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Prof. Dr. Oğuzhan DOĞANLAR

Assist. Prof. Dr. Figen CERİTOĞLU

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Chapter 1

INTERACTIONS BETWEEN CONE PRODUCTION AND GROWTH CHARACTERISTICS IN NATURAL STANDS OF ANATOLIAN BLACK PINE

Yunus ESER[1]

1 Asst. Prof. Yunus ESER: Department of Forestry, Atabey Vocational School, Isparta University of Applied Sciences, Turkey. ORCID ID: https://orcid.org/0000-0001-9575-1162 / yunuseser@isparta.edu.tr

1. INTRODUCTION

Anatolian black pine [*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe] is one of the five sub species as black pine (*Pinus nigra* Arnold.) (Gaussen et al., 1964; Caudullo et al., 2017). The species is one of the most important forest tree species by 4.2 million ha natural distribution which of 18% of Turkish forest area (OGM, 2022). It grows in large area in different ecological conditions of Euro-asia such Cyprus, Russia, Turkey, and Ukraine at between 100 and 1900 m asl. (Figure 1, EUFORGEN, 2009).

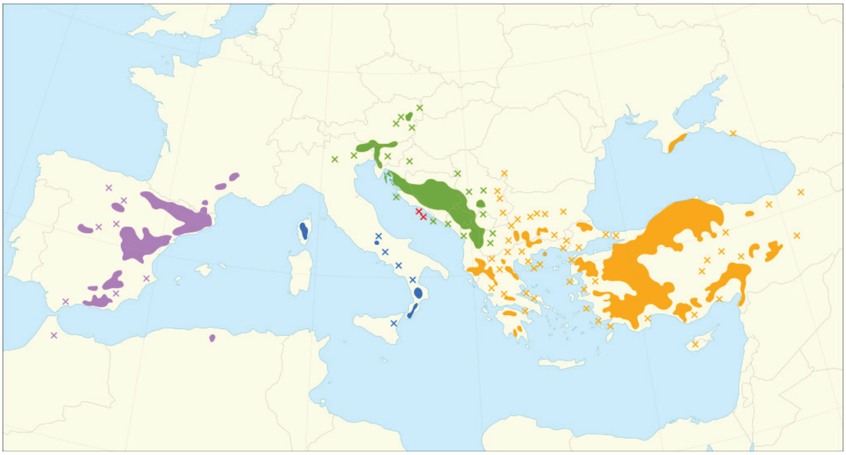

Figure 1. *Natural distribution of Pinus nigra (EUFORGEN, 2009)*

It is also exotic forest tree species in different countries. The species is one of the most important commercial and ecological tree species of afforestation (Ayan et al. 2017) and other forestry practices because of resistance to shadow, drought and frost (Saatcioglu, 1976; Yaltırık, 1993). Many studies were carried out in silvicultural (i.e., Alptekin, 1986; Güner, 2001; Gülcü, 2002; Yazıcı and Babalık, 2011; Uysal, 2015; Ozel et al., 2018; Cercioglu, 2018; Ertugrul and Bilir, 2020; Eser, 2021; Yazıcı, 2022), and other forestry practices (i.e., Eser, 2014; Yazıcı and Catal, 2019) because of large distribution and advantages of Anatolian black pine recently. Ayan et al. (2017) reported that Anatolian black pine is used widely in afforestation practices of Turkey for conversion of degraded forest to productive forest or different forestry purposes. It is getting importance of seed/cone production and estimation of the related growth characteristics in the production of the species.

Estimations of relations among growth and reproductive traits are guide for forest managers in forestry practices. It is clear that the interactions could be extracted for many forestry practices such as wood production. However, while many studies were carried out in natural and artificial populations of different forest tree species (i.e., Boydak, 1977; Nikkanen and Velling, 1987; Eler, 1990; Yazgan and Ozel, 2013; Catal et al., 2018; Yazıcı and Bilir, 2017), there were limited studies in Anatolian black pine (i.e., Bilir et al., 2017; Cercioglu and Bilir, 2018) in estimations of correlations among growth and reproductive characteristics. Besides, it is known that interactions of growth and reproductive characteristics can be effected by many biological and environmental factors (i.e., Yazıcı and Turan, 2016). Relations among some growth and cone productions were discussed based on estimations to contribute forestry practices such as forest tending and seed productions of Anatolian Black pine.

2. CHARACTERISTICS

In this study, fifty trees from each of eight natural stands (Table 1, Figure 2) selected based on habitat classifications (**H1-H8**) of Eser (2014) were sampled (Figure 3).

Figure 2. *Some of the sampled trees*

Figure 3. *Some of the sampled stands*

The growth characteristics as diameter at base (**D_0**), diameter at breast height (**$d_{1.30}$**), and tree height (**TH**) were measured in 2022. Numbers of two-year mature cones (**CN**) of the sampled trees were taken from Eser (2023). In this study, pure stands were sampled from similar crown closure ratio. Besides, the sampled trees were assumed at the same age class in the study.

The habitat classes were compared for the characteristics by model of one-way linear analysis of variance. Relations among the characteristics were estimated at SPSS (SPSS, 2011) package.

Table 1. *Some geographic details of the natural stands*

Habitat classes	Latitude (N)	Longitude (E)	Altitude (m)	Slope%	Aspect
H1	24°47′35″	41°34′810″	1639	45	South-west
H2	25°73′22″	41°55′781″	1454	15	South
H3	24°45′87″	41°35′280″	1549	55	West
H4	25°64′55″	41°53′705″	1445	35	North-west
H5	25°98′72″	41°43′864″	1601	40	North-west
H6	25°43′04″	41°42′589″	1389	20	North-east
H7	24°80′19″	41°40′527″	1256	50	North-west
H8	24°99′33″	41°44′925″	1292	5	North-west

Averages and ranges of the characteristics were given in Table 1 according to habitat classes. H5 had the highest averages of the diameter at base (53.0 cm), diameter at breast height (44.4 cm), and tree height (14.9 m) showed the highest growth in H7. They were the lowest for diameter at base (45.0 cm) in H3, diameter at breast height (36.8 cm) in H8, and tree height (13.1 m) in H6 (Table 2, Figure 4). Cone numbers varied between 39.8 (H6) and 84.2 (H5) (Table 2, Eser, 2023). Similar variations were also reported in populations of the species (Uysal, 2015; Cercioglu, 2018). The results indicated importance of selection of growth characteristics and cone production in the species.

Table 2. *Averages ($\bar{x}$) and ranges of the characteristics in habitat classes*

Habitat	D_0		$d_{1.30}$		TH		CN	
classes	$\bar{x}$*	**range**	$\bar{x}$	**range**	$\bar{x}$	**range**	$\bar{x}$	**range**
H1	48.5^{c}	31.0 - 67.0	41.4^{de}	27.5 - 58.0	10.3^{a}	8.0 - 12.5	63.8^{bc}	22 - 180
H2	48.2^{c}	33.0 - 58.0	39.5^{cd}	31.0 - 52.0	11.4^{c}	10.0 -13.5	73.6^{cd}	32 - 180
H3	45.0^{a}	33.5 - 59.0	37.3^{bc}	27.0 - 50.5	10.8^{b}	8.0 - 13.0	63.4^{bc}	22 -196
H4	51.5^{d}	41.0 - 64.0	42.1^{e}	31.0 - 52.0	13.4^{d}	10.5 - 14.5	71.7^{cd}	24 -168
H5	53.0^{d}	37.0 - 70.0	44.4^{f}	29.5 - 61.0	14.7^{f}	10.5 - 19.0	84.2^{d}	28 - 188
H6	43.1^{a}	27.0 - 53.0	34.3^{a}	23.5 - 46.0	13.1^{e}	11.0 - 15.5	39.5^{a}	12 - 126
H7	45.6^{b}	30.0 - 59.0	37.3^{bc}	25.0 - 50.0	14.9^{f}	12.5 - 18.0	53.2^{ab}	14 - 168
H8	46.0^{bc}	29.0 - 58.0	36.8^{b}	24.5 - 47.0	13.3^{e}	10.0 - 16.0	54.2^{ab}	14 - 180

**; The same letters showed not significantly different at p>0.05 among the stands/ habitat classes.*

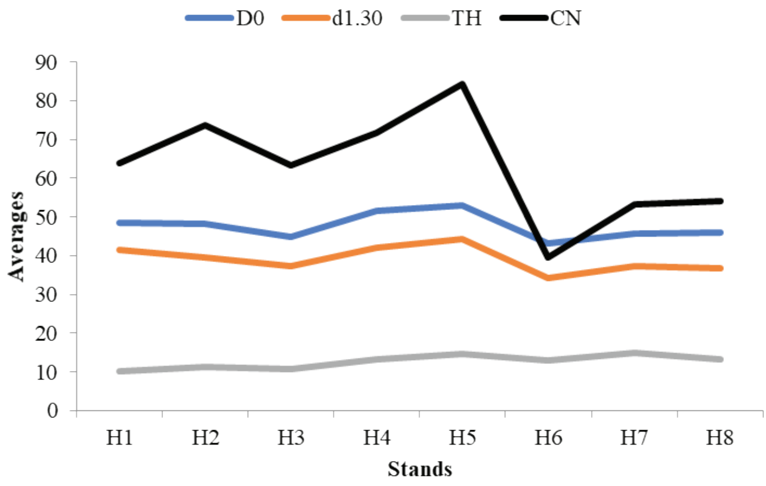

Figure 4. *Averages of the characteristics*

Individual trees of stand/ habitat class showed large differences for the characteristics. For instance, they were ranged from 31.0 cm to 67.0 cm for diameter at base, from 27.5 cm to 58.0 cm for diameter at breast height, from 8.0 m to 12.5 m for tree height in H1 (Table 2, Figures 5 and 6). They were ranged from 33.0 cm to 58.0 cm for diameter at base, from 31.0 cm to 52.0 cm for diameter at breast height, from 10.0 m to 13.0 m for tree height in H1 (Table 2, Figure 7).

