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RELATIONSHIPS BETWEEN EASTERN BEECH FORESTS STAND PARAMETERS AND LANDSAT ETM SPECTRAL RESPONSES IN TURKEY

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ABSTRACT

This paper explores relationships between forest stand parameters and Landsat Enhancement Thematic Mapper (ETM), atmospheric correction applied, spectral responses thorough analyses of study area in Mugada, Bartin and its vicinity where natural beech (*Fagus orientalis* L.) stands. ETM bands and many vegetation indices were examined thorough integration of spectral responses and field vegetation inventory data. Pearson's correlation coefficients were used to interpret relationships between forest stand parameters and TM data. Besides, regression analysis method for the development of multi linear regression models was used. This study concludes that vegetation indices such as KT2 (greenness of the tasselled transform), Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (FPAR), Soil Adjusted Vegetation Index (SAVI) and PC1 (the first component in a principal components analysis) were significantly correlated with forest stand parameters. Some vegetation indices, such as Normalized Difference Vegetation Index (NDVI) and KT3 (Wetness of the tasselled transform), were not significantly with selected forest stand parameters. To estimate the stand parameters by making use of the relations between stand parameters and remote sensing data multiple linear regression models were formed using stepwise regression analysis method. As the resulting product, thematic maps were produced concerning basal area, tree height and volume.

Key words: Atmospheric correction, Fagus *orientalis* L., forest stand parameters, spectral response, vegetation indices

INTRODUCTION

It is important to determine the existing potential of natural and cultural resources. In order to determine this potential, it is necessary to reveal the natural values of the area. Thus, the fact of utilizing areas will be able to be assessed by the demands of the society and with sustainable approaches. Nowadays a total 17.5% of a forest ecosystem of 20.7 million hectare, of which nearly half is fertile, is evaluated as protected area, whereby biological diversity constitutes 1.8% of it (Konukçu, 2001; İnan, 2004). Natural resources rapidly decrease as a result of the increase of consumption in relation to economical development. Forest stand parameters, such as volume, diameter and height are important data needed to assess forest resources. In this context, in projects regarding the determination of forest stands and the actual presence and potential of related resources, the usage of purpose conforming remote sensing data will ensure the acquisition of fast and low-cost data/information (Kachhwala, 1985).

Stand diameter and volume are the characteristics of a forest have most commonly been estimated using computational remote sensing methods. The correctness of the performed image processing methods is very important in the determination of the relation between the features of a stand by the aid of satellite image data. As a method, it is targeted to achieve the desired results by the models, established by using the statistical relations between satellite image data and ground methods. Using segmentation 3 × 3 pixel windows, Hall et al., (2006) image height model had an adjusted R^2 of 0.65 and in parallel with the stand volume was within 4 m^3/ha of field plot values and Lu et al., (2004) found strongly correlated between forest stand parameters and six Thematic Mapper (TM) bands, many vegetation indices such as Principal Component Analysis, Tasselled Cap Transform, Albedo etc. In another study (Freitas et al.,, 2005), three vegetation indices (Normalized Difference

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Vegetation Index (NDVI), Moisture Vegetation Index (MVI) were correlated with measurements of forest structure (tree diameter, tree height and basal area). The vegetation indices are most often used in many applications relevant to analysis of forest stand parameters, however depending on the use of specific biophysical parameters and the characteristics of the study area (Gong et al.,, 1995; Roy and Ravan, 1996; Eklund et al., 2001)

By the increase of the geometric resolutions of satellite image data, more accurate and effective information containing satellite images are concentrated in particularly biomass mapping and the determination of bio-physical parameters of stands. The results of the specifications of the stand, obtained by ground methods, acquired by statistical associations, using different satellite images and corrections, have opened the way for remote sensing techniques and calculations of forest stand parameters in particular. Aboveground biomass (AGB) was strongly related to near-infrared reflectance and NDVI using Landsat 7 Enhancement Thematic Mapper (ETM) data through multiple regression analyses to produce an initial biomass map (Zheng et al., 2004). Fazakas et al., (1999) was used Landsat TM to estimate tree biomass and volume. This estimation method is *k*NN method (Reese et al., 2002; Makale and Pekkarinen, 2004; McRoberts and Tomppo, 2007). Using high spatial resolution images, Astola et al., 2003 found relationship of belonging to stem volume, average stem diameter, stem number and tree species proportions. Besides, using lidar and radar systems, it was predicted forest stand parameters and constructed regression models (Holmgren et al., 2003; Lefsky et al., 2005; Holström and Fransson 2003)

In this study, a geometric correction process is applied to the ETM satellite image of July 4th 2000 and converted into the related projection system. In the work, an atmospheric correction process was applied regarding all areas, in which remote sensing data was used, which could also eliminate the negative effects due to the atmosphere on the image data and negative effects of the topography due to the inclination and aspects. For the work area, a basin with a weighted natural beech (*Fagus orientalis* L.) stand was selected. In this study, the relationships between forest stand parameters and Landsat ETM spectral responses thorough analyses of study area was explored and the results were evaluated

MATERIALS AND METHODS

The study area comprises 1750 hectares in the north of the Western Black-Sea Region and 13 km northwest of Bartın province centre located at 41° 37′ 44″ northern latitude and 32° 11′ 59″ eastern longitude. (Figure 1).The summers are calm and the winters are snowy and rainy in the region. The vegetation term (the warm period, during which the average temperature is +10 °C and above according to Rubner (1960)) lasts seven months (April-October). The relative humidity of the study area, which has a rather humid climate, is about 80%.

