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RESEARCH ARTICLE

Semi-automatic Tree Detection from Images of Unmanned Aerial Vehicle Using Object-Based Image Analysis Method

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Abstract

The aim of this study is detection of trees at low cost, fast and reliably through object-based image analysis method by using high-resolution unmanned aerial vehicles data. The study consists of three basic process stages. In the first stage, high-resolution aerial photographs were obtained by using unmanned aerial vehicles. Aerial photographs with approximately 1 cm spatial resolution were obtained from 30 m. flight height with 80% front overlap and 80% side overlap. Orthorectification, mosaicking, georeferencing and filtering processes were performed on the obtained photographs in order to make them ready for the analysis. Orthoimage in three spectral bands (Red, Green, Blue) and digital surface model were generated by processing the aerial images. The second stage of the study constitutes the most important process steps of object-based classification: They are segmentation and classification. In this phase, various parameters such as scale, shape and integrity were used to obtain the best result. Furthermore, accuracy assessments were performed through field observations. In the classification process step, a specified set of rules applied to segmentation result objects; thus, trees and other classes were determined in the study area. The generation of the rule sets was performed using the height information obtained from digital surface model and spectral data collected from orthoimages. Accuracy analysis was performed in the last stage of the study. The number of trees determined in the classification step was compared with the known number of the trees in the field. As the result of comparison, tree numbers and crown widths were found to be consistent. This study tests and implements a method that detects trees at low cost, fast and high accuracy which can be used in ecological studies and specially in determination of tree density.

Keywords Agricultural planning · Image processing · Object-based classification · Tree detection · Unmanned aerial vehicle

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Introduction

The determination of land qualifications and assets is very important in terms of planning. When making decisions about planning, determining the natural and cultural assets on that land is the guide for making decisions. Determination of the ecological infrastructure such as forests, streams, lakes, meadows and pastures, agricultural texture etc. is the most important data source for land management. Detection of ecosystem assets rapidly and with high accuracy, in addition to this, making planning decisions for the future, will facilitate the management of lands. Besides, exposing agricultural components like determination of the agricultural crop pattern, present and possible product quantity, tree numbers and crown diameters are valuable because they are the most important data sources to direct the food policies of countries and regions. Therefore, studies on determination of the flora have always been among the important agendas of the countries. These auto-detection and automatic extraction studies are increasing rapidly with the development of remote sensing and geographical information systems.

The most important and most frequently used data source is satellites in remote sensing. However, the use of unmanned aerial vehicles (UAV) also known as drone is rapidly increasing in parallel with technological developments today. The most important reason for the use of UAV in remote sensing studies is low cost and practicality. Besides, the availability of high-resolution up-to-date data in a shorter time and high maneuverability can be considered as the advantages of this system. UAV images can be obtained more cost-effectively than airborne LIDAR. Color images can be acquired with a low-cost camera which is integrated to controllable UAV imaging systems. These images are evaluated by classification process in accordance with desired purpose (Lim et al. 2015).

Classification in remote sensing technologies is the process of determining meaningful patterns groups in the image. In this context, pixel-based classification methods are widely used in remote sensing researches. However, comprehensive information content of high-resolution data cannot be completely described in pixel-based approach. Therefore, the use of object-based classification techniques is at the forefront as an alternative. Actually, the object-based classification is a method that uses the texture and context information in addition to spectral information in the image pixels. The basic element classified is not pixels but the objects consisting of pixels group (Sunar et al. 2013). In this scope, various difficulties and inaccurate results are encountered with pixel-based classification in defining objects. These problems can be removed by using object-based analyzing method which combines new spectral structural and hierarchical properties after image segmentation (Peña-Barragán et al. 2011). This method also enables modeling of ecological structure and has potential to obtain correct information in a short time (Strasser and Lang 2015). Besides, various earth objects like buildings, greenhouses and forests were analyzed through object-based classification from high-resolution satellite images. It has been shown that the analyses made are of high accuracy (Coslu et al. 2016). Recently, the trend toward object-based classification from UAV images is remarkable. Object-based image analysis provides a method of integrating unordered rules based on fuzzy logic (Kalantar et al. 2017). In this context, studies indicate that the combination of the data obtained with the UAV with object-based image analysis technique is appropriate and usable (Comert et al. 2016).

