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Monitoring gully erosion from UAV data

Yunus Kaya*1, Nizar Polat1

1Harran University, Faculty of Engineering, Department of Geomatics Engineering, Şanlıurfa, Türkiye

Keywords
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Abstract

Gully erosion is recognized as an important process of land degradation. Continuous monitoring of gully erosion is important to determine the damage caused to the land. Terrestrial imaging systems such as handheld cameras are inadequate for monitoring gully erosion damage. Aerial surveys by Unmanned Aerial Vehicles (UAVs) play an important role in monitoring gully erosion. The aim of this paper is to monitor gully erosion with digital photogrammetry technique using UAV data. In this study, Digital Elevation Model (DEM) and orthophoto were produced with UAV data and the directions of gully erosion were determined. This study is also a preliminary study to determine the multi-temporal change of gully erosion.

1. Introduction

Erosion is an important phenomenon that accounts for 9% of disasters in the world (Galli et al., 2008). Erosion is defined as the movement of soil by wind, rain, floods, etc. and is most common in hilly and mountainous areas (Cruden and Varnes, 1996; Roy and Saha, 2019). Gullies are a typical form of erosion in semi-arid and arid landscapes where high morphological activity and dynamics can be observed (Marzolff and Poesen, 2009). Semi-arid and arid climatic conditions increase the risk of soil erosion through low rainfall regimes, low vegetation cover and recurrent heavy rainfall. Low rainfall and irregular rainfall frequency and distribution, deforestation and low biomass lead to very high amounts of runoff. In addition, the transition from traditional agriculture to a more irregular land use accelerates soil runoff, increasing the risk of erosion. In these areas, gullies are the source and carrier of sediment connecting slopes and channels. Poesen et al. (2002) reported that in semi-arid and arid regions gullies contribute between 50% and 80% to sediment production.

A detailed knowledge of landform and topography allows for various geomorphometric characterizations, calculation of different indices, and understanding of the processes that shape the earth's surface (Tarolli et al., 2019). Various new technologies used in geomorphology have developed a new perspective for field research and visualization of findings. Digital photogrammetry and Structure from Motion (SfM), accurate and cost-effective Digital Elevation Model (DEM) production (Uysal et al., 2015), and high-resolution orthophoto generation (Akca and Polat, 2022) have enabled real-scale and photorealistic visualization of terrains and geomorphological structure in a digital environment (Piegay et al., 2015; Viles, 2016; Polat, 2023). DEMs and orthophotos derived from UAV imagery are used in various earth observation surveys due to their sub-meter resolution and relatively high accuracy in representing the terrain structure (Vanmaercke et al., 2016; Passalacqua et al., 2015). High-resolution DEMs and orthophotos are also frequently used to study gully erosion processes (Nagasaka et al., 2005; Niculiță et al., 2020; Wang et al., 2022). Gong et al. (2019) used SfM technology with UAV data to study gully erosion in an open-cast coal mine dumpsite. In the study, they produced high-resolution orthophotos and DEMs and determined the slopes in the gully erosion zones. Kou et al. (2019) examined the erosion of typical gully heads with UAV data to determine rill erosion. They determined the slopes of upland slope, hill slope and vegetation slope using Digital Surface Model (DSM).

In this study, gully erosion in a region northeast of Şanlıurfa city center was monitored with UAV data. The study provides preliminary information for future multi-temporal gully erosion analysis.

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* **Corresponding Author**

*(yunuskaya@harran.edu.tr) ORCID ID 0000-0003-2319-4998
(nizarpolat@harran.edu.tr) ORCID ID 0000-0002-6061-7796

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2. Methods

UAV technology has been used frequently in landslide (Kuşak et al. 2021), rockfall (Yakar et al. 2023) and cultural heritage studies (Şasi and Yakar, 2017; Alptekin and Yakar, 2021; Karataş et al. 2022; Kanun et al. 2022) in the last decade.

In the region selected as the study area, a flight was performed from a height of 110 m with a DJI Mavic 2 Pro UAV. The flights were performed in automatic grid mode and a total of 251 photographs were taken for the entire study area. In addition, Ground Control Points (GCPs) homogeneously located in the study area were established to produce high resolution orthophotos and DEMs. The photographs obtained from UAV flights and GCP coordinates were evaluated using Agisoft Photoscan software. One of the most important steps of the photogrammetry method is the determination of camera calibrations. In this study, the photographs were calibrated with the self-calibration method using the parameters in the Agisoft software. In order to process the images at a scale of 1:1, the align photos step was performed at high quality. Afterwards, the model was georeferenced by matching the points collected from the field with the points appearing in the software. Since the quality of the DEM is affected by the dense point cloud produced, the dense point cloud was produced with high accuracy. Then the orthomosaics and DEMs of the terrain were exported in high quality. The obtained orthophotos and DEMs were combined in Virtual Surveyor software and flow directions were determined.

3. Results

In this study, point cloud and dense point cloud were produced by evaluating 251 photographs obtained with UAV and 6 GCPs together. The parameters of the DEM and orthophoto produced in the study are given in Table 1, orthophoto in Figure 1 and DEM in Figure 2.

