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Research Article

Multi instrumental documentation and 3D modelling of an archaeological site: a case study in Kizilkoyun Necropolis Area

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ABSTRACT

Şanlıurfa is one of the largest and oldest settlements in Mesopotamia. Such that Şanlıurfa, who saw the sovereignty of civilizations such as Ebla, Akkad, Sumerian, Babylon, Hittite, Hurri-Mitanni, Arami, Assyria, Persia, Macedonia, Rome, Byzantium, has announced in the UNESCO World Cultural Heritage List, which is 7000 years older than the Stonehenge and 7500 years older than the Egyptian pyramids. Located in the center of the city, within the Balıklı göl plateau and the historical Kızılkoyun Necropolis is one of the archaeological sites which was discovered in recent years. Kızılkoyun Necropolis with 75 tombs unearthed during the first work of continuing excavations is a candidate to become Turkey's largest Necropolis. In this study, Kızılkoyun Necropolis was first scanned with a laser scanner, and then with the unmanned aerial vehicle (UAV), photogrammetric products have been produced. The result of the evaluation is a surface model of the rock tombs in the region and some archaeological figures and structures have been transferred to the digital environment.

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Introduction

Şanlıurfa is one of the oldest settlements in Mesopotamia. Such that Şanlıurfa, who saw the sovereignty of civilizations such as Ebla, Akkad, Sumerian, Babylon, Hittite, Hurri-Mitanni, Arami, Assyria, Persia, Macedonia, Rome, Byzantium, has announced in the UNESCO World Cultural Heritage List, which is 7000 years older than the Stonehenge and 7500 years older than the Egyptian pyramids. The importance of Şanlıurfa region increased with the inclusion of Göbeklitepe Archaeological Excavation Area in the vicinity of Şanlıurfa Örencik Village in UNESCO World Cultural Heritage List. It is determined to be 7000 years older than Stonehenge and 7500 years older than the Egyptian pyramids, which dates to 11600 years ago (UNESCO, 2018). Except for Göbeklitepe, there are many unexposed and archaeological remains in Şanlıurfa.

Due to the climate of the region, water resources have always been important for Şanlıurfa and surrounding provinces. Therefore, people who settled in the Şanlıurfa region, which has fertile lands since the beginning of the history of civilizations, have established their settlements close to water resources. Today, Balıklı Göl Plateau, which is an important water resource for Şanlıurfa, has been used as a settlement from past to present. It has been determined that there is a settlement in the south and north of the Balıklı Göl, which is the center of the water resource and named as Edessa [1].

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In the written history period, Phrygia the region passed, Lydia, Hellenistic, Iran, Roman-Byzantine, and Turkish period.

Located between the Euphrates and Tigris rivers on the foothills of the Southeastern Anatolian Taurus, known as Fertile Crescent, there are many immune cultural artifacts in the conventional city center of Şanlıurfa. The archaeological sites, which have traces of certain periods in history, can give information about the lifestyles of civilizations living here. However, archaeological sites may undergo various deformations over time or under the human influence [2]. This study aims to emphasize the importance of documenting archaeological sites that have a precious and sensitive structure. Kızılkoyun Necropolis, which is chosen as the study area, Turkey's largest Necropolis in terms of being an important historical period, narrative texture that can be found in the city is an important archaeological site. Şanlıurfa, formerly known as Edessa, had two Necropolis areas. Edessans built Necropolis because they believed in life after death. It is believed that the people buried here, and their families continued to live in these cities after death. Edessans make their cemeteries in a square or rectangular shape, and some of the entrance parts were processed with a temple facade.

With the development of technology, the process of documentation of historical sites has become risk-free and easy. In this study, laser scanning and aerial photographs were used in this archaeological area; point cloud production, mesh modeling, object modeling, orthophoto map, digital elevation model, and digital terrain model were created. Remote sensing methods play an important role in the detection and preservation of existing and buried archaeological artifacts [3]. The results obtained from these studies can be used for archaeological projects as well as for the documentation of excavation sites [4]. While achieving this process, where the structure needs to be reconstructed the geometric accuracy of the model obtained is important [5, 6]. Also, these methods are used to detect and intervene in damages in the archaeological sites due to various causes [7].

