Cultural Heritage and Science

https://dergipark.org.tr/en/pub/cuhes

e-ISSN 2757-9050

3D modeling of Narlıgöl Natural Heritage with unmanned aerial vehicle data

Hacı Murat Yılmaz [1], Nusret Aktan [2], Adem Çolak[2], Aydan Yaman*[1]

[1]*Aksaray University, Department of Geomatics Engineering, Aksaray, Türkiye*
[2]*Aksaray İl Özel İdaresi, Aksaray, Türkiye*

Keywords
Natural Heritage
Thermal Tourism
UAV
3D Model
Narlıgöl

Research Article
DOI:10.58598/cuhes.1253496

Received:20.02.2023
Revised:30.03.2023
Accepted:05.04.2023
Published:12.05.2023

Abstract

Natural and cultural diversities are one of the important heritages of a society. In conformity with UNESCO's Convention for the Protection of the Intangible Cultural Heritage, it has been noted that such heritage should be protected. Türkiye is among the top five countries that have the most cultural and natural heritage registered in the list of intangible cultural heritage. It is also important for humanity to protect and promote these heritages. Unmanned Aerial Vehicles have been an effective technology in evaluating and documenting the current status of cultural heritages and obtaining their three-dimensional models. In this study, a three-dimensional model of Narlıgöl, one of the important natural heritages of Türkiye and located between Aksaray and Niğde provinces, was obtained with UAV data. In order to detect the changes in our cultural and natural heritage and to take the necessary precautions, these heritages should be recorded and followed up at certain periods. In addition, web-based promotion of these heritages is also important in terms of nature and cultural tourism. For this purpose, the current situation of Narlıgöl natural heritage was documented with UAV data and its three-dimensional model and orthophoto map was obtained.

1. Introduction

Everything that is left to us from the past and our ancestors, is defined as cultural heritage. There are various types of cultural heritage such as movable, immovable, tangible and intangible. These heritages are important to help societies to recognize their own cultures, lifestyles and belief systems. These heritages serve as a bridge between the past and the future. For this reason, it is an important issue to protect them and transfer to future generations. One of the important benefits of cultural heritage is its effects on tourism.

Türkiye is a very rich country in terms of historical, natural and cultural heritage. According to the data of the Ministry of Culture and Tourism, as of 2021, there are 1154 cultural and natural assets registered in the UNESCO World Heritage List worldwide, of which 897 are cultural, 218 are natural and 39 are mixed (cultural/natural) assets. This number is increasing with the World Heritage Committee meetings that take place every year. We have 19 assets included in the UNESCO World Heritage List. Within the scope of the UNESCO agreement on the Protection of the World Cultural and Natural Heritage, States Parties are obliged to submit their inventories (temporary list) of assets eligible for inscription on the UNESCO World Heritage List to the UNESCO World Heritage Centre. We have 84 assets on the World Heritage Tentative List. Cultural heritage must be protected and documented and relief plans should be prepared in order to repair the possible deteriorations. In addition, it is an important task for humanity to increasing its recognition and inclusion of heritages on the tentative list into the world heritage list. Architectural, geodetic and photogrammetric methods were used and are still used for the documentation and tracking of such cultural heritages. Such studies are carried out in a shorter time using Unmanned Aerial Vehicles (UAVs), which have developed in recent years, and the accuracy and cost advantages of the method also come to the fore. In addition, UAV technology

* **Corresponding Author**

(hmuraty@gmail.com) ORCID ID 0000-0002-9725-5792
(nusretaktan@hotmail.com) ORCID ID 0000-0003-2582-9395
(acolak68@hotmail.com) ORCID ID 0000-0002-1187-0955
*(aydan.ketenci@hotmail.com) ORCID ID 0000-0001-8739-066X

Cite this article (APA);

Yılmaz, H. M., Aktan, N., Çolak, A., & Yaman, A. (2023). 3D modeling of Narlıgöl Natural Heritage with unmanned aerial vehicle data. *Cultural Heritage and Science, 4(1), 15-20*

measurements have significant advantages in risky places. UAV is used in engineering services, agriculture, traffic applications and many location-based studies. In the literature, it is possible to come across a lot of work on the documentation of historical and cultural heritage.

