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Utilizing UAVs for rapid spatial data acquisition in disaster management: A case study of Islahiye

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Abstract

This study investigates the application of unmanned aerial vehicles (UAVs) for swift spatial data acquisition in disaster management. Specifically, the focus is on monitoring a landslide and the resulting lake formation in the Islahiye district of Gaziantep, Turkey, subsequent to the Kahramanmaraş earthquakes. Using UAVs, orthophotos and elevation models were generated, enabling accurate visual representations of the affected area. Through data analysis, the landslide volume was estimated at approximately 549,183.8 cubic meters, with the water area of the formed lake measuring approximately 26,731.6 square meters. The findings underscore the value of UAVs as efficient and cost-effective tools for acquiring real-time and precise spatial data in different disaster management stages. UAVs prove advantageous for pre-disaster monitoring, prediction, early warning systems, as well as post-disaster search and rescue operations and recovery endeavors. This study contributes to the existing knowledge on UAVs in disaster management, demonstrating their crucial role in assessing the impact of natural disasters and guiding subsequent response and recovery actions. The calculated values of landslide volume and water area provide essential quantitative information for understanding the magnitude of the event and facilitating appropriate measures. Moreover the study demonstrates the valuable role of UAVs in disaster management by providing real-time and precise spatial data. UAVs prove advantageous for monitoring, early warning systems, search and rescue operations, and recovery endeavors. The findings contribute to our understanding of the impact of natural disasters and aid in guiding appropriate response and recovery actions.

1. Introduction

In today's world, any kind of natural, technological, and human-induced events that we cannot cope with using local resources are referred to as disasters. According to the definition accepted by the United Nations, a disaster is defined as "any natural, technological, or human-induced event that causes physical, economic, and social losses for people, disrupts or interrupts normal life, affects societies, and cannot be managed with local resources" (Kadıoğlu 2008). Our country, particularly Turkey, is constantly exposed to natural disasters such as earthquakes, landslides, and floods, which cause the most loss of life and property (Alptekin and Yakar 2020a; Kusak et al. 2021). Natural disaster causes damage to the surrounding lands, settlements and living creatures by not fitting the amount of water in the riverbed for various reasons (Demir 2021).

The most critical issue during a disaster is the rescue of people alive. Therefore, the first 72 hours after a disaster is a highly critical period that requires rapid and efficient search and rescue operations. In recent years, there has been an increasing demand for low-cost, small unmanned aerial vehicles (UAVs) for various purposes and applications (Alptekin and Yakar 2020b). UAVs are defined as "motorized aerial vehicles that can be remotely controlled autonomously or semi-autonomously without a human pilot, depending on the mission, capable of carrying different payloads and performing specialized tasks within a specific time interval, either in the atmosphere or outside of it, and are reusable" (Blyenburgh 1999; Erdelj 2017; Yakar and Dogan 2017). The first attempts for photogrammetric

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purposes with UAVs were made in 1979 (Eisenbeiss 2009) Nowadays, unmanned aerial vehicles are widely and effectively used in various fields, ranging from defense to entertainment. They are preferred as data acquisition platforms in documenting cultural heritage, archaeological studies, 3D modeling, and many other areas, especially in small areas (Uysal et al. 2017).

Unmanned aerial vehicles are used in different stages of disaster management. Generally, UAVs are used in the following areas in disaster management (Uysal et al. 2013).

- The usage of UAVs in monitoring, prediction, and early warning. UAVs are used for analyzing information for environmental monitoring and prediction, as well as for early warning purposes.
- Integration and sharing of disaster information. UAVs support other applications by bridging different information technologies or consolidating available information from various sources.
- Usage for situational awareness, logistics, and evacuation support. UAVs can assist in collecting information during a disaster, especially about affected individuals and the movements of rescue teams.
- Supporting communication systems. UAVs can help rebuild communication infrastructure that has been destroyed or damaged during a disaster.
- Search and rescue operations. UAVs can be utilized in the search and rescue of missing, injured, and trapped individuals.
- Damage assessment. UAVs can assist in assessing damage using video and imagery.

UAVs can be used for various purposes in disaster management. They offer significant opportunities for rapid and effective utilization in search and rescue operations. However, the proper and up-to-date base maps are required for conducting pre and post-disaster activities. While satellite imagery provides current data, obtaining timely and high-accuracy data is not always possible. UAVs provide valuable contributions to rapid and up-to-date data collection (Yiğit and Uysal 2019). It is necessary to determine the accuracy of the products obtained from these low-cost systems. The aim of this study is to monitor the landslide and the resulting ponding after the earthquake that occurred on February 6, 2023 in Turkey, and to produce a 3D model of the region.

As it is known, earthquakes occurred in Turkey on February 6, 2023, centered in Kahramanmaraş. Many destructions and landslides occurred with the earthquake. One of these landslides occurred in the Islahiye district of Gaziantep. Roads were closed due to landslides and a pond was formed in the area. In this study, the latest situation in the landslide region and the ponding that occurred in the region were monitored by UAV.

2. Method

This section delves into three key aspects of the study: UAV deployment, data collection methods, and UAV photogrammetry techniques, all focused on the specific study area of the landslide and lake formation in the Islahiye district of Gaziantep, Turkey.

Since the study area is mountainous and carries a risk of landslides, it was really difficult to reach the area. Since the landslide is towards a valley, water accumulation has also occurred in the region (Figure 1). For this reason, the relevant area carries more risks.

