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# CREATING GEOGRAPHICAL INFORMATION SYSTEM (GIS) DATABASE WITH UNMANNED AERIAL VEHICLES (UAV) IN ARCHAELOGICAL AREAS; THE CASE OF ANEMURIUM ANCIENT CITY

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**Keywords**
*GIS,*
*Mapping,*
*UAV,*
*Archaeology,*
*Database.*

**Abstract**

The use of Geographic Information Systems (GIS), which have developed rapidly in recent years, in archaeological sites provides a basis for many studies. It is important to produce the permanent records of archaeological sites for the management cultural heritage. While many methods are used to produce permanent records and boundaries, photogrammetry and remote sensing techniques have begun to be preferred within the process by considering their advantages such as low cost, saving time, and completing studies on cultural heritage without contact. In this study, a Digital Elevation Model (DEM) and Orthomosaic were produced using an Unmanned Aerial Vehicle (UAV) in Anemurium Ancient City located in Mersin province. These data were used as a basis, and a relational database was created for GIS. Thus, an inventory study of all stone buildings and roads in the area was conducted, and the data sets were created according to the quality of the remains. Furthermore, the stone buildings in the ancient city were named on an address basis, and a relational database including the boundaries of the country, province, district, and ancient city area was created. This study serves as a guide for studies to be conducted on the management of archaeological sites.

# ARKEOLOJİK ALANLARDA İNSANSIZ HAVA ARACI (İHA) KULLANARAK COĞRAFİ BİLGİ SİSTEMİ (CBS) İÇİN VERİ TABANI OLUŞTURMA: ANEMURİUM ANTİK KENT ÖRNEĞİ

**Anahtar Kelimeler**
*CBS,*
*Haritalama,*
*İHA,*
*Arkeoloji,*
*Veritabanı.*

**Öz**

Son yıllarda hızla gelişen Coğrafi Bilgi Sistemlerinin (CBS) arkeolojik alanlarda kullanılması birçok çalışmaya altlık oluşturmaktadır. Arkeolojik alanların kalıcı kayıtlarının üretilmesi, kültürel mirasın yönetimi açısından önemlidir. Kalıcı kayıtların ve sınırların üretilmesi için birçok yöntem kullanılmakla birlikte süreç içerisinde fotogrametri ve uzaktan algılama teknikleri; düşük maliyetli olması, zamandan tasarruf edilmesi ve kültür mirasları üzerinde yapılan çalışmaların temas olmaksızın tamamlanması gibi olumlu getirileri göz önünde bulundurularak tercih edilmeye başlanmıştır. Bu çalışma kapsamında, Mersin ili Anamur ilçesinde bulunan Anemurium Antik Kent alanında İnsansız Hava Aracı (İHA) kullanarak Sayısal Yükseklik Modeli ve Ortomozaik üretilmiştir. Bu veriler altlık olarak kullanılmış ve CBS için ilişkisel veri tabanı oluşturulmuştur. Böylelikle alanda bulunan tüm taş yapıların, yolların envanter çalışması yapılmış, kalıntıların niteliğine göre veri setleri oluşturulmuş, buna ek olarak antik kent alanında taş yapılar için adres niteliğinde adlandırma yapılmış ve ülke, il, ilçe, antik kent alanı sınırlarını da kapsayan ilişkisel veri tabanı oluşturulmuştur. Bu çalışma, arkeolojik alanların yönetimine ilişkin yapılacak çalışmalar için rehber niteliğindedir.

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## 1. Introduction

Archeology is a science that studies ancient cultures and civilizations and their material remains that have reached the present day and attempts to reconstruct them. Since many years have passed over the remains of ancient cultures and these remains are generally discovered late, excavations are usually carried out to unearth them. The excavation technique, a method that is quite complicated and requires accuracy, constitutes the basic study of archeology. The science of archeology, the main field of study of which is the excavation technique, is also defined as the science of excavation. Along with the fact that it is called the science of excavation, the science of archeology is not just about conducting various studies by unearthing material cultural assets by the excavation method (URL). Archeology is inseparably linked with history and can gain value only when addressed within the framework of history (Sevin, 1999). Thus, it becomes possible for nations and communities to get information about the past and make comments in the political, social, and economic fields.

Cultural and archaeological heritage should have a realistic and accurate appearance for the investigation, interpretation, and management of cultural heritage. It is important to document and conserve ancient roads, cities and stone buildings built with stone materials and bearing the traces of world civilizations. The creation of a sustainable database for GIS by producing digital bases using UAV since it produces 3D data and orthophoto images with low cost and high accuracy provides significant advantages to manage/conserve cultural heritage sites, to conduct scientific studies, and make them suitable for tourism (Tercan, 2017; Avdan, 2014). The rapid and accurate creation of a geographic database for the conservation, planning, documentation, and recording of archaeological sites will be an important step for our country and the world. There are many methods that can be preferred to create a database for GIS in mapping activities carried out in ancient city areas with historical artifacts (Girişken, 2010). Among these methods, the use of a mapping method with UAV provides significant advantages in terms of the conservation of archaeological sites by preventing close contact with them, fast and repetitive data production, obtaining high-resolution images, and low cost (Bendea, 2007; Türk, 2018).

GIS is a computerized mapping system based on the digital processing of spatial data and its attribute information, obtaining, querying, organizing, and analyzing new products using the data entered into the digital media, and revealing their interrelations, and the visualization of the obtained results in the form of graphs, maps, and 3D images (İncekara, 2009). Although GIS continues to work with many techniques, with the integration of remote sensing techniques, the usage areas of these systems have increased, and they have begun to be used for different purposes in many areas. Issues such as recording stone buildings in archaeological sites, performing various analyses, determining the boundaries of these areas, doing planning, and conservation and management of the buildings in the site are possible through GIS. The selection of the right method from among the measurement methods used for GIS in archaeological sites will provide many benefits concerning the production of spatial data and the management of the data produced by considering the parameters such as speed, accuracy, non-contact, and cost. Thus, it becomes possible to model material cultural heritage at the desired level. In a modeling study aimed at providing data as needed and in accordance with the aim of the study, when project planning and the integration of data obtained through different methods are ensured, the targeted outcome will be achieved in the most accurate way (Voltolini et al., 2007).