Erdogan and Mutluoglu [1] obtained an orthophotomap with UAV data, and found the position accuracy to be 5-6 cm and the height accuracy to be 5 cm. Yakar and Mırdan [2] conducted a 3D modeling study of Kalender Baba and Kesikbaş Tomb with an unmanned aerial vehicle in their study. They found that UAV technology provides the users speed, cost, precision and technological superiority in the documentation of historical and cultural artifacts. They stated that the use of UAV and Terrestrial Photogrammetry techniques together is very advantageous in terms of accuracy, speed and cost in 3D modeling studies. Yilmaz et al. [3], performed orthophoto map production with UAV data and observed that the results for small-sized areas gave the expected accuracy. Erdogan et al. [4] made a 3D model of the Karabıyık Bridge with UAV data. Using the SfM (Structure from Motion) method, a 3D model of the bridge was produced with photogrammetric evaluation with 1.2 cm point position accuracy. Remondino et al. [5] stated that photogrammetric studies with UAV are more advantageous than photogrammetric studies with existing systems. As a result of the research, it has been seen that higher resolution images can be reached more effectively with less cost, and UAV has many advantages such as obtaining final products in a short time. Niethammer et al. [6] obtained high resolution images using the UAV platform and non-metric cameras in their studies. They stated that UAV data can be used in landslide studies. In their study, Marangoz et al. [7] compared traditional photogrammetry and UAV data in terms of cameras and result products and stated that the use of UAVs in photogrammetric map production would be a great advantage when creating maps of small areas. Şasi [8] modeled a historical mosque with UAV data and aimed to provide the possibility of restoration in accordance with the original in case of damage to the historical artifact. It has been stated that with the model obtained, solutions can be offered to the problems of many professional disciplines today. Ulvi et al. [9] modeled the Red Church with UAV data and stated that UAV provides great convenience and opportunities in terms of time and cost. Templin et al. [10] modeled Suskie Lake, located in the north of Poland, using a low-cost fixed-wing UAV system for shallow lake shoreline survey in their study. And then, they described the UAV system used for experimental measurements, the obtained results and the accuracy analysis. Final conclusions demonstrate that even a low cost fixed-wing UAV can provide an excellent tool for accurately surveying a shallow lake shoreline and generate valuable geoinformation data collected definitely faster than when traditional geodetic methods are employed.

Yücel and Turan [11] aimed to create 3D terrain models of mine lakes using high-resolution images from an unmanned aerial vehicle (UAV) and to quantify areal changes linked to anthropogenic and meteorological effects over the study period. They were carried out 3D modeling of UAV images with Agisoft software. Its workflow, involving image matching, georeferencing, digital elevation modeling, orthomosaics, 3D point cloud, and 3D textured model creation, was used to generate their 3D terrain model for the mine lakes. Alptekin and Yakar [12], created the Digital Surface Model (DSM) and orthophoto of the study area to measure the pond's volume and 3D surface area in their study.

Vitti et al. [13] performed a flight with a UAV over a water body and produced DSM and orthophoto mosaic images of the water body by using the UAV data. Then, they performed accuracy tests using control points. Panda et al. [14] create a multisensor model of the Lake ZmajevoOko (Lake Dragon eye) and the secondary objective was to obtain morphometric data about the lake. In UAV photogrammetry, a Phantom 4 Pro was used. Then, data collected and a multisensor high-quality model of the lake was created. From the derived models, the volume and surface area of the lake, as well as the length of the lake shoreline were calculated. Landslide that occurred in Karahacılı at the end of 2019 was created and the pre-landslide conditions of the region orthophoto of the region was created by using a UAV [15]. In this way, the landslide areas in the region were easily determined. 3D model of Ucayak cultural heritage located in Mersin was modelled in 3D using an unmanned aerial vehicle (UAV) [16].

