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The Availability of UAV Systems for Agricultural Purposes

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Abstract: Unpiloted aerial vehicles with built-in power system, carrying useful freight, let to fly automatically or by a remote control system are called Unmanned Aerial Vehicles. The UAVs used for various purposes in civil and military fields today, too, have exhibited development as result of developments in aviation, electronics, communications and navigation technologies in parallel with the developments which occurred in the field of science and technology in the 20. century.
These have ensured ease of use and exhibited a rapid increase due to reasons such as, the sensor systems have become smaller, mobility has increased and they can fly at lower altitudes. Use of Unmanned Aerial Vehicles (UAVs) has become widespread in recent times as result of this. Particularly, in addition to imaging studies, use of UAV vehicles has come in the agenda for photogrammetric surveys in small scale areas against manned air vehicles, landslide and erosion monitoring, and for purposes of observing agricultural activities (determining the agricultural crop pattern, observing plant diseases, steering small scale agricultural policies, etc.). In this study the TM-GEO1 unmanned aerial vehicle designed and produced by the Gaziosmanpaşa University (GOU) Geomatics Engineering Department and the firm TEKNOMER has been used. Gaziosmanpaşa University Taşlıçiftlik Campus agricultural land and the Tokat Agricultural Research Institute pilot lands have been selected as the study area.. The test study surface areas are 342,37 hectare and 9 hectare, respectively and the flight altitude has been planned as 100 meters, the flight columns as 80% longitudinal and 60% transversal overlapped. Total 3044 numbers of photos within the campus area and 60 numbers of photos in the agricultural area have been evaluated. The photos obtained have been evaluated by PIX4D software and the image classifications have been made by using the Ecognition Developer software. 41 numbers of Ground Control Points have been included in the evaluation; images have been produced by pixel matching algorithms for the agricultural area. As result of evaluation it has been obtained as RMS=±0.015 m.

Keywords: UAV, Remote sensing, agricultural land planning, image processing

UAV Sistemlerinin Tarımsal Amaçlar İçin Kullanılabilirliği

Öz: Kendi güç sistemi olan, faydalı yük taşıyan, otomatik olarak veya uzaktan komuta sistemi ile uçurulan pilotsuz hava araçlarına insansız hava aracı denmektedir. 20. yüzyılda bilim ve teknoloji alanında meydana gelen gelişmelere paralel olarak havacılık, elektronik, haberleşme ve navigasyon teknolojilerinin gelişmeleri sonucu, bugün sivil ve askerî alanda değişik amaçlarla kullanılan İHA’lar da gelişme göstermiştir.
Sensör sistemlerinin küçülmesi, hareket kabiliyetinin artması ve düşük irtifalarda uçabilmesi nedeniyle kullanım kolaylığı sağlamış ve hızlı bir artış göstermiştir. Bunun sonucu olarak son dönemlerde İnsansız Hava Araçlarının(UAV) kullanımı yaygınlaşmıştır. Özellikle görüntüleme çalışmalarının yanı sıra, insanlı hava araçlarına karşın küçük çaplı alanlardaki fotogrametrik çalışmalarda, heyelan ve erezyon izlemede, tarımsal faaliyetlerin gözlenmesi amacıyla (tarımsal ürün deseninin belirlenmesi, bitki hastalıklarının gözlenmesi, küçük ölçekli tarımsal politikalara yön verilmesi vb.) IHA araçlarının kullanımını gündeme getirmiştir. Bu çalışmada Gaziosmanpaşa Üniversitesi (GOU) Harita Mühendisliği Bölümü ve TEKNOMER firması tarafından tasarlanıp, üretilen TM-GEO1 insansız hava aracı kullanılmıştır. Çalışma alanı olarak Gaziosmanpaşa Üniversitesi Taşlıçiftlik Kampüsü tarım alanı ve Tokat Tarımsal Araştırma Enstitüsü deneme arazileri seçilmiştir. Test çalışması alanları sırası ile 342,37 hektar ve 9 hektar olup, uçuş yüksekliği 100

metre, uçuş kolonları %80 boyuna ve %60 enine bindirmeli olarak planlanmıştır. Toplam 3044 adet fotoğraf kampüs alanı içerisinde, 60 adet fotoğraf ise tarımsal alanda değerlendirilmiştir. Elde edilen fotoğraflar PIX4D yazılımı ile değerlendirilmiş ve görüntü sınıflandırmaları Ecognition Developer yazılımı kullanılarak yapılmıştır. Değerlendirmeye 41 adet Yer Kontrol Noktası dâhil edilmiş, tarımsal alan için piksel eşleme algoritmaları ile görüntüler oluşturulmuştur. Değerlendirme sonucunda RMS=±0.015 m olarak elde edilmiştir.

