ASSESSMENT OF THYME REDUCTION USING MULTI-TEMPORAL SATELLITE DATA AND *IN-SITU* SPECTRORADIOMETRIC MEASUREMENT: ALTIOLUK PLATEAU, KOCAELI-TURKEY

Cankut D. Ince[1,*], Emre Ozelkan[2] and Sinasi Kaya[3]

[1] Kocaeli University, Engineering Faculty, Department of Geomatics Engineering, Umuttepe, 41380, Kocaeli, Turkey
[2] Istanbul Technical University, Agricultural & Environmental Informatics Research Center, 34469, Maslak, Istanbul, Turkey
[3] Istanbul Technical University, Faculty of Civil Engineering, Department of Geomatics, 34469, Maslak, Istanbul, Turkey

Presented at the 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region (MESAEP), September28 - October 01, 2013, Istanbul, Turkey

ABSTRACT

Nature is sensitively fragile to the changes in living bodies like plants, animals and humans that create the balance. The absence, decrease or variation of any pieces in natural life cycle may change this. In this study, the relationship between plant and animal species are examined. It is recognized and observed that the area of thyme, which is one of the most important flora members in Altioluk Plateau-Kocaeli/Turkey, varies depending on the presence of animals. Decrease in stockbreeding highly influences the thyme area in the plateau. The animals instinctively destroy the harmful plants, such as fern, which obstructs the growth of the thyme. Based on this reality, the changes in thyme area were examined using *in-situ* hyperspectral and satellite multispectral remote sensing techniques. In the work done, initially, the hyperspectral signatures of the species that were present in the plateau area were collected on 15. 09. 2012. Afterwards, these signatures were converted to the Landsat spectral specialties and were matched with 8 different dated Landsat images (TM and +ETM) of the plateau varying from 1987 to 2012 using spectral angle mapper (SAM). Finally, the obtained thyme area results were correlated with the animal values using correlation and regression analysis. In conclusion, it can be stated that the thyme area and the total number of animals, which is the sum of bovine, ovine, beehive and horse, were found to be correlated with R = 0.8871 (R^2 = 0.7869).

KEYWORDS:
thyme, stockbreeding, spectral angle mapper, remote sensing

* Corresponding author

1. INTRODUCTION

The presence of animals and plant species are in continuous interaction with each other in nature. Altioluk Plateau/Turkey, which is still regarded as an unspoilt area, hosts different flora species. One of the most important flora species of Altıoluk Plateau is "*Thymus longicaulis C. Presl. longicaulis var. subisophyllus*" [1]. The plateau's thyme flora, which is able to flower from spring to autumn, is under the interest of visitors. Besides, thyme contains essential oil that has antibacterial and antifungal characteristics, and it is well-known that tea of thyme has antioxidant properties [2-6]. Moreover, thyme increases the antimicrobial, antibacterial, anti-oxidative and aromatic properties of honey, and is a quality nectar source for bees, and a herb for dairy cattle [7, 8]. It also contributes to flower honey by providing a good aroma [9, 10]. It is also a natural beekeeper. Thymol in thyme is the main active ingredient used against *Varroa* mite [11].

Thyme presence in the Altioluk Plateau is under threat of ferns that is due to a decrease in the animals. Ferns that are harmful for animal health have been crushed and broken by the animals continuously and inherently [12]. Since stockbreeding activities have been taken over by the big companies (i.e. facilities) from the villagers, the animals started to provide all their needs without any interaction with nature; thus, they do not nibble on the plateau any more, and this fact causes a significant decrease in the thyme-covered areas. Accordingly, shepherds, responsible for animals, do not cut ferns for the obstruction of spore production of ferns. In addition, peasants have abandoned animal husbandry activities because of factors, such as changes in animal husbandry policies in Turkey, or proximity to province of Kocaeli which is a highly industrialized area [13]. Therefore, the peasants do not any more need animals such as horses and bees.

Remote sensing is a useful technique to illustrate the distribution of the species of natural landscapes [14-17]. Spectral angle mapper (SAM), a pixel-based supervised classification technique, defines spectral angle similarity between reference spectra and the target spectra [18]. SAM enables to suppress the impact of the changes on illumination (i.e. shading) to emphasize the target reflectance [19]. SAM has broad application areas, such as land-use/cover mapping [20], agriculture crop mapping [21], mineral mapping [22], tree species classification [23], and wetland mapping [24].

