ÇOMÜ LJAR (2022) Cilt 3 Sayı 5 (36-48)
e-ISSN: 2717-8285
Geliş Tarihi : 20.06.2022
Kabul Tarihi : 30.06.2022
Araştırma Makalesi (Research Paper)

The Effect of Designed Drainage Structures on Landslide Areas: UAV Results of the Güzelyalı Landslide

Oya ERENOĞLU[1] **R. Cüneyt ERENOĞLU[2*]**

https://orcid.org/0000-0003-1235-3009 https://orcid.org/0000-0002-8212-8379

Emin Uğur ULUGERGERLİ[3]

https://orcid.org/0000-0001-5639-1109

[1] ÇOMU, Department of Geography Education, AnafartalarCampus, Çanakkale, Turkey
[2] ÇOMU, Department of Geomatics Engineering, Terzioğlu Campus, Çanakkale, Turkey
[3] ÇOMU, Department of Geophysics Engineering, Terzioğlu Campus, Çanakkale, Turkey

*Sorumlu yazar: ceren@comu.edu.tr

Abstract

Unmanned aerial system has been widely used to produce highly- precise orthomosaics, digital surface models, digital terrain models and three dimensional models in many applications. It is also utilized to determine and to monitor landslide sites using low-cost photogrammetric approach. Particularly, possibility of high precise-sensor acquisition provides substantial information about geometricfeatures and classification for landslides. Landslides are highly erosive processes that dominate soil movement and reshape lands. Therefore, measuring and characterizing landslide volume is essential for disaster prevention and understanding landscape evolution.In this study, a new low-cost drone-based methodology is used to detect soil mass movement caused by rain water drainage constructed to evacuate water in an active landslide area.To do it, the principles, analyzes and results of landslide monitoring are presented by using aerial photographs obtained with the help of high-resolution cameras integrated with unmanned aerial vehicles.For this purpose, an active landslide near Güzelyalı Village (Çanakkale, Turkey) was selected as the study area.Beside the given high-accurate geometric model, the approach has provided fast, efficient and economical solutions.

Key Words: UAV, GPS/GNSS, Photogrammetry, Water drainage, Volume

Tasarlanan Drenaj Yapılarının Heyelan Alanlarına Etkisi: Güzelyalı Heyelanı İHA

Özet

İnsansız hava sistemi, birçok uygulamada yüksek hassasiyetli ortomozaikler, sayısal yüzey modelleri, sayısal arazi modelleri ve üç boyutlu modeller üretmek için yaygın olarak kullanılmaktadır. Düşük maliyetli fotogrametrik yaklaşımla heyelan sahalarının belirlenmesi ve izlenmesi için de kullanılmaktadır. Özellikle, yüksek hassasiyetli algılayıcılar, heyelanlar için geometrik özellikler ve sınıflandırma hakkında önemli bilgiler sağlamaktadır. Heyelanlar, toprak hareketine neden olan ve arazileri yeniden şekillendiren sonucunda erozyona neden olan süreçlerdir. Bu nedenle, heyelan hacmini ölçmek ve belirlemek, afetlerin önlenmesi ve peyzaj evriminin anlaşılması için esastır. Bu çalışmada, aktif bir heyelan alanında suyun tahliyesi için inşa edilen yağmur suyu drenajının neden olduğu toprak kütlesi hareketini tespit etmek için düşük maliyetli insansız hava aracına dayalı yeni bir metodoloji kullanılmıştır. Bunun için insansız hava araçları ile entegre yüksek çözünürlüklü kameralar yardımıyla elde edilen hava fotoğrafları kullanılarak heyelan izleme prensipleri, analizleri ve sonuçları sunulmuştur. Bu amaçla, çalışma alanı olarak Güzelyalı Köyü (Çanakkale, Türkiye) yakınlarında aktif bir heyelan seçilmiştir. Verilen yüksek doğruluğa sahip geometrik modelin yanı sıra, yaklaşım hızlı, verimli ve ekonomik çözümler sağlamıştır.

Anahtar Kelimeler: Insect, Agricultural Pest, Biodiversity, Global Warming, Climate Change