Anahtar Kelimeler: UAV, uzaktan algılama, tarımsal arazi planlama, görüntü işleme

1. Introduction

The developments which occurred in the field of science and technology in the 20. century have caused some innovations to come into the lives of peoples and states. In parallel with the developments in aviation, electronics, communications and navigation technologies, also the Unmanned Aerial Vehicles (UAVs) being used today in civil and military fields and for different purposes have exhibited development (Terkan, 2015). Unmanned Aerial Vehicles are motor air vehicles carrying no human operator. They make use of aerodynamic forces to ensure the lift. These could be controlled by a remote pilot whereas, they could be self-flying systems, as well. Unmanned Aerial Vehicles can be single use only or reusable, they can carry killer or non-killer loads (Newcome, 2004, Koyuncu, 2006)

The history of UAVs started in the ages identical to that of air vehicles. Late in the 19. Century Charles Perley from the USA developed the prototype of the air vehicles named as UAV today (Akyürek, 2012, Terkan, 2015). According to its historical development Unmanned Aerial Vehicles were used for military purposes initially (Turner vd, 2011). The UAVs used in reconnaissance, surveillance and intelligence activities until 2001 began to be used as armed and for assault in Afghanistan for the first time by the USA (Ahmad, 2014), The USA and Israel are the countries which come to forefront in such use worldwide (Terkan,2015).

In parallel with the developing technology, the UAVs which have been started to be used in recent years by integrating into them Global Positioning System (GPS), Inertial Measurement Units (IMU) and high resolution cameras, have been started to be used also in scientific studies for purposes of remote sensing (RS), digital map generation and photogrammetry.

Since, they can fly at lower altitudes the UAVs, it is possible to obtain data at a higher resolution of 1 cm/pixel against obtaining high resolution spatial data within a band of 20-50 cm/pixel by satellite and manned air vehicles (Hunt vd, 2010).

Agricultural purpose mapping studies carried out through traditional methods which total station, GPS, laser scanners, digital cameras and other equipments are being used in, are being generated as based usually on close-range measuring methods. Although precision is high in this method; workforce, time and cost are increasing and in the same time, it causes precision to become lower most of the time in measuring of details which are hard to be attained to or some details can’t be measured at all.

UAV Photogrammetry indeed opens various new applications in the close-range photogrammetry in the geomatics field (Eisenbeiss 2009). Map generation by UAV systems is an integrated method between ground methods and aerial map generation methods. All measuring equipments requiring detail acquisition are being integrated into UAVs flying at low altitude as different from satellites or airplanes. All of spatial data are being implemented aerially and safely excluding ground control points (Nagai vd. 2008).

This study has been carried out in two different agricultural lands in order to test the usability of UAVs in agricultural activities. The first part is; GOU Agricultural Practice Land with the 342.37 hectare and in this part the assessments regarding the physical and geometrical data of sustainable precision agriculture have been examined by UAVs. In the second part it has been dealt with the assessments of integrated camera possessing near infrared band so that it can be determined the plant selection and crop pattern on the terrain within the 9 hectare, Tokat Agricultural Research Institute pilot land.

These are used used in the studies: Canon PowerShot camera, IMU and GPS systems produced for moving platforms integrated into TEKNOMER GEO-1 Multicopter UAV produced by the GOU Geomatics Engineering Department and the firm TEKNOMER. The spatial data of 41 numbers of ground control points covering the study area have been measured by means of four numbers of double frequency Geodesic GNSS receivers (Trimble, Topcon). The 2-hour static GNSS measurements have been assessed in three dimensions (3D) through Leica LGO V.8.3 software as connected to TUSAGA Active system.

2. System Design

These are used in this study: the TEKNOMER GEO-1 Multicopter designed by the GOP University Surveying Engineering Department (Figure 1). The multicopter designed, consists of Bearing platform, Control Unit (IMU, GPS, Mainboard) and Camera systems.