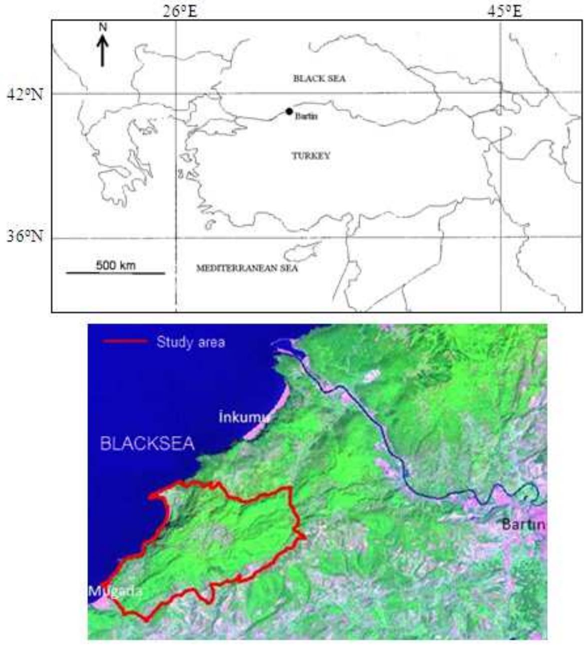

Figure 1. Study area and Thematic Mapper images.

The average altitude of the study area is 200 m. Examining the elevation distribution of the study area according to Özhan (1991), 40% of the area is sloped, 33% is steep and 19% is very steep. Respecting the aspect groups, it is seen that the area has nearly equal areal distribution regarding each aspect. Nearly 85% of the study area is covered with forests, constituted by the dominant Beech (*Fagus orientalis* L.), followed by, depending particularly on the aspect, horn beech, sporadic chestnut and lime trees along with pseudo-maquis (Table 1).

Table 1. Biophysical and land use characteristic in study area.

Soil types	Principal geological formations of research area consist of limestone and andesite rock. These parent materials are quickly dissociated and rich in Ca. the soil of the area is fine-texture and soil type is clay.
Landscape characteristics	Due to take place in the Black Sea coastal region, study area and close district extensive deforestation occurred in past 30-40 years. Mature *Fagus orientalis* L. forests are distributed along rugged terrain
Main tree species	*Fagus orientalis*, *Castanea sativa* (individual case), *Tilia tomentosa* (individual case), *Quercus sp*. (southern aspect)
Average vegetation age	Most successional vegatations are between 35 and 50 years.
Vegetation stand structure	Relatively simple
Average periodic increment (10 years)	About 24.30 m^3/ha
Climate conditions	Rainfall: 1023.6 mm Rainy Season: September-February
Topographic variability	Rugged terrains. The elevation bands from 50 to 400 m.

Reference data and analysis**:** In the study, two topographic maps of the scale 1:25000 (Zonguldak E28-d2, E28-d3) and stand type maps of the Central Forestry Department of the Bartın Forestry Directorate were used. The maps were used at the control of the ground method data and the geometric correction of satellite images. Landsat ETM+ satellite data (WRS: Path 178 and Row 31) was acquired for July 4, 2000, georeferenced to UTM zone 36 projection based on the ED50 datum. Atmospheric correction procedure was applied to all Landsat ETM+ bands except the thermal. In order to generate the numeric terrain model of the study area, the contour lines at each 10 m on the topographic map were digitized. The altitude values of the contour lines were entered into a computer environment. By utilizing the contour lines the Digital Terrain Model (DTM) was generated for atmospheric correction (Figure 2).

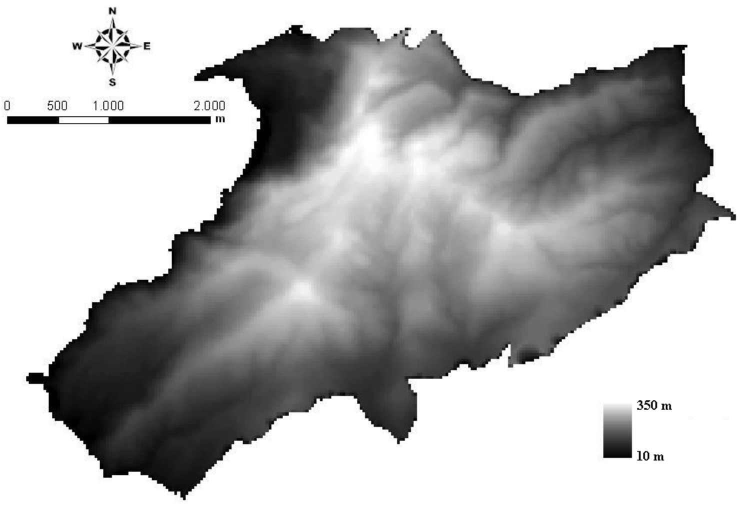

Figure 2. Digital terrain model.