In this study, the relationships between thyme and animals were investigated using *in-situ* spectroradiometric hyperspectral measurements and multispectral satellite images. Briefly, the collected hyperspectral signatures from Altioluk plateau were matched with Landsat images of the plateau by using SAM to determine the thyme areas. Thyme areas and the number of existing animals from 1987 to 2012 were associated with correlation and regression analysis to indicate the strong relationship and balance among this plant and animals. It is also demonstrated that remote sensing is a practical and useful technique to monitor variations in the thyme area, which was determined to be highly correlated with variations in the animal presence, and the obtained results were found to be highly significant.

2. MATERIALS AND METHODS

2.1 Study area

Altioluk Plateau is within the coordinates of 40º37'40''N – 30º06'W in northwest and 40º37'16''N - 30º07'01''W in southeast, with an approximate altitude of 1350 m. Climate of the region is of typical Marmara climate, which is the transition climate among continental, Black Sea and Mediterranean climates. Winter is not as warm as the Mediterranean climate, and not as cold as the Continental Climate, the wintertime can frequently bring snow at high altitudes, with temperatures dropping below zero, and summer is not as rainy as the Black Sea climate and not as dry as continental climate [25]. Although the most appropriate climate for thyme is Mediterranean, as it may resist to cold weather and pursue its growth, it can be stated that the climate of the plateau is suitable for the growth of thyme [26].

2.2 Methods

Generally, the study can be summarized in four steps: i) the spectroradiometric measurements in the plateau area were performed to get the spectral signature (i.e. curves) of the species, ii) the hyperspectral curves were re-sampled to the spectral specialties of Landsat, iii) the spectral signatures of the *in-situ* and satellite remote sensing data were matched to determine the thyme areas using SAM, and iv) values of the determined areas using remote sensing and animal data that is obtained from local government were correlated. The general overflow of data acquisition and result production is shown in Fig. 1.

The coordinates of the measurement points, which were obtained using global positioning system (GPS) device, are shown with black points on 2011 Landsat image in Fig. 1. An ASD Handheld Field Spectroradiometer, which measures within 325-1075 nm wavelengths range, was used to obtain spectral signature of species in the measurement area as shown in Fig.1.