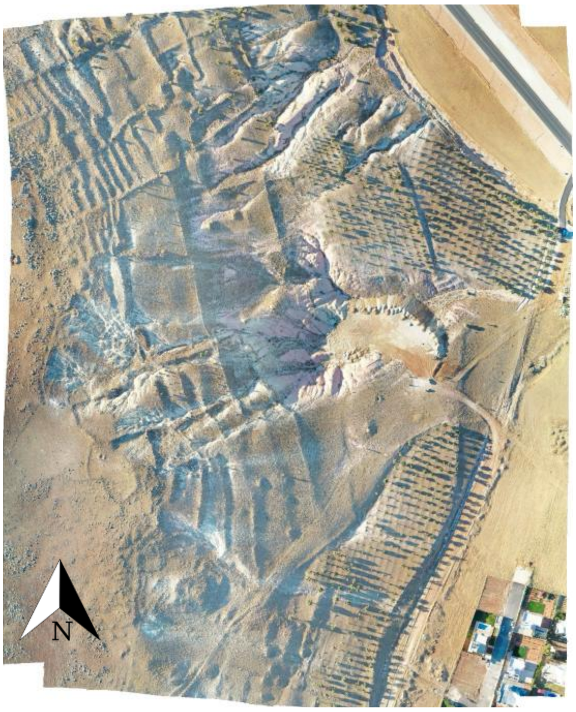

Figure 1. Orthophoto

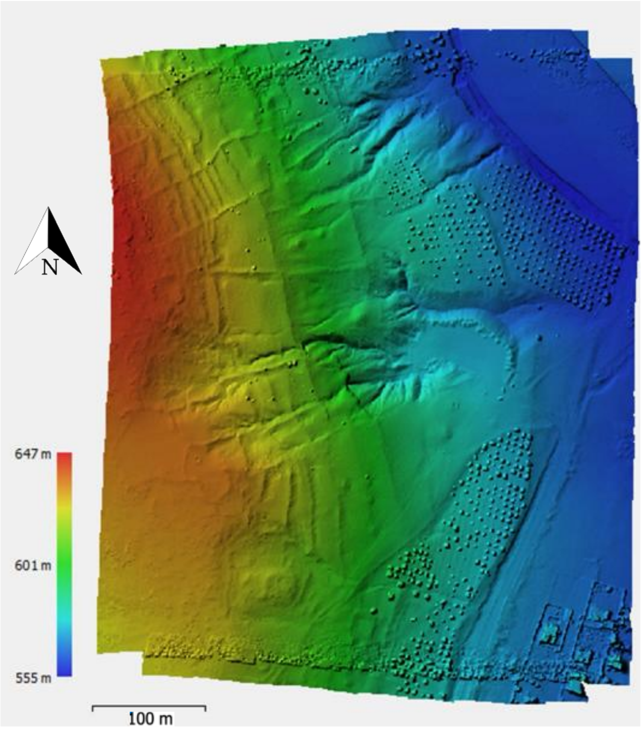

Figure 2. Digital Elevation Model

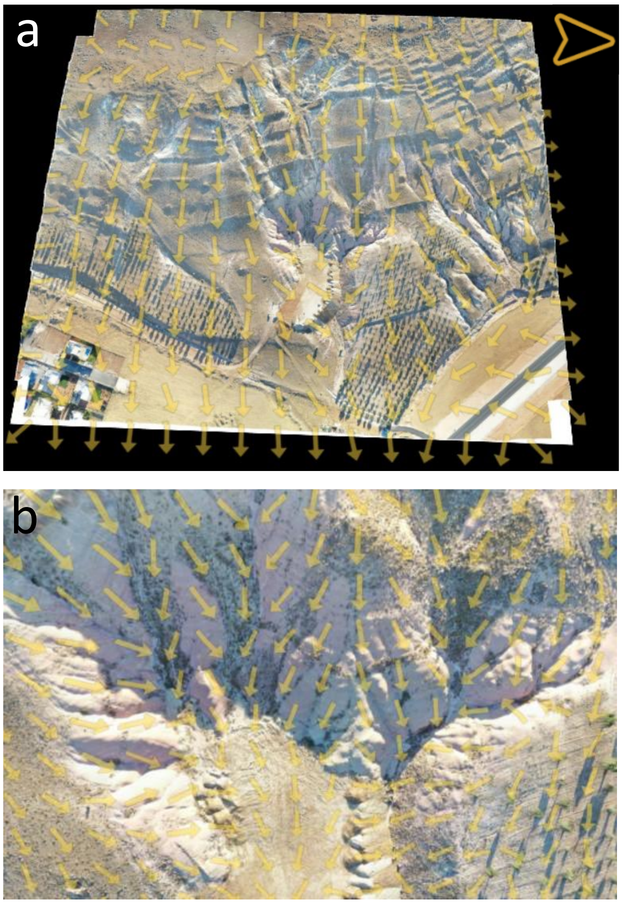

Figure 3. Flow directions, a) General view, b) gully erosion area

Flow directions were determined in Virtual Surveyor software using high resolution orthophoto and DEM (Figure 3).

When Figure 3b is examined, more gully erosion is observed where the flow lines show common orientation. The flow lines have a greater slope in windy areas.

Table 1. Flight and model parameters

Parameter	Value
Flight Area	0.288 km^2
Overlap	80
Camera Angle	90°
Average Altitude	112
Number of Photos Taken	251
Number of Photos Used	251
Planned GSD (cm/pixel)	2.46 cm/pix
DEM Resolution (cm/pixel)	4.91
Point density (points/m^2)	414
Point Cloud Number	4 972 675
Dense Point Cloud Number	135 284 980

4. Conclusion

In this study, monitoring of the erosion zone in the gully erosion region was carried out with UAV photogrammetry. In the study, high resolution DEM and orthophotos were produced from UAV data evaluated together with GCPs. The produced orthophotos and DEMs were visualized in Virtual Surveyor software and flow directions were determined. Since the region is a windy and rainy region, gully erosion is intensely observed in the region. This study includes the first stage of multi-temporal gully erosion analysis. In future studies, the amount of erosion will be determined with measurements made in different seasons and different years and the causes of erosion will be investigated. This study emphasizes the importance of using UAV data in gully erosion areas.

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