In order to collect ground inventory data, the systematic sampling method was used and in distances of 300 × 300 m at a size of total 400 m^2, it was planned to take 64 samples in total. However, during the field studies, performed in July-August 2007, a total of 23 sample areas were cancelled due to the topography and the disturbance of the present homogeneity (as a result of illegal cuts) at some of the selected trial areas, and the measurement of a total of 1600 trees at 41 sample areas was performed (Figure 3). The centre coordinates of each sample area were recorded in the respective coordinate system and datum by the aid of GPS (Global Positioning System). The correctness of each coordinate value obtained from the terrain was controlled on topographic maps of 1:25000, a stand map of the same scale and geometric corrected satellite image data. Since the study to be performed will be realized based on spectral reflection values with a 3 × 3 window size (surrounding the field plot), care was taken that the close proximity regarding each sample area has similar features, meaning on the homogeneity of the vegetation structure.

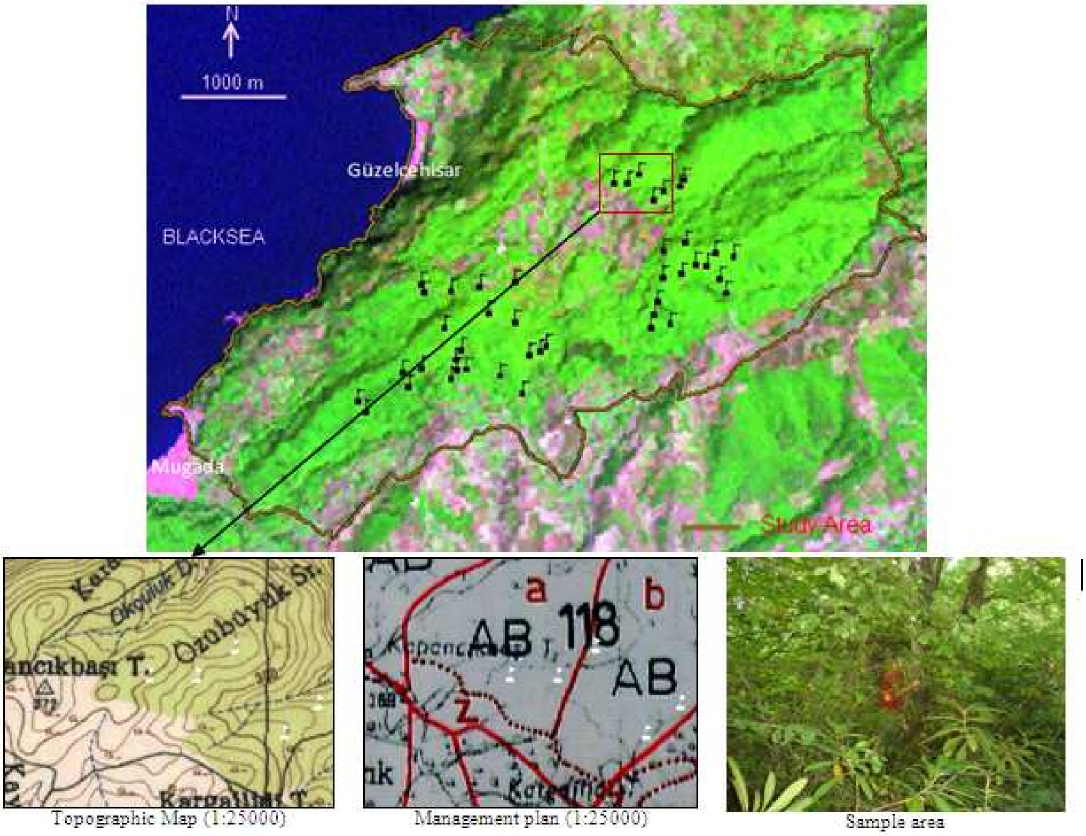

Figure 3. Positions of the sample areas.

In the measurement of stands, the stand or stand type at a definite location is deemed to be a population. The units of the population are constituted by trees. Forest stand is determined by features like the number of trees and their distribution, basal area, tree volume, mean diameter etc. (Kalıpsız, 1993). The trees within each sample were identified. Diameter at Breast Height (DBH) of all trees in the sample areas a diameter higher than 8 cm (DBH >= 8 cm) were measured. DBH was measured with a tree calliper bilaterally and averaged. Besides, the height of the trees in the trial area was determined by utilizing the "Blume Leiss" height gauge. Tree heights at each diameter step were attempted to be measured at as equal a number as possible. Five forest stand parameters were calculated using following formulas.

