PERCENT TREE COVER MAPPING FROM ENVISAT MERIS AND MODIS DATA

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ABSTRACT:

The aim of this study was to compare percent tree cover products of Envisat MERIS and MODIS data of Seyhan River Basin at the Eastern Mediterranean Region of Turkey. In this study, Regression Tree (RT) algorithm was used to estimate percent tree cover maps. This technique is well suited for percentage tree cover mapping because, as a non-parametric classifier, it requires no prior assumptions about the distribution of the training data. This model also allows for the calibration of the model along the entire continuum of tree cover, avoiding the problems of using only end members for calibration.The medium resolution Envisat MERIS with a 300 m and MODIS with a 500 m pixel representation data were used as predictor variables. Three scenes of high resolution IKONOS images were employed as a training data, and testing the accuracy of model. The regression tree method for this study consisted of six steps: i) generate reference percentage tree cover data, ii) derive metrics from Envisat MERIS and MODIS data, iii) select predictor variables, iv) fit RT model, v) undertake accuracy assessment and produce final model and map, vi) compare results. The training data set was derived supervised land cover classification of IKONOS imagery to generate reference percent tree cover data. Specifically, this classification was aggregated to estimate percent tree cover at the MERIS and MODIS spatial resolution.The predictor variables incorporated the MERIS and MODIS wavebands in addition to biophysical variables estimated from the MERIS and MODIS data. Percent tree cover maps were derived from MERIS and MODIS data for Seyhan upper Basin as final outputs. These final outputs consisted of spatially distributed estimates of percent tree cover at 300 m and 500 m spatial resolution and error estimates obtained through validation. This study showed that Envisat MERIS data can be used to predict percentage tree cover with greater spatial detail than using MODIS data. This finer-scale depiction should be of great utility for environmental monitoring purposes at the regional scale.

1. INTRODUCTION

The development of preventive and mitigative measures at the local and regional scales for climate change depends on the understanding of the structures and functions of ecosystems. There are strong relationship between the concentration of key elements and the amount of reflected radiation across the vegetation cover. Quantitative relationships between spectral indices derived from satellite sensor data and vegetation variables such as, percent tree cover can be extrapolated over large areas, provide important inputs to models of global primary production and biogeochemical cycles. Information on canopy cover is of great importance for the study of nutrient cycling, productivity, vegetation stress and for input to ecosystem simulation models.

In the past decade, several efforts to estimate percent tree cover as a continuous variable have been made by utilizing multiple linear regression (MLR) (Zhu and Evans 1994, DeFries *et al*. 2000), linear mixture modelling (LMM) (Iverson *et al*. 1989), and regression trees (RT) (e.g., Herold *et al*. 2003, Sa´ *et al*. 2003, Hansen *et al*. 2003, Hansen *et al*. 2005). Among these techniques, the regression tree technique is well suited for percent tree cover mapping because, as a non-parametric classifier, it requires no prior assumptions about the distribution of the training data (e.g., Herold *et al*. 2003, Sa´ *et al*. 2003, Hansen *et al*. 2003, Hansen *et al*. 2005, Berberoglu et al., 2008). In previous studies, large area tree cover density has been predicted using the regression tree (RT) technique at spatial resolutions of 1 km using Advanced Very High Resolution Radiometer (AVHRR) data (Hansen *et al*. 2000 and 2002). Major new opportunities are presented by the MODIS and MERIS instruments (operational since 1998 and 2002 respectively) which provide greater spectral and spatial resolution than AVHRR with similarly high temporal resolutions.

The aim of this research is to estimate the percent tree cover using both Envisat MERIS and MODIS and to test the relationship between percent tree cover and reflected signals of these satellite sensor data in the Mediterranean environment.

2. STUDY AREA AND DATA

The study area called Seyhan River Basin (Figure 1) is located on the Taurus Mountain chain in the Eastern Mediterranean region of Turkey and has a very high local environmental quality and sensitivity in respect to forest ecosystems.