Nowadays, with the development of unmanned aerial vehicles and remote sensing systems, it has become easier to model objects and determine the terrain surface as it is [8]. However, the use of traditional methods takes a long time and increases costs [9]. But today, with the development of technology and reducing the cost of systems, this difference has begun to decrease. Besides, rapid and reliable measurement methods are required to document historical data [10]. However, unmanned aircraft or terrestrial scanning systems may not always produce a solution when used separately. In such cases, problems can be eliminated by combining two systems [11]. It is important that the devices used in the study are used by experts in the field and the subsequent application is done with professional people in terms of the desired sensitivity of the study.

The study area is an important place to shed light on the history of the region. For this reason, it is important to document the graves unearthed. Due to the different devices used, two different research plans were examined. First of all, measurements were taken outside and inside the historic structure with a laser scanner. Secondly, aerial photographs were obtained by unmanned aerial vehicles (UAV) at a fixed height.

In the restoration studies to be carried out as a result of historical structures affected by disasters, problematic areas can be identified accurately by using a laser scanning method [12]. In the photogrammetric aspect, the low-altitude aerial photographing method was used in the area of the Roman camp of A Cidadela in NW Spain and the best land surface result was obtained by point-based method [13]. When the structure from Motion and terrestrial laser scanning methods were compared, it was found that the SfM photogrammetry methodology obtained better results than the terrestrial laser scanning method geometrically and visually [14].

Study area

In history Şanlıurfa, before entering into the domination of the Romans, Edessa King Abgar Ukkama has accepted Christianity as kingdoms religion. For this reason, Şanlıurfa has played a very important role in the generation of the foundations of Christian faith [15]. Which founded and established in B.C. 132 The Kingdom of Osrhoene lived independently until B.C. 244 and then came under the sovereignty of the Roman Empire. While Edessa was an ordinary city under Roman rule, it became an

important province during the reign of Constantine the Great (A.D. 349). The double pillar in the Urfa fortress from the Osrhoene Kingdom can be seen today.

The Kızılkoyun Necropolis, which was selected as a study area was declared a protected area in 2012 within the traditional archaeological tissue of the city, is located to the north of Balıklı Göl (Figure 1).

