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Determination of pond volume with using an unmanned aerial vehicle

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ABSTRACT

Water management will become a very important topic in the near future. Water scarcity has been seen in most of the world due to drought because of global warming. Water storage is paramount under water scarce situations. Mersin, characterized by the Mediterranean climate, has been negatively affected by climate change. Water retaining structures are needed to build to carry on agricultural activities all year round in the city. Advances in unmanned aerial vehicle (UAV) technologies have made it easier to model engineering projects. In this study, we modelled a site on which a pond will be built in the near future using a UAV. We created the Digital Surface Model (DSM) and orthophoto of the study area to measure the pond's volume and 3D surface area. The pond will become an economic component of the region.

1. INTRODUCTION

Unmanned aerial vehicle (UAV) can be used to model the terrain in very high resolution and accuracy with the help of Global Navigation Satellite System (GNSS). UAV has been frequently used in engineering projects since last decade. Rockfall simulation (Sarro et al. 2018), flood site modelling (Annis et al. 2020), landslide monitoring (Eker et al. 2017), damage caused by earthquake (Dominici et al. 2017), cultural heritage modelling (Şasi and Yakar 2018; Ulvi et. al 2020) are some of the studies that can be performed by using UAV.

Drought, which is a nature produced temporary imbalance of water availability (Pereira et al. 2002) is a serious threat to Turkey. Land surface temperature, which is very important to model the climate change and weather forecast (Orhan et al. 2019), increases each year in Konya, Turkey (Orhan and Yakar, 2016). Precipitation regime has been continuously changing due to global warming. This situation increases the necessity to build water retention structures. Ponds, which are generally used in agricultural activities, can store the dead loss surface water. The increased risk of drought increases the need for ponds. Management of water resources will become the main topic in near future.

We need a Drought Management Plan to increase the efficiency of irrigation system performance. Storage of water is one of the main items in this plan. Ponds are productive investments on agricultural activities.

In Turkey, studies about ponds have increased recently. Demirkıran et al. 2018 have measured dead volume of a pond with bathymetric methods. Keskiner et al. 2020 have created surface runoff models and determined pond volume by using geostatistical models. Akyıldız et al. 2020 have analyzed the use of waste materials of marble quarry as a filling material in a pond construction.

Water scarcity is a significant problem in most Eastern and Southern Mediterranean countries due to economic growth and inefficient usage in agricultural activities (Harmancıoğlu et al. 2008). The clean fresh water scarcity has to be considered with the physical shortage of water (Jia et al. 2020). Global climate change has negatively affected Turkey. Orhan et al. 2017 has investigated the water surface area in Salt Lake by using satellite images, and concluded that meteorological events caused the decrease in the lake area.

To improve water usage efficiency, water retaining structure needs to be constructed. In the design of a water structure, volume and 3D area have to be calculated. Any object that has irregular geometric shape needs to be gridded.

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To model a pond site completely, meteorological, morphological and geological factors of the terrain have to be considered. In addition to these, water balance components, anthropogenic activities, industrial demand and excessive usage is necessary (Swain et al. 2020).

Mersin has fertile farmland. With the increasing in industrial demand, agricultural activities will be an important component of the economic development of the region. Kerimler pond, which will be used for agricultural purposes, will be constructed in near future. In this study, we measured 3D area and volume of the pond site to determine the amount of membrane to be used to prevent leakage.

2. STUDY AREA

Agriculture and tourism are the main income in the region, characterized by Mediterranean climate. There are 55 large and small rivers (Bilici and Everest, 2017) in Mersin, all of which take their source from the Taurus Mountains. Study area is located in Kerimler Village, Mersin (Figure 1). Bahçepınarı groundwater source is located in Kerimler (MÇŞİM, 2018). Mersin, which has very fruitful farmland, has high precipitation rate in summer. Kerimler village got 972.26 mm average yearly rainfall in last 5 years (Figure 2). In 2019, average amount of rainfall is 98.89 mm monthly (Figure 3).

Fujihara et al. 2008 have modelled water usage in Seyhan River Basin, very close to Kerimler village. They concluded that impacts of climate change may decrease available water resources in the basin.