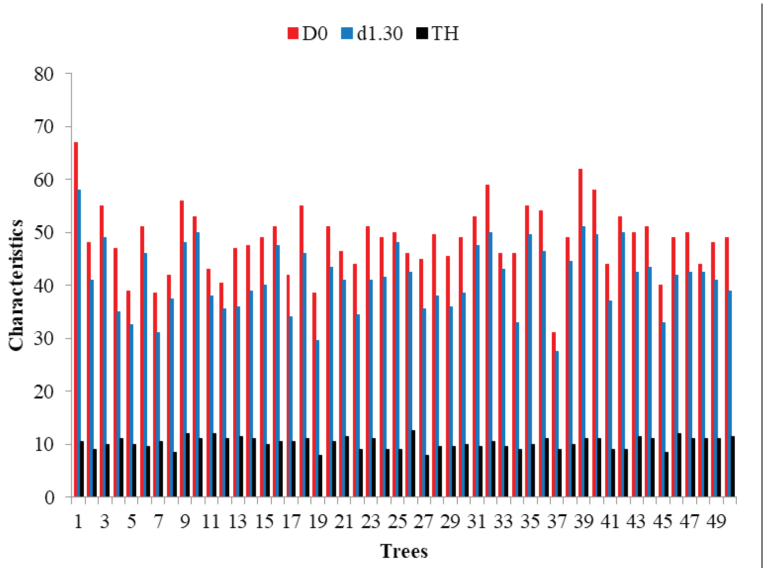

Figure 5. *Individual growth characteristics in H1*

Figure 6. *Individual tree height variation in H1*

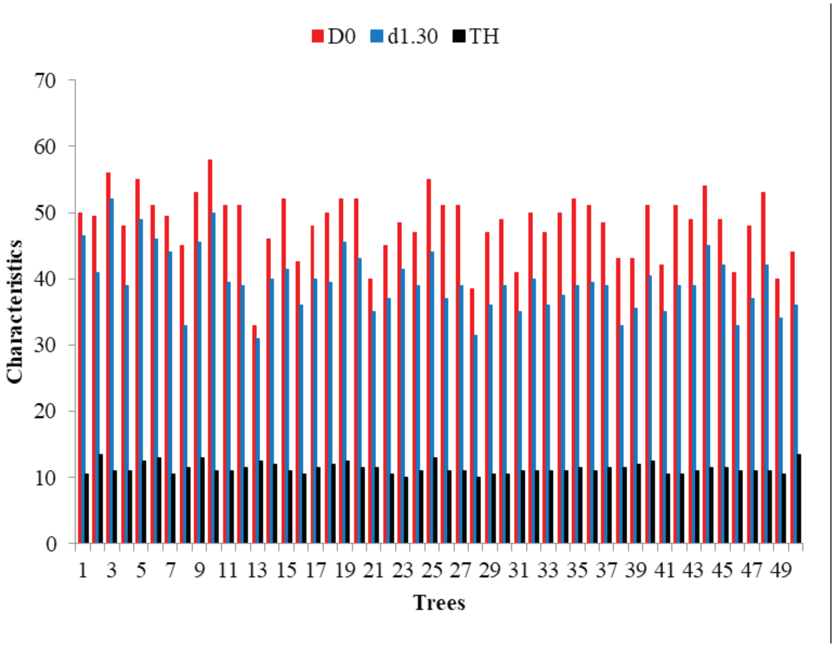

Figure 7. *Individual growth characteristics in H2*

The habitat classed showed significant ($p<0.01$) differences for the characteristics in the stands (Table 3). Diameters at base (**D_0**) of the habitat classes were more homogenous than the other characteristics according to Duncan's multiple range' test (Duncan, 1955). While habitat classes had four homogenous groups for tree height, they were six homogenous groups for the diameters as seen from Table 2.

Table 3. *Results of analysis of variance for the characteristics in habitat classes*

Characteristics	Source of variation	df	Mean Square	F	*P value*
D_0	Between Groups	7	567.858	14.645	.000
	Within Groups	392	38.775		
	Total	399			
$d_{1.30}$	Between Groups	7	551.284	15.326	.000
	Within Groups	392	35.971		
	Total	399			
TH	Between Groups	7	148.443	93.824	.000
	Within Groups	392	1.582		
	Total	399			
CN	Between Groups	7	9738.469	7.335	.000
	Within Groups	392	1327.646		
	Total	399			

3. INTERACTIONS AMONG THE CHARACTERISTICS

The relations among the characters changed for the characteristics according to results analysis of variance (Table 4). The results were well accordance with early report in the species (Uysal, 2015; Cercioglu, 2018). They can be used future estimations in the species. Interactions between diameters and cone production were showed as examples among different characteristics for H2 and H7 in Figure 8.

Table 4. *Relations among the characteristics in habitat classes*

	*r**	D_0	$d_{1.30}$	TH	CN
H1		$.911^{**}$			
H2		$.847^{**}$			
H3		$.926^{**}$			
H4		$.883^{**}$			
H5	$d_{1.30}$	$.918^{**}$	-		
H6		$.924^{**}$			
H7		$.881^{**}$			
H8		$.887^{**}$			
Total		$\mathbf{.915}^{**}$			
H1		$.307^{NS}$	$.295^{*}$		
H2		$.148^{NS}$	$.222^{NS}$		
H3		$.326^{*}$	$.309^{*}$		
H4		$.235^{NS}$	$.278^{NS}$		
H5	**TH**	$.111^{NS}$	$.042^{NS}$	-	
H6		$.239^{NS}$	$.220^{NS}$		
H7		$.467^{**}$	$.511^{**}$		
H8		$.479^{**}$	$.533^{**}$		
Total		$\mathbf{.189}^{**}$	$\mathbf{.152}^{**}$		

H1		.654^{NS}	.053^{NS}	-.023^{NS}	
H2		.109^{NS}	.287*	.180^{NS}	
H3		-.045^{NS}	.031^{NS}	-.012^{NS}	
H4		.158^{NS}	.276^{NS}	.075^{NS}	
H5	**CN**	.196^{NS}	.212^{NS}	-.034^{NS}	-
H6		.126^{NS}	.054^{NS}	.246^{NS}	
H7		.313*	.361*	.043^{NS}	
H8		-.017^{NS}	-.092^{NS}	.203^{NS}	
Total		.235**	.270**	.012^{NS}	

***; Correlation is significant at the 0.01 level, *; Correlation is significant at the 0.05 level, ^{NS}; Correlation is not significant (p> 0.05).*

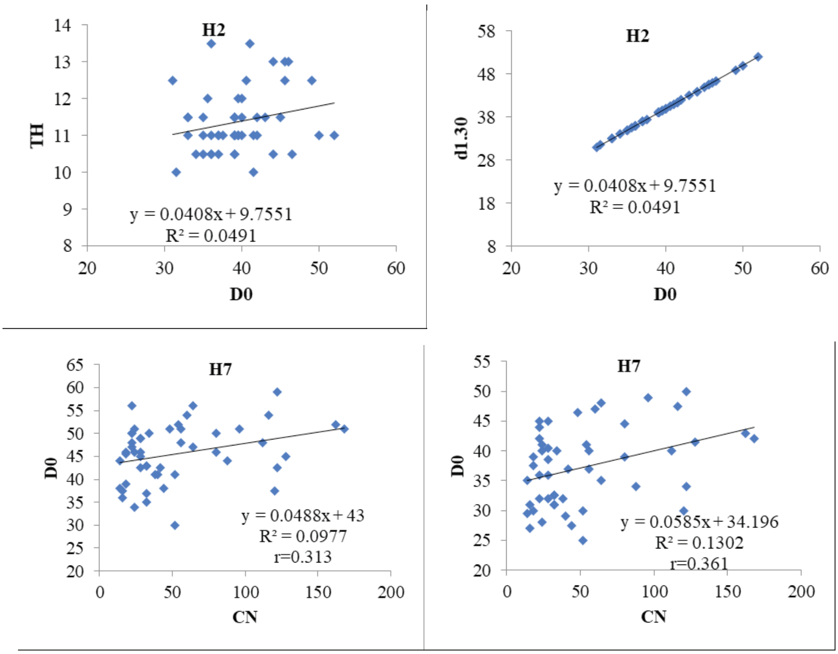

Figure 8. *Interactions among the characteristics in H2 and H7*

4. CONCLUSIONS

Results of the study could be contributive for silvicultural such as forest tending and management of seed sources, and other forestry practices. However, the paper has one year growth and cone data. New studies could be carried out for long term data and different locations. New growth characteristics (i.e., crown diameter, crown volume and stem straight) and reproductive characteristics (i.e., seed production, number of filled seeds, flowering) could be studied in future studies in the species.

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Chapter 2

IMAGE PROCESSING PRACTICES IN AGRICULTURE

Uğur YEGÜL[1], Maksut Barış EMİNOĞLU[2]

1 Dr. Uğur Yegül, yegul@ankara.edu.tr, ORCID ID : 0000-0003-2139-4080 (Corresponding author), Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Ankara University, Ankara, Turkey, 06135
2 Dr. Öğr. Üyesi Maksut Barış Eminoğlu, eminoglu@agri.ankara.edu.tr, ORCID ID : 0000-0003-3264-3636, Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Ankara University, Ankara, Turkey, 06135

Image processing and computer vision applications have increased significantly in recent years. It is widely used in vehicle automation, security systems, robot applications, surveillance of friendly and enemy forces in military fields, agricultural applications, biomedical and medical fields, geographic information systems, design and manufacturing applications (Samtaş and Gülesin, 2011).

In studies using image processing techniques, images are taken from the camera first. Image preprocessing steps are applied to the received images, and feature extraction of the objects of interest is performed. Accurately detecting the objects in the environment is essential for the feature extraction phase. Different methods are suggested in studies for detecting or recognizing objects. Studies for fast and effective object recognition using simple features of objects (Viola and Jones, 2001), recognition with complex background extraction (Hussin et al., 2012), shape recognition, colour recognition, edge and corner recognition, statistical pattern recognition, Various methods such as template matching are used.