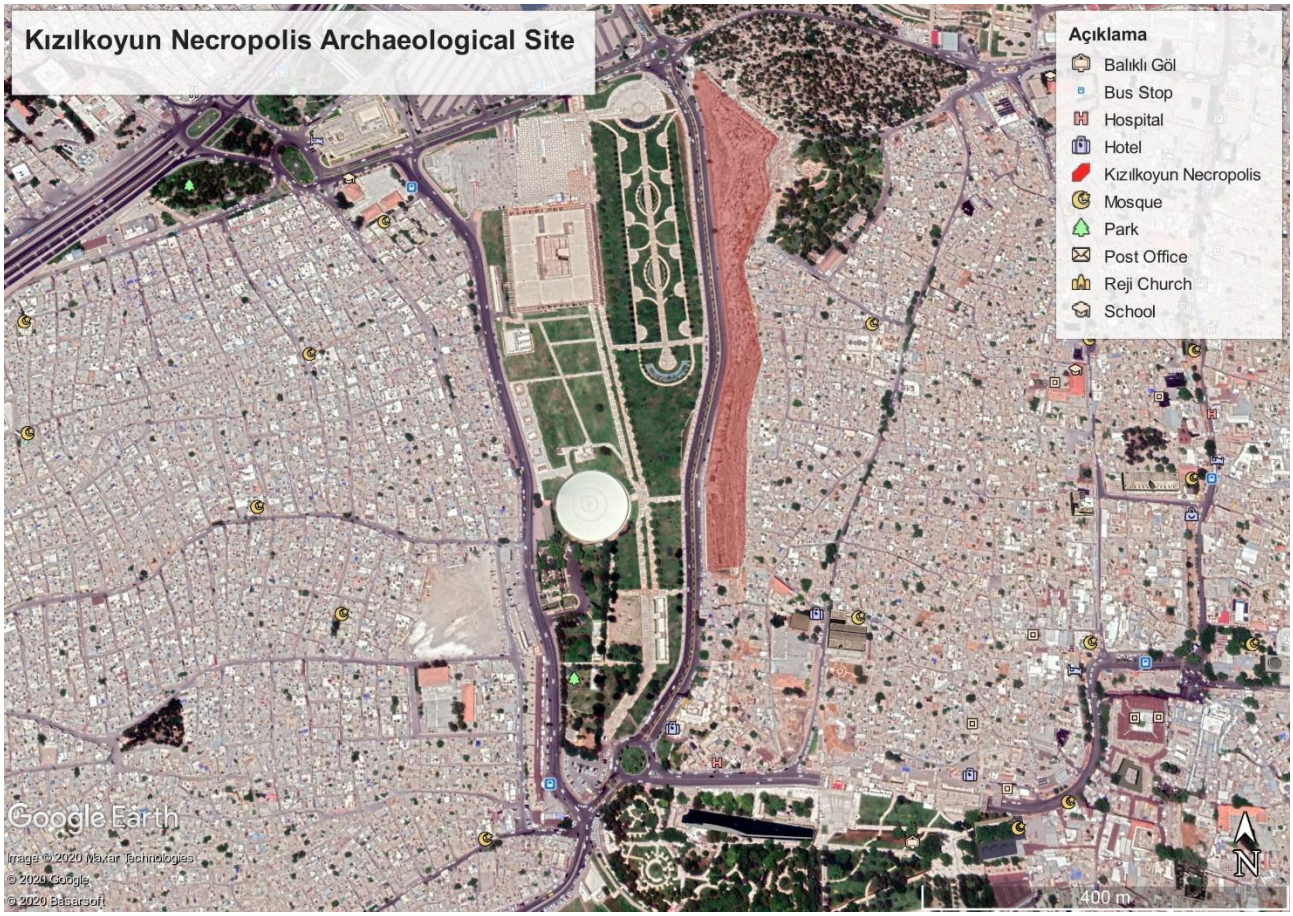

Figure 1. Kizilkoyun Necropolis Archaeological Site

"Kızılkoyun ridges in the city and caves at the foot of the castle emerge as an important cultural identity element" [16]. Although there are many caves in the city, most of them remain under residential areas. The caves emphasizing the historical importance of the city will also shed light on the historical development of the culture of Şanlıurfa. The approximate size of the area is 5 hectares. Kızılkoyun Necropolis is surrounded by protected areas within the zoning plan for conservation in Şanlıurfa Province [17]. The region is also known as a place, where the world's oldest real size human statue has found, when is a pottery-free Neolithic Period Balıklı göl Statue circa 11,500 B.C. [18]. The western walls of Şanlıurfa pass between the archaeological site of the Kızılkoyun Necropolis and the urban archaeological site of Yenimahalle. To the west of the Kızılkoyun Necropolis is the Haleplibahçe archaeological site, to the south is Şanlıurfa Castle and Balıklı göl, to the north is the Bediüzzaman Cemetery. The fact that the region is surrounded by archeological areas increases the importance of the study area. Since the area was not taken under protection in the previous years, the caves were covered with slum structures and it is assumed that caves can be found under these slum areas.

75 cave tombs were unearthed in the area. These cave tombs belong to the Roman period, and in these caves, stone carvings, reliefs and mosaics were found. The area is built on a slope. Where the cave was carved has a calcareous ground structure. The archaeological site should be recorded with 3D documentation methods due to the slopes and the recesses on the monument [19]. Although the structures are cave tombs, thanks to the calcareous structure it has become livable inside the caves.

These tombs in the region are square and rectangular with three single-chamber arcosolium (An ancient arch-shaped cell or niche carved into the rock in underground burial chambers in Roman catacombs.) and three lectia (A kind of armchair used in Ancient Greece and Rome.), front-entry single-chamber arcosolium and three-lectia, front-entry multi-chamber arcosolium and lectia, intertwined two or three-room and one-chamber arcosolium and dromos with lectia. The interior of the burial chambers in the Necropolis area was built in a different architecture (Figure 2).