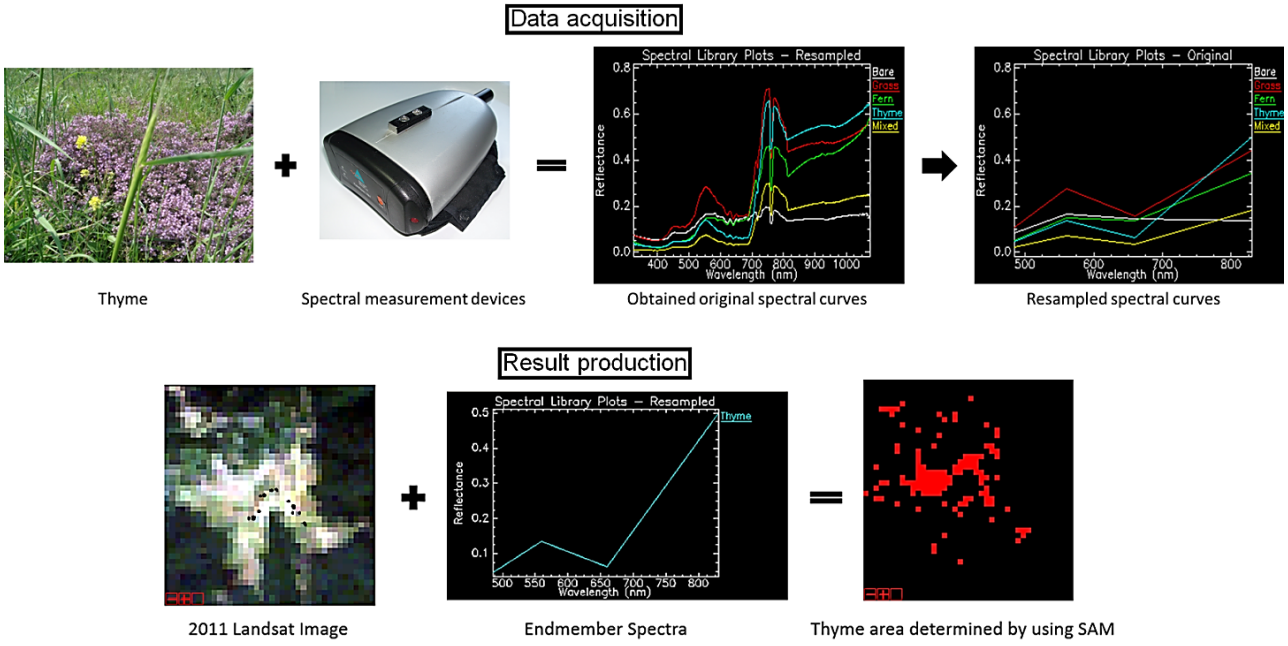


FIGURE 1 – Data acquisition and result production.

18.09.1987 and 20.09.2011 dated Landsat 5 TM and 27.09.1999, 22.09.2003, 24.09.2004, 17.09.2007, 14.09.2009, and 14.09.2012 dated Landsat +ETM satellite images were used to show the multi-temporal changes of the study area. All the used satellite data is obtained from the United States Geological Survey's (USGS) Landsat Surface Reflectance Climate Data Record (CDR) that is atmospherically corrected and has 30-m spatial resolution. Spectral features of the hyperspectral were re-sampled to the spectral features of Landsat multispectral data (as it is well-known that Landsat 5 TM and +ETM have 7 spectral bands) (Fig. 1). Only the first 4 bands (blue, green, red, and near-infrared) of Landsat can match with hyperspectral data. Generated re-sampled data of end member spectra were matched with Landsat images spectral signatures of Altioluk Plateau by using SAM algorithm for the purpose of determining the multi-temporal changes of thyme areas incorporating 8 different images (Fig. 1). SAM is a physically-based spectral classification that uses an n-D angle to match pixels to reference spectra [18, 19, 27] whose expression is given in Equation 1.

$$\theta = \cos^{-1}\left(\frac{\sum_{i=1}^{n} t_i r_i}{\sqrt{\sum_{i=1}^{n} t_i^{\,2} \sum_{i=1}^{n} r_i^{\,2}}}\right) \qquad (1)$$

where; θ is spectral angle created by SAM, n is the number of the studied spectral bands, t and r are the reflectance of the investigated and the reference spectrum.

SAM algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra, and treating them as vectors in space with dimensionality equal to the number of bands (Fig. 2) [18, 19, 27].

The study area, Altioluk Plateau, is within the border of Sultaniye village. Local government data archive of Sultaniye village, which is continuously regenerated by the Community Council of the village with affidavits, including the long-term information of Altioluk Plateau's animal data (Table 1) that was used to associate with long-term (1987-2012) remote sensing analysis results. Remote sensing findings and animal data were correlated using correlation and regression analysis. The results were presented with simple linear regression plots for each animal species, and the correlation values were indicated as Pearson correlation coefficient (R) and coefficient of determination (R^2).

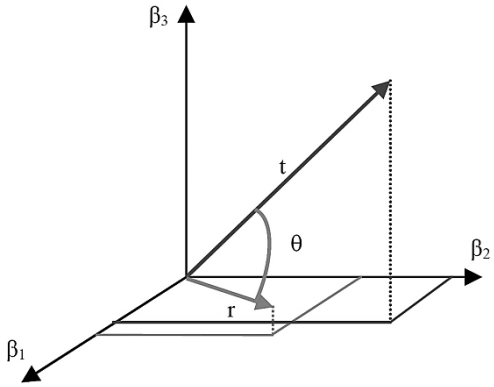


FIGURE 2 – Presentation of spectral angle.