1.Introduction

Since the effective use of photogrammetry, a wide variety of carrier platforms and imaging systems have been used. Many carrier platforms, from helicopters to airplanes, from space shuttles to satellites, have taken their places in the literature according to their suitability for the project. Today, small size UAVs (Unmanned Aerial Vehicles) have reached a practical, reliable and functional level enabling this technology to enter the Geomatics market as an additional platform for spatial data collection (Eisenbeiss, 2009). Although some data is obtained by means of sensors to be mounted on such a device, data collection is carried out using digital cameras in order to obtain higher precision in various applications. In addition to the high sensitivity, it provides the fact that the system is quite economical compared to other measurement methods making UAV-based measurement systems popular. In the last decade, there has been a marked increase in the number of UAV-based applications in robotics, computer vision, processing systems, sensor integration and data processing, geomatics and other different scientific disciplines. If the subject is handled from the geomatics perspective, the system provides important contributions both economically and technically in terms of application areas. However, the UAV measurement technique is in competition with other measurement technologies such as GNSS measurement, terrestrial laser scanning and photogrammetry, and aerial photogrammetry using aircraft or helicopters and medium or large format cameras that already exist in the cartography industry. Many studies have been carried out on subjects such as monitoring the settlements, changes in forest areas, changes in road and water networks, and monitoring of pollution in residential areas or outside the residential areas by using UAV-based imaging technique (Eisenbeiss et al., 2005, Eisenbeiss, 2009; Niethammer et al., 2009; Vogler et al., 2009). The reliability of the UAV system, the quality and accuracy of the final products, easy applicability, low cost and modern method make it widely used in the photogrammetric field today (Sauerbier et al., 2011). Recently, especially some private companies have been producing digital terrain models and orthophotos obtained with UAV-based technology in some of their applications. In addition, the UAV measurement method has been started to be used in monitoring the construction in the land, forest areas, open and closed mines and waste areas and determining the changes in the land (Kun and Özcan, 2019; Wing et al., 2014)). Considering the ease of use and cost of modern UAVs, as well as the reliability, quality and sensitivity of the system, it can be used effectively and widely in mapping applications. Since 2010, the use of UAV technology has continued to develop according to the studies and requirements in the field of cartography and has taken its current form. It has started to be used especially in monitoring the volumetric changes in open and closed mines and determining the deformations caused by these changes (Kun and Özcan, 2019). For example; UAV measurement technique was used to monitor the changes every 3 months in gravel quarries in Switzerland. By using the changes documented by the UAV, a law was enacted in Switzerland in 2012 regarding this study area, and some restrictions were made in the production of gravel. Both monitoring of the volumetric change and the rapid and effective data collection of the method increase the popularity of the system.The use of UAVs is expected to become widespread rapidly due to the added value they provide in documentation and data collection in different sectors. As it is known, monitoring spatial changes in any professional discipline is only possible by regularly monitoring the volumetric changes in the working area. For example; UAV technique was used to monitor the volumetric differences in a 1.08-hectare (120 x 90 m^2 size) gravel pit located in Lucerne, Switzerland (Eisenbeiss, 2009). For this purpose, 11 ground control points were determined in international and local coordinate systems by using differential GNSS measurements. Data were collected in two different periods, 2009 and 2010. Microdrones MD4-1000 quadrocopter was used as UAV vehicle and Olympus EP-1 burst camera was used as camera. It is performed using professional software for camera calibration. This simple procedure takes approximately one hour, including image collection and processing. Camera calibration procedures are repeated before each measurement period. Images were created with 70% and 20% overlaps in the obtained block-lined flight direction. Image orientation is one of the most time-consuming steps in the evaluation of data in the UAV method. Digital Terrain Models (DTM) are obtained during the evaluation process in which internal and external orientation parameters are taken into account. Therefore, orthoimage production can be started only when an error-free DTM is created. Although this procedure is usually an automatic process, manual intervention is required in the stages of determining the focused work area and obtaining the final products. If necessary, single ortho-images in the block can be combined into photomosaic. However, the generalization of ortho-mosaics can be quite time-consuming if there are radiometric differences between the data. When UAV-based measurement and GNSS measurement methods are compared; although the accuracy of GNSS measurement is high, the dot density achievable in a given time is low. However, digital elevation models can be easily derived from the digital terrain model obtained from the UAV method.

The paper (a) presents an UAV-assisted photogrammetric procedure to generate high-accurate digital 3D point clouds and orthomosaics for modeling soil mass movement caused by rainwater drainage in a landslide area; (b) the study area and itsgeological setting; (c) material and methods; (d) data processing and the results; and (e) concluding remarks.

Landslide Modeling using UAV Photogrammetry Approach

In recent years, with the development of digital camera and unmanned aerial vehicle technologies, it has become possible to obtain quality image data. Considering the costs in this context, using the most suitable mapping platform with simple systems and meeting the needs in a shorter time by achieving the desired sensitivity is an approach that will undoubtedly be accepted by the human mind. With the help of the digital camera to be mounted on the unmanned aerial vehicle, it is possible to take high-resolution images. External directional elements can be calculated through the control points of these images, whose locations are determined by GPS in the field, and internal directional elements can be calculated with the calibration process to be made before acquisition. Thus, a terrain model with cm precision can be created. With the unmanned aerial vehicle, both high-resolution and updated data can be obtained at any time. The main purpose in this work package of the project is to monitor landslides and to monitor meaningful changes by evaluating the data obtained by using UAV measurement technique at certain time intervals in landslide areas. Thus, both the effectiveness of the UAV method in monitoring landslides will be tested, and the usability of the UAV method with other Geomatic measurement methods separately and/or integrated will be investigated. Determining the changes in the landslide areas is only possible by monitoring the study area at regular intervals. For this purpose, the integrated use of GPS and UAV technique is a mandatory process, since the locations of the points obtained by GPS are important in image acquisition with the UAV method. The terrain model to be obtained from the images obtained from the UAV depends on the success of the image matching method to be used. Image matching algorithms may not give good results, especially in some areas with weak texture (lowtexture). In such cases, missing areas for which a terrain model cannot be created can be completed with the most up-to-date terrain model obtained from InSAR data. Thus, considering the advantages and disadvantages, the integrated use of three complementary technologies (GPS, InSAR and UAV) will provide a precise, high-resolution and up-to-date terrain model required for deformation analysis. Within the scope of the project, it is aimed to investigate the large-scale mapping of the landslide study areas with the help of a model multicopter to be used as a UAV and a non-metric camera placed on it. The stability of the camera will be maintained during the flight witha special camera carrier containing a kind of gyroscope to protect the camera from the aircraft's engine vibrations and jolts (Smith et al., 2009). It is predicted that the captured images provide suitable ground sampling intervals at an appropriate height. With the use of appropriate software and sufficient accuracy ground control points, the result products have very strong semantic information. Thus, depending on the camera to be used and the appropriate flight altitude, large-scale map production at the desired scale will be produced with the help of UAV. In other words, using the maps to be obtained, landslide mass changes at different times can be determined. These studies will be carried out entirely simultaneously with the geodetic studies. In this context, images of the project regions will be obtained with the UAV and integrated camera. Separate software will be used for camera calibration. Photogrammetric modeling software will be used in the processing of the obtained images. In this study, digital elevation models will be derived from stereo pairs. Later, feature extractions and digital terrain models will be performed by ortho products.