Figure 2. The only enterance with temple facade in Kızılkoyun Necropolis

The status, occupation, and economic differences of the grave owners have led to the grave chambers having different architectures. The predominantly one-room graves, as well as the one-chamber tombs with front entrances, the multi-chamber tombs with front entrances, two or three-chamber tombs, and one-chamber dromos, were found [20].

Later in the divided Roman Empire, Urfa remained within the borders of the Eastern Roman Empire. The city has been under Roman influence for many years and there are Roman works of art in many places. One of these historical monuments from the Roman period is the Kızılkoyun Necropolis. In the 75 caves found in the excavation area, rock tombs, rock carvings, reliefs, two Roman period statues, and one limestone sarcophagus were found inside the rock tombs. Besides, arcosolium and boat grave types were found. Archaeologists were found 1.85 cm long statues in their research and it was found that these statues were soldier statues of the Roman period belonging to 3-4 centuries. However, the soldiers' statues are depicted in the monolithic pedestal, oriental dressed and equipped with military equipment and it is stated that they carry similar style in terms of construction and use limestone in their construction [21].

Significant mosaics and statues were found in the caves. The calcareous structure of the land in determining the time of the establishment of the region shows that the history of these caves can be traced back to the ancient civilizations. “The presence of caves near the area, which is also known as Dergah, shows that the area where the present city of Şanlıurfa is located during the Paleolithic Period and its surroundings are settled” [22].

Preservation of Kızılkoyun Necropolis before declared and conservation - planning process

The area remained empty until 1970. But with the increase in squatter slums in the region began in 1979 in Turkey. In 1971-1972, to pave the way, the IV. Murat Gate, which is between the Haleplibahçe and Governor Fuat Street, was demolished [23]. With the law passed between 1983 and 1985, the slums were legitimized and the rock tombs, stone reliefs and floor mosaics remained under the slums [24]. Şanlıurfa Conservation Development Plan was approved in 1992. As the caves were covered with slums, the aesthetics of the city were negatively affected.

Haleplibahçe, Urfa castle and Ancient Edessa around the area were taken under protection with

the decision taken by the Presidency of Real Estate and Antiquities and Monuments High Council of the Ministry of Culture in 1979, while the area where Kızılkoyun caves were not protected. In the 1/1000 scale Conservation Development Plan announced in 1992, the area was designated as an area that can be considered as parks, children's gardens, fairs and amusement parks. It was declared as a second-degree archaeological site in 2008, but later it was decided to be declared an urban archaeological site. With the decision taken in 2012, the second-degree archaeological site was declared, and the Kızılkoyun Necropolis was registered as the second-degree archaeological site and the urban texture in the southeast of the area where the graves were located was registered as Yenimahalle Urban Archaeological Site.

Before the site was declared a protected area in 2012, 387 houses and workplaces were demolished by Şanlıurfa Municipality. Under these destroyed houses and workplaces, 59 caves with various figures and reliefs were found on the walls. After the works, the Ministry of Culture and Tourism revealed that it was a Necropolis.

In 2015, the Şanlıurfa Cultural Heritage Protection Regional Board; It was decided that the landscaping projects prepared for the Second-Degree Archeological Site of Kızılkoyun Necropolis prepared by Şanlıurfa Metropolitan Municipality. In the Conservation Development Plan, which was put into effect in 2017, Kızılkoyun Archaeological Site; Planning decisions were determined by evaluating them separately as Second Degree and Third-Degree Archaeological Sites (Şanlıurfa Regional Board for the Protection of Cultural Heritage).

Methodology

Nowadays, as the popularity of device usages such as laser scanning and UAV increases, and the number of applications that can be done with these devices has increased significantly. Both methods have advantages and disadvantages compared to each other [25]. Laser scanning devices have a wide range of applications in documenting crime incidents, construction of engineering structures, surveying, and archaeological artifact measurements. In this study, the laser scanning device was used to scan both the work area surface and the tomb interior surfaces. Laser scanning devices are important for the precise production of the model where the sunlight does not enter with little or no penetration, such as tombs [26]. The laser scanning device used in the study is the x300 model of Stonex. This device has a capacity of 40000 dots per second and a 5-megapixel two-angle camera. Also, the device can scan 360 degrees on the horizontal axis and 90 degrees on the vertical axis. The device can detect the closest measuring distance is 1.6 m and the farthest measuring distance is 300 m.