3. RESULTS AND DISCUSSION

Landsat images of the study area were classified to show the temporal changes in thyme area using SAM for each of the 8 different dated images varying from 1987 to 2012 (Fig. 3). In addition, the animal data belonging to the corresponding years are listed in Table 1. The results indicate that the presence of all animal species had decreased dramatically from 1987 to 2012, and as expected, this decrease had an adverse effect on the thyme area. (Table 1, Fig. 3). The decreases were found to be as follows: 68.46 % in bovine, 76.47 % in ovine, 62.96% in bee, 97.14% in horse, 73.72% in total animal data, and accordingly, 54.93% in the thyme area.

TABLE 1 - Thyme area results of SAM and the animal presence values.

Year	Thyme Area (m^2)	Bovine	Ovine	Beehive	Horse	Total Amount of Animals
1987	319500	650	1700	270	70	2690
1999	167400	300	900	170	30	1400
2003	239400	250	1200	200	25	1675
2004	114300	300	950	200	25	1475
2007	160200	325	700	160	15	1200
2009	121500	250	600	120	10	980
2011	108000	220	350	120	5	695
2012	144000	205	400	100	2	707

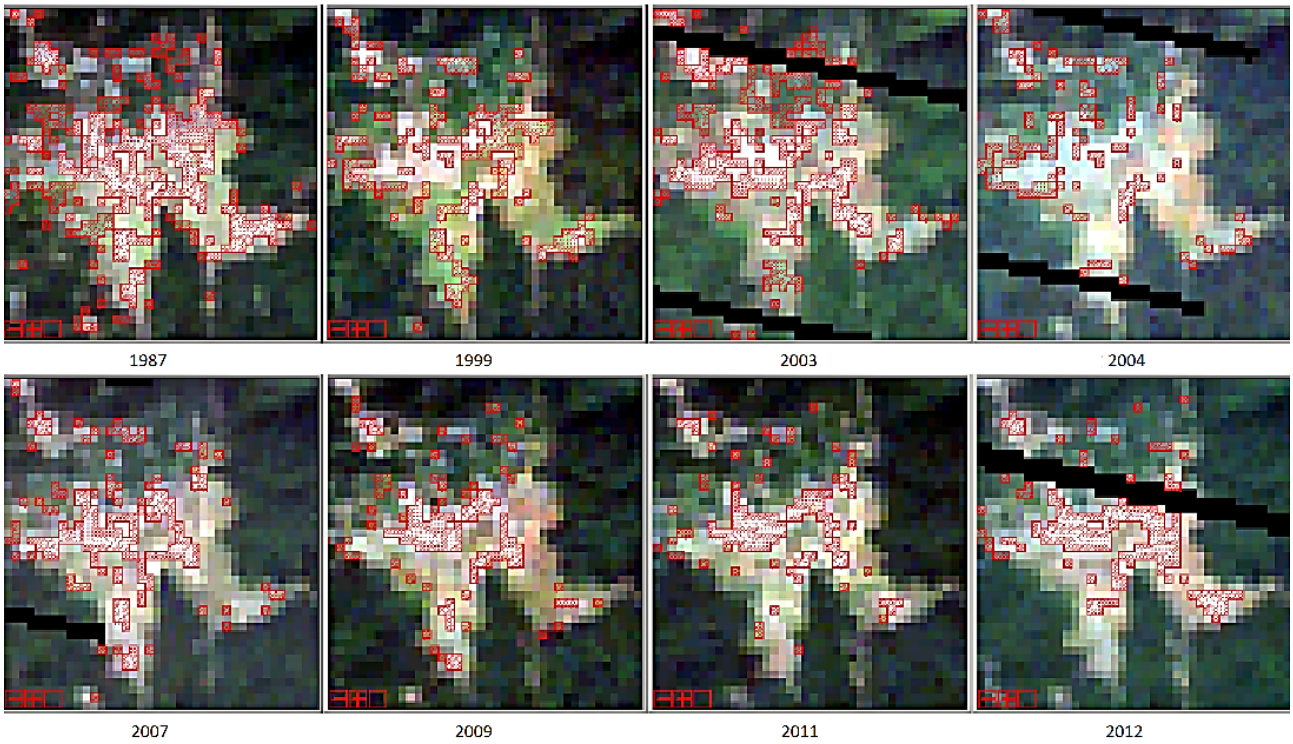


FIGURE 3 – Determined thyme areas of Altioluk plateau using SAM between 1987 and 2012.