Duan et al. [17] used an UAV and Unmanned Surface Boats photogrammetric images in their study. The lake boundary has been extracted based on the UAV real 3D model. The Digital Elevation Model (DEM) of lakebed terrain has been built based on lakebed terrain data collected by USB. Finally, the water storage of the lake was estimated based on the boundary and DEM. They stated that a real 3D model based on UAV data can depict lake boundaries accurately. The modern methods used in documenting the cultural heritages are briefly explained [18].

2. Method

2.1. Study area

Narlıgöl thermal water, located on the Aksaray-Niğde border as shown in Figure 1, is very rich in calcium, sodium and bicarbonate and is healing for various diseases. It is also a natural cultural heritage for domestic and international tourism.

Figure 1. Location of Narlıgöl Natural Heritage in Türkiye

The crater lake Narlıgöl, which fascinates its visitors with its different natural beauty in four seasons, is

located in the middle of Cappadocia. Narlıgöl also draws attention with its thermal tourism potential. Water is extracted from the borehole well on the lakeshore at a temperature of 65 degrees, and this thermal water heals diseases.

Narlıgöl is very rich in calcium, sodium and bicarbonate, and the resources here are used in the treatment of various diseases. Bathing in Narlıgöl is suitable for the treatment of rheumatic and skin diseases, especially psoriasis. At the same time, it provides heliotherapy opportunity by using the appropriate dose. Increases skin and blood flow.

It reduces peripheral vascular resistance and blood pressure, and provides resolution of edema. In addition, it lowers the heart rate, it is stated that it is good for venous failure, hypertension, rheumatic diseases and neurological diseases.

With its natural beauty, Narlıgöl is on its way to becoming a thermal tourism region in Cappadocia. Besides its thermal feature, Narlıgöl fascinates its visitors with its magnificent view. Due to the decrease in the water level in the lake in recent years, Narlıgöl takes the shape of a heart and amazes its visitors with its unique and romantic appearance (Figure 2) [19].

Figure 2. Narlıgöl [19]

Narlıgöl is the only crater lake in the entire Cappadocia region, although it is said that it may have been formed by the fall of a meteor. With an area of approximately three thousand square meters and an altitude of 1371 meters, the depth of the lake reaches 70 - 80 meters. Because this natural heritage is surrounded by high mountains, it remains in a pit, and snow never accumulates and freezing frosts are not seen. In the area where the lake is, there are fairy chimneys and underground cities along the valley extending in the east-west directions of Narköy. While some of the fairy chimneys have 2 or 3 floors, some of them can rise up to 5 floors. The churches with a cross plane carved into these structures belong to the Late Byzantine Period and has been built 10th and 12th centuries AD. One of the five-storey churches in the valley stands out with its frescoes on the ground floor. Although these frescoes have been destroyed until today, they stand out with their depictions of saints and Jesus [20].

2.2. UAV

For the first time in history, an unmanned air vehicle was used in a military incident, which was recorded as the first unmanned aerial attack. This event happened in 1849, when the Austrians sent explosive –filled unmanned balloons to Venice, Italy. The development and production of aircraft with the aim of flying truly remotely, that is, unmanned, coincides with the First World War for the first time. Here, Unmanned Aerial Vehicles, which are defined as flying vehicles that do not contain human sand can be controlled from the ground thanks to a communication system, in short, UAVs, came into active use especially after the Second World War [9].

UAVs provides a great advantage over normal aircraft due to its low production, purchasing, fuel and flight costs [21-22]. More importantly, these vehicles do not pose a risk of injury or loss of life during the mission, as they are uncrewed. For the same reason, they are lighter than conventional aircraft and can stay in the air longer with the same amount of fuel.

On the other hand, the disadvantages for UAVs are that their danger perception ability is not as strong as a human, that they can pose a danger if the ground control connection is broken, and that they are vulnerable to air attacks by manned aircraft. However, these disadvantages are tried to be minimized with R&D activities in data transfer and artificial intelligence technologies. On the other hand, further increasing the flight times will allow these vehicles to be used widely in the near future [23].

Unmanned aerial vehicles are divided into groups according to their various features and usage purposes. The most important reason for grouping unmanned aerial vehicles is to choose the most suitable one according to the purpose and characteristics of the project.