As a result of the widespread use of computer vision, studies such as monitoring product quality in agriculture (Wu and Sun 2013), crop irrigation (Hof and Wolf, 2014), spraying, harvesting, product classification, and product development are carried out (Latha et al., 2014). In addition, in the field of agriculture, in various studies using image processing techniques, peach (Kurtulmuş et al., 2013; Sert et al., 2010), apple (Sert et al., 2010; Sofu et al., 2013), wheat (Demirbaş and Dursun). , 2007), hazelnut (Bayrakdar et al., 2015; Guvenc et al., 2015), cherry (Balcı et al., 2016; Beyer et al., 2002), walnut (Ercisli et al., 2012), almond (Jain and Dubes, 1988) etc. fruits are classified, and their characteristics are determined. To determine these features, the objects investigated are classified in size, type or quality using digital image analysis, classification, and clustering.

Image Processing Techniques

The image processing method is similar to the visual system of humans. Image processing can be defined as using images by computers after taking images through digital image receivers, processing them, and interpreting the image according to the desired purpose (Çankaya et al., 2013; Jahne, 2004). Noise is unwanted data that occurs in digital images, and it can cause image distortion and loss of details. Image processing algorithms reduce noise (Küpeli and Bulut, 2020). Filtering can be done in spatial and frequency domains. Median filtering aims to reduce noise to a great extent with minimal blurring (Zhu and Huang, 2012). Converting a digital image to a binary image defined as black and white is called the thresholding method, and it is used to reduce noise in the image and object detection.

Thresholding is one of the most important methods used for image segmentation. The primary purpose of thresholding is to separate the objects from the image's background. Generally, global and optimal thresholding techniques are used. Threshold values are calculated on the image with the Otsu method developed by Nobuyuki Otsu in 1979 (Otsu, 1979). The concept of Otsu is creating a binary image in a sequence (image matrix) by making the parts below a certain threshold 0 and the parts above it 1. An edge is a set of connected pixels at the boundary between two regions. In other words, it is a sharp change in the brightness ratio in any part of the image. With edge detection on the image, objects in that image can be detected, their number can be subtracted, and their properties can be determined. The differentiation of the colour values of the pixels on the image determines edge detection algorithms. Various algorithms are used for edge detection in image processing: Sobel, Canny, Prewitt, Laplacian Zero-Cross, etc.

Agricultural Practices

Uras and Okursoy carried out this study in 2007 to demonstrate that the wear of the plough end irons can be determined by using image processing techniques and other methods. For this purpose, the trial version of Global Lab Image 2 Streamline software was used. They reported that the average wear amount was determined as 33.6 g da-1 due to sensitive weighing measurements. The average wear amount determined by the image processing technique and the wear amount determined due to the planimeter measurements were reported as 61.6 cm2 and 61.8 cm2 as the projection area, respectively. It has been determined that the wear of the end irons working in the parcels with high soil compaction is more. On the other hand, it has been reported that the wear seen in the plough end bars decreases as one goes from the front body to the rear body.

Demirbaş and Dursun, in their study in 2006, aimed to determine some physical properties of some wheat varieties, such as length, width, thickness, projection area, circumference, degree of sphericity and different shape coefficients by using an image processing technique. Thirteen different wheat varieties were selected for bread and durum wheat. Samples were prepared by placing wheat grains with 10%, 12%, and 14% seed moisture content on paper in 3 different positions. These were transferred to the computer environment as files with TIFF extension, passed through a scanner, and evaluated with the "UTHSCSA Image Tool Version 3.0" image processing program. In the operating results, They reported that the image processing technique could be used successfully in determining some physical properties of wheat grains due to the high correlation coefficient between the measurement results made by hand and image processing.

Within the scope of the study conducted by Polatçı et al. in 2017, kiwi fruit was dried at 60, 65 and 70 ºC drying air temperatures with 0.5 and 1 cm slice thickness. The experiments used a Presica brand X.M. 10 SE model instant moisture analyzer. To observe the changes, images were taken perpendicular to the slices at certain time intervals during drying. In the experiments, the drying efficiency of kiwi at different temperatures, the product's colour analysis and the product's chemical changes were determined, and the area loss and Heywood Circularity Factor (HDF) were determined by the image processing method. When the drying process is examined, the shortest drying time at 70 °C for 0.5 cm thickness is 4 hours, and the longest is 16 hours for 1 cm thickness at 60 °C. In the image processing analysis, it was determined that an area reduction of approximately 900 mm2 occurred. It was reported that there was no statistical difference between the fresh and dried product in the 0.5 cm thickness experiment at 60 °C drying air temperature, and the drying air temperature was an essential parameter in terms of the quality characteristics of the product in the experiments with kiwi.

The goal of the work by Yldz et al. (2017) was to use image processing techniques to quickly compute the plant crown projection area. The tests made use of images of broccoli (Brassica oleraceae L.) plants. The plants were distinguished from the ground using the program developed using MATLAB software by leveraging differences in their color spaces. By dividing the size of the recognized frame area by 2, the real area of the plant was determined. The areas were also measured using a planimeter in the same photos, and their timing and accuracy were compared. According to a report, there is a linear association (R^2=0.983) between the areas determined by image processing and the areas determined by planimeter.. In addition, it has been reported that the area was calculated in 0.002 seconds with image processing, while the measurement was performed in approximately 564 seconds with a planimeter.

According to Sabanc and Aydn (2015), utilizing chemical herbicides and hoeing are the most efficient ways to control weeds in sugar beet farming. It is also claimed that overusing chemical control causes significant environmental issues. For this reason, weeds between the rows in sugar beet agriculture were identified using image processing techniques, and a variable-level herbicide delivery model was realized on the weed. This was made possible by the development of the precision spraying robot. Although the precision spraying robot's nozzle height is 30 cm and its speed is 8.928 cm s-1, it has been found that when pesticides are applied to an area of 1.6 m2, 55.22% less spraying is required than with conventional spraying. The amount of spraying liquid applied to the weeds at eight different speeds of the precision spraying robot was measured. It has been determined that increasing the speed of the spraying robot causes a decrease in the amount of spraying liquid applied to the weeds.

In the study carried out by İncekara and Selek in 2020, cherry, which is a sweet-flavoured, juicy and stone fruit type with around 1500 varieties in the world, has calcium, zinc, potassium, fibre, vitamin C, iron, thiamine, riboflavin, niacin, magnesium, E. and reported that it is rich in vitamins B6. They also stated that cherries are widespread worldwide, but Turkey is in the first place with a share of 35% among the top 6 countries that produce the most cherries worldwide. This study uses image processing methods to classify the cherry fruit according to its size. In order to do this, a study was conducted to categorize the fruits as small, medium, and large after they were scanned using the Matlab R2013a program. Cherries were shown in the study in independent, non-overlapping images. In this manner, a 100% categorization success rate was attained. The categorization success, though, is thought to suffer if the cherries overlap. It will be categorized by international standards, become one of the essential export products, and contribute more to the nation's economy if cherry fruit is classified using image processing techniques rather than traditional classification methods.

Işık and Güler (2003) reported that in engineering studies on the evaluation of agricultural products, knowing the dimensional properties of the product is an essential parameter for machine designs related to the product, and determining the dimensional properties is possible with the use of appropriate calculation and experimental methods. This study determined the Golden Delicious apple cultivar's surface area using an image processing technique.

Balcı et al. (2016) reported that either a new image would be obtained or a meaningful result would be obtained from the image as a result of image processing based on the acquisition and processing of input images with different techniques, in which computer-aided image processing, which is based on the human visual system, has entered every aspect of our daily life. This study was carried out to determine the size of Napoleon cherries grown in Turkey. First, the cherries' pictures were taken, and the image was transferred to the MATLAB environment. The calibre of each cherry in this image, that is, how many millimetres in diameter, was tried to be determined by using image processing. An application-oriented study of image processing techniques aims to classify products more accurately. In this way, it has been reported that the financial losses of the manufacturer can be prevented by pricing the products as they deserve during the sales.

According to Kaymak et al. (2019), image processing techniques can be used to extract new interpretations or a lot of numerical information from an image. Apple cultivation, which has a significant role and relevance among agricultural pursuits, was the subject of this study. Using image processing techniques, the study seeks to identify and count the red apples on the trees in an apple orchard. To achieve this goal, the software was created in a computer environment. Using digitally transmitted photos of the apple tree and image processing algorithms, the software locates the apples on the tree. Marking the centers of the discovered apple items allowed for apple counting. The program can record live video, still images, and snapshots.The red apples on the tree were determined with 78.47% success in terms of colour. It has been reported that this situation can be considered successful for apple detection in terms of colour with image processing methods.

According to a 2012 study by Sabanc et al., image processing is now the most successful technology used in classification machines. This study uses image processing methods and an artificial neural network to categorize potatoes according to size. Prior to classification, potatoes with an abnormal outer surface and morphological defects were found using the herbaceous approach and eliminated. The size classification of unremarkable potatoes was then completed. The system was trained for this by employing multi-layer artificial neural networks with images of tiny, medium, and giant potatoes. Artificial neural networks and image processing were done in the study using MATLAB software. Using image processing techniques and artificial neural networks, the classification success of potatoes has been examined.

On the other hand, Konda et al. (2000) examined the internal characteristics of reddish oranges, which have a sweet taste, called lyokan, a Japanese fruit, instead of their external characteristics, and performed a classification application. This is because, in some regions, this fruit is given different names, and some believe it has a medium-sized red and shiny surface, while in some regions it is not. To eliminate this uncertainty, the classification process was carried out by evaluating the sugar and acid content in the fruit. As a result of the study, it was stated that the performance of the artificial neural network could be improved by using more training sets.