2.1. UAV Platform

UAV platforms are a very important alternative and solution for studying and exploring our environment (Nex and Remondino, 2014). All peripheral units in this study have been integrated into the TM-GEO1 multicopter vehicle designed by the Gaziosmanpaşa University Geomatics Engineering Department (Figure 2). The wingspan of the platform is 1.30 m, height 0.34 m and weight 3.6 kg. And, the flight weight is 4 kg. All of the sensors have been mounted on the bearing platform to ensure intregrity of operation. During taking photos the bearing platform, exercises duty by a speed of 10 m/sn. It has the capacity to perform duty except during rainy and snowy weather conditions. The specifications of the bearing platform have been given in Table 1.

Figure 1. TEKNOMER GEO1 Hexacopter System

Şekil 1. *TEKNOMER GEO-1 Hexacopter sistemi*

Figure 2.UAV platform

Şekil 2. *İHA platformu*

2.1. Camera System

In this study, Canon PowerShot SX 260 HS digital CMOS camera (given Figure 3) is used and its specifications are shown in Table 2. All the sensors were tightly fixed on the UAV to have constant geometric relations. Calibration of CMOS camera is calculated for interior orientation parameters. Estimation of relative position and altitude among the sensors is also conducted. All the sensors are synchronised by GPS receiver. Video camera is also put on the UAV. The video camera sends images to the ground on real time to monitor. UAV has minimum payload, so it is necessary to think about weight to flight long period (Nagai at al, 2008).

2.3. Control Unit

The flight controller is the nerve center of a drone. Drone flight control systems are many and varied, from GPS enabled autopilot systems flown via two way telemetry links to basic stabilization systems using radio control hardware.

Table 1. Platform technical specifications
Çizelge 1. *Platform teknik özellikleri*

Specification	Technical Detail
Weight	3.6 kg
Wing Span	103 cm
Payload	4 kg
Height	34 cm with GPS Antenna
Range	4 km
Endurance	30 min
Speed	7 m/sec
Maximum Speed	110 km - 30 mm /sec
Radio Control	24 GHz
Frame Transponder (FPV)	5.8 GHz
Telemetry Radio	433 MHz
GPS	5 Hz – 72 channels
Battery	6S li-po 35C 6200 Mah
Monitor	32 Channels 5.8 GHz DVR 7 inch LED system
Gimbal	2 Axes Brushless Gimbal
Motors	22 x 12 Brushless Motor 80T revolution 136 watt
Frame	16 mm 3K Carbon
ESC	45 Ampere 400 Hz
Prop	13 x 55 inch Carbon

Figure 3. Canon digital camera
Şekil 3. *Canon dijital fotoğraf makinası*

Today's flight control systems have several sensors available to them such as GPS, barometric pressure sensors, airspeed sensors and so on. The major contributors to the flight calculations are still the gyros, coupled with accelerometers. As the name implies, accelerometers measure acceleration which can be due to gravity, a high G turn, or stopping force. Accelerometers, however, are not enough since an accelerometer in free fall will measure 0 G's. Furthermore, turning forces will confuse a system trying to operate solely on accelerometer data. That's where gyros become important as gyros measure rate of rotation about an axis and they can be used to measure pitch and roll of an aircraft.

Inertial Measurement Units (IMU) are devices which read these sensors and execute sensor fusion algorithms to determine current position and attitude. Just about every full scale aircraft produced today has some form of IMU inside it.

Even smartphones can act as an IMU. If given an IMU the ability to control the platform it's riding on, it will become a flight controller. The answer of how a flight controller takes data from gyros, accelerometers, and other sensors, convert it into a stable flight platform is in some clever mathematics and software. The core of most flight controllers is a software algorithm called a Proportional Integral Derivative (PID) control loop. When choosing a flight controller, a number of popular open source flight controllers as well as commercial systems that are used today can be taken into consideration. The Naza controller is the preeminent commercial control system available used by many professional and hobbyist pilots on a daily basis. Naza gives basic flight control, attitude hold, and return home functionality with a simple interface (URL2).