UAV photogrammetry has been used frequently in engineering projects in the last decade [24]. Using of unmanned aerial vehicles (UAVs) are becoming more effective tools for researchers for their applications [25]. In recent years, UAV applications have been used quite frequently to create orthomosaics, digital elevation models (DEM), 3D point clouds and 3D terrain models [26]. UAV photogrammetry is one of the most effective methods for 3D modeling the topography [27]. Unmanned aerial system can be a cheap, easy to use, on-demand technology for gathering remote sensing data [28]. High-resolution 3D model can be generated using pictures taken from UAV [29].

Although the first use of unmanned aerial vehicles was for military purposes, they have a wide range of uses, from hobby use to engineering projects, archaeological studies, agricultural activities and analysis use [30]. Some of the usage areas can be listed as digital terrain models, digital elevation models, digital surface models, city maps, geographic information system, land information system, three-dimensional model creation [31]. The use of unmanned aerial vehicles and their contributions have been investigated in terms of the detection of material deterioration of historical buildings, protection applications [32].

2.3 Field and office studies

In the study area, 695 pictures were taken with a camera with a resolution of 18.2 Mpixels at a ground sample distance of 7.7 cm. The flight plan is shown in Figure 3 and the red dots represent the area where the lake is located. The eBeeSenseFly UAV with real-time kinematic positioning was used in the study (Figure 4).

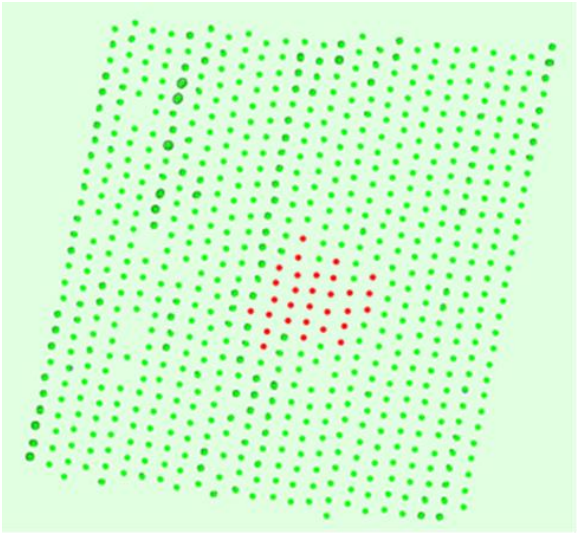

Figure 3. Flight plan and pictures

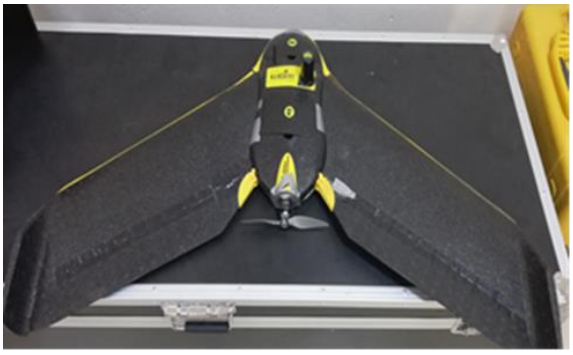

Figure 4. eBeeSenseFly RTK UAV

Figure 5. Orthophoto of Narlıgöl

Orthophoto maps were produced by evaluating the pictures in the PIX4D mapper program (Figure 5). In addition, digital surface model (Figure 6), dense point cloud (Figure 7), and three-dimensional model (Figure 8) of the study area were produced.