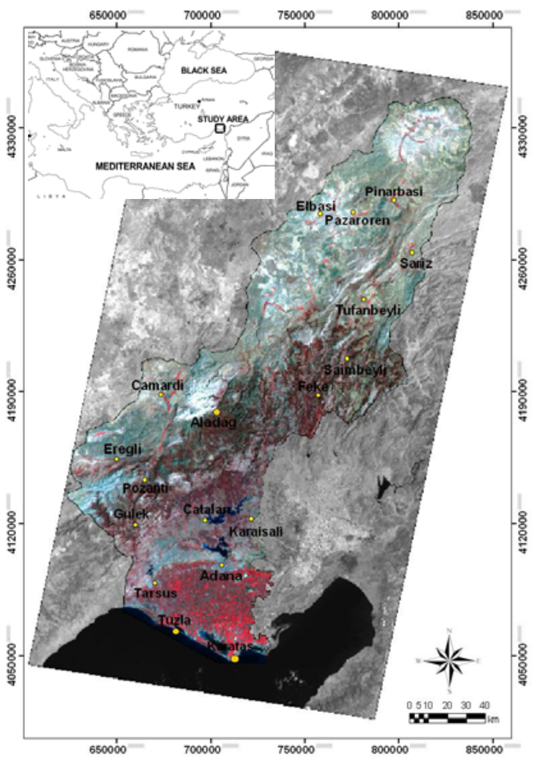

Figure 1: Location of the Seyhan River Basin.

The basin covers an area of approximately 21 720 km^2. and comprises pure and mixed conifer forests. These forests are classified as a Mediterranean evergreen cover type (Koppen, 1931) and estimated to be approximately 100 years old from tree cores. Dominant tree species are Crimean pine (*Pinus nigra)*, Lebanese cedar (*Cedrus libani)*, Taurus fir (*Abies cilicica*), Turkish pine (*Pinus brutia)*, and juniper (*Juniperus excelsa)*. The climate is strongly influenced by the topography. The Northern side of the basin has terrestrial components of Central Anatolian climate. This part has the precipitation around 350-500 mm. The highest precipitation occurs at the highlands of central Seyhan Basin, particularly around Aladag region, is about 1500 mm. The region between coastal zone and Taurus Mountains characterized by dry and hot summers and rainy and warm winters and precipitation in the range of 600-800 mm is defined as a semi-arid 3rd degree meso-thermal, Mediterranean climate. Dominant soils of the forest stands are classified as Lithic Xerorthent of Entisol and developed on fluvial and lacustrine materials during the Oligocene Epoch (Soil Survey Staff 1998).

Three sub-scenes of multi-spectral IKONOS imagery representing different types of forest cover recorded in May 2002 were used as training and testing data. An Envisat MERIS and MODIS image of 19 August 2003 was selected as they were relatively free of haze and cloud. A variety of GIS data were available for this study. Land use information has been provided by land use classification from Landsat ETM imagery and several mapping campaigns. Other data utilised in the analysis included 1:25,000 scale Government Forestry Department and topographic maps and aerial photographs.

3. METHODOLOGY

This study utilised the commonly applied technique, RT model to predict percent tree cover within a Mediterranean type forest using Envisat Medium Resolution Imaging Spectrometer (MERIS) and MODIS data. The methodology employed can be divided into three phases, which include: i) generate reference percentage tree cover data, ii) derive metrics from Envisat MERIS data, iii) select predictor variables, iv) fit RT models, v) undertake accuracy assessment and vi) produce final model and map (Figure 2)

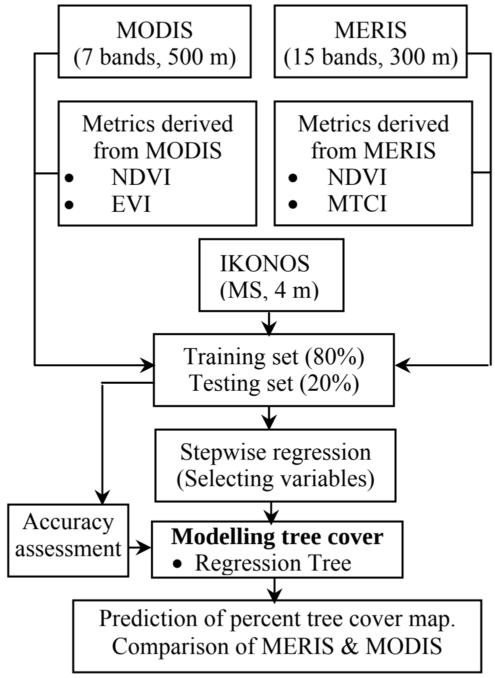

Figure 2. Summary of percent tree cover prediction using the two data set

IKONOS images with a spatial resolution of 4 m were used to derive reference percent tree cover data needed to train the model. The coverage of this IKONOS data set was equal to 1232 Envisat MERIS pixels. Vegetation biophysical variables including: normalised difference vegetation index (NDVI), MERIS terrestrial chlorophyll index (MTCI) (only for MERIS) and enhanced vegetation index (EVI) (only for MODIS) were derived in addition to 15 and 7 spectral bands of MERIS and MODIS data respectively. A new index called MTCI developed by Dash and Curran (2004) is a ratio of the difference in reflectance between band 10 and band 9 and the difference in reflectance between band 9 and band 8 of the Envisat MERIS.