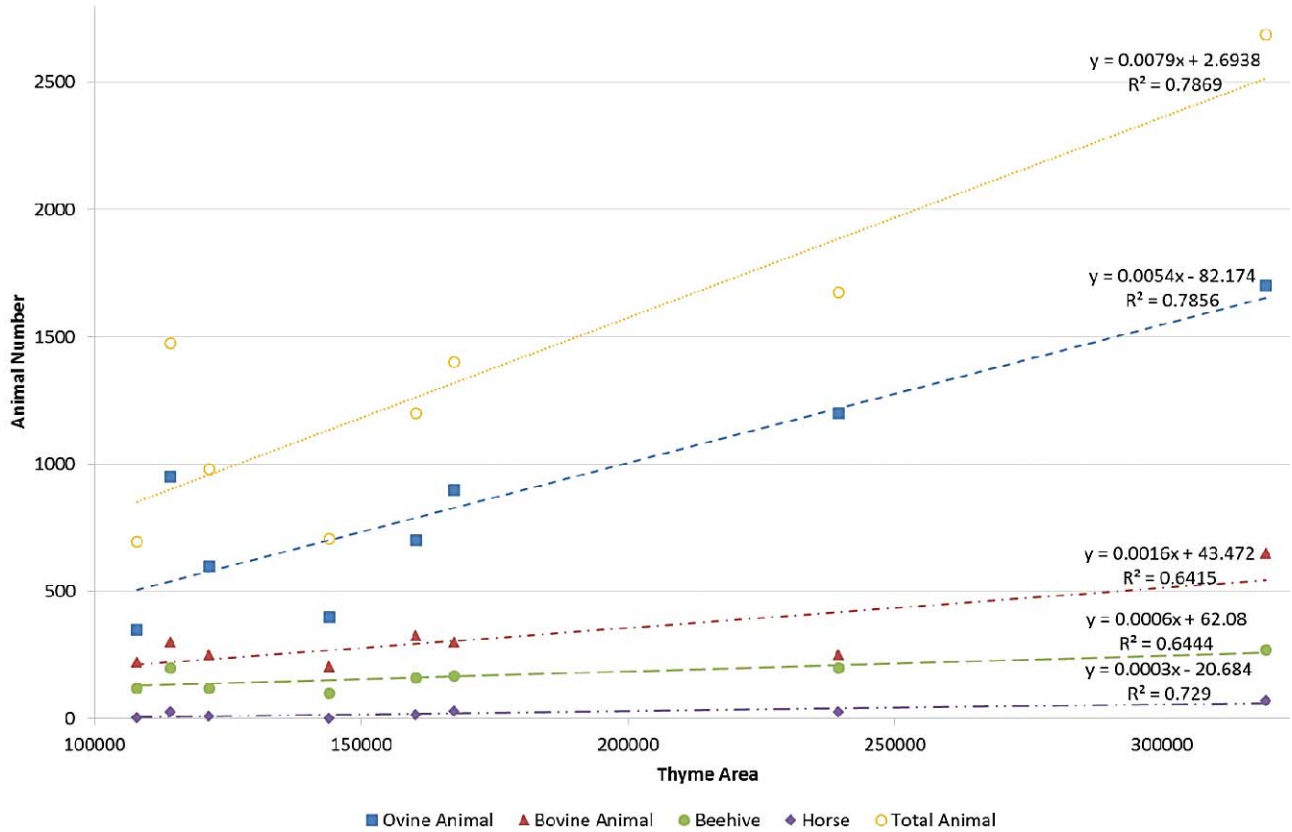


FIGURE 4 – Correlations between animal presence and thyme areas (m^2) using SAM between 1987 and 2012

The animal data of each species and the thyme area values were analysed by correlation and regression analysis. The results were given in simple linear regression plots in Fig. 4. From 1987 to 2012, variations in thyme area were found to be highly correlated with variations in total animals (bovine and ovine animals, horse, and bee) figured with R = 0.8871 (R^2=0.7869), for ovine animal with R = 0.8863 (R^2 = 0.7856), for horse with R=0.8538 (R^2= 0.7290), for beehive with R=0.8028 (R^2=0.6444), and for bovine animal R=0.8009 (R^2=0.6415) (Fig. 4). All correlation results of the study are significant and classified as strong and high correlated, which is defined as R>0.8 [28].