To achieve precise measurements with laser scanning devices, it is important to determine the scan locations well and to prepare and follow the appropriate plan. Pay attention to the common points in each scan area and install the device at these points. While selecting a reference point in the scanned areas, it should be noted that the same objects can be seen again in the acquired images. Measurements should be repeated in sections with a high level of detail and these sections should be revealed in more detail. In this study, the closest measuring distance of the device is taken into consideration when making measurements.

The UAV that we use in practice is the Octo V3 model of the Turkuav with 8 propellers. The device is equipped with a 20.2-megapixel camera with its flying equipment. In the measurements made with UAV, a detailed flight plan was prepared for the region to be displayed. Obstacle heights in the area where the measurement is to be performed are well defined and the flight height of the UAV is adjusted according to this plan. Operators using the devices did not change from the beginning to the end of the application and human errors that might occur were minimized.

Application

In this study, two different measurement platforms, laser scanner and UAV were used and therefore two different methods were applied to perform documentation of historical places.

Laser scanning application

Based on the technical characteristics of the device used in the study, the measurement was previously planned and the maximum yield from the device was calculated. Considering the

limitations such as the minimum measuring range of the device and the narrow archaeological study area we made multiple measurements and minimized possible data losses. The point cloud was obtained from the laser scans of the region and the object model was created (Figure 3).

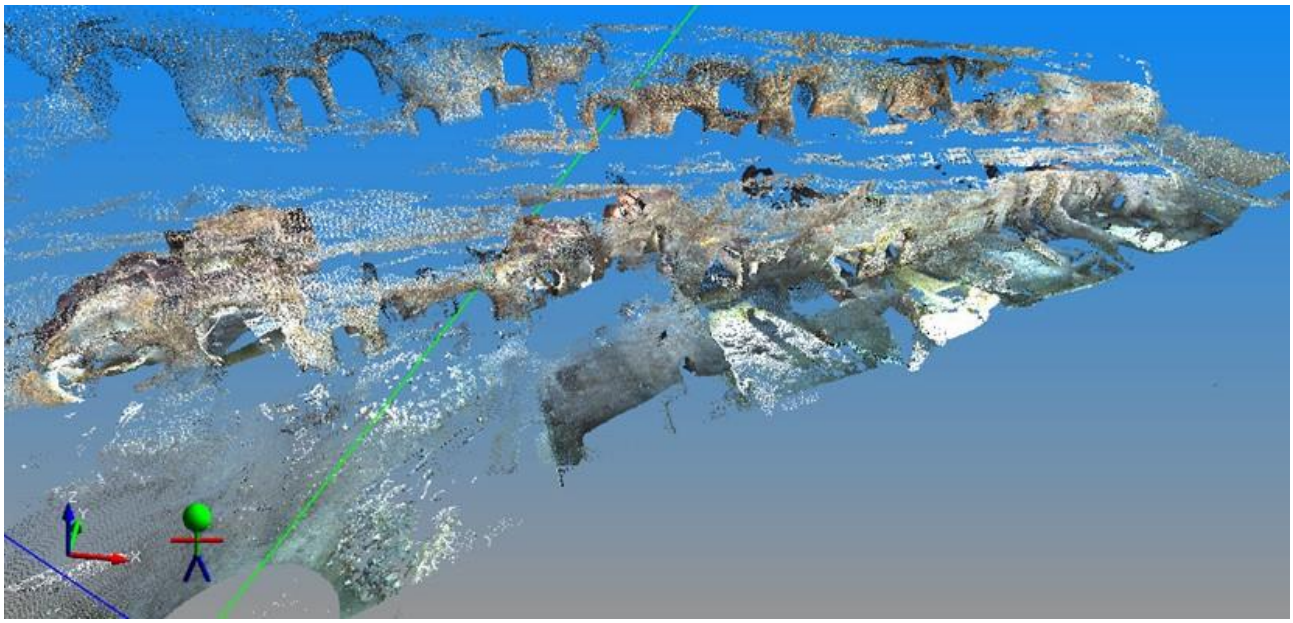

Figure 3. Kızılkoyun Necropolis Overview (Point Clouds)

As the result, data required a photographed model, we paid attention to the time of the measurement. Measurements were made the morning hours when the device would not be exposed to direct sunlight and the shadow would be as low as possible for the accuracy of the results.