Table 2. Canon digital camera specifications (URL1)
***Çizelge 2.** Canon dijital kamera özellikleri*

Specification	Technical Detail
Dimensions	2.4 x 4.2x 1.3 inches
Weight	8.2 lb
Type	Superzoom
Megapixels	12 MP
Sensor Type	CMOS
Sensor Size	6.2 x 4.6 (1/2.3”) mm
Media Format	Secure Digital,Secure Digital High Capacity,Secure Digital Extended Capacity
Battery Type Supported	Lithium lon
Maximum ISO	3200
35 mm-Equievalent (Wide)	25 mm
35 mm-Equievalent (Telephoto)	500 mm
Optical Zoom	20 x
Image Stabilization	Optical
LCD Size	3 inches
LCD Dots	460000
LCD Aspect Ratio	4:3
Viewfinder Type	None
Video Resuletion	720 p, 1080 p
Interface Ports	Mini USB,Mini HDMI
GPS	Yes
Waterproof Depth (Mfr.Rated)	0 feet
Boot Time	1.8 seconds
Recyle Time	0.5 seconds
Shutter Lag	0.2 seconds
Lines Per Picture Height	1939

3. Study and Application Areas

This study has been carried out in two different agricultural areas to test the usability of UAVs in agricultural activities. These are;

3.1. Agricultural planning purpose study and determining use of land (Gaziosmanpaşa University campus agricultural land)

In this part of the study drone flights have been implemented in the Gaziosmanpaşa University campus area (Figure 4). In order the GOP University campus area can be assessed as a whole; 3242 numbers of vertical aerial photos have been taken as 80% longitudinal, 60% transversal overlapped. 3044 photos of these aerial photos have been used to generate orthomosaic. The height for taking the photos has been determined as 100 meters. The orthomosaic generated for agricultural areas has been directed and scaled in the Turkish National Reference Network (TUREF). For such purpose it has been established 41 numbers of ground control points distributed in line with the land and position, height data have been obtained with precision (Figure 5). As result of the assessment made on purpose of planning the agricultural lands; Root Mean Square (RMS) has been calculated as ± 1.5 cm, Ground Sampling Distance (GSD) ± 3.44 cm. Brief data on the assessment have been given in Table 3.

As shown in the Table 3 the result report is generated as result of an assessment process which has lasted for approximately 19 hours. It has been generated the orthomosaic image of a 342 hectare area and has been determined the image coordinate system and ground control points which are in WGS84 coordinate system and in use of result data it has been determined as TUREF/TM36.

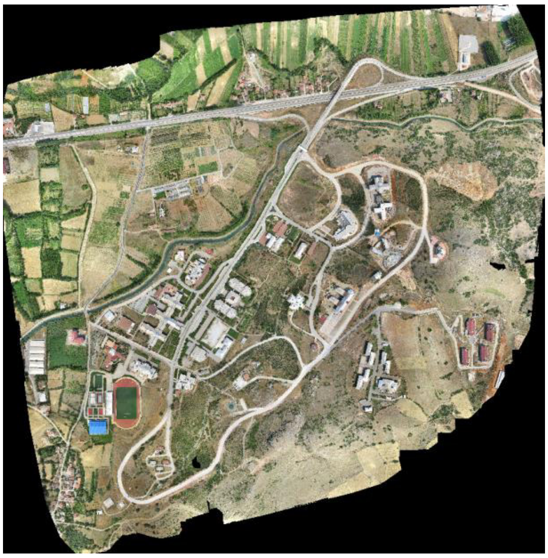


Figure 4. GOP University study area
Şekil 4. *GOP Üniversitesi çalışma alanı*

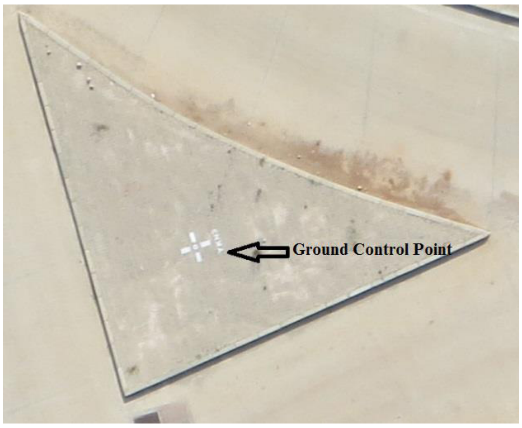


Figure 5. Ground control point established on the land for orthomosaic
Şekil 5. *Ortomozaik için Yer Konrol Noktası*

With such data obtained it has become possible to acquire any and all metric data about the campus area and the agricultural lands located within it. Numerical data such as, length, surface area, gradient can be obtained from the land model and orthomosaics generated. The metric data of the areas located within the campus site and planned to be used for agricultural purposes, the areas remaining outside the plan and the roads, have been shown in Figure 6.