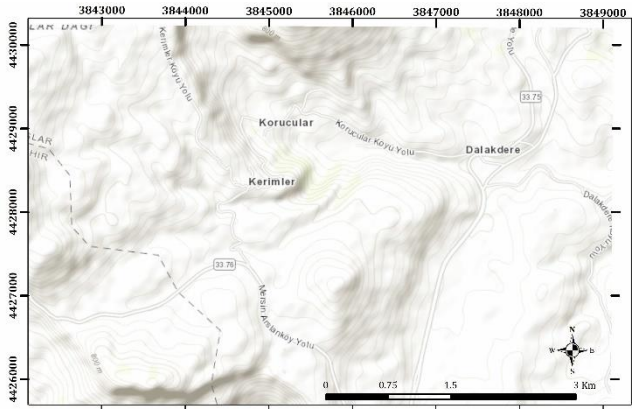

Figure 1. Location map of the study area

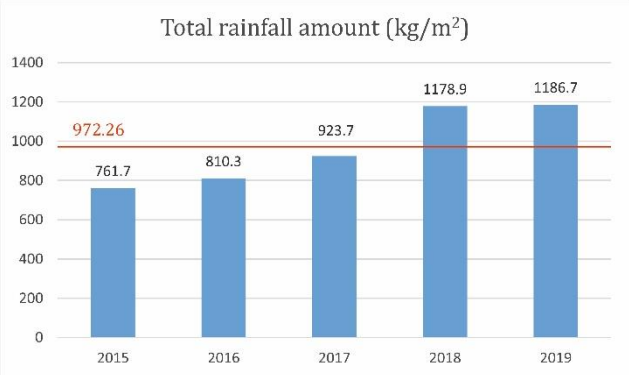

Figure 2. Total amount of rainfall in last 5 years

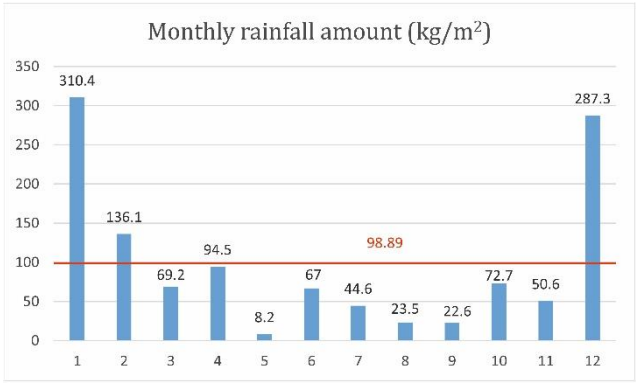

Figure 3. Monthly rainfall amount in 2019

The study area is located in between right-lateral (dextral) Kırkkavak fault and left-lateral (sinistral) Ecemiş Fault. Geyik Dağı, Aladağ, Bolkar Dağı, Bozkır, Antalya and Alanya units are the major tectono-stratigraphic units giving the complex nappe structure in Central Taurides (Özgül, 1983). Lower-Middle Miocene aged Karaisalı formation consists of limestone, is seen in Kerimler village (Figure 3).

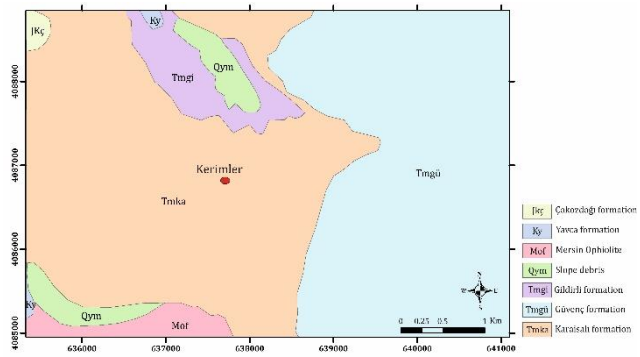

Figure 4. Geological map of the study area (Simplified from MTA, 2009)

3. METHOD

Photogrammetric methods allow users to create 3D model of the objects with higher accuracy (Ulvi and Yiğit 2019). Modeling the terrain in 3D with using a UAV has solved many engineering problems. Ulvi 2018 has measured the volume terrain by using a UAV. Kaya et al. 2019 have measured the volume of pond.

In this study, we used Anafi Parrot (Figure 5) to take pictures of the study area. Flight plan (Table 1) was prepared in Pix4Dcapture mobile application. In the study area, seven Ground control points (GCP) were determined homogenously to georeference the area (Figure 6).

Structure from motion (SfM) is the most preferred technique to create 3D model of the object from 2D pictures, which were taken with high overlap ratio.

There are many commercial software, which can model the terrain using pictures taken with UAV. Agisoft Metashape, which is user-friendly software, was used in this study.