Since the region where the study was conducted in Şanlıurfa, we also paid attention to air temperature. The operating temperature of the device is at most 50 centigrade degrees and the device cannot operate consistently at noon. For this reason, we chose morning hours (7 p.m. to - 11 p.m.) when the sun was usually behind the caves and the device did not see the sun.

Figure 4. (Left) In-Cave Relief Detail (Point Cloud), (Right) In-Cave Relief Detail (Modeled Image)

In the study, planning of measurements and apply on the study area is important. In application, we made a measurement plan and complete measurement so that the detail points appear in as many measurements as possible. 24 measurements were taken from the study area. Each of these measures was obtained from different connection points and all were adjusted to see each other. We have paid attention to the detail points that will be the reference in each of the measures. At the measurements taken, the corner point was tried to be taken as much as possible (Figure 4). Laser scanning data were evaluated in the Reconstructor software. The mean pixel sensitivity in 24 groups measure was ± 3.5 cm. In the study, pixel sensitivity varies

according to the level of detail required in the project.

Unmanned aerial vehicle application

We used 8-winged octocopter of the Octo V3 model of TurkUAV brand. We have checked some flight procedures. Firstly, we checked the weather conditions (temperature, pressure, humidity) at the time of flight of the region. To identify the obstacles that may be encountered in the area where the flight will take place, the dangerous high objects on the land were checked before the flight in the area. Secondly, a flat surface was chosen as possible for the UAV to be able to take off smoothly. Before starting the flight, pre-flight preparations checked step by step and then the flight started. The study area has a steep and sloped terrain. Therefore, to avoid the risk of the UAV crashing anywhere, flights were carried out at a safe height of 50 meters. The fixed-height flight is important for the consistency of data and easy calculation.

The points shown in Figure 5 show the route of the UAV at the time of flight and the photo-shooting points.

Figure 5. Flight Area

Flights were made in the morning when the shadow was minimal. It is very important to prepare a flight plan previously for the flight area. Thus, flight time, flight area was determined, and it was determined whether there was an obstacle during the flight and the flight plan was prepared accordingly. 99 photographs were used in the study evaluated with Pix4D software. The application area is modeled with these images and the application area is modeled by clothed images to the resulting point cloud (Figure 6).

Figure 6. Modeled View of the Caves

At the end of the evaluation, ground sample distance was 1.26 cm/pixel. In addition, orthophoto, digital elevation models and digital terrain models of the region have been created (Figure 7).

An obtained outcome such as images and models can be used in archiving historical places, modeling important artifacts found in archaeological excavations and restitution projects.