UAV is defined as the whole of integrated systems consisting of three components, including a pilotless aircraft system, remote control system, and command-control communication medium between them. UAV consists of communication, software and equipment for planning, flight and management purposes (To-run, 2017). It is known that it is possible to perform airborne measurements, DEM creation and orthophoto production studies with 3D data of the land by the UAV photogrammetry method (Cryderman et al., 2015, Draeyer et al., 2014, Torun 2016). In order for stone buildings in archaeological sites to reach the present day without any damage and thus to make correct determinations about the past, attention is paid to ensure that any work done in the area is fast and accurate without or with minimal contact with stone buildings. Considering parameters such as speed, accuracy and non-contact operation, the UAV technique is a method that should be preferred while creating a database for GIS in archaeological sites.

In the literature, in the studies conducted in archaeological sites, the required products were obtained using UAV and GIS methods, and the targeted outcomes were achieved. In the study conducted by Ulvi et al. (2020), it was concluded that keeping the digital data of historical artifacts in the digital environment will provide benefit and convenience in the studies of various disciplines and in their transfer to future generations. Türk (2018) reported that one of the usage areas of UAV was the science of archeology and that the use of UAV in this area was highly important, and he indicated that useful studies could be conducted for many needs such as certification, recording, and introduction of cultural heritage. In his study, Tercan (2017) produced 731 high-resolution images of an ancient city and caravan road belonging to the Ottoman Empire period using UAV. He tested the accuracy of the UAV system by the conventional ground surveying method and concluded that UAV photogrammetry systems were an appropriate method to obtain detailed and accurate 3D data in the documentation of ancient cities and caravan roads. In his study, Kısaağa (2016) created a base inventory that would help archaeological studies using GIS techniques to comment on issues such as the reasons for the settlers of the period to choose the area, for what purposes they were in this area, the surface model of the region and the relations of the settlers based on the topographic features of the study area, which included prehistoric and historic-period settlers. The maps visualized as a result of the analysis helped archaeologists to interpret the socio-cultural, economic, and demographic characteristics of the ancient city of Knidos. In their study, Güleç et al. (2015) developed a spatial database and user interface model by taking the historical settlement area and its buildings within the boundaries of Denizli province as an example with up-to-date software. The GIS model, which works over the web server, is obtained by making six different software technologies interactive with independent working principles and also provides all visitors who want to obtain information about historical settlements and archaeological buildings with information about where important settlements and buildings are located, how to reach these areas, their history, the relevant academic studies, and visual information. In their study, Liritzis et al., (2015), conducted a detailed study on the use of digital technology in cultural heritage studies in the context of archaeological sciences and gathered the trends in this field under main headings. They explained one of the titles among these trends as "Remote Control Aircraft (drones)". In his study, Aria (2013) investigated the significant improvement of GIS in archaeological site studies in the last quarter-century and its effect on archaeological sites. He developed a database application for GIS and investigated its results. The aim here was to investigate the feasibility and effectiveness of geographic data sets using the existing technologies and archaeological data standards, to identify the barriers to their implementation, and to show a new path for GIS-driven innovation in this area. In his study, Girişken (2010) examined the historical development of legislation on the importance and conservation of cultural heritage and conducted research on the deficiencies in the legislation in our country and the destruction caused by urbanization processes in archaeological sites. Furthermore, the researcher evaluated the models for the importance of GIS in archaeological studies and planning stages, the geodetic measurement techniques used and their benefits, and the management of urban archaeological heritage in different countries. In his study, Levent (2009) performed the systematic collection, archiving, management, and analysis of geographical objects with a geographic data set that was created with GIS and free of unnecessary information regarding data attributes and in which the necessary rules and restrictions were determined. In their study, Conolly and Lake (2006) investigated the usability of GIS in archeology based on the fact that GIS is a powerful technology that offers analytical possibilities to investigate the spatial organization of human cultural and environmental relations. Nevertheless, they provided some real-life examples of how GIS could be used to increase the understanding of the human culture within a spatial framework, the presence of a wide range of ways, and how GIS could and did work in archeology.

In this study, Ground Control Points (GCPs) were determined in an archaeological site by the GNSS technique, a flight was performed with UAV, and an orthophoto of the area was created. First, the geographical equivalents of stone buildings were formed as vectors by using this orthophoto as a basis, and the data on the road and boundary in the area were geographically created from the orthophoto, and attribute information was added. Data sets were created for the whole digitized details, and a relationship was established between them. Furthermore, a unique value was assigned on an address basis for each stone building. The studies were carried out based on a relational database, and accordingly, the database was designed. Thus, a geographic database was created using the orthophoto produced by a fast, accurate, and contactless method. In conclusion, the stone building inventory in the archaeological site, the boundaries of the road, country/province/district and ancient city were created and addressed, and it was aimed to use the database and orthophoto produced in this study for the documentation, recording, conservation, management, monitoring, and planning of this area.

## 2. Material and Method

Anemurium Ancient City, with an area of approximately 400 000 m2 in the town of Ören in Anamur district of Mersin province, is located at a point where the southern and eastern slopes of Kargagedik Mountain meet the sea (Figure 1). The name of the city means 'windy nose' (Tekocak, 2018).

Although it is not certain by whom and when the city was founded, it is considered that the name of the city dates back to the Hittites. According to the available resources, Anemurium ancient city was first settled in the 4th century BC. In the 3rd century BC, some building remains were found with the settlement in the area where the walls on the acropolis are located. In the 1st century BC, it became an important city in terms of trade due to its proximity to Cyprus. In the major earthquake that occurred in 580 AD, the city was seriously damaged, and the buildings were damaged. The churches and aqueducts that were started to be built in the last century were mostly damaged by this earthquake, and they were largely destroyed (Tekocak, 2018).


**Figure 1.** The Location of Anemurium Ancient City

In this study, it was made possible to document the site, to conduct various studies/analyses by producing an orthophoto quickly and accurately and creating geographic data sets on this image as mentioned above, and to conserve, plan and monitor the archaeological site, and it was an important study for both Anatolian archeology and world archeology. In addition, Photogrammetric studies performed with the help of UAVs allow the documentation to be more comprehensive and realistic as the possibilities of taking photographs increase (Yakar,2017).