It is shown in Figure 6; the current status of use of 29.5 hectare is agricultural lands. Through this it can be done by monitoring and tracking of the present land use. It is shown in Figure 7; the planned agricultural lands of the campus site and the areas which have remained unused.

On the orthomosaic generated by means of vertical aerial photos; it has been made the process of selecting the areas planned to be used for agricultural purposes and the area possible to be used is shown in Figure 6. Moreover, it has also been determined the roads and the engineering structures within the campus. The gradient and height differences could be determined by the help of the land model generated (Figure 8). Furthermore, it can be generated by software the longitudinal and transversal sections of the desired segments of the land without requiring any other additional measurement. Such data ensure us to gather information on subjects like, selecting the right product for agricultural lands, irrigation, drainage, erosion.

Table 3. Reports Regarding the Photogrammetric Assessment
Çizelge 3. *Fotogrametrik Değerlendirme Raporu*

Process Step	Description
Project	kampus_pro_010815
Camera Model Name	CanonPowerShotSX260HS_4.5_4000x3000 (RGB)
Average Ground Sampling Distance (GSD)	3.44 cm / 1.35 in
Area Covered	3.4237 km2 / 342.369 ha / 1.3226 sq. mi. / 846.451 acres
Image Coordinate System	WGS84
Ground Control Point (GCP) Coordinate System	WGS84
Output Coordinate System	TUREF / TM36
Processing Type	full Aerial nadir
Feature Extraction Image	Scale 1
Time for Initial Processing (without report)	18h:59m:06s

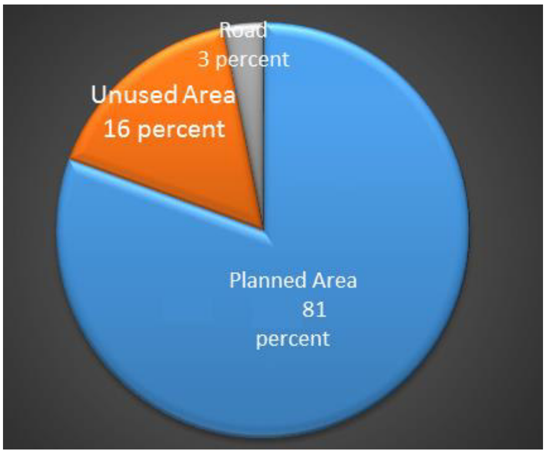


Figure 6. The present status of use of the agricultural lands
Şekil 6. *Tarımsal alanların kullanım durumları*

Figure 7. Determination of the agricultural lands within the campus site
Şekil 7. *Kampüs alanında tarımsal alanların belirlenmesi*

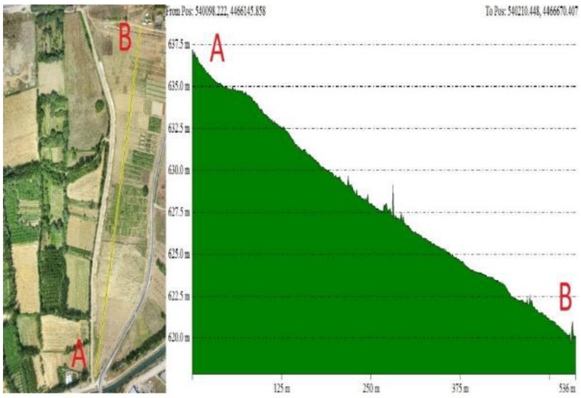
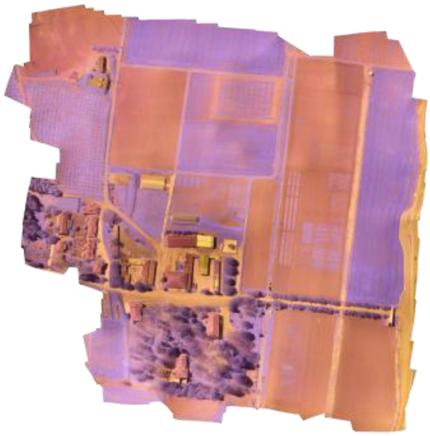


Figure 8. Gradient analysis between A-B points
Şekil 8. *A-B noktaları arası gradient analizi*

3.2. Use of Unmanned Aerial Vehicles in Agriculture by Remote Sensing Technique

Remote sensing is defined as the science of obtaining information about the physical qualities of an object without having any direct contact with it (Lillesand and Kiefer,1994). Due to the current and accurate data they provide through remote sensing technology the unmanned aerial vehicles and satellites; are being used frequently in agricultural practices. Determining the land cover or land use exhibits significance for agricultural policies and a sustainable land management, control. Supply and detection of such data occur as result of classifying the images recorded by UAVs and satellites. The process of classification can be described in Figure 9 as sorting the pixel groups which are homogeneous in the image by making use of image interpretation processes according to their qualities of interest and the features of land usage (Chandra and Ghosh, 2007).