$$\text{MTCI}=\frac{R_{753.75} - R_{708.75}}{R_{708.75} + R_{681.25}} \quad (1)$$

where $R_{753.75}$, $R_{708.75}$, $R_{681.25}$ are the reflectances in the centre wavelengths of the Envisat MERIS standard band setting.

EVI is an 'optimized' index designed for the MODIS sensor to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The atmospheric resistant index was done by adding information from the blue wavelength and two empirical correction constants C1 and C2.

The equation takes the form,

$$EVI = \frac{NIR - RED}{NIR + C1^{*}RED - C2^{*}BLUE + L}(1.5 + L).$$

where, **L** is the canopy background adjustment that addresses non-linear, differential NIR and red radiant transfer through a canopy, and **C1** , **C2** are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. EVI is designed to be more sensitive to dense vegetation compared to NDVI, which tends to saturate for high chlorophyll density. This also means that EVI is more linearly related to the fraction of green cover as compared to the nonlinear relation between NDVI and fraction of green cover. This feature of EVI facilitates comparing data of different scale covering heterogeneous distributed vegetation

Predictor variable selection involved feature selection for the most relevant input variables for the percent tree cover modelling. This was accomplished using the Stepwise Linear Regression (SLR) method. The IKONOS data set was split into two subsets; training and testing. The two models were fitted using the most relevant input variables selected using the SLR method. Relationships between tree cover density and these selected MERIS and MODIS input variables were modelled using RT techniques with the reference data derived from IKONOS images. The accuracy of the final model was estimated through validation using testing data. Model performance was measured using the correlation coefficient (*r*) between the predicted and actual tree cover values. Final outputs consisted of spatially distributed estimates of percent tree cover at 300 and 500 m spatial resolution and error estimates obtained through validation.

4. APPLICATION AND RESULTS

The modelling and prediction within the RT analysis is accomplished through a recursive binary partitioning of "training" data, sampled from the IKONOS imagery, so that values are representative of the entire dataset. These samples are then used in the production of rule sets. The relevant variables were determined by SLR for estimating percent tree cover. The following variables were selected for the analysis of MERIS: Bands 2, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, NDVI and MTCI; and MODIS: Bands 1, 2, 4, NDVI and EVI. The brightness values of pixels in these wavebands are the predictor variables and the known tree cover proportions of a pixel are the target variable of the regression tree. The intensity values were input to the regression tree, and the predicted tree cover proportions were obtained (Figure 3).

The percent tree cover predictions resulting from MERIS and MODIS wavebands together with indices plotted against the reference data. It is clearly seen that regression tree model with MERIS produced the most accurate result. Overall, the precision of predicting percent tree cover increased from 0.64 to 0.74 with the MERIS data. The precision of predicting percent tree cover were also analysed based on forest cover classes and elevation. The forest cover includes broadleaf deciduous forest (BDF), mixed broadleaf and needle leaf forest (MBNLF), needle leaf evergreen forest (NLEF). The predicted percent coverage of BDF and MBNLF was overestimated slightly by MERIS whereas, NLEF was underestimated significantly by MODIS (Figure 4). The histogram of the percent tree cover distribution for each class was significantly differed for MODIS and MERIS. The prediction of variation between MODIS and MERIS was also seen at different altitudes, particularly large differences took place at the altitudes of 700 and 1700 m. This is mainly due to spatial resolution of the both data sets (Figure 5). The distribution of the predictions varied largely within these altitudes. For example, tree cover at lower altitudes dominated by NLEF. The prediction error of MODIS was larger than MERIS around this altitude. However, MODIS was more accurate at higher altitudes where covered by Crimean pine ***(Pinus nigra).*** Additionally, Results derived from MODIS were insensitive to sparse tree coverage (Figure 5).