Study Area and Geological Setting

The Güzelyalı landslide area is located on the Southern shore of the Dardanelles, within the borders of Güzelyalı village, Canakkale (Turkey). The study area is located at the coordinates of 40°03'27.71" N– 26°21'26.65" E, at the approximately 100 m above sea level of the Sarıcaeli Landslide, which occurred in the Güzelyalı village of Çanakkale Province Central District (Figure 1). The landslide is approximately 2 km away from Güzelyalı village center and approximately 11 km from Çanakkale city center. Some terrestrial photos visually verify that the width of the landslide is approximately 130 m and its length is approximately 150 m (Figure 2).

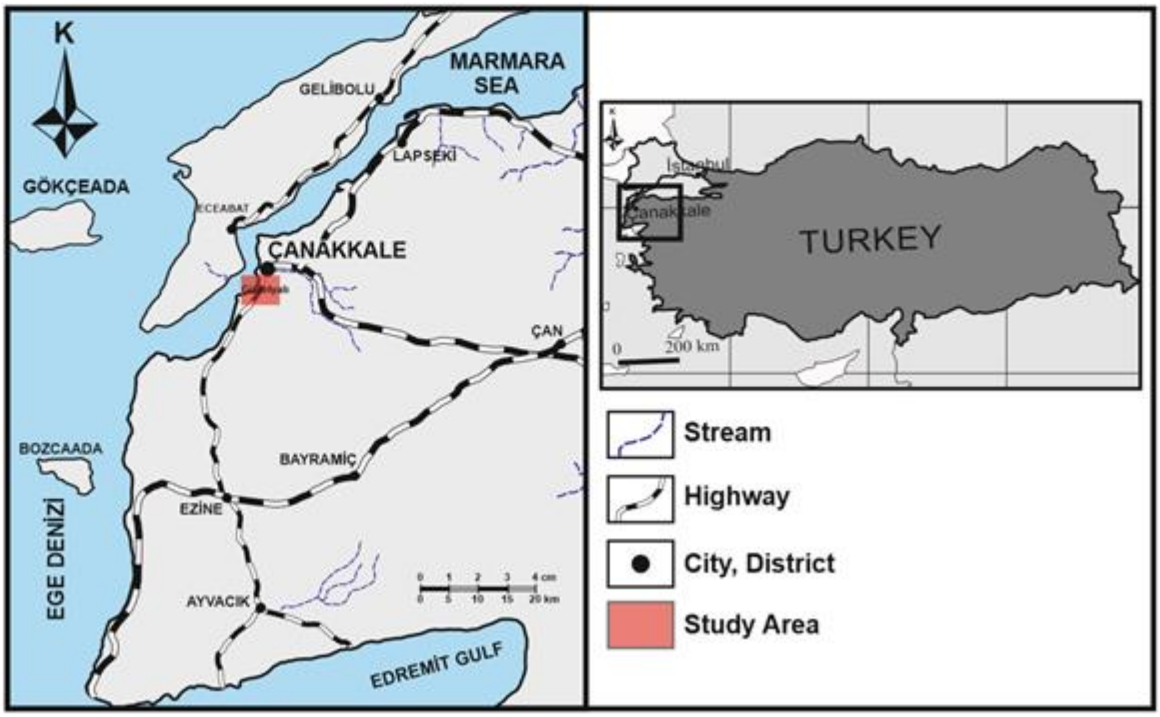

Figure 1. Location map of the study area.

Figure 2. The view of the landslide area on the satellite image and terrestrial photographs of the landslide surface cracks.

In Güzelyalı and its surroundings, units belonging to the Çanakkale formation (Şentürk and Karaköse, 1987) consisting of marine sediments crop out (Figure 3). Çanakkale formation,the Gallipoli formation of Saltık (1974) corresponds to the Gazhanedere, Kirazlı and Alçıtepe formations. Its general lithology is composed of conglomerate, sandstone, mudstone, siltstone, marl, calcaranite and oolilic limestones. Atabey et al. (2004) defined the Çanakkale formation, which was deposited in environments such as coastal, lagoon, and tidal channels, as three members: The Güzelyalı member, the İntepe member and the Tekkedere member.

Units belonging to the Güzelyalı member of the Çanakkale formation crop out in the Güzelyalı landslide region, which is one of the study areas. The Güzelyalı member studied in the region is predominantly composed of medium grained sandstone, to a lesser extent mudstone, claystone and carbonate units at lower levels.