Oblique imaging in UAVs is also preferred in determining the green areas and forests. However, as in the case of individual tree detection, it is still insufficient for data processing and information extraction. Technically, 3-step algorithm is used to detect the trees in oblique view images taken from the UAV to fill this void. The first stage is classification based on the k-means clustering and RGB-based vegetation index derivation to obtain vegetation cover maps. Then, proposing new property parameters by synthesizing the texture and color parameters to identify vegetation and finally marker-controlled basin segmentation and individual tree detection based on shape analysis (Lin et al. 2015). In this scope, individual tree detection and evaluation of ecological characteristics have importance in ecological planning. In the framework of olive tree-growing programs, low-cost UAV images are used to estimate these parameters. GIS analysis and object-based classification technique are preferred for calculation of parameters from orthomosaic image and digital surface model produced by UAV. The results confirm that there is a high similarity between the remote sensing estimate and the field measurements of the crown parameters (Díaz-Varela et al. 2015).

This study aims to detect trees through object-based image analysis method by using UAV data. Accuracy analysis of the trees determined by this method based on the comparison of the data obtained by manual digitization. The study consists of three basic processing stages. In the first stage, data were collected from study area and prepared for the analysis. Then, segmentation and classification processes were performed through object-based classification method. In the classification stage, the study area was determined according to the tree and other classes by applying the determined rule set to the objects obtained as a result of segmentation. In accuracy assessment stage of the study, number of the trees determined by the classification was compared with the number of trees determined with manual digitization.

Study Area

This study was carried out in Kumluca district of Antalya which is one of the most important tourism destinations and agriculture areas in Mediterranean Region of Turkey. It has a high agricultural potential and lies between the Antalya Bay and the gulf of Fethiye at 36°21′N and 30°15′E. It is 95 km far westward from Antalya central district (Fig. 1). The district is surrounded by the Mediterranean Sea from south, Kemer from east, Korkuteli from north, Antalya central district from northwest, Elmalı and Finike from west. Winters do not pass harsh in this district so agricultural crop production is rather high. In