Hannan and Burks (2004) proposed a study on automatic citrus harvesting. This research stated the importance of developing CCD camera systems, sensors, image processing methods and innovations in robot arm technology. To harvest citrus fruits, the fruits in the image were determined by determining the characteristics of the fruits first. Afterwards, they compared the harvesting performed mechanically with the harvesting performed robotically. It has been stated that the system used for robotic harvesting is flexible because there is more productivity gain with less labour due to robotic harvesting, and higher goods are obtained per work volume. As a result of the inflexibility of the system used for mechanical harvesting, low production was achieved in terms of transaction volume, and it was revealed as a result of the study that there is low productivity in the face of high labour (Kahya and Arın, 2014).

Zhao et al. (2009) determined the quality of fruits using real-time image processing techniques. With the help of a machine they developed, the fruits' texture properties, size and colour analyses were determined. Researchers working on pear as a fruit variety suggested that quality standards could be determined for other fruits and vegetables (apple, cucumber, tomato, peach, mushroom, etc.) with the study.

Hannan et al. (2010). Segmentation of fruits consisted of shape and colour analysis techniques and an environment-based determination. In the developed study, it has been reported that the detection rate of fruits can exceed 90% with the improvement of changing lighting conditions.

Kurtulmuş and Vardar (2013) conducted a study to detect young peach fruits in their branches, a training set was created for this process, and two different image scanning methods were developed. A colour-based segmentation process was applied to separate the fruits from the background. The image scanning method used in the research is scanning the image in horizontal and vertical directions with a sliding sub-window on the image. This method aims to prevent fruits that are very close to each other with the determined step distance from being perceived as a single fruit. According to the proposed first image scanning method, the success of various classifiers was compared, and it was observed that the highest success belonged to the ANN algorithm with 77%, and according to the second proposed scanning method, it was again the ANN algorithm with a rate of 81%. Similarly, problems related to lighting conditions were encountered in the study, and not all of the young fruits could be detected. It has been reported that this study on images taken with a CCD camera is promising with its success rate.

Kuncan et al. (2013), using image processing methods, the colour of the olives was determined on a real-time system, and the classification process was carried out. Euclidean distance method in HSV colour space and RGB colour space and Mahalanobis distance in RGB colour space was used to distinguish olives according to their colour. The classification process was applied according to the essential qualities of the olives. It was observed that the Mahalanobis distance method was the most successful method, with a success rate of 97%. This is because this method operates using the standard deviation values of objects.

Payne, Walsh et al. (2013) determined the crop yield of mango fruit by image analysis using the segmentation method. In their work, they performed segmentation using RGB and YCbCr colour spaces. They created the data set in 3 different situations according to the lighting intensity and determined the product classification per tree as low, medium and high efficiency. In the last stage, the total yield calculation was carried out. The study performed poorly on images with direct sunlight and trees with a large crop.

Kanimozhi and Malliga (2017) studied classifying immature and ripe fruits using colour coding. After the image is taken, the citrus fruit is separated from the background by preprocessing and using the grassy thresholding method. Then, after applying the edge detection algorithm, they transformed the images into HIS colour space after morphological processing. Then, they performed the classification process by making a textural analysis. As a result of the study, it was reported that higher successful results were obtained in ripe fruits, the lighting factor adversely affected the study, and the camera's position was an essential factor.

Yaşar and Akdemir (2017) carried out a study with artificial neural networks and image processing techniques on the yield of orange trees with a high production rate in Turkey. In the study carried out, they classified the images according to their approximate illuminance levels to provide light balance on the colour images; Afterwards, they applied image enhancement techniques on the separated images, used half of the obtained images in the training and half in the test class according to the artificial neural network algorithm, and performed the tree-fruit load calculation with the cross-validation method. The application has been reported to have a success rate of 89.8%.

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Chapter 3

IMPORTANCE OF POLLEN ANALYSIS IN HONEY: MELISSOPALYNOLOGY

Memnune ŞENGÜL[1], Seda UFUK[2]
İsa Arslan KARAKÜTÜK[3], Sefa AKSOY[4]

1 Prof. Dr., Ataturk University Faculty of Agriculture Department of Food Engineering, Erzurum/Turkey/ORCID: 0000-0003-3909-2523/memnune@atauni.edu.tr
2 Artvin Directorate of Provincial Agriculture and Forestry/ORCID: 0000-0001-6250-6670
3 Ataturk University Graduate School of Natural and Applied Sciences Department of Food Engineering, Erzurum/Turkey/ORCID: 0000 0002 0317 2882
4 Ataturk University Graduate School of Natural and Applied Sciences Department of Food Engineering, Erzurum/Turkey/ORCID: 0000-0003-0849-8088

INTRODUCTION

Beekeeping has been practiced in Turkey as well as in many parts of the world since ancient times. In particular, Turkey's rich flora has made it one of the most suitable countries for beekeeping. There are 12.476 natural plant species in Turkey, and 450 of those are known as honey plants, which are crucial for beekeeping. Turkey has one of the highest potentials for beekeeping in the world due to its climate, rich botanical diversity and its location as a transit point between the continents of Asia and Europe. Although products such as honey, pollen, bee bread, propolis, royal jelly, bee venom, apilarnil, and beeswax are obtained as a result of beekeeping activities carried out as a traditional agricultural activity in our country, especially in rural areas, honey is the most well-known and therefore the most produced and consumed product (Özkök & Bayram, 2021). With an annual production of over 7 million beehives and 103 thousand tons of honey, it ranks second in the world after China (Özkök et al., 2018).

Honey is defined by the Turkish Food Codex Communique on Honey (No: 2020/7), as a natural sweet and flavourful product, which can be formed by combining it with various nectars of plants or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants. The water content can be declined and the storing methods in honeycombs to ripen and mature after nectar collection. Honey can be described as blossom honey or honeydew honey according to its plant source. The aromatic, sweet, and viscous qualities of honey, which is mostly made of reducing sugars like fructose, glucose, sucrose, and almost 25 different oligosaccharides as well as other minor chemicals, make it a desirable and nutrient-rich diet (Maieves et al., 2020; Machado et al., 2021). Even though carbohydrates are the leading component, including almost 95% of the dry weight of honey, it also includes other types of substances. For example, esters, enzymes, organic acids, vitamins, minerals, volatile components, hydroxymethylfurfural (HMF), phytochemicals, and other solid materials collected by honey bees (Kirs et al., 2011; Selvaraju et al., 2019; Machado et al., 2021). Honey components and characteristic features are changed by geographical location, seasons, floral and entomological sources, environmental conditions, beekeeping and processing features, and also storage conditions (Selvaraju et al., 2019; Rosdi et al., 2016; Yildiz et al., 2022).

Honey can be classified as monofloral or unifloral; when it is composed predominantly of a single botanical origin or multifloral; when it derives from different plant varieties blooming at the same time (Milosavljević et al., 2021; Yildiz et al., 2022). "Monofloral honey" refers to the predominance of pollen obtained from a certain plant rather than a honey that only contains a single type of pollen (Bodor et al., 2021) and harvesting of absolute monofloral honey may not be very frequent (Addi & Bareke, 2021). While multifloral honeys are generally referred to by the name of the region where they are produced (Anzer honey, Bayburt honey, Kars honey, Ardahan honey, etc.), unifloral honeys are predominantly referred to by the name of the plant from which they originate (chestnut, lavender, thyme, etc.). Various unifloral flower honeys are produced from plant sources such as citrus, heather, cotton, sunflower, chestnut, and linden that bees use as nectar sources in different geographical regions of our country (Özkök & Bayram, 2021). Each country has established their own country's honey standards as a result of the analysis of honey with different physical and chemical structures obtained from their own nectar plants. Turkish Food Codex Honey Communique is essential for honey standards in Turkey (Yurtsever, 2004). In order for some unifloral honey types produced in Turkey to be labeled with the name of the relevant plant, the minimum ratio of this plant to be represented by the pollen grain is required by the Republic of Turkey. It has been added to the Turkish Food Codex Communique on Honey (No: 2020/7), revised by the Ministry of Agriculture and Forestry in 2020. Within the scope of this paper, unifloral honey types are classified into three different groups: normal, under-represented, and over-represented unifloral honey types. The following Table.1 shows three groups and their minimum content of pollen.

Table.1. Minimum Pollen Contents of Honey with Botanical Source Specified (Turkish Food Codex Communique on Honey (No: 2020/7))

Representation of Pollen	% (Min)	Botanic Origin	Type of Pollen
Normal-represented unifloral honey	%45	Astragalus	*Astragalus spp.*
		Heather	*Calluna vulgaris Erica spp.*
		Rapeseed	*Brassica napus*
		Alfalfa	*Medicago sativa*
		Sunflower	*Helianthus annus*
		Clover	*Trifolium spp.*
		Vitex	*Vitex spp.*
		Lacy phacelia	*Phacelia tanacetifolia*
Over-represented unifloral honey	%70	Chestnut	*Castanea sativa*
		Eucalyptus	*Eucalyptus spp.*
Under-represented unifloral honey	%15	Acacia	*Robinia pseudoacacia*
	%10	Citrus	*Citrus spp.*
		Rosemary	*Rosmarinus officinalis*
		Thyme	*Thymus spp., Origanum spp., Tymbra spp., Coridathymus spp.*
	%5	Linden	*Tilia spp.*

Honey is a traditional food item that has been used by people for centuries due to its many beneficial properties. It is a popular substance due to both its different health effects and also with its sweetening properties. Therefore, honey has an important economic value in the world (Delport et al., 2022). Because of their unique flavour, taste and odor, monofloral honeys are often regarded as better quality and are preferred by consumers, thus attaining higher market values (Özkök et al., 2018). Unifloral honey is characterized by the inclusion of parameters such as pH, moisture content, sugar content, color, and conductivity. Determining these parameters gives us information on the source of unifloral honey, plant type, honey freshness, and honey origin (Karatas et al., 2019). Although honey is commonly used as a health product, due to its high commercial value, it is frequently falsified or given misleading labels in order to increase profits (Selvaraju et al., 2019). Since honey has benefits and high nutritional value, its price is typically higher than that of other sweeteners. One of the reasons for testing honey and its qualities is to determine its authenticity because adulterated honey is frequently reported on a global scale. Multiple nations adulterate honey with sugar, beet or corn (glucose) sweeteners, invert sugar, saccharose syrups, and high fructose corn syrup (HFCS). The use of sweeteners (such as cane sugar or refined beet sugar), artificially feeding honey bees during the nectar flux, early honey harvesting (which shows that sucrose was not completely converted into glucose and fructose), the use of filtrating resins by ionic exchange, and falsification of botanical or geographic origin are examples of adulteration methods (Fuentes Molina et al., 2020). Currently, the botanical and geographic origins of honey must be identified, and certain compounds (carbohydrates, proteins, minerals, polyphenols, organic acids, amino acids, vitamins, and volatile compounds) can be found to confirm its authenticity (Mureşan et al., 2022; Pauliuc et al., 2022). There are numerous analytical methods to measure honey authenticity have been utilized to notice honey frauds (Figure 1).