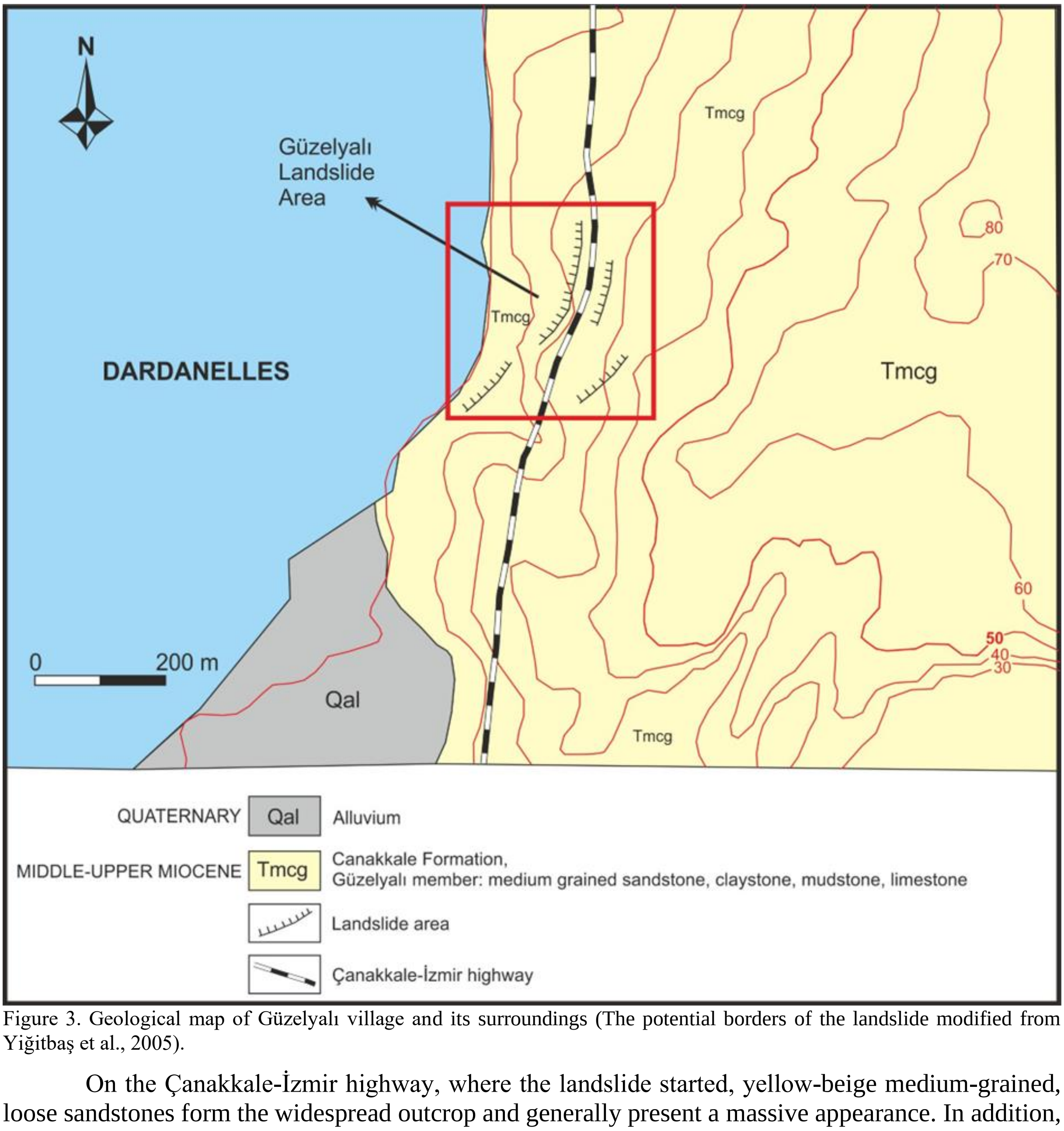

Figure 3. Geological map of Güzelyalı village and its surroundings (The potential borders of the landslide modified from Yiğitbaş et al., 2005).

On the Çanakkale-İzmir highway, where the landslide started, yellow-beige medium-grained, loose sandstones form the widespread outcrop and generally present a massive appearance. In addition, there are hardened, well-cemented sandstone layers varying between 1-8 cm in thickness between loose sandy units. The layers measured from these sandstones have a position of N70W/19NE. It is also possible to see these sandstones as large and small blocks scattered in the loose material. In areas with loose sandy material, abundant crack surfaces were formed. At the slightest contact, the grains of sand are immediately dispersed. In the lower part of the sandy level, there are gray colored mudstones and thin claystone bands are found in these mudstones.

It is striking that some environmental factors, as well as geological units and topography factors, play a role in the realization of mass movements in the study area in Güzelyalı. For example; It is seen that the drainage culvert, which is used for the transfer of rain water on the upper side of the Çanakkale-İzmir Highway, is first poured into a pit on the opposite side of the road and then conveyed to the sea via a canal system (Figure 4).

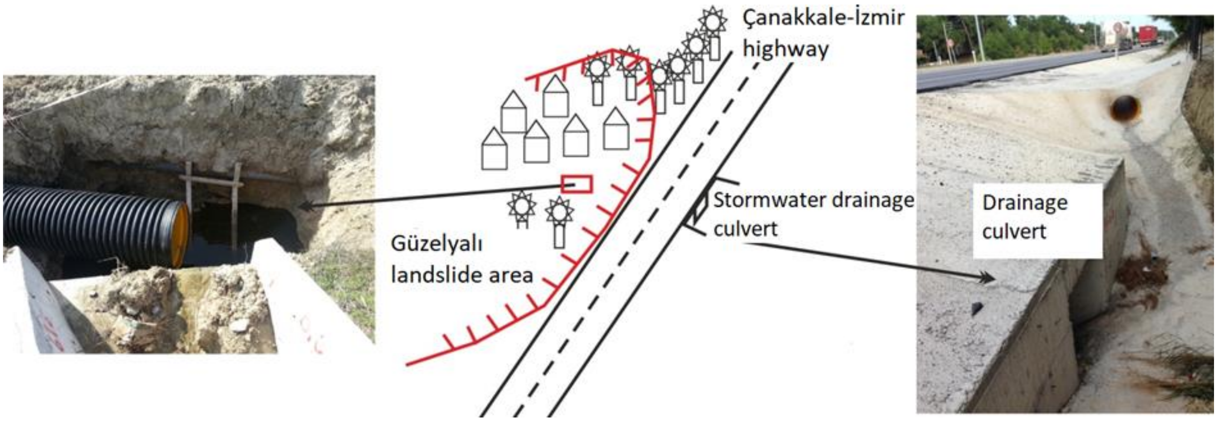

Figure 4. Stormwater drainage culvert thought to have affected the Güzelyalı landslide (UTM: 445325 E, 4434504 N).

Both the unstable conditions of the geological units and the water holding properties of the claystones in it, and especially the weight of the water affecting the soil in this area, increase the weight of the mass in the region. It is observed that there is an intense and significant soil mass movement in the stormwater drainage region after heavy rains, especially in the last wet seasons (Figure 5).

Figure 5. Soil mass change, surface deformation and its effect on vegetation caused by the drainage design on terrestrial photos.