Number of trees (NUM): $Number\ of\ trees = \Sigma Number\ of\ trees \times A$ (N/ha) (1)

Average Stand Diameter (ASD): $\bar{d} = \frac{\sum d_i}{n}$ (cm) (2)

Basal Area (BA): $G_{1.30} = \sum \frac{\Pi}{4} d_{1.30}^2$ (m^2/ha) (3)

Average Stand Height (ASH): $\bar{h} = \frac{\sum h_i}{n}$ (m) (4)

Stand Volume (VOL): $V = \sum V_i$ (m^3/ha) (5)

Image pre-processing and advance of vegetation indices: Geometrical rectifications, radiometric and atmospheric correction of remotely sensed data are often required for many applications (Lu et al., 2002). The satellite images used in the study were received with only the failures due to the sensor being corrected, but the environmental caused failures due to the atmosphere and topography and due to the object were not corrected. For this purpose, geometric correction process was performed in order to establish the balancing model of the relation between the image coordinate system and earth coordinate system (Lillesand and Kiefer, 2004). In this research, ETM image were geometrically rectified into UTM projection using control points taken from topographic maps at 1:25000 scale. The nearest neighbourhood method was used and a root-mean square error of less than 0.8 pixel was obtained for ETM image. Due to the fact that as the sampling method the pixels obtained from the original image were associated to the nearest pixel location on the numerical corrected image, nearest neighbourhood resampling technique affecting the original pixels the least was applied.

The Atmospheric Correction was applied to ETM image data (Chaves, 1996; Ouaidrari et al., 1999; Zhang et al., 1999; Song et al., 2000; Liang et al., 2001) which method is suitable for a specific project depends on the objective of the study and atmospheric data available. The most valuable data to be obtained from remote sensing sensors is sun radiation within a definite band, reflected from any object on the Earth's surface or the emitted thermal radiation (Sarıkaya, 2006). Atmospheric correction is an application in order to obtain data regarding the real reflection values of surface temperatures and objects on satellite images. The atmospheric correction software (ATCOR), used in the study, has been developed by Dr. R. Richter from the German Aerospace Centre (Richter 1996; Richter 1998; Richter 2008). The terrains in this study area are dominantly rugged, hence, the ATCOR-3 module of the PCI Geomatica 9.1® was used (PCI Guide, 2005). The gain and offset, and sun elevation angle were obtained from the ETM image header file. Looking at the configuration of the atmospheric correction parameters (ATCOR-3) used in the study, the parameters; aerosol types, atmospheric definition, solar zenith and azimuth, visibility, adjacency and calibration (Table 2).

Table 2. Used to study the technical characteristics of Landsat ETM+ and parameters of atmospheric correction procedures.

Acquisition Date	2000-07-04
Sensor	Landsat-7 ETM+
Band Combination	1,2,3,4,5,7
Location	Ul Lat = 42.7243004 Ul Lon = 31.1021290 Ur Lat = 42.3644676 Ur Lon = 33.5827637 Ll Lat = 41.1399345 Ll Lon = 30.7223053 Lr Lat = 40.7881851 Lr Lon = 33.1447487
Sun_Azimuth Sun_Elevation	127.7101082 63.1439777
DTM	10 m
Aerosol Type	Rural
Atmospherical Condition	Humid
Calibration File	Geomatica_V91\Atcor\Cal\Landsat7\ Etm_Std1
Visibility	25 km

After geometric rectification and atmospheric correction, a variety of vegetation indices were calculated for study area. These vegetation indices are summarized in Table 3. These included, SAVI, NDVI, LAI, FPAR (Baret and Guyot, 1991; Choudury, 1994), Surface Albedo, PCA and KT (Crist and Kauth, 1986) were applied (Table 3).

Merging of field data end ETM spectral responses: The sample data can be linked to ETM individual bands or the vegetation indices derived from ETM image to extract the spectral responses for each field plot. A plot size from the field was about 0.45 times image pixel size. In calculations in this study, the arithmetic means of radiance values within 3 × 3 pixel window surrounding the target pixel were used for each Landsat ETM+ band and vegetation indices. It is provided that the mean pixel value for each image band and vegetation indices was computed from these homogeneous pixels. The Pearson's correlation coefficient analysis was utilized in the analysis of the relations between the forest stand parameters and ETM+ spectral response relationships. In order to be able to establish a model of the stand parameters, determined with measurements on the terrain, and independent variables, which were spectral reflection values of satellite image data, a multiple linear regression modelling was performed with the package statistics software SPSS 15.0. ® The models producing the highest adjusted R^2 were determined as the best function to model stand structure.

Table 3. Selected remote sensing vegetation used in research

Vegetation Indices	Formula
NDVI	NIR-RED / NIR+RED
SAVI	(NIR-RED)/(NIR+RED+L)(1+L), L=0.5
PCA	-
KT Brightness (KT1) Grenness (KT2) Wetness (KT3)	 0.3037ETM1+0.2793ETM2+0.4743ETM3+0.5585ETM4+0.5082ETM5+0.1863ETM7 -0.2848ETM1+-0.2435ETM2+-0.5436ETM3+0.7243ETM4+0.0840ETM5+-0.1800ETM7 0.1509ETM1+0.1973ETM2+0.3279ETM3+0.3406ETM4+-0.7112ETM5+-0.4572ETM7
LAI FPAR	$-1/a_{2*}\ln(a_0\text{-VI}/a_1)$, (VI=SAVI), a_0=0.5, a_1=0.65, a_2=0.60 C[1-A exp(-B LAI)] A=1, B=0.4, C=1
ALBEDO	ETM1+ETM2+ETM3+ETM4+ETM5+ETM7

RESULTS

The correlation between the reflection values in the visible spectrum of ETM+ satellite was higher. Therefore, the red band, important for the vegetation indices, and infrared bands reflection values were used in the statistical analysis. Selected forest stand parameters were significantly related to some vegetation indices but no related ETM bands depending on the characteristics of the study areas. All of the data contained in the six bands ETM, except the thermal band, was squeezed into the three band component for PCA (Lillesand and Kiefer, 2004). Due to the fact that the information content of the first band resulted in 84% after the conversion of the PCA, the first band was used in this study. Selected forest stand parameters have correlations with ETM and vegetation indices reflectance values (for the full 3 × 3 window) depending on the characteristics of the study area. Table 4 summaries the correlation coefficients between the selected stand parameters and ETM bands, vegetation indices in the study area.