Figure 1. A general view of landslide area

The DJI Mavic 2 Pro is a successful system with features such as an effective range of 8 km, a maximum flight time of 31 minutes, 4K recording with a Hasselblad camera, a 1" CMOS sensor, GPS sensor, 4-way obstacle sensing, automatic return to home, and a weight of approximately 1 kg. The UAV used in the study is depicted in Figure 2.

Figure 2. DJI Mavic 2 Pro UAV

A photogrammetric flight plan covering 0.349 km^2 area was made and a total of 180 aerial photographs were taken with 80% overlap. After obtaining the aerial photographs, it is necessary to process them photogrammetrically and to obtain photogrammetric products that will meet the needs. At this point, unlike classical photogrammetry, the motion-based detection (Structure from Motion -SfM) approach is widely used in UAV photogrammetry. SfM operates under the same basic conditions as photogrammetry. It uses overlapping images to obtain the 3D structure of the object of interest. SfM allows to produce many products such as matching photos, generating sparse and dense point cloud, three-dimensional model, digital elevation model and orthophoto. Image processing steps can take serious time. For this reason, it is highly recommended to use high-performance computers for full software performance. Many commercial software such as Agisoft are widely used in studies using SfM.

3. Results

Aerial photographs taken within the scope of the study were processed with the SfM approach. The first product obtained in this context is the sparse point cloud. Photographs connected by 326 298 points in total were stabilized to produce a dense point cloud. Dense point cloud with 157 965 014 point gives us all the details we took in the photo in three dimensions (Figure 3).

Figure 3. UAV based photogrammetric dense point cloud

Using the 3D information we obtained, we produced the digital elevation model of the region and the high resolution orthophoto behind it (Figure 4).

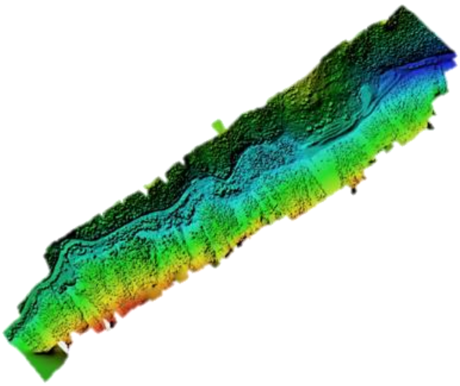

Figure 4. UAV based digital elevation model and the high resolution orthophoto of the region

4. Discussion

Some analyzes related to the study area were made. First, a sample profile of the soil pile was obtained (Figure 5). According to the profile study obtained, the height difference within a distance of 300 meters reaches 40 meters.

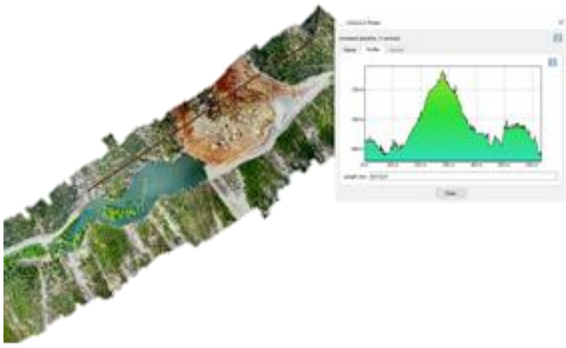

Figure 5. Investigation profile of landslide

Calculation of the approximate volume of the soil pile the spread area of the landslide was determined manually and the approximate volume was calculated using the best fit plane (Figure 6). Accordingly, the volume of 549183.8 cubic meters of soil was calculated in an area of 928 612 square meters.

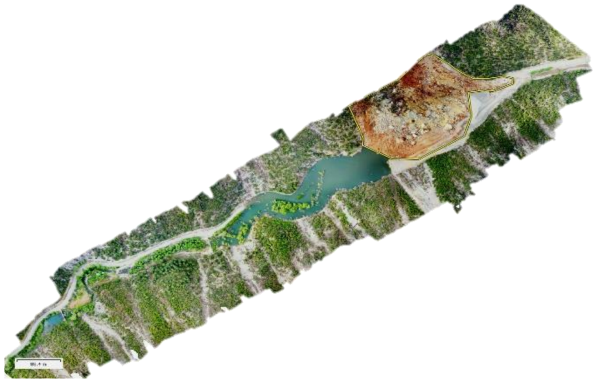

Figure 6. Calculation of the approximate volume and the spread area of the landslide

The pond area formed in the area closed as a result of the landslide was also observed with the obtained orthophoto (Figure 7). According to the calculation made, the water area is 26731.6 square meters.

Figure 7. Calculation of the approximate area of formed pond

5. Conclusion

Orthophoto, which form the basis of many engineering projects, are essential for effective and successful disaster management. In disaster management, there is a need for fast and accurate spatial data. The use of UAVs as data acquisition platforms for obtaining real-time, accurate, and reliable data is increasing in disaster management. Unmanned aerial vehicles provide significant convenience in the production of necessary spatial data in different stages of disaster management. They enable the rapid and accurate acquisition of spatial data required for monitoring work processes, prediction, and early warning during the pre-disaster stage, as well as for risk and damage reduction and preparedness. The use of UAVs in the post-disaster phase facilitates fast and efficient search and rescue operations and recovery efforts. In this study, an orthophoto and elevation model of the landslide and lake formation area that occurred after the Kahramanmaraş earthquakes was produced by using UAV, and the approximate volume (549183.8 m3) and area (928 612 m2) calculations of the landslide and the pond area (26731.6 m2) were made.

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