

As can be seen in Fig. 4 and table 2, during the 1987 to 1989, more than 24,400 hectares of forest areas destroyed in the seventeen regions, and have been transformed into non-forest areas. About half of this destruction has been compensated, when the environmental protection programs were started at 2000. consequently, about 11774 hectares of forests have been rehabilitated from 2000 to 2002.

Time series	Date		Class Area (hectare)			
	Previous	Next	C1 NF	C2 LF	C3 MF	C4 DF
T3-T2	1987-89	2000- 01	24433	-3115	-16929	-4392
T4-T3	2000-01	2002	-11774	994	-2050	12824
T4-T2	1987-89	2002	12659	-2121	-18979	8432

Table 2: Statistical summary of FCD results

4. CONCLUSIONS

In this study, the FCD model was applied to the Hyrcanian forest, north of Iran, in order to investigate the degradation and rehabilitation events from 1987 to 2002. The results reveal that during the 1987 to 1989, more than 24,400 hectares of forest areas destroyed. However, management of the forest, particularly after 2000, demonstrates that the natural environmental quality of the area has been maintained and improved.

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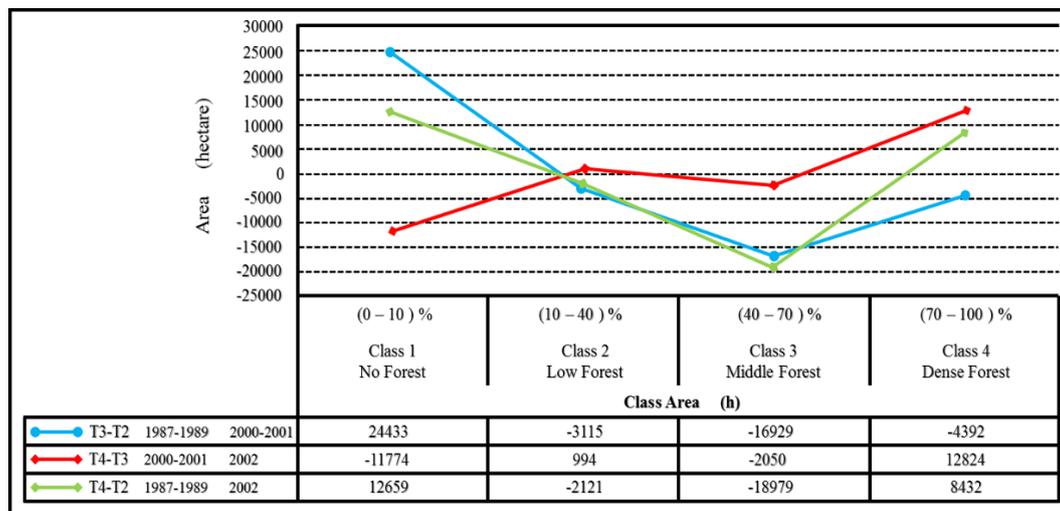


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