In the ancient city area, which is of great importance for the world and Anatolian archeology, a lot of equipment was used in field surveys. First, a mobile phone for camera purposes (mobile phone is also equipment used for the Pix4D Capture application required for the management of the UAV), Phantom-3 UAV through which we performed the flight, 1 SATLAB SL500 GNSS and 1 range pole for GCP measurement, and lime and spray to mark the GCP were used to photograph the structures and general view in the area.

Before the flights in the field, the GCP was established homogeneously in the ancient city area to accurately coordinate the DEM of the orthophoto image to be produced and the solid model. The distribution of these points was determined by the integration of the land environment and office environment using both the field map and satellite image during the field trip. The locations were selected by considering the flight altitude, ground sampling value, and therefore the scale of the map while determining the distributions of the points. During the field trip, 25 points were measured homogeneously in the ancient city with an area of 400 000 m2. During the optimization, the points were established so that they would be visible on the image and their midpoints would be apparent. The measurement of the mentioned 25 points was completed by connecting to TUSAGA-Active stations with a SATLAB SL 500 GNSS instrument, and the points measured were marked with the help of lime and red spray. The same procedure was repeated for 25 points, and the values given in Table 1 were obtained as a result of the measurements (3° International Terrestrial Reference Frame-96 (ITRF-96)). After completing the GCP measurements, the display of the points with known coordinates on the Google Earth satellite image in the office environment was useful for facilitating both the flight plan stage and the post-flight office work stage (Figure 2).

**Table 1.** Location Information of GCP

| Date/Time | Point | Right **(m)** | Up**(m)** | Elevation Height **(m)** | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 2019-06-29-12:45:22 | 1 | 482280,978 | 3987833,257 | 33,781 | 36°01'13.73667" | 32°48'12.34324" |
| 2019-06-29-12:51:34 | 2 | 482298,893 | 3987915,12 | 32,886 | 36°01'16.39383" | 32°48'13.05212" |
| 2019-06-29-12:56:36 | 3 | 482331,332 | 3988020,135 | 34,199 | 36°01'19.80307" | 32°48'14.33923" |
| 2019-06-29-13:01:35 | 4 | 482369,874 | 3988081,002 | 32,645 | 36°01'21.78033" | 32°48'15.87366" |
| 2019-06-29-13:05:48 | 5 | 482409,621 | 3988163,924 | 35,038 | 36°01'24.47328" | 32°48'17.45445" |
| 2019-06-29-13:10:28 | 6 | 482472,604 | 3988294,436 | 36,236 | 36°01'28.71170" | 32°48'19.95951" |
| 2019-06-29-13:13:54 | 7 | 482532,313 | 3988404,613 | 36,398 | 36°01'32.29014" | 32°48'22.33555" |
| 2019-06-29-13:22:21 | 8 | 482409,835 | 3988331,667 | 35,729 | 36°01'29.91554" | 32°48'17.44959" |
| 2019-06-29-13:27:06 | 9 | 482291,769 | 3988304,202 | 43,61 | 36°01'29.01676" | 32°48'12.73626" |
| 2019-06-29-13:30:46 | 10 | 482287,697 | 3988202,784 | 42,567 | 36°01'25.72608" | 32°48'12.58182" |
| 2019-06-29-13:36:48 | 11 | 482258,143 | 3988361,907 | 52,827 | 36°01'30.88675" | 32°48'11.38860" |
| 2019-06-29-14:39:42 | 12 | 482209,536 | 3988225,923 | 48,716 | 36°01'26.47167" | 32°48'09.45824" |
| 2019-06-29-15:03:44 | 14 | 482191,075 | 3988073,044 | 44,521 | 36°01'21.51044" | 32°48'08.73331" |
| 2019-06-29-15:06:00 | 15 | 482208,133 | 3987953,848 | 36,226 | 36°01'17.64436" | 32°48'09.42422" |
| 2019-06-29-15:09:57 | 16 | 482168,909 | 3987923,229 | 44,735 | 36°01'16.64839" | 32°48'07.86020" |
| 2019-06-29-15:13:42 | 17 | 482139,52 | 3987941,545 | 54,07 | 36°01'17.24070" | 32°48'06.68498" |
| 2019-06-29-15:16:51 | 18 | 482121,676 | 3987987,547 | 58,353 | 36°01'18.73200" | 32°48'05.96858" |
| 2019-06-29-15:20:12 | 19 | 482127,884 | 3988037,514 | 57,58 | 36°01'20.35354" | 32°48'06.21244" |
| 2019-06-29-15:26:37 | 20 | 482132,552 | 3988105,166 | 65,837 | 36°01'22.54875" | 32°48'06.39338" |
| 2019-06-29-15:31:57 | 21 | 482137,579 | 3988168,146 | 65,889 | 36°01'24.59244" | 32°48'06.58904" |
| 2019-06-29-15:35:54 | 22 | 482143,238 | 3988229,354 | 69,001 | 36°01'26.57863" | 32°48'06.81008" |
| 2019-06-29-15:39:36 | 23 | 482168,908 | 3988322,013 | 70,662 | 36°01'29.58657" | 32°48'07.82780" |
| 2019-06-29-15:44:08 | 24 | 482159,777 | 3988383,678 | 75,234 | 36°01'31.58662" | 32°48'07.45812" |
| 2019-06-29-16:05:43 | 25 | 482251 | 3988329,807 | 54,892 | 36°01'29.84484" | 32°48'11.10589" |