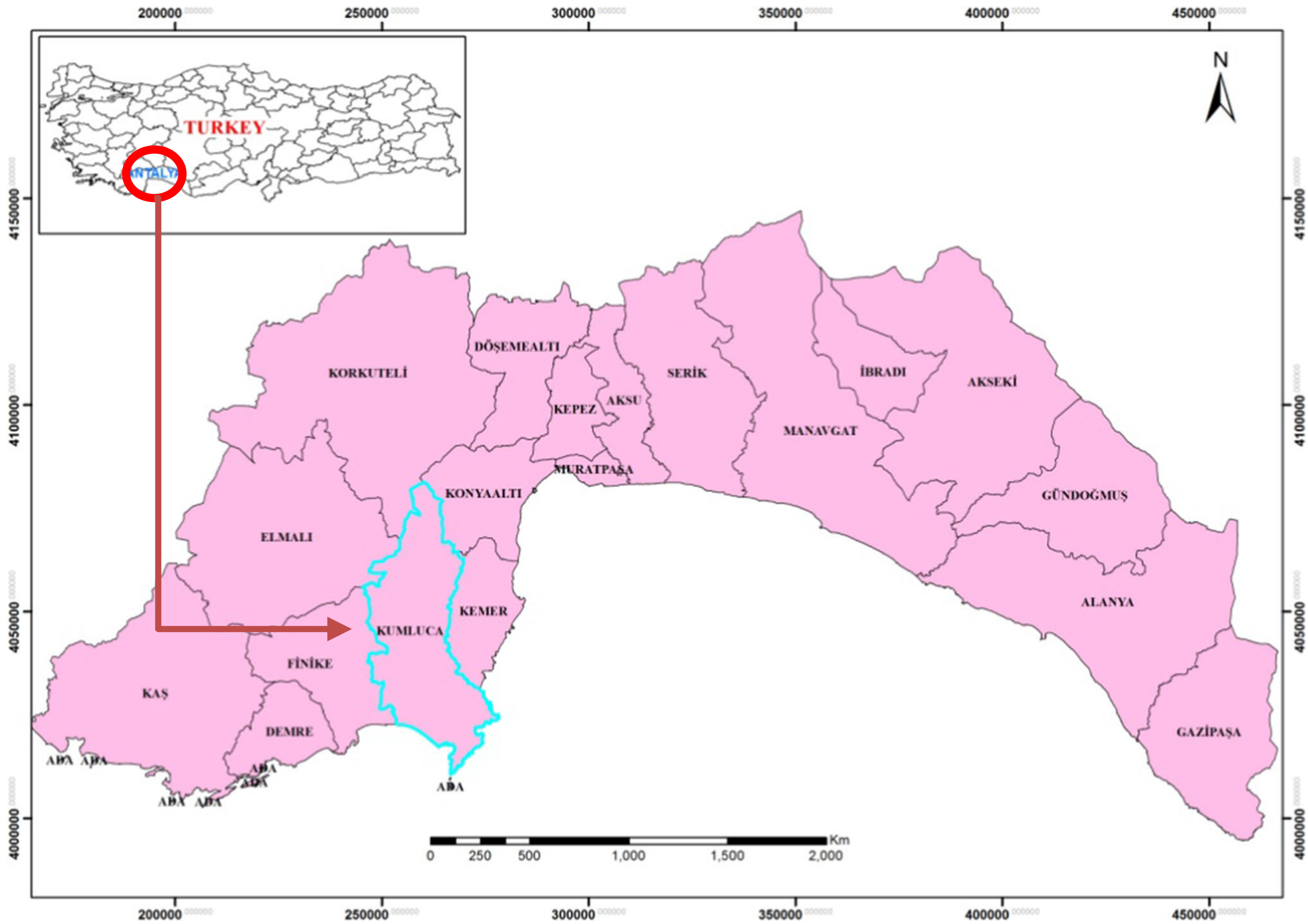


Fig. 1 Study area

addition, suitable topography, climate, soil and water conditions ensure the development of agricultural activities like greenhouses in this district (Kumluca Kaymakamligi 2017). The study area is approximately 4.1 ha agricultural land where orange (*Citrus cinensis*) is produced.

Data Sets

In this study, the essential data sets are high-resolution images obtained from UAV (DJI Phantom 3 Standart). The internal and external routing parameters of the 12 megapixel camera were set. In order to prevent disturbances in the image taken, windless and open air flights were performed. The properties of flight details are given in Table 1, respectively. Pix4D mobile was used for planning UAV's flight. Thirty meter flight height with 80% front overlap and 80% side overlap also middle level flight velocity were chosen in flight plan by using this software.

Since the number of images obtained in the test area depends on the size of the test area, a total of 46 images were taken and analyzed for this area. Pix4D mobile was used for planning UAV's flight. Orthomosaic image and digital surface model were generated from taken images. In the first stage of the study, manual digitizing on images were performed with ArcGIS software. E-Cognition software which is recently very popular was used for the image processing stage.

Table 1 Properties of flight

Parameters	Values
Flight altitude	30 m
Horizontal overlap	%80
Vertical overlap	%80
Flight time	Approx. 16 min
Spatial resolution	1.8 m
Image size	4000 × 3000 RGB
Calibration	Internal optimization
	External optimization
	Automatic rematch