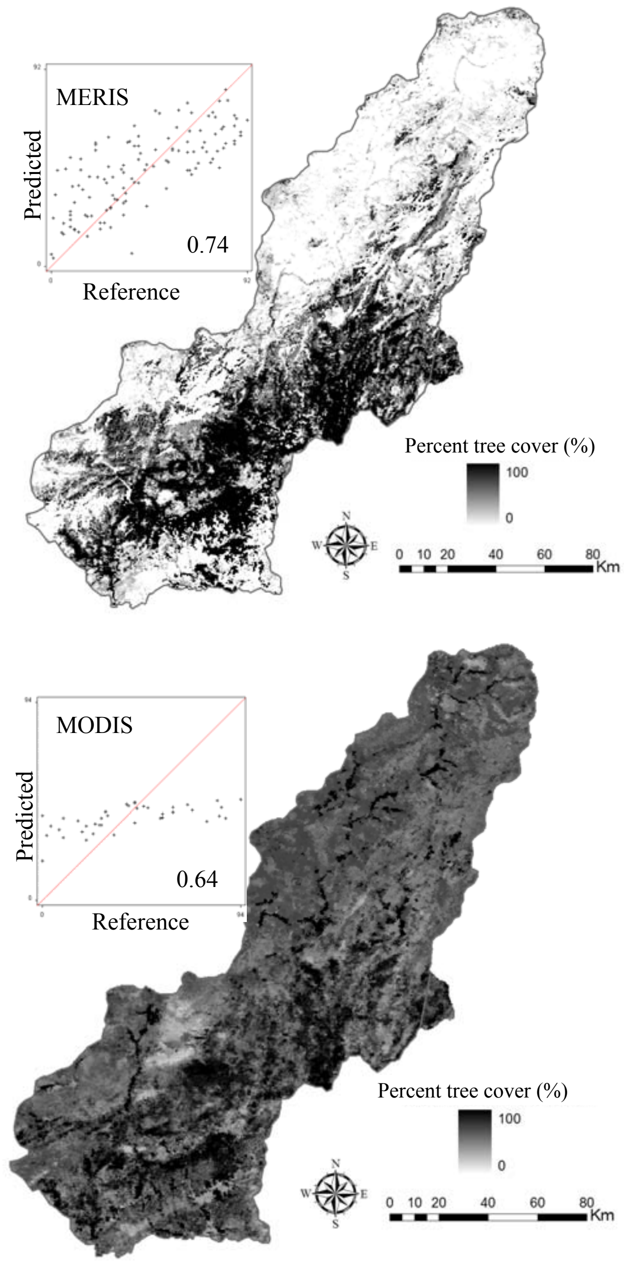

Figure 3. Percent tree cover predictions resulting from MERIS and MODIS data using RT model.

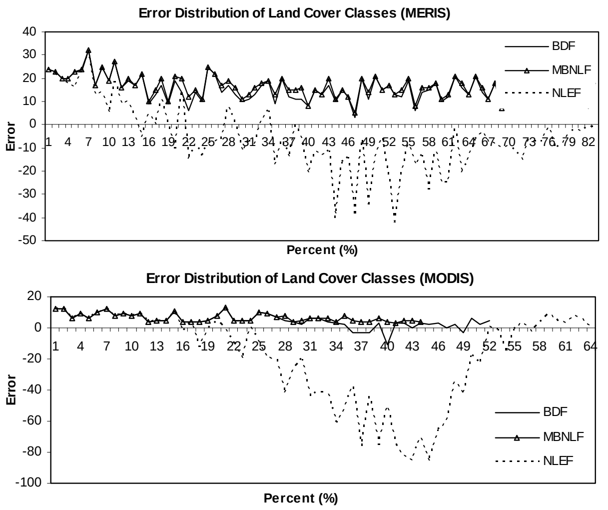

Figure 4. Error distribution patterns showing divergence from the reference data.