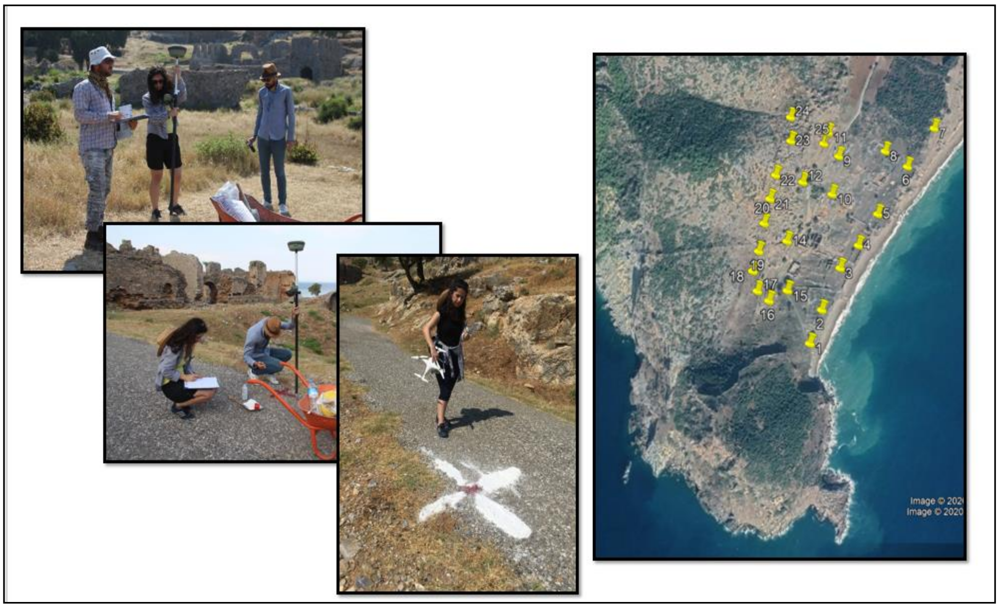

**Figure 2.** Measurement of GCPS And Their Location on Google Earth

After determining the GCP and completing the measurements in the field, a total of 7 flights were performed using the Phantom-3 UAV with a weight of 1380 grams, an image size of 3000*4000, a flight time of approximately 15-20 minutes and a camera resolution of 12 megapixels. With 7 flights performed in the ancient city with an area of approximately 400 000 m2, it was determined that the transverse overlap rate was 80% and the longitudinal overlap rate was 60%, flights were performed for 39 minutes, and as a result of this study, a total of 649 aerial photographs were obtained. During the study, the flight plan was made, as shown in Figure 3, and the flights, including the information presented in Table 2, were completed.

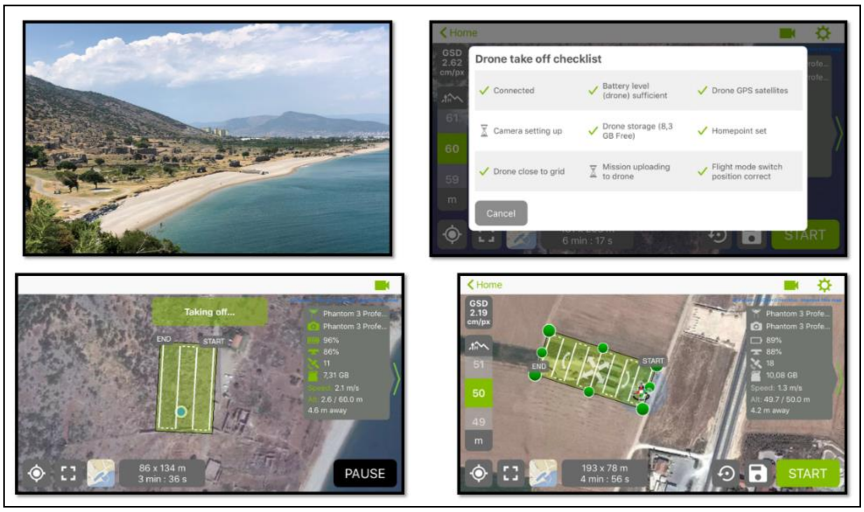


**Figure 3.** Flight Plan

**Table 2.** Flight Information

| Flight | Facade Length | Flight Area (m²) | Flight Time (minute) | Flight Height (m) | Number of Satellite | Transverse Overlap Rate | Longitudinal Overlap Rate |
|---|---|---|---|---|---|---|---|
| 1 | 372*431 | 160.332 | 9 | 60 | 18 | 60 | 80 |
| 2 | 225*328 | 73.800 | 7 | 60 | 16 | 60 | 80 |
| 3 | 159*168 | 26.712 | 3 | 60 | 15 | 60 | 80 |
| 4 | 181*293 | 53.033 | 6 | 60 | 14 | 60 | 80 |
| 5 | 243*332 | 80.676 | 7 | 60 | 15 | 60 | 80 |
| 6 | 86*134 | 11.524 | 3 | 60 | 11 | 60 | 80 |
| 7 | 85*178 | 15.130 | 4 | 60 | 12 | 60 | 80 |
| TOTAL | | 421207 m² | 39 min. | | | | |

As a result of the flight studies, all aerial photographs were added to the application using the Agisoft PhotoScan software, and the photographs were combined. A sparse point cloud image consisting of approximately 300 000 points, a dense point cloud consisting of approximately 31 000 000 points, a 3D solid model consisting of 2 000 000 surfaces, DEM and orthomosaic images of 20 000*30 000 size were obtained from 649 aerial photographs of 3.51 GB using the virtual machine with a 32 GB Ram 12 Core virtual operating system Win 2012 r2 Data Center. The results of the study were examined, and as a result of the optimization, data with X, Y, Z positioning accuracy below 10 cm was produced, and it was considered to have a suitable accuracy for the study to be conducted (Figure 4, Figure 5). Furthermore, the resolution area was selected as "highest" in the Agisoft PhotoScan application in order to produce the highest quality orthomosaic image, which was intended to be used as a basis in the creation of a database, and accordingly, orthomosaic production progressed slower than low-resolution production. It took about 6-8 days, and photo combining, orthomosaic production, 3D solid model and DEM production were performed at once.