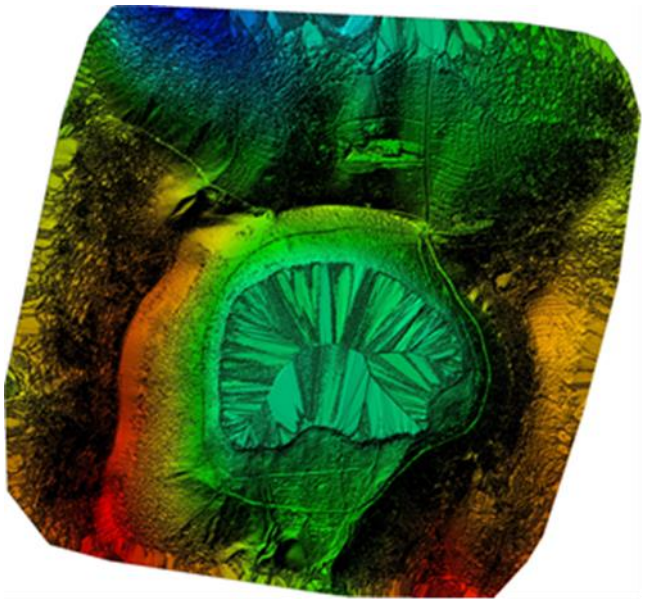

Figure 6. Digital Surface Model of Narlıgöl

Figure 7. Density point cloud of Narlıgöl

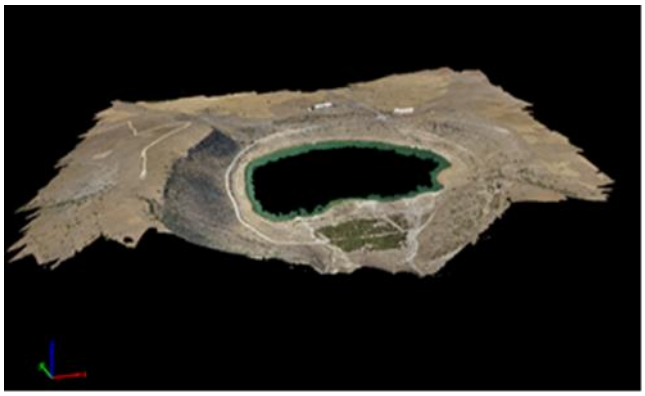

Figure 8. 3D model of Narlıgöl

3. Results

Natural and cultural heritages are very important for human history. The study of natural heritage largely depends on conservation because global climate change, natural disasters, mass tourism, terrorism, and human negligence greatly affect changes in the landscape [14]. It is an important issue to carry out modeling studies at

certain periods in order to protect the current status of these heritages, to detect the deteriorations that occur when necessary and to take the necessary precautions. In addition, such three-dimensional modeling studies should be carried out worldwide on behalf of humanity in order to promote such cultural and natural heritages for tourism purposes and to monitor them in web-based environments.

In this study, 3D point cloud, high-resolution orthophoto, and digital surface model and 3D model were created in the Pix4D software for Narlıgöl.

An area of 4.334 km^2 was used in the study. After bundle adjustment, root mean square error was determined and control measurements at the detail points has been made. The results obtained are shown in Table 1.

Table 1. Error values obtained as a result of calculations

Root Mean Square Error (pixel)	0.206
mx at detail points (cm)	1.43
my at detail points (cm)	1.13
mz at detail points(cm)	8.70

4. Conclusion

3D documentation involves collecting, processing, reproduction, and presentation of geospatial data by determining the position, shape, and dimensions of an object or area in three-dimensional space to preserve the current state of cultural or natural heritage [14]. The term "natural heritage" for physical, biological, and geological features, formations, and sites of exceptional value from an aesthetic or scientific point of view has been used [14,33].

In this study, an orthophoto and three-dimensional model of Narlıgöl, which is a natural crater lake within the borders of Aksaray and Niğde provinces, a candidate for thermal tourism, was created with UAV data. It has been observed that UAV technology can be applied especially in small, hard-to-reach and risky areas with the advantage of time, cost and accuracy. Such studies are especially important for the protection of our natural heritage. The present study, based on photogrammetric methods, shows that 3B modelling of a lake project can be modelled in a practical way by using a UAV. It has been seen that the obtained position and height accuracies are at sufficient levels as in many studies in the literature. It is considered that such studies can be used as a base for future studies in terms of monitoring the status of cultural and natural heritages and observing possible deterioration and changes. In this study, high-resolution UAV imaging is a rapid and appropriate method in 3D modeling for natural heritage studies has been seen.

Acknowledgement

We thank Aksaray Special Provincial Administration for the data.