Material and Method

In the research, the DJI Phantom 4 Pro + drone has been used to collect high resolution aerial photos. The Phantom 4 Pro+ is an intelligent camera drone from DJI which offers a 3-axis-stabilized gimbal camera. The number of pixels held by this camera is 20 MP with a 1" CMOS sensor capability to shoot up to 4K/60fps video and also photo bursts at up to 14 fps. There has been an update in the hull from its last version, Phantom 4 which now features an alloy of magnesium that is constructed to increase the rigidity and reduce the weight. The system of flight autonomy adds a dual rear-vision sensor along with the sensing of infrared so that the obstacle sensing can be done for a total of five directions and avoidance for four directions. The primary feature of Phantom 4 Pro+ is high-luminance display that comes integrated into remote controller. The onboard camera accompanies a 1-inch 20-megapixel CMOS sensor for the Phantom model. It also has a custom-engineered lens which is made of 8 components that are arranged in 7 groups. A mechanical aperture is boasted by the camera which eliminates the distortion of rolling shutter that occurs while capturing images of objects that are moving fast or when they are flying at high speed along with a mechanical focus.The next most important thing apart from the number of pixels for the image quality is the sensor size as a larger sensor has a dynamic range, boosted low light performance and better signal-to-noise ratio. The presence of 1" 20MP CMOS sensor in Phantom 4 Pro+ is nearly 4 times the size of 1/2.3" sensor. This sensor generally takes help of larger pixels, has maximum ISO that goes up to 12,800 and an increased contrast.

Well calibrated cameras are required in high-accuracy works like digital surface modeling. Camera calibration determines information about the camera that improves accuracy in subsequent studying projects, i.e. the camera's focal length, lens distortion, format aspect ratio and principal point. In this study, we used PhotoModeler's camera calibrator based on the field calibration project using calibration sheets including the coded targets. A series of overlapped images were collected using The Phantom 4 Pro+ drone integrated digital camera both in the direction of flight and between adjacent stripes. A quad-rotor open source project has been used and improved by modifications of the software and the electronic circuit in order to comply with the requirements for the landslide modeling study.

A UAV flight was planned to model the soil mass change caused by the drainage design in the landslide area. Photo and line spacing were selected to obtain 80% and 60% forward and side overlap of the images, respectively. Average flying height was 50 m above the ground. Flying speed was about 30 km/h. Flying time was 20 min. Figure 6showed a sample digital image taken by UAV. The flight had its own set of 5 GNSS control points. Targeted ground control points were established to control the UAV photogrammetry. The GNSS receivers utilized for the survey of photogrammetric control pointswere SATLAB SL600. For RTK measurements, these dual-frequency geodetic instruments have a manufacturer’s stated accuracy specification of ±1 cm +1 ppm RMS horizontal, and ±2 cm + 1 ppm RMS vertical. The GNSS RTK was utilized to position at the centre of the targets (Figure6). The 252aerial photos were taken in 9 passes in a uniform grid pattern.

Figure 6. Ground control point and locations of ground control points in the aerial photo

For the processing of the collected aerial photos, the photogrammetric principles will be implemented using computer vision techniques such as automatic feature detection, Structure-from-Motion (SfM) and dense matching. In the other words, advances in computer vision and image analysis have led to the development of a novel photogrammetric approach called SfM when coupled with Multi-View Stereo (MVS) offers a fully automated method capable of producing high resolution DEMs with low cost consumer grade cameras. Later on, the georeferenced 3D point clouds and orthomosaics will be obtained from the oriented images.

Data Processing and Results

Photogrammetric bundle adjustments and Dense Surface Model (DSM) computations of the images were done in an automated manner employing Agisoft PhotoScan Professional (version 1.2.3). The digital aerial images were processed in order to obtain the photogrammetric results (Figure 7).

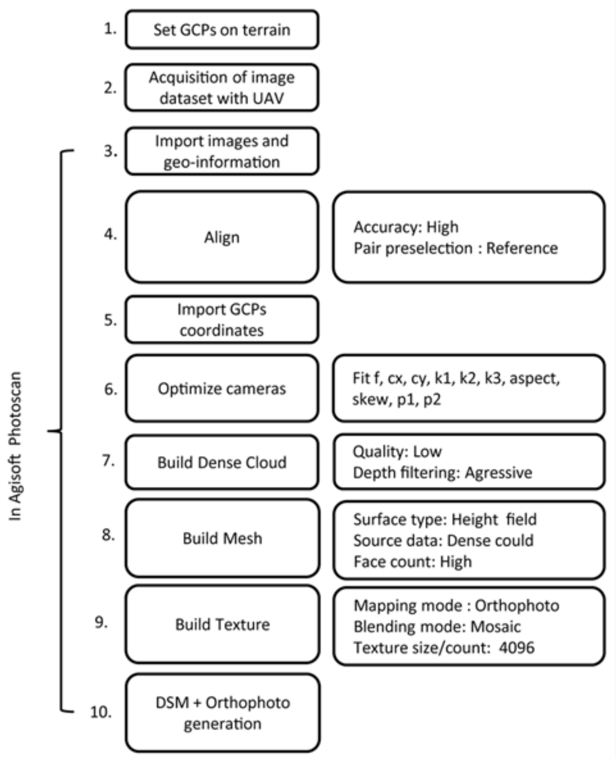

Figure 7. Workflow used for photogrammetric results and parameters.

The data regarding the area of the drainage-induced surface deformation are included in the data processing software. The photo import and reconstruction phase of the flight route is the earliest phase. It is a collection of a number of format photos in the evaluation software. The general is automatically recreated with the flight line with these photos. From the resulting data, it was seen that the DJI Phantom 4 Pro + images have 80% and 60% forward and side overlaps. Forward and side overlaps are used to create a stereoscopic image. Stereoscopic vision allows an object such as an aerial photograph taken from different camera positions to be created from two different perspectives. In the flight field, a three-dimensional image of the Earth's surface will be visible at a smaller scale, often referred to as a model. Therefore, data mapping results using the drone can also produce very high resolution images and also produce a three-dimensional view of the area of drainage-induced surface deformation from the recorded object.