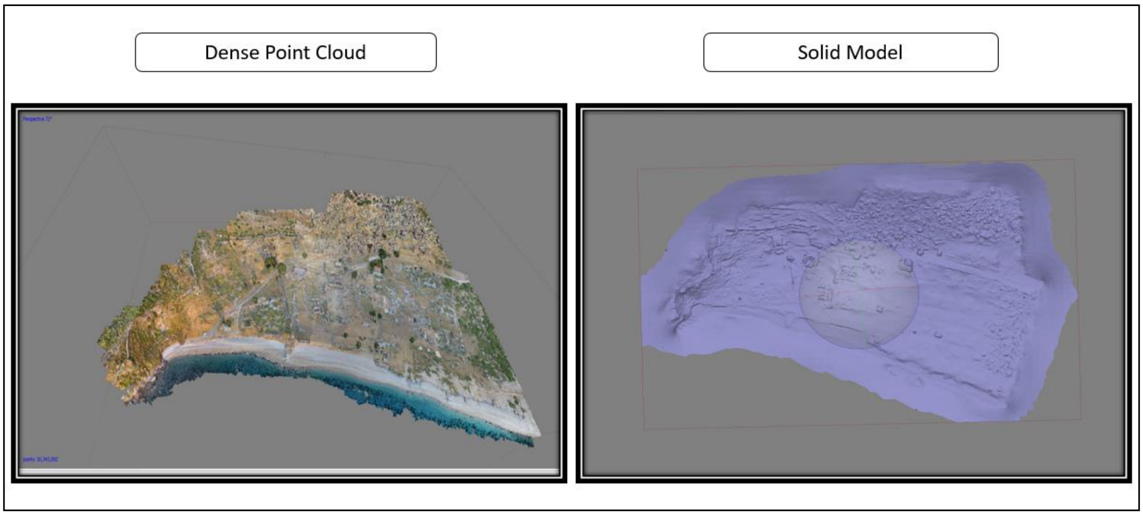


**Figure 4.** Dense Point Cloud and Solid Model

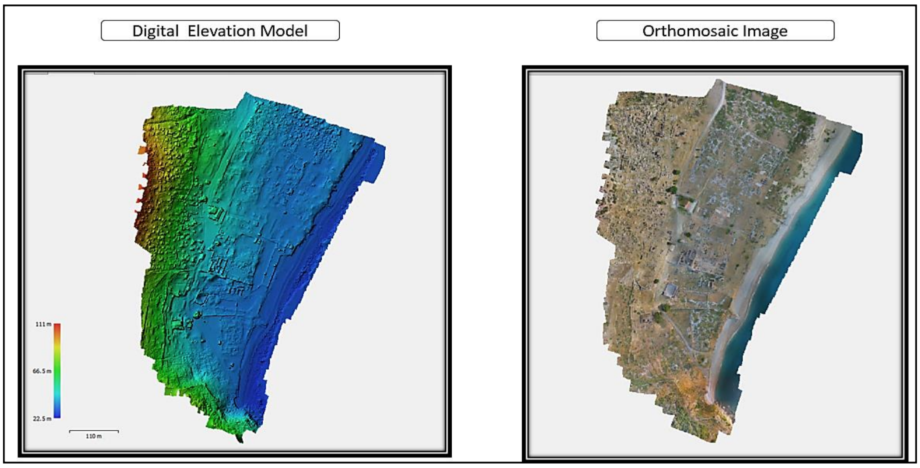


**Figure 5.** Digital Elevation Model and Orthomosaic Image

To produce a usable and sustainable database in the ancient city area, which was the main aim of this study, the basis to be used, in other words, the orthomosaic image produced was displayed in the ArcMap 10.4.1 software, and also, in this program, the stone buildings were digitized, and the database was designed. In addition to conducting a literature search for table data at the stage of preparing a relational geographic database, information such as the investigation of all stone buildings, the date of construction of the stone buildings and their intended use was obtained by physically existing in the field, and it was associated with the geographic data in the system. We were in Anemurium ancient city on 26.06.2019, both field investigations were conducted, and information on stone buildings was obtained together with the excavation team. To create the data sets, various sources were reviewed to record all components in the field such as cultural heritage, boundaries, buildings, and roads built later in the ancient city, and investigations were conducted during the time in the field.

Before the database design, the required information such as the diversity of buildings in the field, the boundaries of division into regions, the attributes of the stone buildings in the area, the province and district of the ancient city, and the orthomosaic image of the area was completed from the field, the general network or with the products produced. Thus, it will be useful to evaluate the available data and design a usable database that can be developed in the future. First, the data sets forming the basis of the database were created and collected under six headings, including Stone Building, Transportation, Urban Area, Boundary, Address and Post-Built Buildings (Figure 6), and classes were created as the subheadings of the data sets. The attribute information of these classes was kept in separate tables, and it was ensured that geographic data and verbal information could be displayed simultaneously. Depending on the suitability of the areas where different information belonging to each class would be stored, while some of them were the areas with a "subset" and in which one of the subheadings added to the database design must be selected, some of them were the areas where information was entered manually based on the user's request. All stone buildings in the area with the cultural heritage property or that were built later and had no cultural heritage property were digitized and separated according to their class. The information on the country, province, and district of the ancient city was produced using ArcGIS application examples verbally and as vector and downloadable information on the website of the General Directorate of Mapping.

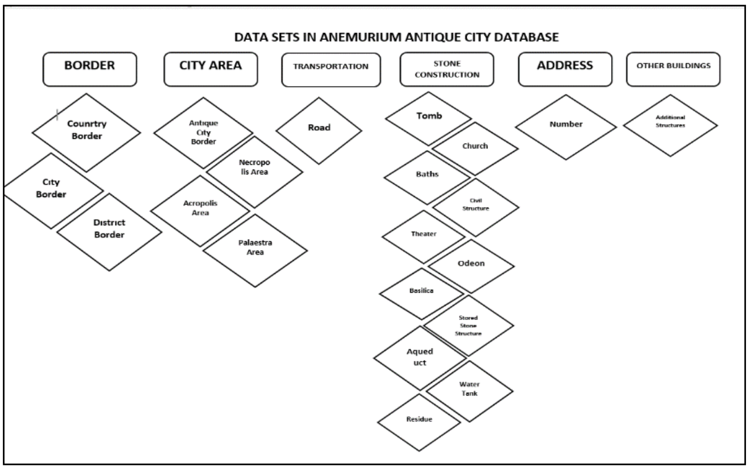


**Figure 6.** Data Sets in Anemurium Antique City Layers

While designing the database, it was designed based on a relational database, and it was primarily considered useful. The relationships were established as in the examples presented in Figure 7, such as country and province, province and district, district and ancient city, structure and number. For example, from the value in the 'Code' area of the country layer to the value in the 'CountryCode' area of the Province layer, it is observed to be associated. Likewise, if the 'Code' area value in the Ancient City Area layer and the 'AncientCity Code' value of the Necropolis area layer are the same, it indicates that it is associated and directly connected.