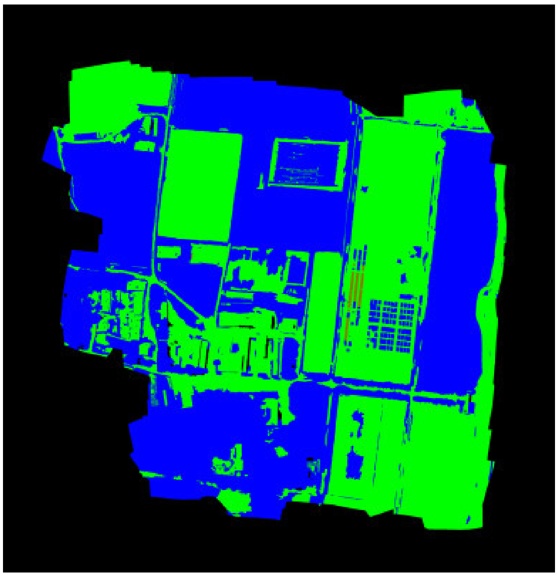


Figure 9. Example of classification for target product determination on agricultural lands
Şekil 9. *Tarımsal alanlardaki hedef ürün tespiti için sınıflandırma örneği*

The process of classification could be done as object and pixel based. In pixel-based classification; grouping is made by considering the pixel pixel spectral reflections. Pixel-based classification can be applied on the image as controlled and uncontrolled. And, in object-based classification; classification process is being made by bringing together the parameters determined depending on the scale and the similar pixel groups (segmentation) (Figure 10). By such means it is generated segments by bringing together the pixels having similar qualities instead of working with millions of pixels (Kalkan and Maktav, 2010).

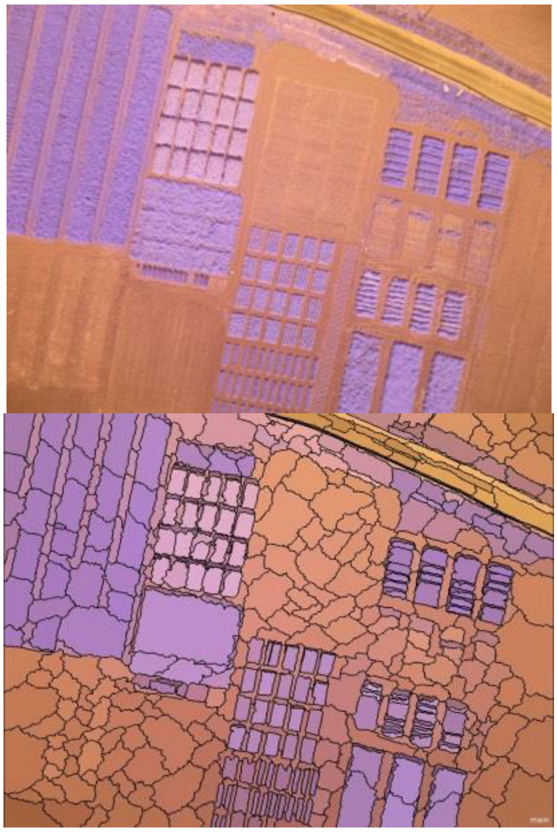


Figure 10. Segmentation example (GOU Agricultural Application Area)
Şekil 10. *Segmentasyon örneği (GOÜ Tarımsal Uygulama Alanı)*

Due to the multispectral cameras which can be integrated into the Unmanned Aerial Vehicles, it could be obtained data in wavelengths that human eye can't detect. By means of such data it could be made detection of precision agricultural applications, annual crop estimate and various plant diseases. Near infrared band which remains outside visible zone has been used frequently in agricultural practices of remote sensing due to its sensitivity to plant cover. The chlorophyll content in plants gives quite a high reflection value in the infrared band thus it could be discriminated easily from other land surfaces (Cracknell and Hayes, 1991).