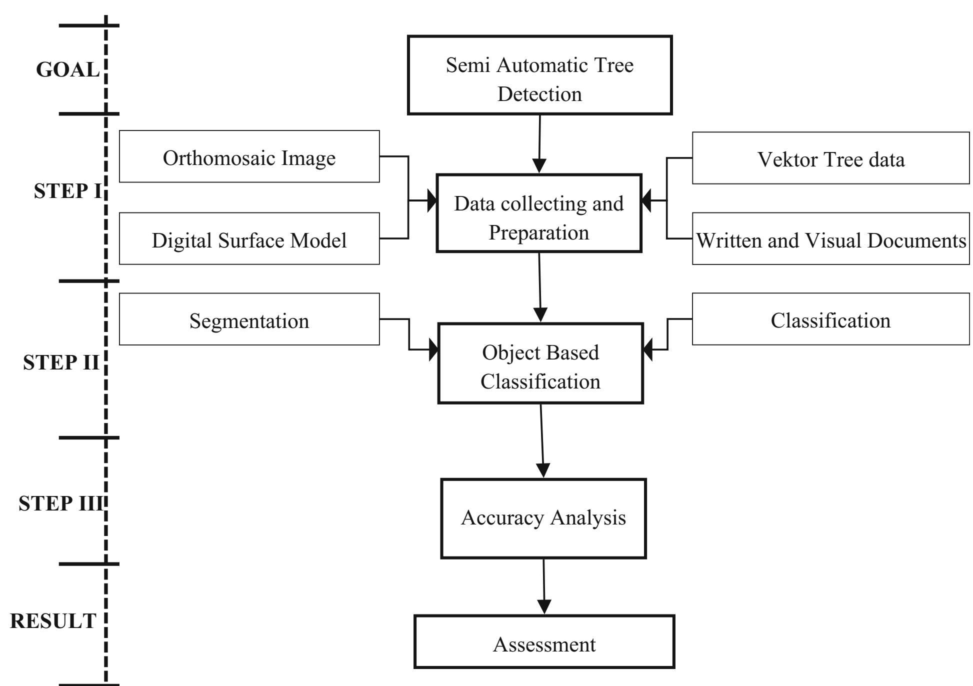
Methodology

Study method consists of three basic stages. These are: data collection and preparation, object-based classification and accuracy assessment (Fig. 2). Firstly, autonomous flight plan was created in the data collection and preparation stage. The orthomosaic image and the digital surface model of the field were produced from the high-resolution images after the flight. Besides, manual digitization was performed from high-resolution orthomosaic image. The trees were determined as vector data and compared with sample points taken by GPS from the ground. Object-based classification was performed in the second stage of the study. The most important processing stage of object-based classification is image segmentation. Segmentation process should be achieved with the most suitable parameters for a good classification result and object detection. The success of the segmentation process mainly relies on scale parameter, shape and integrity criterions (Rahman and Saha 2007; Tehrany et al. 2013). The most suitable parameters and criteria for this study, 35–0.5–0.1 values, respectively, were determined with users' experiences, tests and visual analysis. The segmentation algorithm applied to orthomosaic image is multiresolution segmentation. It is aimed to keep heterogeneity at the lowest level and increase homogeneity by using this segmentation algorithm. In this phase, the BGR band weights in the orthomosaic image were determined as 1, and the weight of the digital surface model was determined as 2. In addition, in order to increase the quality of the segmentation process, vector tree data generated in the first stage is used as thematic layer. In the last stage of the study, accuracy assessment analysis was carried out. In this context, trees determined according to object-based classification result were compared with vector tree data obtained by manual digitization. Number of trees obtained by object-based classification was compared to ground truth data.

Results and Discussion

Orthomosaic image and digital surface model with spatial resolution of 1.8 cm were produced by using UAV (Figs. 3 and 4). Trees and crown areas were determined by manual digitization using orthomosaic image (Fig. 5). In the analysis phase of the study, trees and tree crown areas were determined semi-automatically by using object-based classification method. While the weights of the bands in the orthomosaic image determined as 1, the weight of the digital surface model as additional band entered as 2 at segmentation sub-stage. In order to increase the segmentation quality, it has been observed that adding the ready substantial vector tree data as a thematic layer is positively influenced the segmentation process. The flatness of the ground in the study area was appropriate in terms of the use of the digital surface model in the rule set created by object-based classification. While trees were being classified, the threshold value determined by digital surface model was used in this stage.