Author contributions

Hacı Murat Yılmaz: Editing, Methodology **Nusret Aktan:** Visualization, Investigation **Adem Çolak:** Data curation, extended analysis **Aydan Yaman:** Original draft preparation, writing-reviewing

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Erdoğan, A., & Mutluoglu, O. (2020). İnsansız Hava Araçları ile Harita Üretim Çalışmalarında Farklı Yüksekliklerde Yapılan Uçuşların Konum Doğruluğuna Etkisi. *Türkiye İnsansız Hava Araçları Dergisi*, *2*(1), 28-35.
2. Mirdan, O., & Yakar, M. (2017). Tarihi eserlerin İnsansız Hava Aracı ile modellenmesinde karşılaşılan sorunlar. *Geomatik*, *2*(3), 118-125.
3. Yılmaz, H. M., Karabörk, H., & Yakar, M. (2000). Yersel fotogrametrinin kullanım alanları. *Niğde Üniversitesi Mühendislik Bilimleri Dergisi*, *4*(1), 1.
4. Erdoğan, A., Kabadayı, A., & Akın, E. S. (2021). Kültürel mirasın fotogrametrik yöntemle 3B modellenmesi: Karabıyık Köprüsü Örneği. *Türkiye İnsansız Hava Araçları Dergisi*, *3*(1), 23-27.
5. Remondino, F., Barazzetti, L., Nex, F., Scaioni, M., & Sarazzi, D. (2012). UAV photogrammetry for mapping and 3d modeling–current status and future perspectives. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *38*, 25-31.
6. Niethammer, U., James, M. R., Rothmund, S., Travelletti, J., & Joswig, M. (2012). UAV-based remote sensing of the Super-Sauze landslide: Evaluation and results. *Engineering Geology*, *128*, 2-11.
7. Marangoz, A. M., Karakış, S., & Numan, A. B. (2019, April). Geleneksel Fotogrametri ile İnsansız Hava Aracı (İHA) Verilerinin Kullanılan Kamera ve Sonuç Ürünleri Bakımından Karşılaştırılması. In *17th Turkey Scientific and Technical Conference* (Vol. 25, p. 27).
8. Şasi, A. (2020). Ak Camii'nin İnsansız Hava Aracı ile Fotogrametrik 3B Modellenmesi. *Türkiye İnsansız Hava Araçları Dergisi*, *2*(1), 1-7.
9. Ulvi, A., Yakar, M., Yiğit, A. Y., & Kaya, Y. (2020). İHA ve yersel fotogrametrik teknikler kullanarak Aksaray Kızıl Kilise'nin 3 Boyutlu nokta bulutu ve modelinin üretilmesi. *Geomatik Dergisi*, *5*(1), 22-30.
10. Templin, T., Popielarczyk, D., & Kosecki, R. (2018). Application of low-cost fixed-wing UAV for inland lakes shoreline investigation. *Pure and Applied Geophysics*, *175*, 3263-3283.
11. Yucel, M. A., & Turan, R. Y. (2016). Areal change detection and 3D modeling of mine lakes using high-resolution unmanned aerial vehicle images. *Arabian Journal for Science and Engineering*, *41*, 4867-4878.