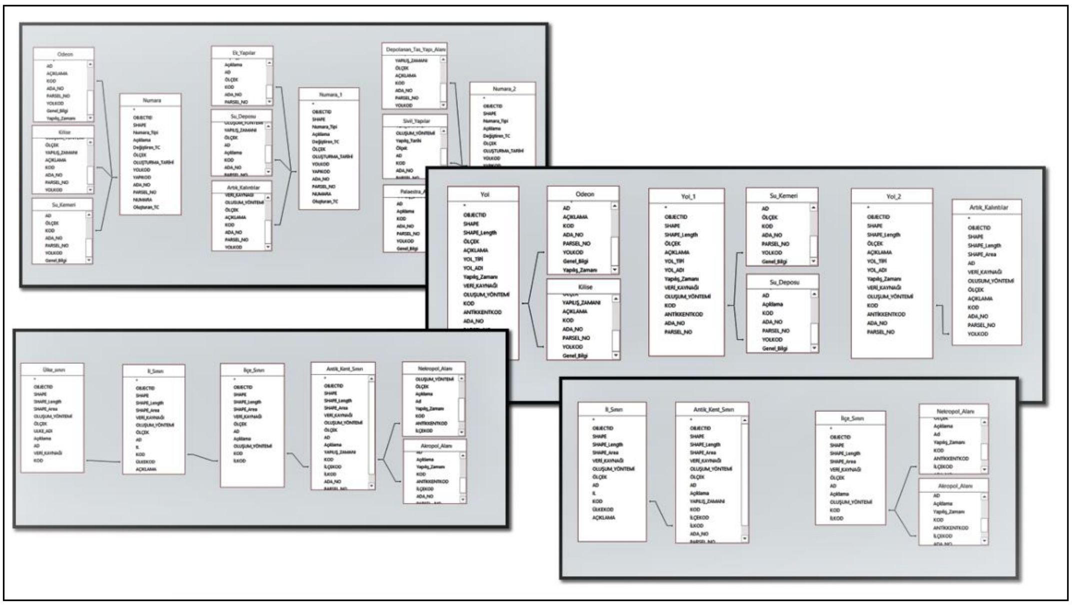

**Figure 7.** Examples of Inter-Class Relationships

Furthermore, one unique address value was given for each stone building and associated with the relevant building so that it would be on an address basis and the stone building investigated for any reason could be determined in the fastest way. These values were designed differently and uniquely based on the data classes.
Information on the explanation of all layers, general information texts, on what scale they were produced, the date of construction, from where the data were produced, what the method of formation was, and island and parcel was entered manually. However, in the ancient city area, each of the following areas:

1. Data Source
2. Method
3. Scale
4. Type of Church
5. Type of Number
6. Type of Turkish Bath
7. Type of Area (For additional building layer)
8. Type of Road

has unique subsets, and the user only has to choose one of these subsets (Figure 8). The names, codes, and subheadings of the areas with subsets are presented in Table 3.

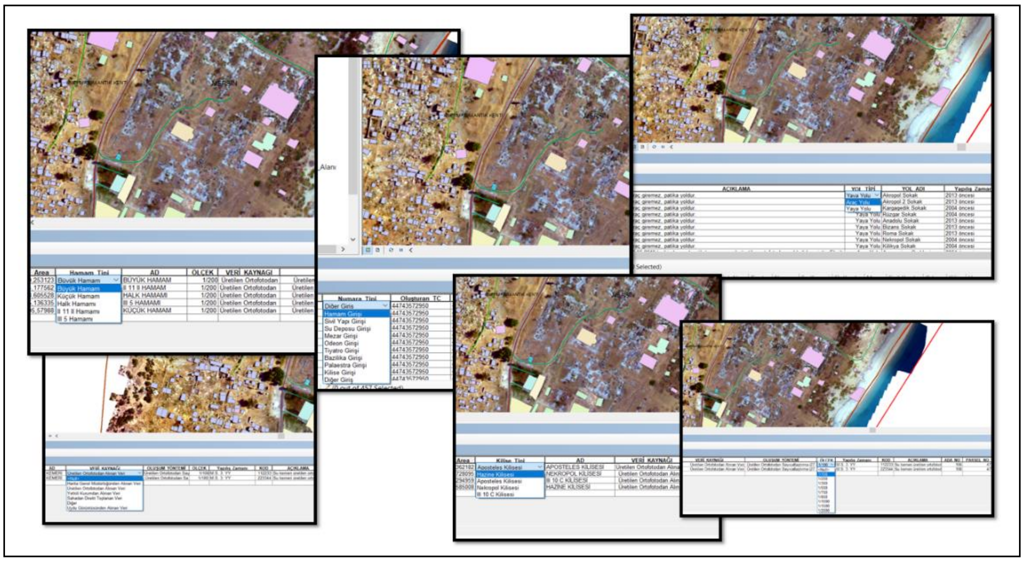

**Figure 8.** Examples of The Areas With a Subset

**Table 3.** Areas Including Subsets

| Code | Data Source | Method | Scale | Church Type | Number Type | Bath Type | Area Type | Road Type |
|---|---|---|---|---|---|---|---|---|
| 1 | Data Received from General Directorate of Mapping | Digitizing from Orthophoto | 1/100 | Treasure Church | Bath Entrance | Great Bath | Area to Stay | Vehicle Road |
| 2 | Data Taken from Satellite Image | Digitizing from Google Satellite Image | 1/200 | Aposteles Church | Church Entrance | Small Bath | Cafe / Restaurant | Sidewalk |
| 3 | Data Taken from the Produced Orthophoto | Digitizing from Bing Satellite Image | 1/300 | Necropolis Church | Civil Structure Entrance | Public Bath | Car park | |
| 4 | Data Received from Authorized Authority | Digitization from Orthophoto Produced (27.06.2019) | 1/500 | Church III 10 C | Theater Entrance | II 11 II Bath | Fountain | |
| 5 | Data Collected Directly from the Field | Production with GPS Technique | 1/700 | | Water Tank Entrance | III 5 Baths | Garden | |
| 6 | Other | Free Production | 1/800 | | Grave Entrance | | Other | |
| 7 | | Other | 1/1000 | | Odeon Entrance | | | |
| 8 | | | 1/1500 | | Basilica Entrance | | | |
| 9 | | | 1/2000 | | Palaestra Entrance | | | |
| 10 | | | | | Other | | | |

All details such as country, province, district, ancient city, Acropolis Area, Necropolis Area, Turkish Bath, Church, Odeon, Basilica, Theater, water channels, and water reservoir were produced as shown in Figure 9 and Figure 10.