As it is known, photo alignment is used to identify points in each photo and to match the same point in two or more photos. The process of aligning photos will generate the first 3D model, camera position, and photo in each recording, as well as sparse point clouds that will be used later.

At the stage of aligning the photo, a selection can be made according to the requirement for the desired accuracy. Low accuracy may be preferred for an initial inspection, such as viewing the overlapping extent of images, while the highest accuracy may be preferred for the actual image production stage. The "Pair Preselection" option is used in the software during the alignment process of the photographs. If the drone camera is GPS integrated (geo-tagged), that is, it has default coordinates, reference mode should be used. If the photo has no coordinates (not geotagged), the generic mode is used (Figure 8).

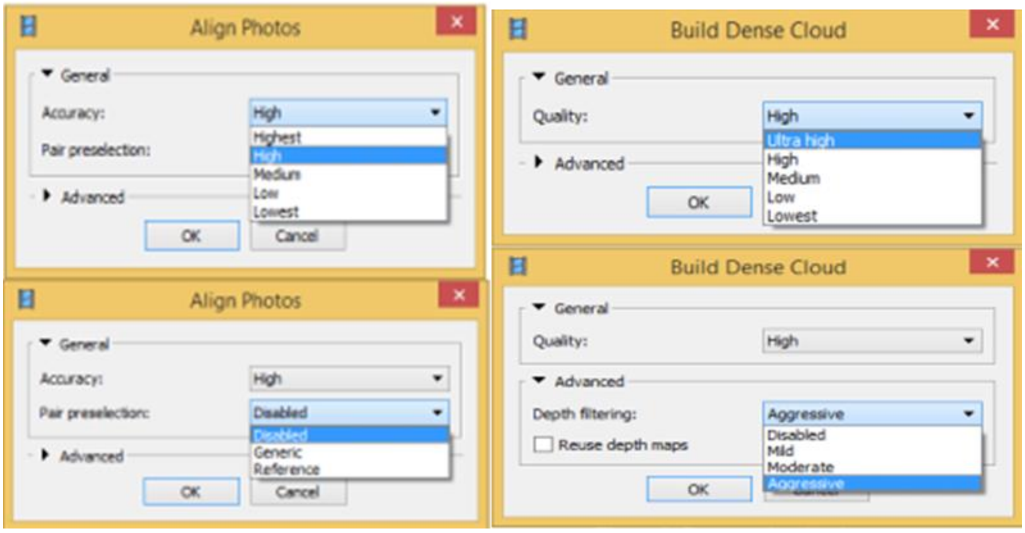

Figure 8. Software align photo buttons and dense point cloud process.

The next stage is the data rectification process. Rectification is the reexposure stage in which the average photographic scale is determined by removing the tilt in an aerial photograph. At this stage, aerial photographs are rectified using the Ground Control Point (GCP). With the rectification, aerial photographs are scaled completely vertically / without tilting and averagely, and absolutely every photograph is made to the desired scale. The entry of the Ground Control Point (GCP) coordinates, measured with the help of high precision GNSS measuring technique, is carried out to provide a 3D coordinate reference (XYZ) to the result of the alignment photo stage. Thus, by improving the geometric quality of the 3D model created, a Digital Elevation Model (DEM) and orthophoto of the region where surface deformation occurs due to drainage is produced.

After aligning the photos, Dense Point Clouds processing is performed and GCP accuracy testing is performed. Quality and Depth Filtering selections are applied in the production of Dense Point Clouds. There are options for quality that range from Lowest to Ultra High, depending on processing time. Also, the filtering for the depth parameter shows how a suspected high point noise (outliers) is handled. Its properties are usually the value of its height, which is much larger or much smaller than the points around it. It is intended to reconstruct complex 3D models for light filtering. Aggressive filtering with many details is designed for the reconstruction of simple and undetailed 3D models.

The next step is the 3D model, or mesh, which is one of the main outputs of aerial photo processing. The 3D model is used as the basis for making both Digital Surface Model (DSM) and digital Terrain Model (DTM) as well as orthophoto DEM. During creation, a mesh appears with the Mesh Parameter option. There are two options for Surface Type, Elevation Field and Random. Arbitrary is used for general 3D models such as buildings, statues and others. Elevation Field is used for Earth surface objects such as Terrain and spatial structures such as pipe networks, cables and others. Elevation Field is used to render the orthophoto. Dense Point Cloud from the previous processing stage can be used for Source Data. There are options from Low, Medium to High for Face Count parameters. In addition to the three options above, there are two additional options, interpolation and point classes. There are two options for interpolation itself, interpolated and extrapolated. Interpolated mode allows automatic interpolation of multiple spaces between raw photos. The extrapolated option is not used in orthophoto processing.

A texture model is a 3D physical model of the appearance in the photo overlay. Texture models are exported to various 3D model formats that can then be used to create 3D models via other desktop software. Texture Parameter option is available during texture model creation. For the maximum and minimum intensity, the maximum and minimum intensity of the overlapping pixels are used (Figure 9). The next step in the software process in which aerial photographs are evaluated is the creation of a Digital Elevation Model (DEM). The Digital Elevation Model is a digital area model in raster/grid format, which is generally used in spatial analysis/GIS based rasters. DEM data can often be reduced to elevation information, slope, aspect, cut and fill, visibility, watershed, and more to modelling. There are two terminologies associated with DEM, these are DSM (Digital Surface Model / height calculated from the surface cover of the land such as the roof of the building, tree canopy, bridge, etc.) and DTM (Digital Terrain Model / calculated height from the ground level). The process for creating a digital elevation model (DEM) is shown (Figure 9).