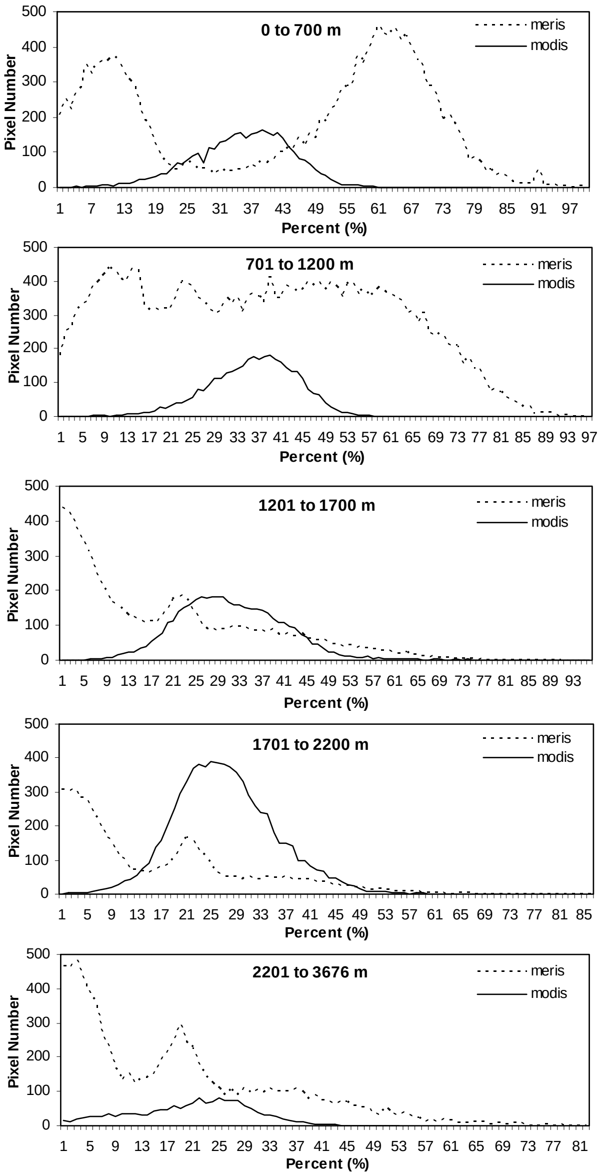

Figure 5. Percent tree cover distribution patterns at different altitudes.

The error distribution patterns for each imagery clearly indicated how predictions diverge from the reference data. The MERIS data generated prediction errors throughout most of the range of percent tree cover, and the prediction error was more evenly distributed compared to that of the MODIS imagery. MODIS predictions for NLEF had the largest error range approximately in the 30% to 60% true cover region. Turkish pine *(Pinus brutia)* and a mixture of juniper *(Juniperus excelsa)* and Turkish pine occupy the largest portion of this range with 37% and 18% coverage respectively. However, error decreased positively through 0%, and through 100% tree coverage. The MERIS produced the largest percentage of samples with zero or close to zero prediction error. For both data sets figure 4 shows that the prediction error of NLEF decreases in the mixing regions where the true coverage ranges between 30% to 60%, and error increases through more pure regions (for both bare ground or full coverage of trees) except MODIS.

5. CONCLUSIONS

This paper evaluated factors influencing the accuracy of percent tree cover mapping from MERIS and MODIS imagery of Mediterranean forest cover. The suitability of MERIS and MODIS imagery for predicting percent tree cover in the Mediterranean region using RT technique was assessed. The comparison was based on prediction accuracy using IKONOS derived percent tree cover images as a testing data set.

The main findings of this study were:

- Envisat MERIS data hold great potential for predicting percent tree cover and more accurate than MODIS data because of their spatial and spectral resolutions. Although a single date MERIS and MODIS images were used in this study, the outputs were reasonably accurate. The accuracy of the result is likely to be increased by including multi-temporal images.

- RT was appropriate for handling the variability present in Mediterranean forest coverage. It is a promising approach for modelling percent tree cover with both MERIS and MODIS imagery. It also allows calibration of the model along the entire continuum of tree cover, avoiding the problems of using only endmembers for calibration.

- Percent tree cover was predicted slightly less accurately with the MODIS. The overall model predictions were relatively less accurate compared to the literature. This is most likely due to the complex and highly variable nature of the Mediterranean type forest which has sparse coverage and high species diversity. Additionally, utilizing single date data rather than composites or temporal data was another limiting factor. Envisat MERIS composites will be available through the ESA GLOBCOVER project (Arino *et al*. 2007).

In general, this study showed that Envisat MERIS data can be used to predict percentage tree cover with greater spatial detail than using MODIS data. This finer-scale depiction should be of great utility for environmental monitoring purposes at the regional scale.

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