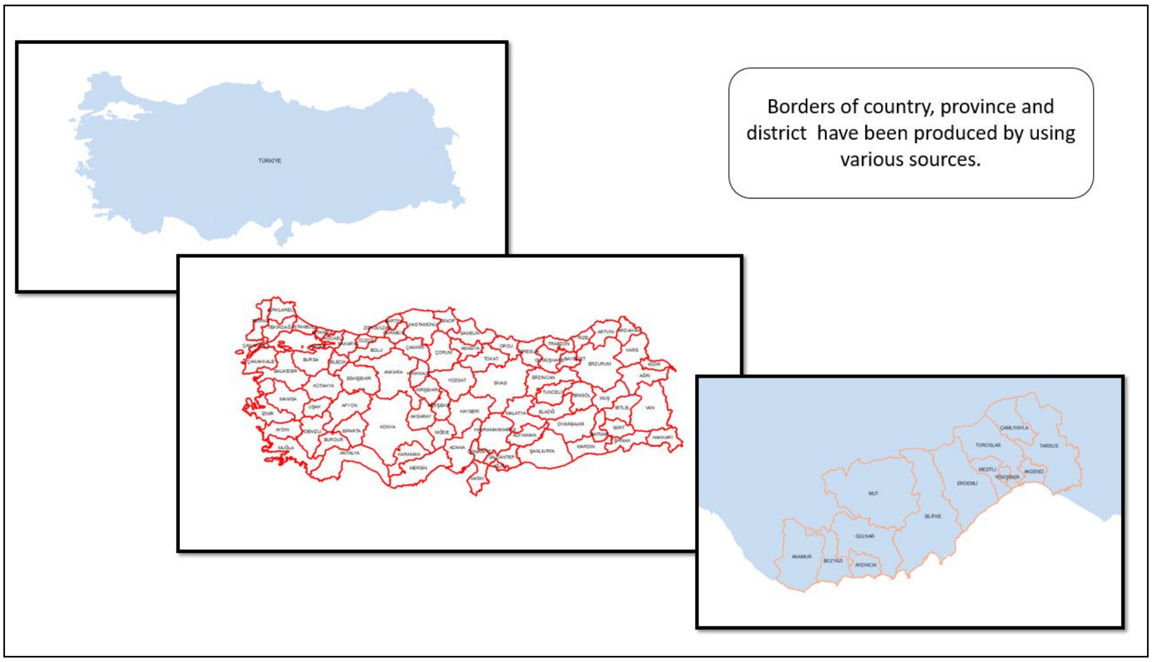


**Figure 9.** Creation Of Country, Province, And District Boundaries

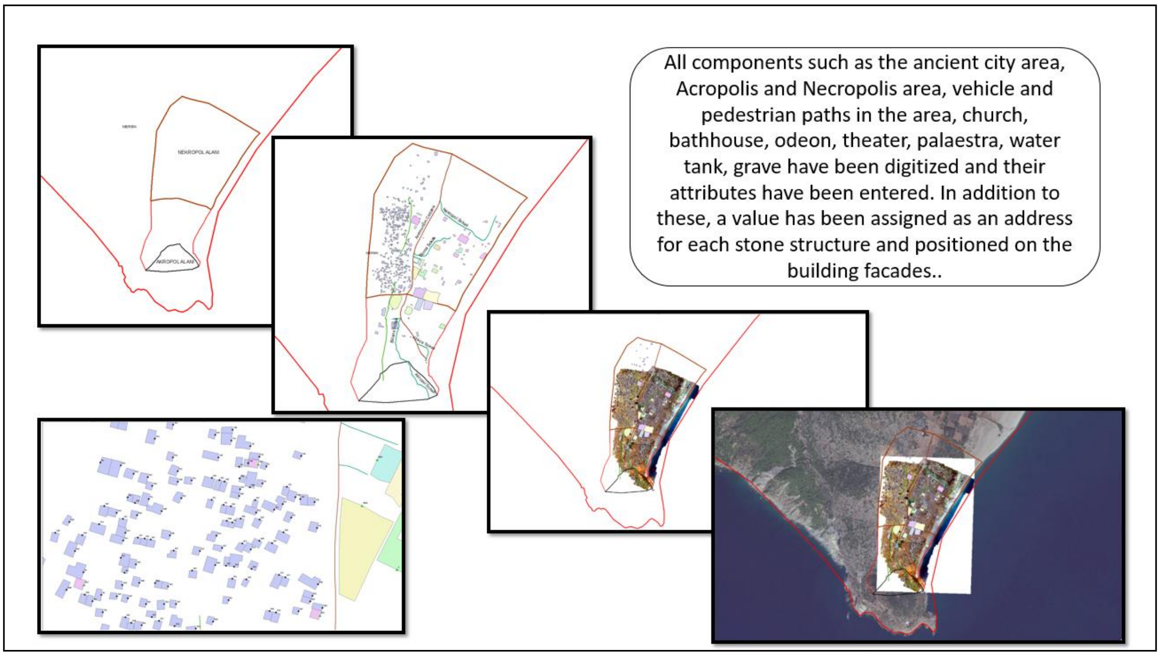


**Figure 10.** Digitization of All Data in The Ancient City Area

## 3. Result and Discussion

As a result of the application and literature search, it has been understood that UAV platforms are now a source for the studies such as inspection, surveillance, mapping, recording, and 3D modeling and can also be used in archaeological sites. It has been understood that the recording of cultural heritage in archaeological sites and turning the recorded heritage into a sustainable system will be beneficial for many situations such as preserving the history that sheds light on the future, transferring it to the future, contributing to tourism, and creating a basis for other archaeological studies.