Unifloral honeys, which mainly contain pollen from one plant species, are of higher quality and therefore more expensive than multifloral honeys, reinforcing the need for appropriate analytical techniques that can identify the authenticity of unifloral honeys (Voyslavov et al., 2021). Honey labeled as having a specific floral origin must come entirely or largely from the specific floral source and exhibit the organoleptic, physicochemical, and microscopic characteristics of the source, as specified in international food standards and therefore monofloral honey is more expensive than polyfloral honey (Pauliuc et al., 2020).

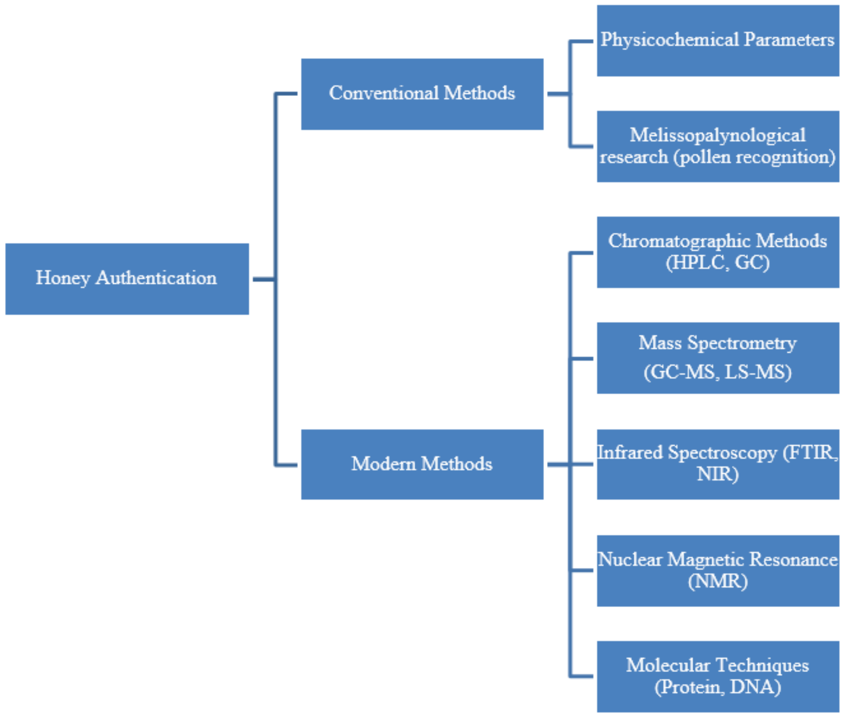

Figure 1. Classical and modern analytical methods utilized for honey authentication (Ling Chin, & Sowndhararajan, 2020)

Pollen, an essential component of the diet for bee larvae, is collected by honey bees while they are gathering nectar from flowers. Anthers: the male reproductive organs of flowering plants produce pollen which is a fine powder. It has been stated that in cases where pollen, which is of great importance for the nutrition of bees, is insufficient, the population in the bee colony decreases and the resistance of bees to negative external factors such as pathogens and pesticides decreases (Mutlu et al., 2017). Pollen is full of vitamins, minerals, phytosterols, proteins, phenolic compounds, flavonoids, amino acids, and lipids. Because it includes all the essential amino acids required by the human body, bee pollen is known as the "only fully complete diet" (Feás et al., 2012). The essential amino acids in pollen are arginine, histidine, leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine; non-essential amino acids are proline, glycine and serine (Genç & Dodoloğlu, 2002). The chemical composition of the pollen and the proportion of the components are shown below in Table 2 (Schmidt, 1997).

Table 2. The chemical composition of pollen (Schmidt, 1997)

Component	Proportion
Energy	2.46 kcal/g
Protein	23.7%
Carbohydrate	27%
Lipid	4.8%
Phosphor	0,53%
Potassium	0,58%
Sodium	0,044%
Calcium	0,225%
Magnesium	0,148%
Zinc	87 ppm
Copper	14 ppm
Iron	140 ppm
Nickel	4,5 ppm
Thiamine	9,4 ppm
Niacin	157 ppm
Riboflavin	18,6 ppm
Pyridoxine	9 ppm
Pantothenate	8 ppm
Folic acid	5,2 ppm
Biotin (vitamin H)	0,32 ppm
Vitamin C	350 ppm
Carotene	95 ppm
Vitamin E	14 ppm

It has been supported by various studies and research that pollen has a protective and curative effect in many diseases due to its high nutritional value and the vitamins, proteins and minerals it contains. In addition to nutrients, it also contains phenolic components. It is reported that pollen has antibacterial, antifungal, antioxidant and anticancer properties (Onbaşlı, 2019). According to the researches, pollen has been proven to strengthen memory, prevent anemia, regulate metabolism, calm the nervous system, and strengthen immunity. Additionally, it is effective in the rehabilitation of radiation and cancer, regulation of sexual functions, treatment of wounds and skin problems, beauty and prostate disease. It also has effects on human health via its hypolidemic, hypoglycemic, fibrinolytic and antimicrobial properties. Although, pollen has positive effects on human health, it is not correct to generalize that all pollen is harmless. Pollens that the bees are not interested in are among the pollens with low nutritional value, difficult to digest or poisonous (Waykar & Alqadhi, 2016). It is reported that pollen may contain substances with toxic effects in its content (Ötleş, 1995). Moreover, some pollen can cause allergies.

The pollen that honey bees gather gets into the honey and stays there. In order to identify the honey's botanical origin, the pollen present in the honey is utilized. Louveaux et al. (1978) collected pollen in 4 main groups according to their presence in honey are shown in below Table 3.

Table 3. The pollen groups according to their presence in honey (Louveaux et al., 1978)

The amount of Pollen in honey	Group of Pollen
Over 45%	Dominant pollen
Between 16-45%	Secondary pollen
Between 3-15%	Minor pollen
Less than 3%	Trace pollen

Palynology, a science that studies pollen grains and spores and a fairly new branch of science, has gained significance rapidly due to its contribution to other disciplines and has found application areas for numerous purposes (Erdtman, 1963). Palynology, which is the study of pollen grains, is commonly used in archaeological, paleoenvironmental and geological research and studies to control the floral taxonomic groups existing in a sample (Lau et al., 2018). It was first used as a terminology by H. A. HYDE in 1944. Important studies on this subject are seen in the works of a scientist named Von POST in the 1916s. Later, the work of this scientist was followed by Iversen, Faegri, Erdtman and Wodehouse (Aytuğ, 1967). The most significant application area of palynology is plant systematics. In phylogenetic classification, in addition to morphological, ecological and anatomical features, palynological features are also utilized in the diagnosis of species, subspecies, geographical forms and hybrids of plants. Palynology has many application areas and these fields include Palinotaxonomy, Paleopalynology, Pharmacopalynology, Iatropalynology, Phytopathological Palynology, Forensic Palynology and Melisopalynology (Erdtman, 1963).

Melissopalynological research (pollen recognition) is the identification and measurement of pollen in honey. These investigations involve both quantitative and qualitative microscopic analysis of the pollen in honey to determine its floral or botanical origin, which is crucial for standardizing honey, identifying its geographic origin and type, and understanding the foraging ecology of honey bees. Analyzing pollen can also indicate whether honey has been modified or contaminated with toxic pollen. This technique assists in separating multifloral honey from unifloral honey or other honeys of a certain type with great commercial value. The pollen spectra discovered also gives details about the flowering plants the bees in the study area utilize. For beekeepers to increase honey production, knowledge of the botanical sources of honey is essential (Rosdi et al., 2016;

Herrero et al., 2002). This pollen analysis information has commercial value since dominant floral types of honey can be sold for a higher price than mixed or unknown floral sources of honey, as the unifloral honeys always provide similar physico-chemical and organoleptic properties and are well valued for commerce (Nadaf et al., 2017). To sum up, with the pollen in honey, it is possible to get an idea about the geographical origin, botanical origin, aroma and taste of honey. On the other hand, honey produced from plants containing poison can be prevented from reaching the consumer. Although melissopalynological analysis is a common method to determine honey's characteristics, it is expensive, time-consuming, and requires highly skilled personnel (Voyslavov et al., 2021). In addition, this strategy does have different limitations, such as the method for counting and identifying pollen, the difficult and time-consuming task of interpreting the results, or the limited applications for determining geographical origin. Therefore, the limits of pollen analysis can be overcome by combining it with physicochemical and sensory characteristics (Karabagias et al., 2018) it means that physicochemical and organoleptic analyses should typically be used in addition to melissopalinology. In order to categorize honey according to its botanical origin, a detailed interpretation of all the data is needed (Pauliuc et al., 2020).