Fig. 2 Flowchart



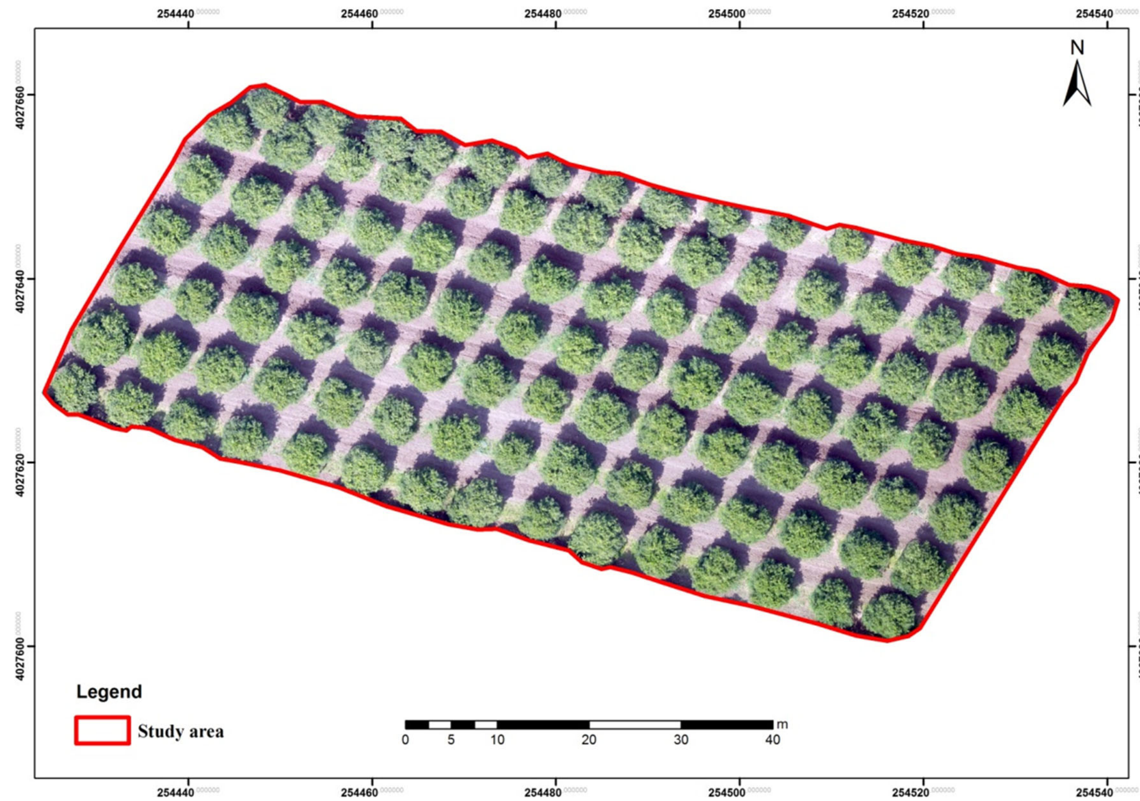


Fig. 3 Orthomosaic image

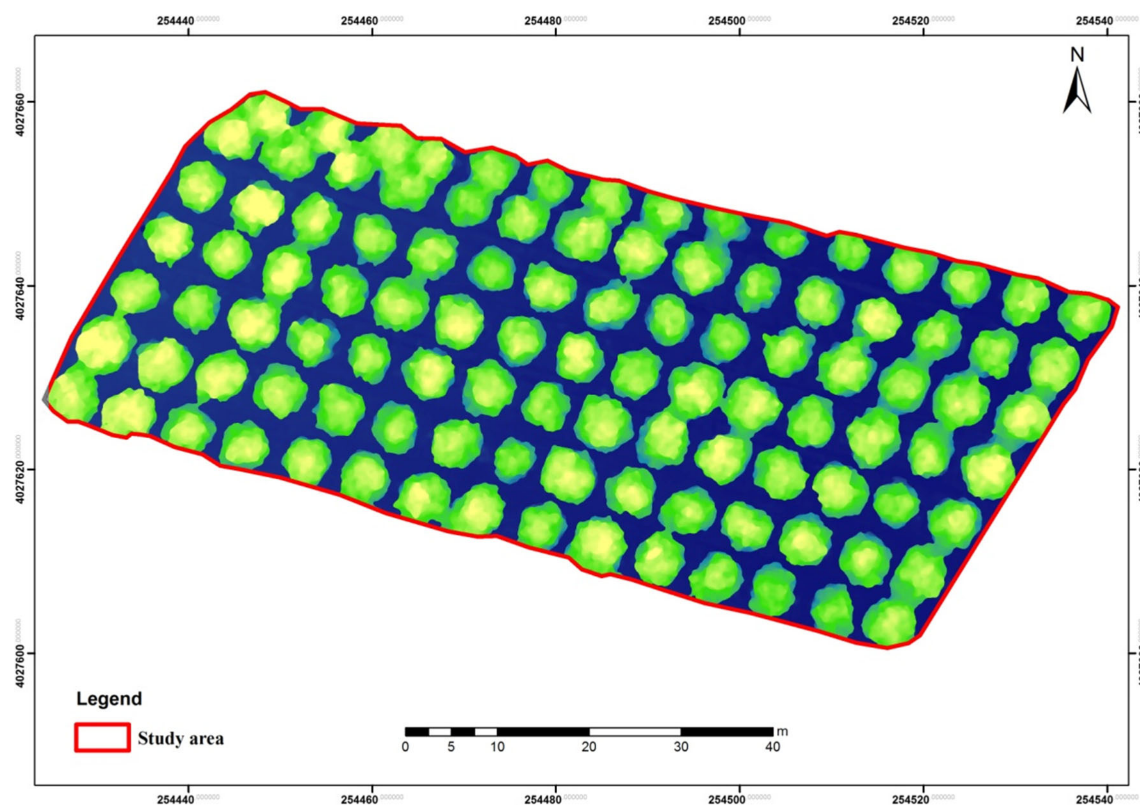


Fig. 4 Digital elevation model

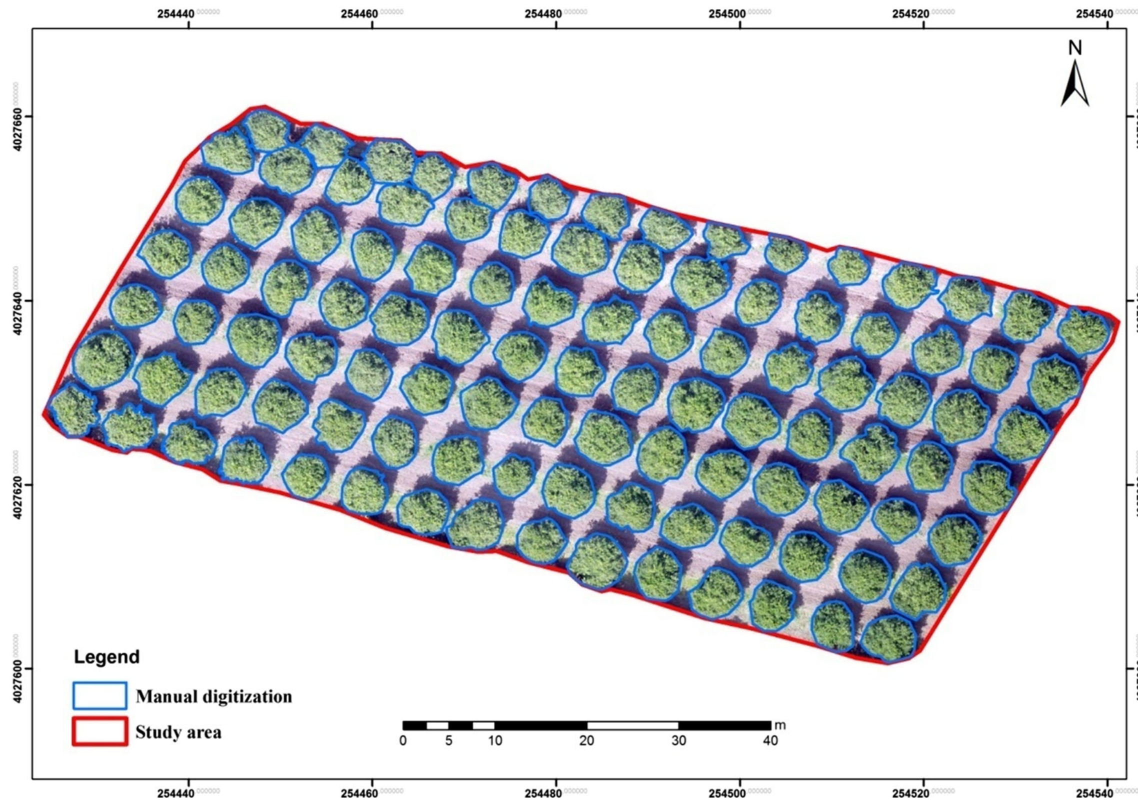


Fig. 5 Manual digitization

In this study, tree numbers and tree crown areas were compared and 87 out of 105 orange trees in the field can be completely detected by object-based classification (Fig. 6). Accuracy rate of detected tree numbers in this study is 82.86%. However, it was seen that the crowns of 18 orange trees in the north of the study area were mixed with each other (Fig. 7). Eight of the 18 trees in this area and also each two of other 10 trees were determined as one tree due to the problem caused by the crown structures. The total crown area obtained by visual analysis and manual digitization of orange trees in the study area is 2283.30 m^2, and total crown area determined by object-based classification technique is 2413.42 m^2. According to these results, the difference between crown areas is 130.12 m^2.