In Anemurium Ancient City, all cultural heritage and non-cultural heritage stone buildings in the ancient city were digitized, and data sets were created for this purpose. The subsets determined according to the needs, fitted values on an address basis were assigned for each layer produced, and the system was ensured to be utilizable. Within the scope of the study, 1 country, 81 provinces, 13 districts of Mersin province, 1 ancient city area, 1 Necropolis Area, 1 Acropolis Area, 10 roads, 383 tombs, 38 residual remains, 14 stored stone buildings, 5 Turkish baths and 5 additional buildings, 4 churches, 3 civil buildings, 2 aqueducts, 1 theater, basilica, odeon, water tank, and palaestra area, and 457 numbers on an address basis were created (Table 4). The values on an address basis for each data set were named with a certain harmony within themselves, and the system was ensured to be organized and easily detectable.

**Table 4.** All Layers Created For The Ancient City Area, Their Numbers And Production Methods

| Layers | Number | Description |
|---|---|---|
| Country | 1 | The country border has been produced by using the country border, which can be downloaded from General Directorate of Map (GDM), and the ArcGIS training set applications. |
| Province | 81 | 81 provincial borders were produced by using the provincial border, which can be downloaded from GDM, and the ArcGIS training set applications. |
| District | 13 | By using the district border that can be downloaded from GDM and ArcGIS training set applications, 13 district borders of Mersin were produced. |
| Ancient City Area | 1 | Anemurium Ancient City Area (current border) was created by using the produced orthomosaic data and Bing image. |
| Necropol Area | 1 | Necropol Area was created by using the produced orthomosaic data and Bing image. |
| Acropol Field | 1 | Acropol Area was created by using the produced orthomosaic data and Bing image. |
| Road | 10 | Road data (pedestrian / vehicle) was produced by using the produced orthomosaic data. |
| Tomb | 383 | By using the orthomosaic data produced, the grave data in the Necropolis area were produced. |
| No Longer | 38 | By using the orthomosaic data produced, the residual residue (stone structures that are the remains of other structures and have no connection with the residue) data were produced. |
| Stored Stone Structure | 14 | Using the produced orthomosaic data, the Stored Stone Structure (small areas where the stones from the renewal and cleaning process are collected) data were produced. |
| Bath | 5 | Using the produced orthomosaic data, the data of the baths in the area were produced. |
| Additional Structure | 5 | Using the orthomosaic data produced, the data of the Additional Structures (buildings built later in the Ancient City area and without historical value) were produced. |
| The Church | 4 | By using the orthomosaic data produced, 4 types of church data in the area were produced. |
| Civil Structure | 3 | Using the orthomosaic data produced, the Civil Structure data in the area were created. |
| Aqueduct | 2 | By using the orthomosaic data produced, Aqueduct data were created in the form of 2 different pieces in the area. |
| Theater | 1 | Using the orthomosaic data produced, Theater data in the area was created. |
| Odeon | 1 | By using the orthomosaic data produced, Odeon data in the field was created. |
| Basilica | 1 | Using the orthomosaic data produced, the Basilica data in the area was created. |
| Water Tank | 1 | Using the orthomosaic data produced, the Water Tank data in the area was created. |
| Palaestra Area | 1 | Palaestra Area data in the area was created by using the produced orthomosaic data. |
| Number | 457 | As an address for all stone structures created, each layer has a different design and a number was created on the facade of the building. |

In this study, both fast and low-cost orthophoto production was provided with the help of UAV in the ancient city area, and a relational database was created for GIS by using the produced image and digitizing it. Thus, it was ensured that the ancient city area was recorded, conserved, planned, and made suitable for tourism, its address was defined, and it provided a basis for many studies. When the data obtained as a result of the study in which a database for GIS was created using UAV in the archaeological site were examined by considering parameters such as speed, time, cost, sustainability and accuracy, it was found that they would provide significant advantages to documentation, recording, conservation, tourism, tracking, and detection studies in archaeological sites. It was revealed that it was highly important to use GIS in order to ensure the correct transfer of cultural heritage from the past to the next generations by working in harmony with technology and without deterioration and the geographic/verbal information, and to benefit from UAVs by considering the contactless, low cost, accuracy, and speed criteria in the creation of the system. Considering that the study conducted in Anemurium Ancient City provides many advantages as mentioned above, it was considered that its application in ancient city areas in our country and the world would be a useful study for Anatolian and world archeology.

As a result of the study, it was concluded that UAVs were usable tools for uncovering stone buildings due to their accurate coordinate information and were suitable platforms for producing the necessary basic data in the documentation of material cultural assets. In this inventory and database design study conducted in the archaeological site with UAV, an orthomosaic image of less than 10 cm of the X, Y, Z positioning accuracy was obtained by flying from a height of 60 m, and a digital basis was created for many studies, and it was considered that it would be beneficial to conduct similar mapping studies in all archaeological sites in the future and that different data production methods could be used in case of detailed analysis for each stone building separately.
It would be correct to list the gains obtained by creating a database for GIS with UAV in archaeological sites as follows.

- It was found that fast, contactless, and sensitive data can be produced with UAV.
- The inventory study of all material cultural assets was conducted.
- It was ensured that the most important parameters for archaeological sites were recorded, conserved, and monitored.
- The production and archiving of all components of the area were ensured.
- A database was created in which the analysis needed on the area could be performed.
- Digital data were produced as a basis for management and planning that would be used primarily for contribution to tourism and in many areas.
- The easy availability and monitoring of stone buildings were achieved by performing addressing designed in specific standards for each class.
- The data and database suitable for studies to be carried out to prevent historical artifacts smuggling were created.

## 4. Conclusion

In conclusion, after the field and office work, the orthomosaic image of Anemurium Ancient City with less than 10 cm of the X, Y, Z positioning accuracy was obtained by flying from a height of 60 m, DEM, 3D images were produced with the help of UAV, and a relational database was created using these data as a basis in determining the data sets created for geographic information systems and in digitizing processes. Detectability and traceability were made possible by assigning unique values on an address basis to this database. The use of bases produced contactless, low-cost and rapidly with UAV, and recording all cultural heritage in the area and determining the boundaries by creating a relational database were considered important steps for Anatolian and world archeology.

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## Conflict of Interest

No conflict of interest was declared by the authors.

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