For both quality control (QC) and processing control of honey, routine determination of physicochemical parameters [water content, electrical conductivity, sugar content, fructose/glucose ratio, enzyme activity, color, optical rotation, pH value, acidity, and hydroxymethylfurfural (HMF) content] is frequently used (Lazarević et al., 2017). Also, sensorial and microbiological factors that use to assess the quality of honey. The low protein content, high viscosity, and natural acidity of honey all work to reduce the quantity of atmospheric oxygen penetration, which lowers the likelihood of pathogen presence (Machado et al., 2022). The final values of these characteristics in honey are influenced by a variety of variables. The ambient humidity, the volume of nectar flow, colony health, and beehive ventilation are the main determinants of water content. The amount of additional enzymes varies depending on a number of variables, such as nectar collecting, nectar flow quantity and sugar content, bee age and diet, colony strength, temperature, etc. Temperature and heating time, storage conditions, the usage of metallic containers, and the chemical characteristics of honey, which are connected to the floral source from which the honey has been harvested, all affect the development of HMF in honey. It is also possible to know the botanical origin of honey based on several physicochemical factors, including electrical conductivity and sugar content (Lazarević et al., 2017).

Honey is not a sterile product due to two major sources of contamination, the first of which includes pollen, nectar, honeybee digestive systems, dust, air, and soil, all of which are very challenging to handle. Good manufacturing practices can be used to control secondary sources, such as people who manipulate honey, food handlers, cross-contamination, equipment, and buildings (Machado et al., 2022).

The assessment of honey authenticity was said to depend on a number of factors, including moisture content, electrical conductivity, diastase activity, fructose, glucose, sucrose, and hydroxymethylfurfural (HMF) concentration. It has been observed that melissopalynology, a key method for identifying pollen sources, can distinguish between different botanical sources of honey (Hempattarasuwan et al., 2019; Voyslavov et al., 2021).

Certain criteria, as outlined in the Turkish Food Codex Communique on Honey (No: 2020/7), must be met for a product to be labeled as honey. These criteria include the values of specific physicochemical characteristics and/or the pollen content of the honey, in order for it to be defined as monofloral.

Procedures of Pollen Analysis

The main principle of this analysis is based on the extraction of pollen from honey and its examination under the microscope. In this way, it enables the evaluation of honey both qualitatively (determining the types of pollen in honey and the proportions of these species in honey) and quantitatively (counting the pollen particles) (Louveaux et al., 1978; Lutier & Vaissière, 1993).

Analysis begins with the preparation of samples. Honey is made completely homogeneous by means of heating to melt the crystallized and solidified parts of the honey and ensure homogenization of honey. It is heated up to 40-45^{o}C and also up to 60^{o}C in some sources. It is mixed at the same time during the heating process is carried out. Alternatively, vortex can be used. Later, homogenized honey is prepared for centrifugation by mixing with the amount of distilled water determined for dilution. Some of the samples prepared for centrifugation are taken and put into centrifuge tubes and the samples are then centrifuged. Centrifugation speed varies between 3000 rpm and 5000 rpm in different studies. Also, centrifuge time varies between 10 minutes and 20 minutes depending on the centrifuge speed. After centrifugation is done, the sample is washed with distilled water to remove the sugar and then emptied again. The remaining residue is dehydrolyzed with glacial acetic acid and centrifuged again. After the evacuation process has been carried out, the residue is acetolysed. The remaining precipitate is centrifuged again with ethyl alcohol to try to get all the pollen grains. After centrifugation, the supernatant is removed and the remaining precipitate is dissolved again with ethanol. Obtained pollen grains are dissolved with a drop of water on the slide and observed with a light microscope or scanning electron microscope (Louveaux et al., 1978; Lutier & Vaissière, 1993; Sniderman et al., 2018).

For pollen identification, a light microscope (frequently an upright microscope with bright field contrast) is utilized to analyze the pollen. The shape, size and surface structure of pollen grains vary significantly depending on the species or family, which is imperative for analytical differentiation of pollen species. As a result, microscopic examination of the pollen grain can often be utilized to categorize the plant of interest, or at least its family. Microscopic examination of honey also gives an idea about the particles it contains and the different degrees of crystallization for different honeys (Pospiech et al., 2021).

Analysis in general terms, pollen analysis consists of three main parts: preparing honey sample dilution, extracting pollen with the help of centrifuge, and examining the obtained pollen under the microscope. In addition, there are studies showing that faster and more pollen is obtained with the filtering technique instead of centrifugation in the analysis.

Importance of Pollen Analysis in Honey

Pollens determined by pollen analysis method have taken the role of indicator of the sources they belong to. With this method, it is possible to understand from which plants the bees take nectar. Most honey is named after the type of pollen detected by this method. For example, if the pollen amount of the acacia tree is high in a honey analysis, this honey is considered as acacia honey among the people (Kelez, 2008).

In addition, pollen analysis can provide an idea about the crystallization rates of honey. In addition, pollen analysis plays an important role in the food safety evaluation of some types of honey that may cause toxic effects. For example, pollen analysis is used in the identification of rhododendron (*Rhododendron spp.*) honey, which is produced in Turkey, especially in the Black Sea region, and can have a toxic effect if consumed. In addition, the total pollen count is found to be low in honey adulterated with sugar, which can be counted among the benefits of melissopalynological analysis applied to honey. As can be understood from these evaluations, palynological analysis in honey contributes to the evaluation of the quality of honey from different perspectives. (Özkök & Bayram, 2021).

CONCLUSION

All food products, including honey, must now satisfy a number of certificates and quality standards before being marketed due to the rising demand for high quality and clearly defined food goods. Because of its high nutritional value, honey is utilized as a traditional meal and as a supportive treatment for a number of ailments. It is crucial that the honey offered for human use meets the necessary standards of quality. In conclusion, the assessment of honey authenticity relies on a number of factors, including moisture content, electrical conductivity, diastase activity, fructose, glucose, sucrose, and hydroxymethylfurfural concentration. In addition, melissopalynology, a key method for identifying pollen sources, can distinguish between different botanical sources of honey.

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Chapter 4

MONITORING THREE DECADES OF FOREST COVER CHANGE USING LANDSAT IMAGERY IN BOZDAĞLAR REGION, TURKEY[1]

Eylül MALKOÇ[2], Engin NURLU[3]

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2 Landscape Architecture Department, Faculty of Architecture, Trakya University, 22100, Edirne, Turkey, ORCID: 0000-0003-1873-2931, e-mail:eylulmalkoc@trakya.edu.tr

3 Department of Landscape Architecture, Faculty of Agriculture, Ege University, 35100, Izmir, Turkey

Introduction

Forests are essential for the continuity of the ecosystem services and biodiversity as well as they play a key role in climate change mitigation strategies (Global Forest Resources Assessment 2005). The projected human population by 2050 is to be 9.6 billion and the expected dramatic growth will be in the undeveloped countries in the world (UN, 2022). Increase in population growth leads to the need of more energy production, food and many other commodities with some negative impact on forests (i.e. forest cover loss and deforestation) as well as all natural resources in different parts of the world (UN, 2022). According to Allen and Barnes (1985), growing populations, agricultural expansion, increasing demand for wood have been the main driving forces of deforestation in worldwide but mainly in developing countries.

Remote sensing technologies and satellite images play a vital role on timely and accurate information about the past and current status of the world's forest (Hansen et al., 2013). Remote sensing technology has successfully been used to monitor vast and inaccessible locations such as mountainous area, since the 1960's therefore, it become a recognised technology to monitor the changes over the landscape (Teillet et al., 1997). In particular, medium remote sensing satellite data, such as Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+) and Landsat Operational Land Imager (OLI) enable a detailed monitoring of Earth's land cover changes, with 30 m spatial and 16-day temporal resolution (Townshend et al., 2012). Chowdhury (2006) used remote sensing data to develop spatially explicit models to understand the driving forces of deforestation in Mexico. Xiong et al. (2020) used remote sensing data to investigate the deforestation patterns of a mountainous region in Zhejiang Province, Chania which is under the process of national forest restoration for some time. Their study showed that between the years of 2001 and 2018 266,984 hectares of forest was lost due to population growth and agricultural expansion.

Singh et al., 2014 used Landsat time series data and applied SVM to monitor long term mangrove forest change in India and the accuracy of the classification results were around %90. Li et al. (2013) compared three different machine learning algorithms RF, SVM and decision trees over Landsat time series data and the results showed better accuracies for the RF and SVM classification algorithms. Schwieder et al. (2016) monitored Brazilian Savanna using SVM algorithm with %96 overall accuracy for the results. Together with Landsat time series data spectral reflectance signatures such as Tassled Cap, Normalised Vegetation Index, Modified Vegetation Index and SAVI are being used to understand the state of leaf and canopy (Jackson and Huete, 1991).

Turkey, specifically Bozdağlar region and its surroundings have a huge wealth of biodiversity in plant and animal species, which makes it environmentally valuable and sensitive at the same time (Koçman, 1984). The ecological importance of Bozdağlar region has led to some research over the plant and animal species located there. Such as Anlaş et al. (2011) observed the flora and fauna richness of Bozdağlar Mountain continuously in their studies. Over the past few decades, land cover in this region experienced major changes due to population growth and anthropogenic activities. The increasing demand for agricultural production from the two closest cities: Izmir and Manisa, has put the forest cover under the risk of deforestation. Therefore, increases in agricultural and built-up areas have become a major driving force of forest cover changes in the region. Consequently, the upper and lower borders of the forest cover in the study area have changed over time. The upper borders of evergreen trees of *Pinus nigra* –usually up to 1600 m- dropped to 1200-1300 m, and shrub compositions have increased their lower borders to 250-300 m –usually starting from sea level (Koçman, 1984; Townshend et al. 2012).