It was found that there is a statistically significant correlation between the total crown areas of trees found with manual digitization and object-based classification ($P < 0.001$, $R^2 = 0.99$) even if not all the trees were discriminated with object-based classification.

Conclusions

The results of this study show that trees can be semi-automatically determined with high accuracy using the object-based classification technique from high-resolution images obtained from UAV. The advantage of this method over other automatic tree determination methods is that it is low cost and generates data at high accuracy in a short time. In previous studies, digital surface model and normalized digital surface model have been used to perform tree detection with UAV LIDAR and laser scanning technologies (Dian et al. 2016; Reddy et al. 2018; Kestur et al. 2018) and in parallel with these studies, this study has also yielded high accuracy (Wallace et al. 2014; Bulatov et al. 2016). Especially with automatic tree detection using UAV and lidar technology, this method has much less data density and is independent of the distortions caused by high point cloud density. Thus, the used method requires less analysis and less time than other methods. Not only the developments in UAV systems enable the data to be produced with high resolution and high speed but also enable to determine earth objects easily (Malek et al. 2014). The orthomosaic image, digital surface model and vector tree data of UAV images used in this study were obtained in Kumluca district of Antalya. The result of the study indicates that the crown areas of trees can be determined semi-automatically using object-based classification method, but problems may arise due to the interference of crowns while tree numbers are determined. It is thought that the main source of these problems is that the trees which are not planted according to the optimum planting distance cannot