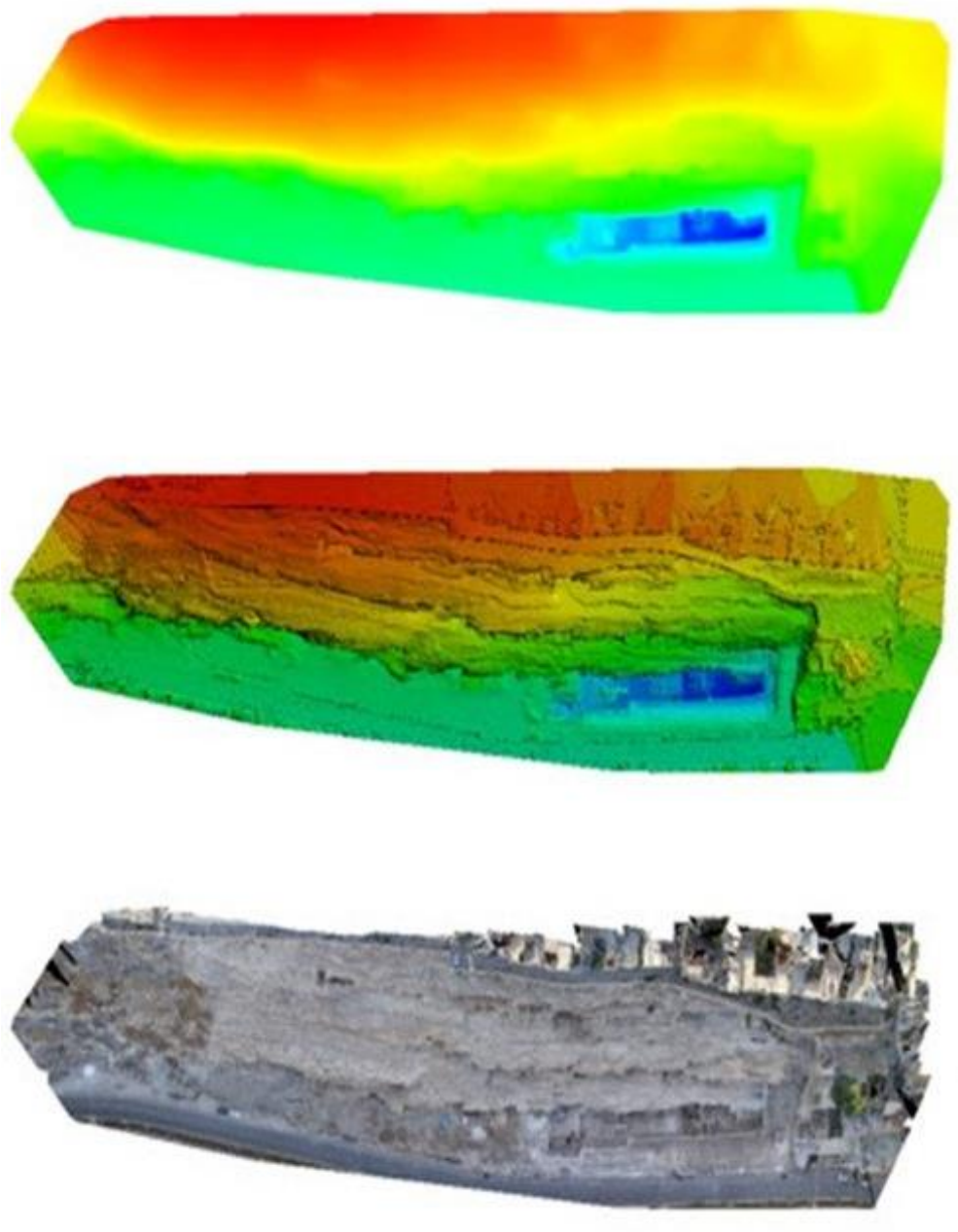

Figure 7. DEM (Top), DTM (Middle) and Obtained Orthophoto (Bottom)

Conclusions

At the end of the study, the Necropolis was modeled with both laser scanning devices and UAV to obtain high accuracy results. In the historical artifact measurements, UAV and laser scanning methods were applied without damaging and contact artifacts and it was found to be a more advantageous tool in terms of both time and accuracy compared to classical measurement methods. It has been found that there are narrow areas that the device cannot see during application and this problem can be solved by using the apparatuses of the device. Besides,

the structure of land was modeled with the digital elevation models and digital terrain models.

The study is important to shed light on the existence of historical artifacts and to document the existing artifacts. In the next studies, historical artifacts requiring a high level of detail in the region will be explored and the places where the depth analysis should be performed will be re-evaluated.

Furthermore, by combining image-based data with laser-scanned data, the deficiencies of the generated model can be eliminated when the methods are used separately. We can have information about the inner sections by measuring the laser scanning method of the grave parts that cannot be entered by unmanned aerial vehicles. However, due to the scattering caused by the material used in the structure and the sun, the laser scanning method did not give good results and the quality products were obtained by the photogrammetric method. It is seen that by combining the data which is obtained on different platforms, the laser scanning method and the image-based method can eliminate each other's deficiencies.

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