Table 4. Correlation coefficients between forest stand parameters and ETM band, vegetation indices in the study area

	ETM 3	ETM 4	ETM 5	ETM 7	SAVI	NDVI	PCA
ASD	-.091	.067	-.040	-.058	.424(**)	.123	.355(*)
BA	-.029	.290	.183	.138	.693(**)	.116	.669(**)
ASH	.003	.189	.048	-.035	.570(**)	.074	.499(**)
CRC	.018	.207	.244	.191	.134	.006	.251
NUM	.080	.281	.244	.217	.497(**)	-.029	.505(**)
VOL	-.040	.243	.161	.123	.643(**)	.123	.590(**)

	KT1	KT2	KT3	ALBEDO	LAI	FPAR
ASD	.457(**)	.487(**)	-.020	.411(**)	.392(*)	.380(*)
BA	.590(**)	.792(**)	-.223	.708(**)	.761(**)	.755(**)
ASH	.498(**)	.690(**)	-.066	.549(**)	.670(**)	.652(**)
CRC	.087	.080	-.240	.220	.264	.276
NUM	.359(*)	.513(**)	-.217	.500(**)	.570(**)	.569(**)
VOL	.541(**)	.720(**)	-.220	.651(**)	.696(**)	.690(**)

*: P <0 .05, **: p < 0.01

The visible, near and middle infrared wavelengths were not significantly correlated with forest stand parameters; however, vegetation indices most and strong correlations correlation with selected stand parameters. Vegetation indices were most correlated with BA, ASH, VOL and NUM, but NDVI and KT3 were not significantly correlated with forest stand parameters. NDVI and KT3 have weak correlation with forest stand parameters due to homogeneity vegetation structure, land-use and canopy homogeneities in the study area. SAVI was significantly correlated with ASD and NUM and strongly correlated BA, ASH and VOL. PCA was significantly correlated with ASD and NUM and strongly correlated BA, ASH and VOL. KT1, KT2 and ALBEDO was significantly and strongly correlated ASD, BA, ASH, NUM and VOL. Since the NDVI have weak statistical relationship with forest stand parameters at the performed study, the SAVI was used for the generation of the LAI. LAI and FPAR, LAI used in the calculation of, was significantly correlated with ASD and strongly correlated BA, ASH, NUM and VOL.

The forest stand parameters have high correlations with vegetation indices in study area, marking the impacts of different characteristics. The stand structure in study area may be an important factor significantly relationships between vegetation indices spectral signatures BA, VOL and height because these parameters related to forest stand density and species. The optical sensors mainly canopy information and the canopy density regular in study area for this reason NUM had weaker correlations with vegetation indices than did the others. This results in better relationships of vegetation indices with BA, ASH and VOL than ASD and NUM in study area.

Regarding each stand parameter of the ETM+ bands and vegetation indices, in order, simple linear or multiple linear regression models were established. Based on the variable addition and elimination method (Stepwise Selection), KT2 was selected for ASD; KT2, ETM4, ALBEDO, NDVI for BA; KT2, ETM7, LAI, ETM3 for ASH; LAI for NUM and KT2 for VOL (Table 5).

Table 5. Model summaries

Model summary (BA)			
Adjusted R^2	Std.Dt..	F	D.W.
0.617(a) 0.650(b) 0.701(c) 0.753(d)	6.048 5.787 5.350 4.860	65.574 38.207 32.207 31.487	1.652

a. KT2
b. KT2, ETM4
c. KT2, ETM4, ALBEDO
d. KT2, ETM4, ALBEDO, NDVI
Dependent variable: **BA**

Model summary (ASH)			
Adjusted R^2	Std.Dt..	F	D.W.
0.462(a) 0.538(b) 0.582(c) 0.581(d) 0.625(e)	2.638 2.445 2.327 2.328 2.204	35.384 24.291 19.548 28.764 23.205	1.996

a. KT2
b. KT2, ETM7
c. KT2, ETM7, LAI
d. ETM7, LAI
e. ETM7, LAI, ETM3
Dependent variable: **ASH**