4. CONCLUSIONS

In this study, indicating the interaction between thyme areas and the animal presence using remote sensing techniques was intended. For this purpose, *in-situ* hyperspectral and satellite multispectral remote sensing data were integrated. The temporal changes of thyme area were determined and correlated with local government statistical data of animal species. The results, which were found to be highly significant, demonstrated that remote sensing techniques allow rapid and reliable analysis, especially when used together with data from different sources. This study emphasizes the importance of remote sensing for the purpose of monitoring nature.

For future researches, different classification techniques such as Linear Spectral Unmixing, Spectral Information Divergence and Spectral Feature Fitting can be compared. Moreover, different satellite images with different spatial and spectral resolution can be examined and compared. The phenological development of thyme can be considered, and the field studies can be extended to different seasons. The variations in meteorological parameters, such as temperature and precipitation that influence the phenological stages of thyme can be interesting to examine. In the present study, the interaction between thyme and fern was evaluated due to the field observations and the literature knowledge; in addition to this, the fern areas can be determined and the variations in thyme area can be investigated by considering the variations in fern area in the future studies.

ACKNOWLEDGMENT

The authors would like to thank “USGS” for Landsat images, “Kocaeli Province, Kartepe District Directorate of the Ministry of Food, Agriculture and Livestock” for gathering animal data, and “The Center for Satellite Communications & Remote Sensing” for their permission to use spectroradiometer devices.

The authors have declared no conflict of interest.

REFERENCES

[1] Kizilarslan, C. and Ozhatay, N. (2009) Local names of some plants from the south part of İzmit (Northwest Turkey). J. Fac. Pharm. Istanbul, 40 (2008-2009), 37-46.

[2] Baser, K.H.C., Ozek M., Tumen, G. and Sezik, E. (1993) Composition of the essential oils of Turkish origanum species with commercial importance. Essent.Oil Res., 5, 619-623.

[3] Ozguven, M. and Kirici, S. (2002) Composition of the essential of thymus vulgaris l.clones of different origins in the Çukurova conditions. Workshop on Agricultural and Quality Aspects of Medicinal and Aromatic Plants. May 29-June 01-2001 Adana/ TURKEY, 243-254.

[4] Kizil, S., Uyar, F., and Sagir, A. (2005) Antibacterial activities of some essential oils against plant pathogens. Asian Journal of Plant Sciences, 4, 225-228.

[5] Aydin, S. (1996) Origanum onites L. pharmacology of oil-under water (in Turkish). Anadolu Universities’ Health Sciences Institute. Ph.D Thesis, 229.

[6] Knezevic, S.V., Kosalec, I., Babac, M., Petrovic, M., Ralic, J., Matica, B. and Blazekovic, B. (2012) Antimicrobial activity of thymus longicaulis c. presl essential oil against respiratory pathogens. Central European Journal of Biology, 7:6, 1109-1115.

[7] Ortiz, P.l., and Fernandez, I. (1992) Microscopic study of honey and apiary pollen from the province of Sevilla. Acta Botanica Malacitana, 17, 83-93.

[8] General Directorate of Forestry (2013) Honey forest action plan (in Turkish). http://web.ogm.gov.tr/diger/BalOrmani/Dokumanlar/BAL_ORMANi_EYLEM_PLANi.pdf

[9] Sonmez, B. (2004) Honey's Place and Importance in Human Health (in Turkish). Uludag Bee Journal, August, 127-130.

[10] Mamary, M.A., Meeri, A. and Habori, M. (2002) Antioxidant activities and total phenolics of different types of honey. Nutrition Research, 22, 1041-1047.

[11] Calderone, N.W. (1999) Evaluation of formic acid and a thymol-based blend of natural products for the fall control of Varroa jacobsoni (Acari: Varroidae) in colonies of Apis mellifera (Hymenoptera: Apidae). Journal of Economic Entomology, 92, 253-260.