In order to monitor the plant development on the Tokat Agricultural Research Institute land (Figure 11) and to determine target product in terms of use of Unmanned Aerial Vehicles for agricultural purposes flights have been implemented in two different times. The flights have been made in 10-day intervals on the poppy cultivated site. In the study it has been desired both discrimination of the poppy plant from the other crops present on the land and observing its spectral reflections in different times.

Figure 11. Photos of the application area
Şekil 11. *Uygulama alanı fotoğrafları*

Classification work has been made on the images obtained after the first flight has taken place. Because, in this study it has been preferred object-based classification method, segmentation process with proper parameters has been made prior to classification (Figure 12).

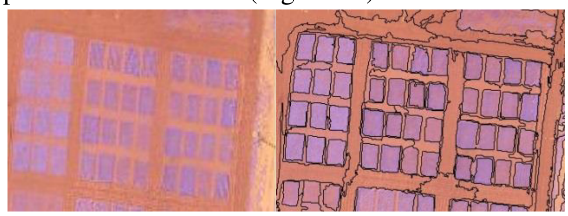


Figure 12. Segmentation process
Şekil 12. *Segmentasyon işlemi*

Then, later on, classification process has been made on the images and discrimination and identification work of the poppy plant from the other plants has been made. The classified images have been shown in Figure 13.

During the first flight above the poppy cultivated areas since the plant is in its initial phases still, it has become difficult to detect it. Hence, the classification accuracy of the poppy has been found as 75%. And, in assessments after the second flight 10 days later, the classification accuracy has been found as 88%. It has been detected that the NDVI values of the poppy plant on the classified image is close to zero in the first phase and the values have exhibited increase towards positive in the second flight data.

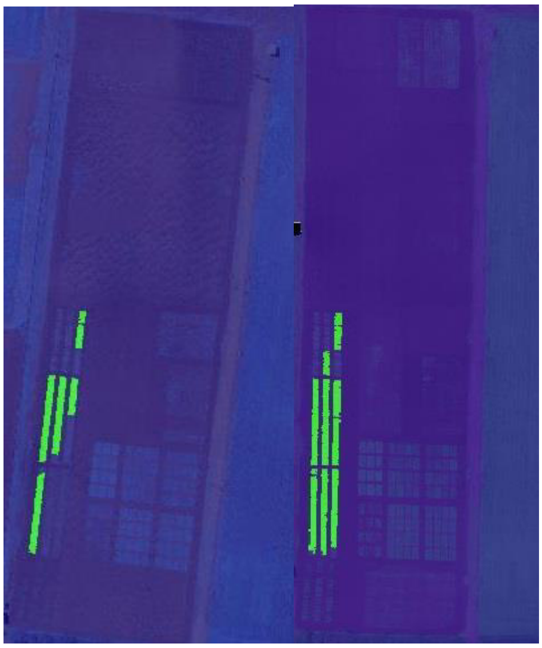


Figure 13. Classifications made in different times for poppy detection
Şekil 13. *Haşhaş bitkisi için farklı zamanlarda yapılan sınıflandırmalar*

4. Conclusions and Recommendations

At the end of this study it could be attained that high precision data about agricultural lands and their surroundings can be obtained more rapidly than classical measurements as result of evaluating the images obtained from UAVs by proper software. It is seen that they could be used easily in agricultural works such as, sustainable land planning, determination of the crop pattern, observation of plant development and diseases, crop estimates, drainage works. Furthermore, it is possible to acquire high resolution images in a shorter time without being dependent on satellite images which are difficult to provide in terms of time and cost. While it would take a long time and require a high cost to generate the metric data for land planning of a 342 hectare area by means of ground measuring techniques as it was done in the initial phase of the study, the entire area has been mapped with a precision of ± 3,44 cm by means of the UAVs and its 3-dimensional model has been obtained in a much shorter time. It could be necessary to wait for the timely development of the plants or monitor frequently their development phases in order to be able to discriminate the plants more easily. Because in such cases it would be expensive and more difficult to provide the satellite images, use of UAVs would ensure advantage. In addition to these, when it is required data supply in periodic terms in agricultural planning, measurements could be made repeatedly on the land models acquired. As a conclusion it has been seen that the photogrammetric images obtained from UAVs could be used readily in precision agricultural practices.

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