Model summary (ASD)			
Adjusted R^2	Std.Dt.	F	D.W.
0.217(a)	3.383	12.110	1.904

a. KT2
Dependent variable: **ASD**

Model summary (NUM)			
Adjusted R^2	Std.Dt.	F	D.W.
0.307(a)	313.126	18.741	2.242

a. LAI
Dependent variable: **NUM**

Model summary (VOL)			
Adjusted R^2	Std.Dt.	F	D.W.
0.506 (a)	53.279	41.934	1.630

a. KT2
Dependent variable: **VOL**

The multivariate exponential regression function resulted in the best model performance for prediction BA, ASH and VOL. Using Landsat ETM+ band 4 and vegetation indices KT2, ALBEDO and NDVI as forecaster variables of basal area, the adjusted R^2 was 0.753 with a standard devotion (Std. Dt.) of 4.86. For the exponential model of height using Landsat ETM+ band 3,7 and vegetation indices LAI, the adjusted R^2 was 0.625 with a standard devotion (Std. Dt.) of 2.20. For volume using vegetation indices KT2, the adjusted R^2 was 0.506 with a standard devotion (Std. Dt.) of 53.28 (Table 6). The models ($R^2 \geq 50.00$) presented in Table 6 were used to generate basal area, stand height and stand volume image output (Figure 4).

Table 6. Regression models for estimation stand parameters

	Regression Parameters ($Y = B_0 + B_1X_1 + ... B_nX_n$)				
	B_0	B_1X_1	B_2X_2	B_3X_3	B_4X_4
ASD	-8.260	0.127(KT2)			
BA	-78.677	0.53(KT2)			
	-77.638	0.623(KT2)	-0.112(ETM4)		
	-67.067	0.467(KT2)	-0.152(ETM4)	0.168(ALBEDO)	
	-82.592	0.376(KT2)	-0.154(ETM4)	0.252(ALBEDO)	0.116(NDVI)
ASH	-18.781	0.170(KT2)			
	-17.718	0.196(KT2)	-0.051(ETM7)		
	-11.274	0.066(KT2)	-0.068(ETM7)	0.118(LAI)	
	-6.805	0.073(ETM7)	0.167(LAI)		
	-9.373	-0.115(ETM7)	0.179(LAI)	0.058(ETM3)	
NUM	-976.183	11.394(LAI)			
VOL	-576.479	3.73(KT2)			

DISCUSSION

While BA, ASH and VOL of natural beech (*Fagus orientalis* L.) stands were significantly correlated to Landsat ETM+ band 3, 4, 7 and vegetation indices KT2, LAI, ALBEDO and NDVI (Table 5). Some vegetation indices, such as NDVI and KT3, were not significantly with selected forest stand parameters. Lu et al., (2004) concluded that linear transformed indices such as PC1, KT1 and ALBEDO were most strongly correlated with forest stand parameters (BA, ASD and ASH). In parallel to this work, NDVI and KT3 were weakly and not significantly correlated with selected forest stand parameters. Also, Lu et al., (2004) concluded that SAVI was not significantly correlated except with selected forest stand parameters (ASD and ASH) in Bragantina study area. But, SAVI was significantly correlated with selected forest stand parameters in this study. So, the SAVI was used for the generation of the LAI. For mapping of aboveground biomass and stand volume the pixel values within the 3 × 3 pixel window surrounding the centre pixel of the field plot were averaged for each Landsat ETM+ band (Hall et al., 2006). The image height model had an adjusted R^2 of 0.65 from ETM+ bands 3, 4 and 5. Also, correlation coefficients generated from tassel cap brightness, greenness and wetness were respectively *R*-values of -0.52, -0.53 and 0.45 (Statistically significant at p=0.05). In this study, image height model had an adjusted R^2 of 0.653 from ETM+ bands 3, 7 and vegetation indices LAI and correlation coefficients generated from tassel cap brightness, greenness and wetness were respectively *R*-values of 0.498, 0.69 and -0.066 (Statistically significant at p=0.05). Hall et al., (2006) concluded that the study focused on method development to estimate stand parameters for conifer component due to the obvious dominance of conifer species. This study focused on method development to estimate select forest stand parameters for the deciduous component (dominance of deciduous species, mostly *Fagus orientalis* L.). The ratio and aspect of *R* values regarding tassel cap culminated in different due to the fact that site conditions and tree species.