However, no research however has been conducted to map and monitor forest cover change with a specific focus on Bozdağlar region using remote sensing datasets, i.e., satellite imagery so far. Hence, we decided to fill this knowledge gap using satellite imagery i.e. Landsat data and Support Vector Machine algorithm which is one of the most well-known supervised machine learning technique in regards to its high efficiency with fewer sample areas (Dhingra & Kumar, 2019). Bozdağlar environmental and socio-economical value brings the urge to map and monitor forest cover change regularly and accurately, as a clear understanding of the spatial and temporal transformation for the last three decades is of critical importance. In this study, we acquired three Landsat TM/ETM/OLI images for the years of 1986, 2000, 2016 and performed SVM algorithm to classify the land cover classes in Bozdağlar region. The objectives of this study are: (1) to map forest cover for years of 1986, 2000, 2016; (2) to monitor and quantify the forest cover change for the period of 1986-2016. By means of this study we also aimed at being informative to the decision and policy makers about the emergency of the situation.

Materials and Methods

Study area

Bozdağlar region is located between the eastern boundaries of Izmir in the West and the city of Manisa in the North (Figure 1). The study area (38°26’ - 38°7’ N, 27°24’ - 28°42’ E) has a total surface of 310,165 ha. It has a widely patchy and heterogeneous landscape with a mean altitude of 1000-1200 m above the sea level and the highest peak is

2159 m. It is characterised by Mediterranean climate which is temperate-humid in summer and mild in winter. The average minimum temperatures during winter is 6°C and during summer 27.5°C while the mean monthly precipitation ranges between 800 and 1100 mm for the last 30 years. The Bayındır-Ovacık Wildlife Protection and Improvement Area (5,788 ha.) within the study area is increasing the ecological importance of Bozdağlar region. The target species to protect in the protection area is *Capreolus capreolus*. The dominant vegetation in the study area consists of evergreen forests of *Pinus brutia* Ten., *Pinus nigra* L. and *Pinus nigra* ssp. *pallasiana*, and shrubs composed of *Quercus coccifera*, *Quercus cerris*, *Quercus infectoria*, *Laurus nobilis*. The study area includes Ödemiş, Torbalı, Bayındır, Turgutlu, Alaşehir and Salihli counties (Figure 1).

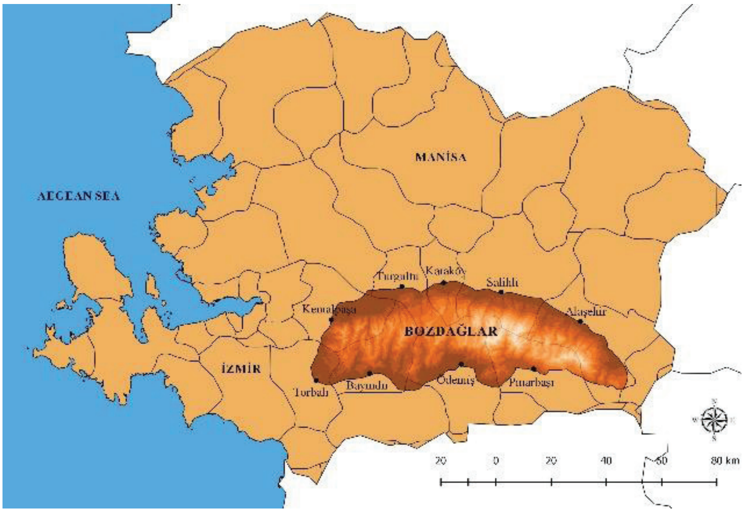


Fig 1 *Location of the study area*

Remote sensing data and pre-processing

The following remotely sensed cloud-free satellite images were used in this study to map and monitor forest cover change: Landsat 5 (Thematic Mapper-TM sensor), Landsat 7 ETM+ (The Enhanced Thematic Mapper Plus) and Landsat 8 (Operational Land Imager-OLI sensor). A total of three images covering the study area were acquired from United States Geological Survey (USGS) website (http://glovis.usgs.gov/). Landsat TM image was obtained on 20.July.1986, ETM+ 16.June.2006, OLI on 06.July.2016. The TM, ETM+ and OLI images have different number of spectral bands but similar spectral ranges (e.g., blue: 0.45-0.52µm, green: 0.52-0.60µm, red: 0.63-0.69µm, NIR: 0.76-0.90µm, SWIR1: 1.55-1.75µm, and SWIR2: 2.08-2.35µm). More detailed information about the Landsat images used in this study can be found in Table 1.

Table 1 *Data sources of Landsat TM, ETM+, OLI remotely sensed images used in the study.*

Year	Satellite	Sensor	Acquisition Date	Wavelength (µm)	Spatial Resolution (m)
				Band 1(Blue) 0.45-0.52	30
				Band 2(Green)0.52-0.60	30
				Band 3(Red) 0.63-0.69	30
1986	Landsat 5	TM	20.July.1986	Band 4(NIR) 0.76-0.90	30
				Band 5(SWIR1) 1.55-1.75	30
				Band 6(TIR) 10.40-12.50	120
				Band 7(SWIR2) 2.08-2.35	30
				Band 1(Blue) 0.45-0.52	30
				Band 2(Green) 0.52-0.60	30
				Band 3(Red) 0.63-0.69	30
2000	Landsat 7	EMT +	16.June.2000	Band 4(NIR) 0.77-0.90	30
				Band 5(SWIR1) 1.55-1.75	30
				Band 6(TIR) 10.40-12.50	60
				Band 7(SWIR2) 2.09-2.35	30
				Band 8(PAN) .52-.90	15
				Band1(UltraBlue)0.43-0.45	30
				Band2(Blue) 0.45 - 0.51	30
				Band3(Green) 0.53 - 0.59	30
				Band4(Red) 0.63- 0.67	30
2016	Landsat 8	OLI	06.July.2016	Band5(NIR) 0.85- 0.87	30
				Band6(SWIR1)1.56 - 1.65	30
				Band7(SWIR2)2.10-2.294	30
				Band8(PAN) 0.50 - 0.67	15
				Band9(Cirrus) 1.36 - 1.38	30
				Band10(TIR1)10.60-11.19	100 * (30)
				Band11(TIR2)11.50-12.51	100 * (30)

All the acquired raw satellite images were geo-referenced with Universal Transverse Mercator (Zone 35) projection with the World Geodetic System (WGS-84) datum. Satellite imagery is affected by a number of distortions that result from differences in sensor calibration, solar and atmospheric effects on the signal received by the satellite sensor. These effects were minimized using radiometric correction to obtain the most accurate results when working with more than one image. The USGS provides radiometrically corrected Landsat imagery as high-level products through its Earth Resource Observation and Science (EROS) Centre Science Processing Architecture (ESPA) online interface. Initially, radiometrically corrected (through the ESPA) Landsat images, were required from the USGS with the EROS Science Processing Architecture interface and the analysis was carried out with these images.

Image transformation technique was applied to the spectral bands. This technique was used to re-express and enrich the information content within the remotely sensed images (Mather et al., 2011). The images created as a result of the image transformation contain more information than the original image in determining the vegetation. During the image transformation technique, addition, subtraction, multiplication and division operations and different calculation criteria were applied. The images resulting from image transformation were used as a stand-alone and/or ancillary data with satellite images. In this study, the Normalised Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index (MSAVI) and Enhanced Vegetation Index (EVI) were created with image transformation technique and used as ancillary data in determining various features of vegetation (Campbell 2011; Telliet 1997). NDVI is one of the most commonly used vegetation indices with a specific focus on 'chlorophyll' of plants. By taking the ratio of red (R) and near infrared (NIR) bands from a remotely sensed image, NDVI can be calculated on a per-pixel basis. The formula for calculating NDVI is:

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

Landsat Surface Reflectance-derived SAVI is calculated as a ratio between the R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types.

$$SAVI = ((NIR - R) / (NIR + R + L)) * (1 + L) \quad (2)$$

MSAVI aims to reduce the background and soil effects in the satellite image and try to overcome some limitations of NDVI. The formula for calculating MSAVI is:

$$MSAVI = (NIR - R) * (1+L) / (NIR + R+L) \quad (3)$$

where R, NIR are the red band and near infrared band reflectance respectively, and L is the soil brightness correction factor. EVI aims to be more sensitive to changes in areas with high biomass and minimise the results of atmospheric conditions on vegetation index values. The formula for calculating EVI is:

$$EVI= 2.5* [(NIR - RED) / (NIR + C_1 * RED - C_2 * BLUE + L)] \quad (4)$$

where NIR, RED and BLUE are atmospherically corrected surface reflectance and C_1, C_2 and L are coefficients to correct for atmospheric conditions (Campbell 2011; Telliet 1997).

Support vector machine land cover classification

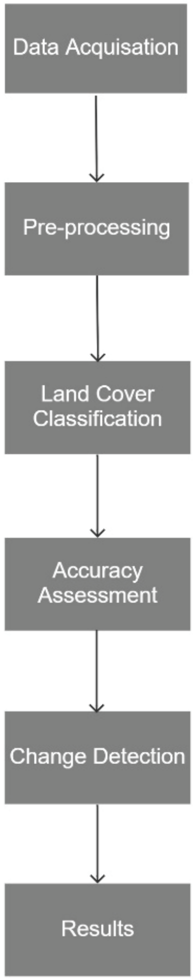
Land cover maps for 1986, 2000 and 2016 were generated by a pixel-based classification technique, known as Support Vector Machines (SVM) algorithm (Huang et al. 2010). SVM, used extensively in recent years to classify satellite images, is based on statistical learning theory with machine learning. Unlike the maximum likelihood classification, the SVM is a non-parametric classifier (Meyer 2017). SVM maps input data into a high dimensional feature space where it may become linearly separable (Pal et al. 2005). The basic idea of SVM is to separate the input training data into two classes through a hyperplane with the maximal margin. Hyperplane is created in the original N-dimensional space between the points of two various classes (Huang et al. 2010; Meyer 2017). All vectors lying over the hyperplane are labelled as +1, while on the other side are labelled as -1. According to this, the new data can be used to classify the group to which a new record should belong. After the acquisition of the decision surface, the classification and categorization can be done. SVM algorithm was performed to classify all the land cover classes obtained were aggregated in two classes: forest and non-forest (Table 2). R programming language (package e1071) was used to perform SVM algorithm, carry out statistical analysis and display the classification results.