12. Alptekin, A., & Yakar, M. (2020). Determination of pond volume with using an unmanned aerial vehicle. *Mersin photogrammetry journal*, *2*(2), 59-63.
13. Vitti, D. M. D. C., Marques Junior, A., Guimarães, T. T., Koste, E. C., Inocencio, L. C., Veronez, M. R., & Mauad, F. F. (2019). Geometry accuracy of DSM in water body margin obtained from an RGB camera with NIR band and a multispectral sensor embedded in UAV. *European Journal of Remote Sensing*, *52*(sup1), 160-173.
14. Panđa, L., Šiljeg, A., & Marić, I. (2022). Multi-Sensor 3D Modeling of Natural Heritage: Example of the Lake Zmajevo Oko.
15. Kusak, L., Unel, F. B., Alptekin, A., Celik, M. O., & Yakar, M. (2021). Apriori association rule and K-means clustering algorithms for interpretation of pre-event landslide areas and landslide inventory mapping. *Open Geosciences*, *13*(1), 1226-1244.
16. Alptekin, A., & Yakar, M. (2021). 3D model of Üçayak Ruins obtained from point clouds. *Mersin Photogrammetry Journal*, *3*(2), 37-40.
17. Duan, P., Wang, M., Lei, Y., & Li, J. (2021). Research on Estimating Water Storage of Small Lake Based on Unmanned Aerial Vehicle 3D Model. *Water resources*, *48*, 690-700.
18. Korumaz, A. G., Dülgerler, O. N., & Yakar, M. (2011). Kültürel mirasin belgelenmesinde dijital yaklaşimlar. *Selçuk Üniversitesi Mühendislik, Bilim ve Teknoloji Dergisi*, *26*(3), 67-83.
19. http://www.gulagac.gov.tr/narligol
20. https://www.kulturportali.gov.tr/turkiye/aksaray/gezilecekyer/narli-gol
21. Ceylan, M. C., & Uysal, M. (2021). İnsansız hava aracı ile elde edilen veriler yardımıyla ağaç çıkarımı. *Türkiye Fotogrametri Dergisi*, *3*(1), 15-21.
22. Karabacak, A. (2021). İnsansız hava araçları (İHA) İle enerji nakil hatlarının ölçülmesi üzerine derleme. *Türkiye Fotogrametri Dergisi*, *3*(1), 1-8.
23. Ulvi, A., Varol, F., & Yiğit, A. Y. (2019). 3D modeling of cultural heritage: the example of Muyi Mubarek Mosque in Uzbekistan (Hz. Osman's Mushafi). In *International Congress on Cultural Heritage and Tourism (ICCHT)* (Vol. 115, p. 123).
24. Kanun E, Alptekin A, Karataş L & Yakar M (2022). Theuse of UAV photogrammetry in modeling ancient structures: A casestudy of "Kanytellis". Advanced UAV, 2(2), 41-50.
25. Karataş, L., Alptekin, A., & Yakar, M. (2022). Detection and documentation of stone material deterioration in historical masonry structures using UAV photogrammetry: A case study of Mersin Aba Mausoleum. *Advanced UAV*, *2*(2), 51-64.
26. Alptekin, A., & Yakar, M. (2020). Heyelan bölgesinin İHA kullanarak modellenmesi. *Türkiye İnsansız Hava Araçları Dergisi*, *2*(1), 17-21.
27. Yakar, M., Ulvi, A., Yiğit, A. Y., & Alptekin, A. (2022). Discontinuity set extraction from 3D point clouds obtained by UAV Photogrammetry in a rockfall site. *Survey Review*, 1-13.
28. Karataş, L., Alptekin, A., Kanun, E., & Yakar, M. (2022). Tarihi kârgir yapılarda taş malzeme bozulmalarının İHA fotogrametrisi kullanarak tespiti ve belgelenmesi: Mersin Kanlıdivane ören yeri vaka çalışması. *İçel Dergisi*, *2*(2), 41-49.
29. Kanun, E., Alptekin, A., & Yakar, M. (2021). Documentation of cultural heritage by photogrammetric methods: a case study of Aba's Monumental Tomb. *Intercontinental Geoinformation Days*, *3*, 168-171.
30. Yakar, M., & Doğan, Y. (2017). Silifke Aşağı Dünya Obruğunun İHA Kullanılarak Üç Boyutlu Modellenmesi. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, *17*(4), 94-101.
31. Yılmaz, H. M., Aktan, N., Çolak, A., & Alptekin, A. (2022). The use of unmanned aerial vehicle (UAV) data in village development plans: A case study of Aksaray Yaylak Village. *Mersin Photogrammetry Journal*, *4*(2), 68-72.
32. Karataş, L. (2022). Integration of 2D mapping, photogrammetry and virtual reality in documentation of material deterioration of stone buildings: Case of Mardin Şeyh Çabuk Mosque. *Advanced Engineering Science*, *2*, 135-146.
33. Boehler, W., Heinz, G., & Siebold, M. (2001). Topographic information in cultural and natural heritage visualization and animation. *International Archives of Photogrammetry and Remote Sensing*, *34*(5/W1), 56-61.