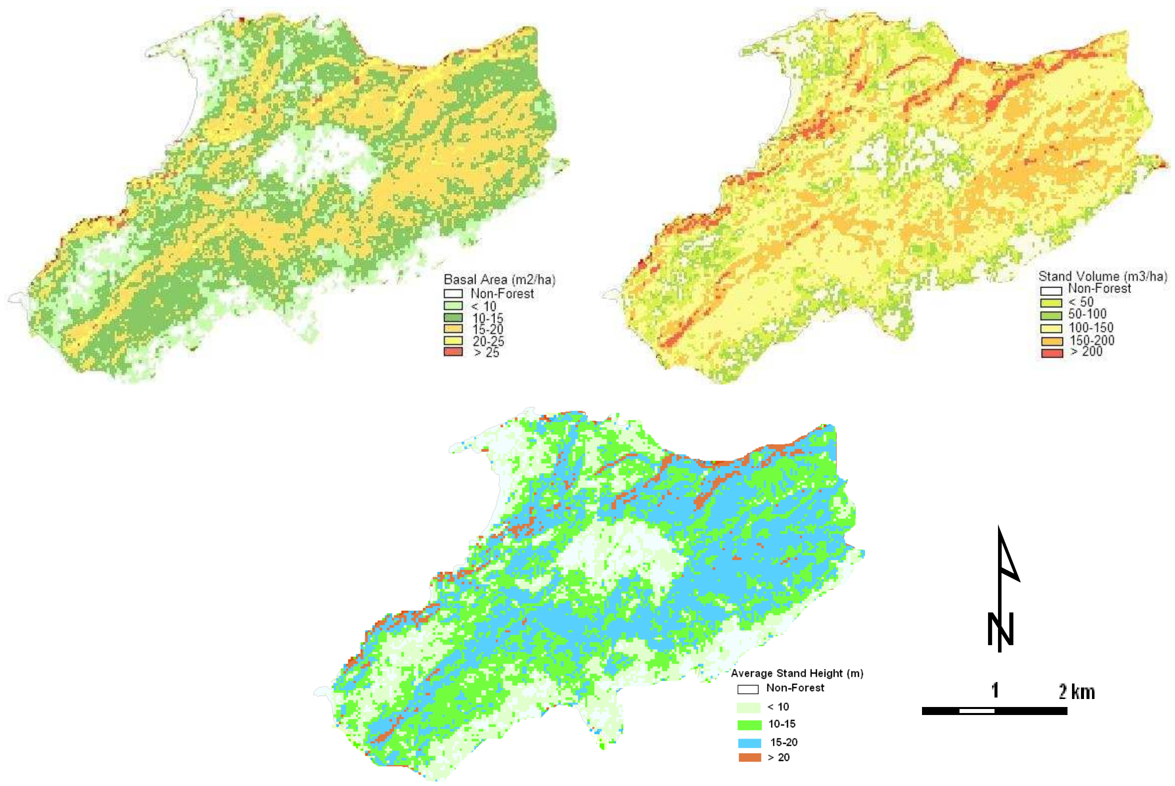

Figure 4. Modelled Basal Area, Stand Volume and Height estimates for the study area.

Freitas et al., (2005) concluded that three vegetation indices (normalized difference vegetation index (NDVI), moisture vegetation index using Landsat's band 5 (MVI5) and moisture vegetation index using Landsat's band 7 (MVI7)) were correlated with measurements of forest structure and models were also developed. At the same time, NDVI was not significantly with selected forest stand parameters for humid and dry seasons. In this study, despite its weak statistical relationships with forest stand parameters, NDVI contributed the established model. The accuracy of elevation and aspect analysis (Carter, 1992) used for atmospheric correction procedure depends on the DTM. In general, DTM resolution 0.25 times the geometric resolution of the satellite image data is enough (Goodenough et al., 1990). In this study, DTM resolution was ~0.35 times the geometric resolution of the Landsat ETM+. The desired DTM resolution ratio increases the accuracy of the results.

CONCLUSION

By the utilization of the Landsat 7 ETM+ image data, vegetation indices KT2 (greenness of the tasselled transform), Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (FPAR), ALBEDO, Soil Adjusted Vegetation Index (SAVI) and PC1 (the first component in a principal components analysis) were significantly correlated with forest stand parameters (especially as Basal Area, Average Stand Height and Stand Volume). In order to be able to make definitions regarding the forest stand based on the relations between remote sensing data and the stand parameters, spectral based regression models were developed. Multiple linear regression models were generated by using the staged regression analysis (Stepwise Selection) method regarding the estimation of stand parameters by the utilization of the relations between the stand parameters and remote sensing data. Models developed for small sampling land plots were applied on the whole of the study area. In future, the study for beech (*Fagus orientalis* L.) stands is going to set an example in ways: providing faster and less expensive observation or measurement, providing inventory estimates, and producing forest thematic maps. The accuracy and practicability of the study depends to different biophysical environment of study area. Also, the deficiencies of available data –especially DEM data used as template in atmospheric correction- were factor in the accuracy study. It is a fact that forest inventory studies at regional and global scales will be valuable by this method regarding time and costs.