[12] Hartig, K. and Beck, E. (2003) The bracken fern (*Pteridium Arachnoideum* (Kaulf.) Maxon) dilemma in the Andes of Southern Ecuador. Society for Tropical Ecology, ECOTROPICA 9, 3-13.

[13] Yurdakul, S. (2007) Transformation needs of livestock sector in the EU harmonization process (in Turkish). State Planning Organization Expertise Thesis, Publication No: DPT: 2707, General Directorate of Economic Sectors and Coordination, ISBN 975 – 19 – 4013 - 1.

[14] Kaya, S., Seker, D.Z. and Tanik, A. (2012) Analysis of urbanized areas using V-I-S components model. Fresenius Environmental Bulletin, 21:11, 3243-3248.

[15] Seker, D.Z., Kaya, S., Alkan, R.M., Tanik A. and Saroglu, E. (2008) 3D coastal erosion analysis of Kilyos-Karaburun region using multi-temporal satellite image data. Fresenius Environmental Bulletin, 17:11b, 1977-1982.

[16] Kaya, S. (2007) Multi-temporal Analysis of Rapid Urban Growth in Istanbul Using Remotely Sensing Data. Environmental Engineering Science, 24:2, 228-233.

[17] Musaoglu, N., Seker, D.Z., Kabdasli, S., Kaya, S., and Duran, Z. (2004) Using remote sensing and GIS for the assessment of visual attributes; case study of the south coastal zone of Turkey. Fresenius Environmental Bulletin, 13:9, 854-859.

[18] Yonezawa, C. (2007) Maximum likelihood classification combined with spectral angle mapper algorithm for high resolution satellite imagery. International Journal of Remote Sensing, 28:16, 3729-3737.

[19] Chen, J., Wang, R. and Wang, C. (2008) A multiresolution spectral angle-based hyperspectral classification method. International Journal of Remote Sensing, 29:11, 3159-3169.

[20] Petropoulos, G.P., Vadrevu, K.P. and Kalaitzidis, C. (2013) Spectral angle mapper and object-based classification combined with hyperspectral remote sensing imagery for obtaining land use/cover mapping in a Mediterranean region. Geocarto International, 28:2, 114-129.

[21] Rao, N.R. (2008) Development of a crop-specific spectral library and discrimination of various agricultural crop varieties using hyperspectral imagery. International Journal of Remote Sensing, 29:1, 131-144.

[22] Van der Meer, F. (1997) Mineral mapping and Landsat thematic mapper image classification using spectral unmixing. Geocarto International, 12:3, 27-40.

[23] Peña, M.A., Cruz, P. and Roig, M. (2013) The effect of spectral and spatial degradation of hyperspectral imagery for the Sclerophyll tree species classification. International Journal of Remote Sensing, 34:20, 7113-7130.

[24] Jollineau, M. Y. and Howarth, P. J. (2008) Mapping an inland wetland complex using hyperspectral imagery. International Journal of Remote Sensing, 29:12, 3609-3631.

[25] Sensoy, S., Demircan, M., Ulupinar, Y. and Balta, Z. (2008) Climate of Turkey (in Turkish). http://www.mgm.gov.tr/FILES/iklim/turkiye_iklimi.pdf

[26] Bayram, E. (2003) Thyme production (in Turkish). Ege University, Agricultural Application and Research Centre. Technical Bulletin, 42, ISSN 1300-3518.

[27] Luc, B., Deronde, B., Kempeneers, P., Debruyn, W. and Provoost, S. (2005) Optimized spectral angle mapper classification of spatially heterogeneous dynamic dune vegetation, a case study along the Belgian coastline. The 9th International Symposium on Physical Measurements and Signatures in Remote Sensing (ISPMSRS). Beijing, October 17-19, 2005.

[28] Taylor, R. (1990) Interpretation of the correlation coefficient: A basic review. Journal of Diagnostic Medical Sonography, 6:1, 35-39.

Received: June 05, 2014
Accepted: June 13, 2014

CORRESPONDING AUTHOR

Cankut D. Ince
Kocaeli University
Engineering Faculty
Department of Geomatics Engineering
41380 Umuttepe, Kocaeli
TURKEY

E-mail: cankut00@yahoo.com

FEB/ Vol 23/ No 12/ 2014 – pages 3007 – 3012