Table 1. Flight plan

Property	Value
Flight height	47 m
GSD	1.57 cm/px
Overlay ratio	80%
Angle	90°
Flight time	6 min 52s

Figure 5. Anafi Parrot

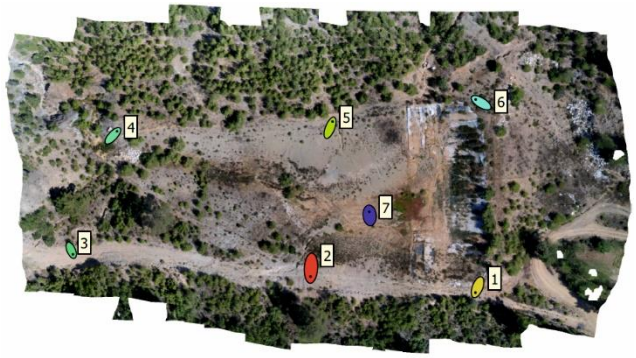

Figure 6. Ground control points

4. RESULTS

Modelling the project was performed in Agisoft Metashape software. The steps were implemented as described by Alptekin and Yakar 2020. The results of modelling is shown in Table 2. Digital Surface Map (DSM) (Figure 7) and orthophoto (Figure 8) of the study area were created. Resolution of DSM will be improved with using a UAV that has high resolution.

We import DSM and orthophoto to Virtual surveyor software to draw boundary of pond (Fig 8), point grid and create Triangulated Irregular Network (TIN). We modified TIN until we have satisfied. We import TIN to Netcad software to determine the volume of the pond site. The results are shown in Table 3.

Table 2. Modelling results

Property	Value
Number of images	92
Flying altitude (m)	54.4
Ground resolution (cm/pix)	1.63
Coverage area (km^2)	0.0298
Resolution of camera	4608*3456
Number of GCP	7
Error amount of GCP (cm)	4.92
Resolution DSM (cm/pix)	6.51
Alignment accuracy	Medium
Filtering mode	Aggressive

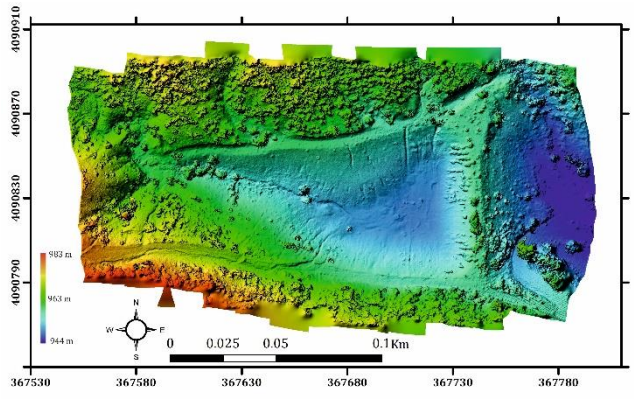

Figure 6. DSM

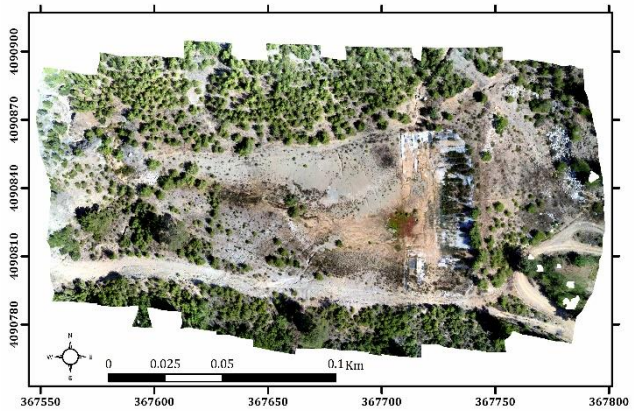

Figure 7. Orthophoto

Figure 8. Boundary of pond

Table 3. Results of the study

Item	Value
3D surface area (m^2)	11404.84
2D surface area (m^2)	9704.39
Volume of pond site (m^3)	31369.34

5. DISCUSSION

Water drought plan has to be prepared as the rainfall regime has been changing. Detailed basin river maps should be prepared for efficiently use the water. To prevent the surface water loss, hydraulic structures should be constructed.

In addition to photogrammetric studies, remote sensing and geotechnical analyses should be carried to design a pond. Permeability and porosity of the soils in the study area should be measured in the laboratory to combine hydrodynamics of the region with the terrain. Groundwater flow pattern has to be determined for using the pond effectively.

In UAV photogrammetry, when the flight height increases, the resolution of each photo decreases. In this study area, there were trees with high elevation near the pond site. UAV may hit to the trees. Therefore, we increased the flight height in flight plan and it caused the decrease in resolution. Manually taken photos with less flight height may give better output.

The coordinates of the GCPs were taken by a GPS. The internet connection in the study area was very weak. Therefore, we took the coordinates with only one epoch. When we have the opportunity to increase epoch number, we will get more precise coordinates. In that case, the error amount of GCP will decrease.

6. CONCLUSION

In this study, volume and 3D surface area of a site that will be used as a pond were calculated using a low-cost UAV. The present study, based on photogrammetric methods, shows that an engineering project can be modelled in a practical way by using a UAV. Geology of the region is very complex. Detailed geological maps should be prepared in order to understand hydrogeological properties of the city. In a master plan, the information of each water retaining structure should be known.

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