REFERENCES

- Astola, H., Bounsaythip, C., Ahola, J., Häme, T., Parmes, E., Sirro, L., Veikkanen, B., 2004. HighForest – Forest parameter estimation from high resolution remote sensing data. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Istanbul, Turkey, Vol. XXXV, Part B, pp. 335-341.
- Baret, F., Guyot, G., 1991. Potentials and limits of vegetation indexes for LAI and APAR assessment. Remote Sensing of Environment, 35 (2–3), 161–173.
- Chaves, S., 1996. Image-based atmospheric corrections revisited and improved. Photogrammetric Engineering & Remote Sensing, 62, 1025–1036.
- Choudhury, B.J., 1994. Synergism of multispectral satellite observation for estimating regional land surface evaporation. Remote Sensing of Environment, 49, 264-274.
- Crist, E.P., Kauth, R.J., 1986. The tasseled cap demystified. Photogrammetric Engineering and Remote Sensing, 52 (1), 81-86.
- Eklundh, L., Harrie, L., Kuusk, A., 2001. Investigating relationships between Landsat ETM sensor data and leaf area index in a boreal conifer forest. Remote Sensing of Environment, 78, 239–251.
- Fazakas, Z., Nilsson, M., Olsson, H., 1999. Regional forest biomass and wood volume estimation using satellite data and ancillary data. Agricultural Forest meteorology, 98-99, 417-425.
- Freitas, S.R., Mello, M.C.S., Cruz, C.B.M., 2005. Relationship between forest structure and vegetation indices in Atlantic Rainforest. Forest Ecology and Management, 218, 353-362.
- Gong, P., Pu, R., Miller, J.R., 1995. Coniferous forest leaf area index estimation along the Oregon transects using compact airborne spectrographic imager data. Photogrammetric Engineering & Remote Sensing, 61, 1107–1117.
- Goodenoughl, D.G., Deguisel, J., Robson, M.A., 1990. Multiple expert systems for using digital terrain models. In. Proceedings of IGARS'90, Washington, pp. 96.
- Hall, R., J., Skakun, R., S., Arsenault, E., J., Case, B., S., 2006. Modelling forest stand structure attributes using Landsat ETM data: Application to mapping of aboveground biomass and stand volume. Forest Ecology and Management, 225, 378-390.
- Holmgren, J., Nilsson, M., Olsson, H., 2003. Estimation of tree height and stem volume on plots using airborne laser scanning. Forest Science, 49, 419−428.
- Holström, H., Fransson, J.E., 2003. Combining remotely sensed optical and radar data in kNN-estimation of forest variables. Forest Science, 49, 409−418.
- İnan, M., 2004. Remote sensıng data for determınıng forest resources. Ph. D. Thesis. İstanbul University.
- Kachhwala, T.S., 1985. Temporal monitoring of forest land for change detection and forest cover mapping through satellite remote sensing. In. Proceedings of the International 6th Asian Conference on Remote Sensing, Hyderabad, pp. 77-83.
- Kalıpsız, A., 1993. Forest mensuration. Forest Faculty, No: 3793, Istanbul University.
- Konukçu, M., 2001. Forests and Forestry. T. R. Ministry of Development, No: 2630.
- Lefsky, M.A., Hudak, A.T., Cohen, W,B., Acker, S.A., 2005. Patterns of covariance between forests stand and canopy structure in the Pacific Northwest. Remote Sensing of Environment, 95, 517-531.
- Liang, S., Fang, H., Chen, M., 2001. Atmospheric correction of Landsat ETM+ land surface imagery—part 1: methods. IEEE Transactions on Geosciences and Remote Sensing, 39, 2490-2498.
- Lillesand, T.M., Kiefer, R.W., 2004. Remote sensing and image interpretation. New York: John Wiley & Sons.

- Lu, D., Mausel, P., Brondizio, E., Moran, E., 2004. Relationships between forest stand parameters and Landsat TM spectral responses in the Brazilian Amazon basin. Forest Ecology and Management, 198, 149-167.
- Makela, H., Pekkarinen, A., 2004. Estimation of forest stands volumes by Landsat TM imagery and stand-level field-inventory data. Forest Ecology and Management, 196, 245–255.
- McRoberts, R.E., Tomppo, E.O., 2007. Remote sensing support for National Forest Inventories. Remote Sensing of Environment, 110 (4), 412-419.
- Özhan, S., 1991. Land-use technique. M. Sc. Thesis. Istanbul University.
- PCI Guide, 2005. Geomatica focus user guide. Canada: PCI Geomatica.
- Quaidrari, H., Vermote, E.F., 1999. Operational atmospheric correction of Landsat TM data. Remote Sensing of Environment, 70, 4-15.
- Reese, H., Nilsson, M., Sandstrom. P., Olsson, H., 2002. Applications using estimates of forest parameters derived from satellite and forest inventory data. Computers and Electronics in Agriculture, 37, 37-55.
- Richter, R., 1996. A spatially adaptive fast atmospheric correction algorithm. International Journal Remote Sensing, 17, 1201-1214.
- Richter, R., 1998. Correction of satellite imagery over mountainous terrain applied. Optics, 37, 4004-4015.
- Richter, R., 2008. Atmospheric/Topographic correction for satellite imagery. ATCOR-2/3 user guide. Wessling: DLR IB 565-01/08.
- Roy, P.S., Ravan, S.A., 1996. Biomass estimation using satellite remote-sensing data–an investigation on possible approaches for natural forest. Journal of Biosciences, 21, 535–561.
- Rubner K (1960) Die pflanzengeographischen grundlagen des waldbaues. Berlin: Neumann Verlag.
- Sarıkaya, Ö.V., 2006. Water quality analysis in the Golden Horn (Haliç) with the help of Ikonos imagery. M. Sc. Thesis. Istanbul University.
- Song, C., Woodcock, C.E., Seto, K.C., Lenney, M.P., Macomber, S.A., 2001. Classification and change detection using Landsat TM data: When and how to correct atmospheric effects? Remote Sensing of Environment, 75, 230-244.
- Zhang, M., Carder, K., Muller-Karger, F.E., Lee, Z., Goldgof, D.B., 1999. Noise reduction and atmospheric correction for coastal applications of Landsat Thematic Mapper imagery. Remote Sensing of Environment, 70, 167-180.
- Zheng, D., Rademacher, J., Chen, J., Crow, T., Bresee, M., Le Moine, J., Ryu, S., 2004. Estimating aboveground biomass using Landsat 7 ETM+ data across a managed landscape in northern Wisconsin, USA. Remote Sensing of Environment, 93, 402-411.