Table 2 *Land cover classes and their descriptions.*

	Land cover classes	**Description**
1	Forest	Natural and artificial forests
2	Non-forest	All the other land cover classes

The methodology used in this study comprises various steps. The step-by-step processes are presented as a flowchart in Figure 2.

Fig 2 *Major steps to map forest cover and monitor its change using Landsat TM, ETM+ and OLI images*



Accuracy assessment for the classification

Accuracy assessment is crucial in land cover classification, to determine the quality of the classification results. Confusion matrix is a standardized and commonly used method to measure the accuracy of results. To assess the accuracy of land cover classification, the original images and validation data set were used. Confusion matrix was computed in R using Caret package version 6.0-76 (Khun, 2018).

Change detection matrix

Change detection matrix of land cover changes is produced from the quantitative description of system state and state transition in system analysis (Meyer, 2017). In the change detection matrix (Table 3), A, B, C, D represent each land cover type at the time T1 and T2. P_{AB} refers to the amount of the total area of land cover type A converted to land cover type B during the period T1-T2. P_{AA} represents the amount of the land cover type A that has not changed during the period T1-T2. P_{A+} and P_{+A} refer to the total amount of the land cover type A at time T2 and T1, respectively (Vittek et al., 2014; Stow, 1999).

Table 3 *The description of change detection matrix of land cover classes*

		T1				
		A	**B**	**C**	**D**	**Total**
	A	$\mathbf{P_{AA}}$	P_{AB}	P_{AC}	P_{AD}	P_{A+}
T2	**B**	P_{BA}	$\mathbf{P_{BB}}$	P_{BC}	P_{BD}	P_{B+}
	C	P_{CA}	P_{CB}	$\mathbf{P_{CC}}$	P_{CD}	P_{C+}
	D	P_{DA}	P_{DB}	P_{DC}	$\mathbf{P_{DD}}$	P_{D+}
	Total	P_{+A}	P_{+B}	P_{+C}	P_{+D}	**P**

The annual rate of forest cover change can be monitored using satellite imagery and measured with spatial analysis (FAO 1995). The annual rate of forest cover change is calculated by comparing the area under forest cover in the same region at two different times. According to the FAO (1995) the annual rate of forest cover change, derived from the Compound Interest Law and should be calculated as: $q = (A_2 / A_1)1/(t_2-t_1) – 1$, where A_1 and A_2 are the forest cover as time t_1 and t_2 respectively. In this study the annual rate of forest cover change was estimated during the period from 1986 to 2016 (FAO 1995; Puyravaud, 2003).

Results and Discussion

Validation data set was established to determine the classification performance of land cover classes. It was generated from the areas outside the sampling data and used for testing the SVM classification results. For both land cover classes, randomly distributed and equal number of sampling pixels were selected (400). Overall Accuracy (OA) which is the total classification accuracy, and kappa coefficiency, a discrete multivariate technique of use in accuracy assessment, were used to measure the performance of SVM classification algorithm (Foody, 2002). The confusion matrix was calculated by associating the land cover maps generated with SVM algorithm with the validation data set. Consequently, OA and kappa values were calculated from the confusion matrix for 1986, 2000 and 2016 (Table 4).

Table 4 *Overall Accuracy and Kappa Coefficient*

Assessment Coefficient	**1986**	**2000**	**2016**
Overall Accuracy (%)	94	94	93
Kappa Coefficient	0.93	0.92	0.92

The Overall Accuracy for 1986, 2000 and 2016 were 94%, 94% and 93% with kappa values of 0.93, 0.93 and 0.92, respectively. It is generally considered that the OAs above 90% and kappa coefficient above 0.9 represent a good classification (Foody, 2002). As a secondary and supplementary validation, the forest cover map of 2000 was compared with Global Forest Watch (GFW) Tree Cover map to test the accuracy of the forest cover classification results. GFW, collaboratively generated by Global Land Analysis & Discovery lab at the University of Maryland, Google, USGS and NASA, displays tree cover over globally (except for Antarctica and a number of Arctic islands) for the year 2000 at 30 × 30 m spatial resolution. (Hansen, 2013). The GFW Tree Cover map and forest cover map of 2000 showed 80% of overlapping in forest cover class.

Land cover in the study area 1986, 2000 and 2016

A change map was generated and then compiled to display the specific nature of the changes between the two land cover maps of 1986 and 2016 which indicated the changes. The two land cover maps of 1986 and 2016 were compared on a pixel-by-pixel basis using a change detection matrix (Table 5). The change matrix has been produced as an output of change detection process using QGIS 2.18.2 software. The unclassified pixels were excluded in the process. According to the change detection matrix, 37,555 ha of forest cover remained unchanged, whereas 39,816 ha of forest cover are transformed into non forest class which includes shrubs, cropland, open areas and artificial surfaces. Overall forest cover in Bozdağlar decreased from 77,371 ha to 47,773 ha in the last three decades.

Table 5 *Change detection matrix of land cover classes*

	2016		
1986	**Forest**	**Non-forest**	**Total (ha)**
Forest	**37,555**	39,816	77,371
Non-forest	10,218	**222,562**	232,780
Total (ha)	47,773	262,378	**310,151**

Area and proportions of each land cover class for the year 1986, 2000 and 2016 are summarized in Table 5. The proportions of each class for the three years are also shown in Figure 3. Forest was covering 24.9%, 18.7% and 15.4% of the study area for the three years respectively. The total area of forest cover declined 24.8% and 17.6% during the periods of 1986-2000 and 2000-2016 (Malkoç, 2017).

Table 6 *Area statistics and proportions of each land cover type for the three periods and percentage change from 1986 to 2000 and 2000 to 2016*

Land Cover Classes	1986		2000		2016		Percentage Change	
	Area (ha)	Percent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)	1986-2000	2000-2016
Forest	77.371	24.9	58.160	18.7	47.773	15.4	-24.8	-17.6
Non-forest	232.780	75.1	251.991	81.3	262.378	84.6	8.2	4.0

The annual rate of deforestation in the study area over the past three decades was calculated as -0.015 according to the formula derived from Compound Interest Law. This ratio was lower than the annual global deforestation rate of -0.23 provided by FAO, which means that the annual rate of deforestation in Bozdağlar is lower than the average deforestation rate in the world (FAO,1995). The layout of the land cover classification map for the three years were manipulated using QGIS 2.18.2 software (Figure 4). The classification maps show the extent and spatial distribution of the two land cover classes derived from Landsat- 5 TM, Landsat-7 and Landsat-8 OLI images from 1986, 2000 and 2016. Areas classified as forest in 1986 were mostly in the west and southwest of the study area, and they significantly decreased between 2000 and 2016.

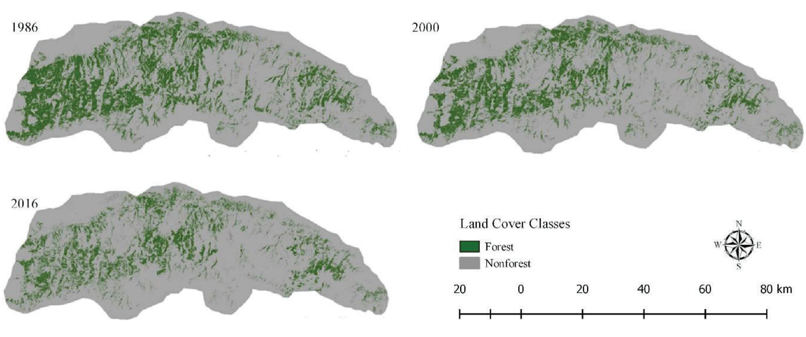


Fig 3 *Land cover classification maps of Bozdağlar for 1986, 2000 and 2016 using SVM algorithm*

Conclusions

Remote sensing is one of the most effective tools to monitor land cover changes in mountainous areas, exposed to land cover change and deforestation. The spatial complexity of the mountains and rapid changes in forest cover make remote sensing techniques an essential tool to regularly monitor the landscape and generate accurate data. In this study satellite data and remote sensing techniques were used to map forest cover in the Bozdağlar region and to monitor forest cover change for the years of 1986, 2000 and 2016. Landsat- 5 TM, Landsat-7 and Landsat-8 OLI imagery covering the study area provided a time-series data support. This study is the first attempt to use remote sensing techniques and perform SVM algorithm to map and monitor forest cover change in the study area for the last three decades.

A quantitative analysis was conducted on how forest cover changed over the 30 years period. Spatial and temporal changes of forest cover during this period were located and compared by using geographical information techniques. The significant decrease of forest cover identified in the west and southwest of Bozdağlar region can be explained with the proximity to the big cities of Izmir and Manisa. The changes in Bozdağlar region were represented by change detection matrix. The change detection matrix was connected with the proportion of changes in each land cover type. The results indicated that there has been a continuous and significant forest cover loss between the years 1986-2016 in Bozdağlar region, although the annual rate of deforestation is at a slower pace than the global annual rate of deforestation. The forest, including the protected areas, is much lower

than in the past and are also under the risk of deforestation in the future due to the conversion of the forest into various land cover types.

Mapping, monitoring and quantifying the results of growing populations and anthropogenic activities on forest cover can facilitate the design of efficient and sustainable land use planning policies in the study area. Through the generation of accurate mapping information, this study provides useful outcomes to the management and planning institutions, for implementing better decision on sustainable forest management. Moreover, the magnitude of mapping and monitoring forest cover change should be promoted by management and planning institutions, in order to inform the public about the past and current situation of their lands. The results of this study can contribute to strengthen the coordination and cooperation among management/planning institutions and the public, support land cover changes monitoring in Bozdağlar region and provide solid scientific information for decision makers to formulate policy for sustainable land use management here and in similar regions of Turkey.

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