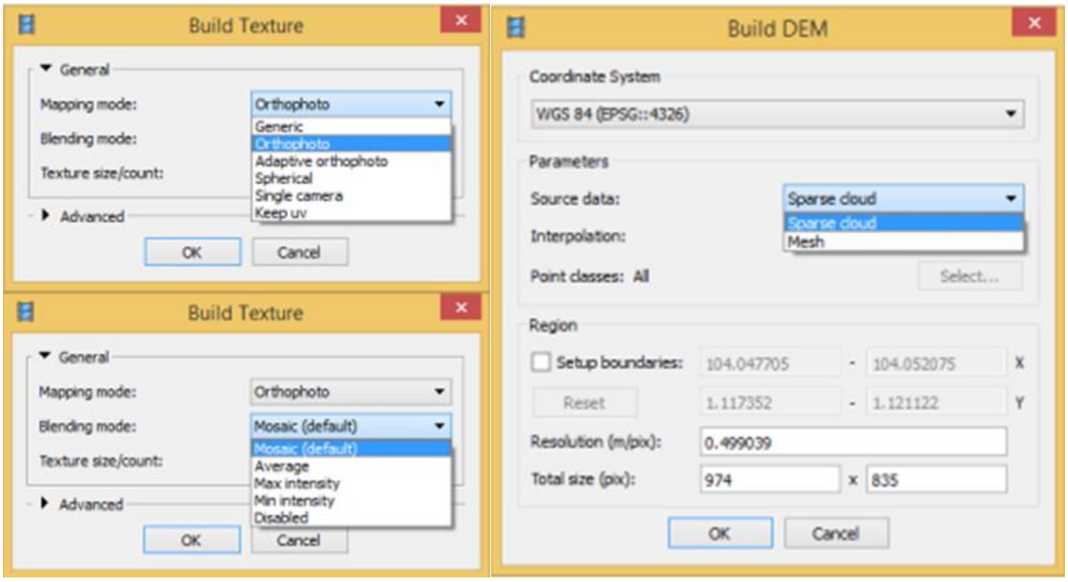

Figure 9. Build texture model and build digital elevation model (DEM) processes.

The last step in the process of obtaining photogrammetric products from aerial photographs is orthophoto production by UAV. Orthophoto is an aerial photograph in which geometric errors are corrected using DEM and GCP. Thus, the mapping process is carried out without any scale inconsistency throughout the study area. Orthophoto is made after Dense Point Clouds, Mesh and DEM production stages. Orthophoto stage includes Orthomosaic Parameter selection. For projection selections, a choice is made between geographic coordinates or plane/projection coordinates. For the surface parameter, the DEM created in the previous step is selected. There are three options for blending mode options, Mosaic, Average, Max Density, and Min Density. The process of creating orthophotos is shown in (Figure 10).

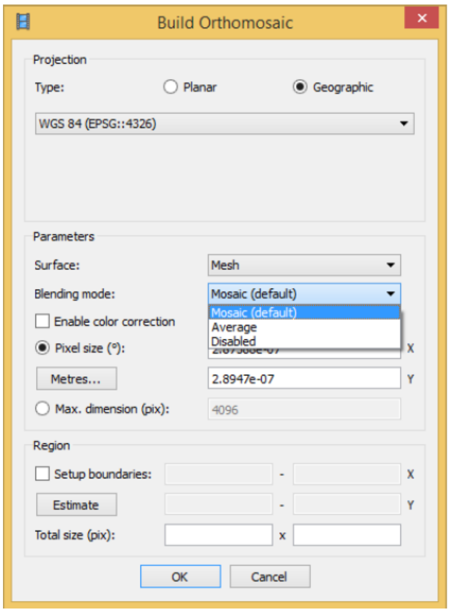

Figure 10. Build orthophoto process.

UAV-assisted digital photogrammetry based on structure frommotion (SfM) algorithms was used to derive a very high spatial resolution DSM and orthophoto mosaic (1 mm). For the digital imagery,2.2 million point textured mesh of the pile were derived from a14.1 million point DSM. Dense surface model andthe other sub-models obtained from digital imagery are seen inFigures11a–f.

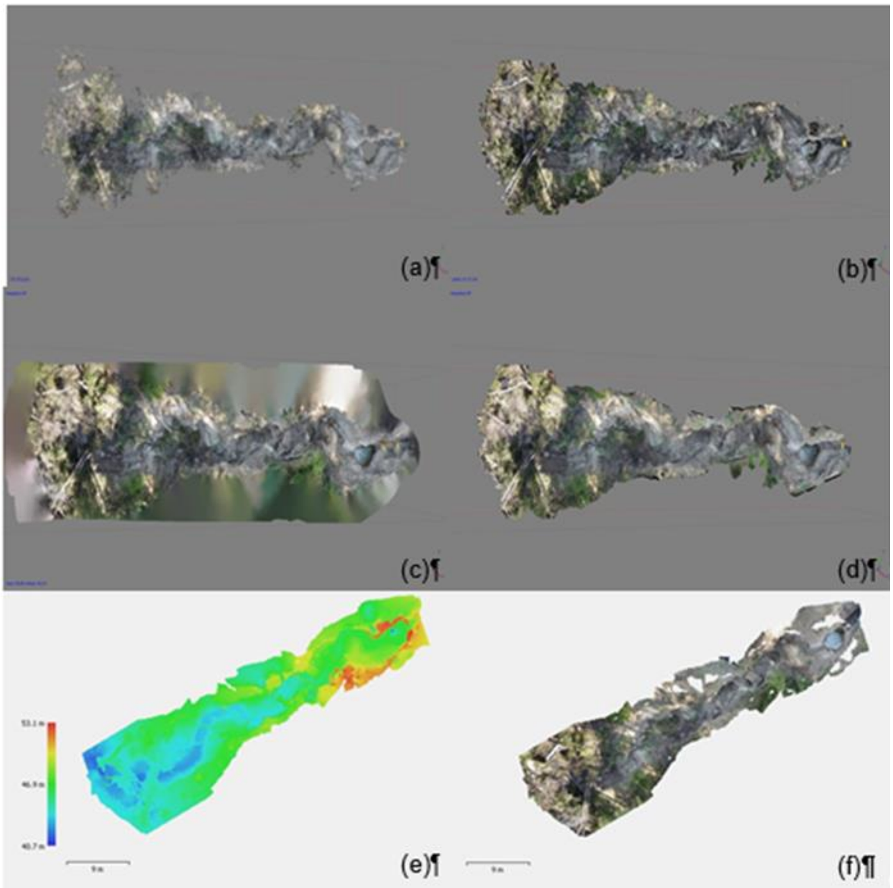

Figure 11. Photogrammetric results: (a) Tie points, (b) Dense cloud model, (c) 3D model, (d) Tiled Model, (e) DEM, (f) Orthomosaic.