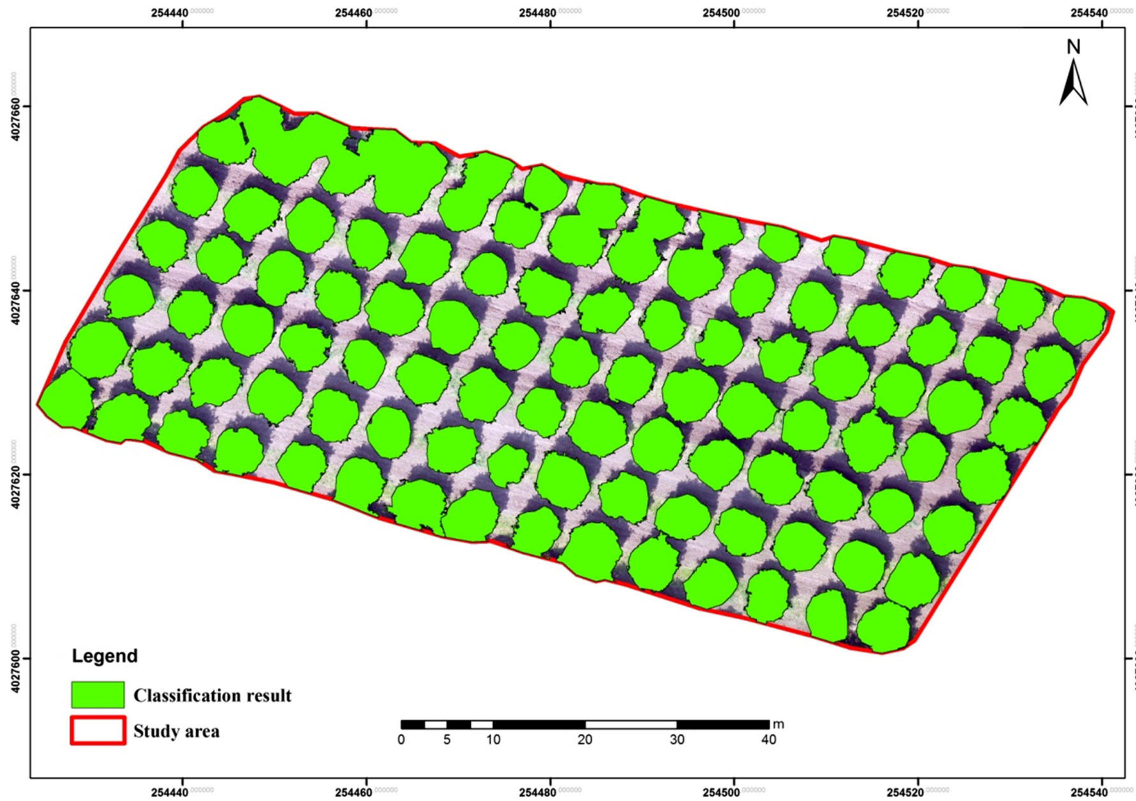
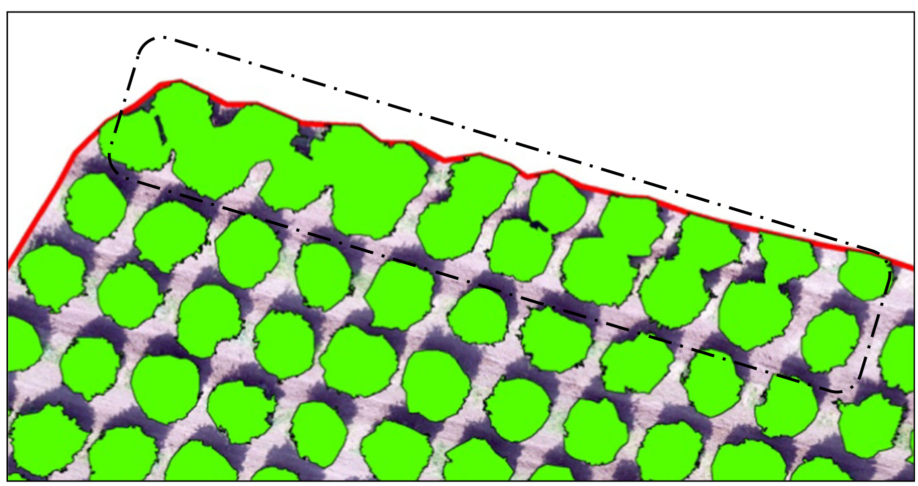


Fig. 6 Classification result

Fig. 7 Indiscriminate trees



benefit equally from the growing environment factors. Within the scope of the applied method, it is revealed that the tree crowns should not touch each other in order to determine 100% of the number of trees and crown areas. This will only be possible by the application of suitable pruning techniques. In general, in order to be able to use the results of this and similar studies in more precise applications, it is necessary to avoid the problem of shadowing in orthoimages and digital elevation model obtained from UAV. In the later stages of this study, the same method will be tested in different areas with different species of tree groups. Thus, it is envisaged that this method can be utilized in yield estimates for large areas, especially for agricultural production.

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