After obtaining orthophoto and DEM as well as other final products in the photogrammetric evaluation software, Virtual Surveyor software was used for drawing and volume calculations. Virtual Surveyor software offers 3D drawing on photorealistic models with the help of photogrammetric result products. Then, producing the necessary details in the Virtual Surveyor software, the volume of the emptied soil formed in the area of surface deformation caused by the stormwater drainage culvert was calculated. After the triangulation process in the Virtual Surveyor software, the undeformed ground level was taken as the reference surface and the volume of the discharged soil was calculated.

As a result, the volume of the void region is 1,130.436 cubic meters due to the massive position change caused by the faulty drainage grille using photogrammetric result products produced with the help of aerial photographs obtained with the aid of unmanned aerial vehicles.

As a conventional geodetic measurement method, the same region was measured in the field with a GNSS/CORS measuring device. As a result of the classically collected data, the volume of the void area was calculated as 1,129,846 cubic meters. In addition to the fast, effective and economical results of photogrammetry based on unmanned aerial vehicles, it is an indication that the difference between the volume amounts obtained by both methods is at an acceptable level.

Conclusion

As in many engineering applications, the most basic requirement in estimating the effects of natural disasters is to frequently produce up-to-date maps and models with high location information. With the help of these periodically obtained maps, planning for future studies and modeling is carried out quickly and with high accuracy. Producing such maps and models with the support of unmanned aerial vehicles saves time and costs and has higher accuracy. It is very important to estimate the damages in landslide areas with high accuracy and up-to-date. In this study, a half-hour field study and an office work significant soil mass movement caused by the stormwater drainage culvert is modeled, which was developed to eliminate the ground problem in the landslide areawith UAV. In addition, the volume calculations was carried out with the numerical models such as DEM produced from UAV. In addition, the volume of landslide area was calculated with the data from GNSS/CORS. The volume calculations fromthese two methods showed consistency between 99%; this difference is at an acceptable level in terms of disaster monitoring. As a result of the study, it has been seen that UAV technology can be used in an up-to-date and effective manner in detecting massive soil deformations in landslide areas. Moreover, UAV technology gives faster and more cost-effective results than conventional methods.

Acknowledgement

This work was supported by Çanakkale Onsekiz Mart University The Scientific Research Coordination Unit, Project number: SBA-2021-3628.

Conflicts of Interest

The authors declareno conflict of interest.

References

Agisoft PhotoScan User Manual: Professional Edition, Version 1.2

Atabey, E., Ilgar, A., Sakıtaş, A., 2004. Çanakkale Havzasının Orta-Üst Miyosen Stratigrafisi, Çanakkale, KB Türkiye, MTA Dergisi, S. 128, s.79-97, Ankara

Eisenbeiss, H., 2009. UAV Photogrammetry. PhD Dissertation, ETH Zurich, Nr. 18515.

Eisenbeiss, H., Lambers, K., Sauerbier, M., Zhang, L., 2005. Photogrammetric documentation of an archaeological site (Palpa, Peru) using an autonomous model helicopter, In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, CIPA, Torino, Italy, Vol XXXIV5/C34, pp. 238-243.

Kun M., Özcan B., 2019. Maden Ocaklarında Insansız Hava Aracı Kullanımı: Örnek Bir Saha Çalışması. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi. 21(2), 554-564.

Niethammer, U., Rothmund, S., Joswig, M., 2009. UAV based remote sensing of the slow moving landslide SuperSauze, In: Landslide processes, CERG Editions, Strasbourg, pp. 69-74.

Saltık, O., 1974. Şarköy-Mürefte sahalarının jeolojisi ve Petrol olanakları: TPAO Rap. 879, 30 s.

Sauerbier, M., 2011. Investigation of UAV Systems and Flight Modes for Photogrammetric Applications. The Photogrammetric Record 26(136), 400-421.

Smith, M.J., Chandler, J., Rose, J., 2009. High spatial resolution data acquisition for thegeosciences: kite aerial photography. Earth Surface Processes and Landforms, 34, 155–161.

Şentürk, K., Karaköse, C., 1987. Çanakkale Boğazı ve dolayının jeolojisi. MTA Rap. no: 9333, (yayımlanmamış) Ankara.

Vogler, A., Eisenbeiss, H., Aulinger-Leipner, I., Stamp, P., 2009. Impact of topography on crosspollination in maize (Zea mays L.). In: European Journal of Agronomy, 31, pp. 99-102.

Wing, M.G., Burnett, J., Johnson, S., Akay, A.E., Sessions, J.,2014 A low-cost unmanned aerial system for remote sensing of forested landscapes, International Journal of Remote Sensing Applications, 4(3), 113-120.

Yiğitbaş, E., Baba, A., Bozcu, M., Deniz, O., Kürçer, A., Kaya, M.A., Şengül, E., Ekinci, Y.L., Köse, K., 2005. Güzelyalı (Çanakkale) 27-J Paftası Kuzeydoğu Kesiminde Heyelan Etüd Raporu. Çanakkale Onsekiz Mart Üniversitesi, Mühendislik Mimarlık Fakültesi Jeoloji Mühendisliği Bölümü, Döner Sermaye Projesi, 112.