The use of low-cost RPAS application for erosion bank monitoring

K. A. Santos[1]*, T. P. Carvalho[2], T. A. Mendes[3] & K. T. M. Formiga[1,2]

[1]*Postgraduate Program in Environmental Science. Universidade Federal de Goiás (UFG), Goiânia, Goiás, Brazil*

[2]*School of Civil and Environmental Engineering, Universidade Federal de Goiás (UFG), Goiânia, Goiás, Brazil*

[3]*School of Engineering, Instituto Federal de Educação, Ciência e Tecnologia de Goiás (IFG) and Pontifícia Universidade Católica de Goiás (PUC Goiás), Goiânia, Goiás, Brazil*

** Corresponding author email: Kamila_santos@discente.ufg.br*

Highlights

- Excellent efficiency in the application of a low-cost RPAS for the acquisition of topographic data
- Agility in collecting and processing erosivity data
- The DoD method decreases as areas with loss or accumulates with altitude differences.

Introduction

Water erosion is a fundamental stage of river morphology, and it is necessary to follow and monitor them in order to have robust risk management, avoiding socio-environmental problems, material losses, as well as water quality. With the process of urbanization and expansion of cities, water erosion becomes one of the; socio-environmental problems caused by this development (Shikangalah et al., 2016; Wang et al., 2018).
The integration between remote sensing and GIS platforms in geomorphology studies, in addition to stipulating soil loss, also enables the construction of a spatial erosion distribution model. Digital Elevation Model (DEM) is widely used in environmental monitoring and can be applied for a better understanding of what occurs behind geomorphological processes. One of the ways to acquire DEMs is through remotely piloted aerial systems (RPAS). A way frequently addressed in geomorphological studies is the use of DEM, through multitemporal analysis of changes in geomorphology between the subtraction of the posterior DEM from the previous DEM. This subtraction results in a model that shows the differences between the two rasters. In this study, a low-cost RPAS was used to perform flights in the study area, thus being able to perform the temporal analysis. The study area has a history of flooding and, as a consequence, the erosion of its channel, but studies are lacking in the hydrographic basin to be able to know its magnitude and frequency.

Methodology

Data acquisition and processing

The Barreiro stream monitoring took place between December 2018 and September 2019, with two flights covering a 1 km stretch of the stream. To work with the data generated in an existing reference system is necessary to survey the field, through a ground support network - Ground Control Points (GCP). GCPs are visual markers whose coordinates are known to be obtained through a high-precision Global Navigation Satellite System (GNSS) receiver using the Real-Time Kinematic (RTK) method. The control points were signaled on the ground through powder plaster distributed over the area.

Dem of Difference

When it is possible to apply multitemporal DEM from a study area, geomorphology and its changes can be analyzed using the Dem of Difference (DoD) method, where altitude differences are available on the cell scale (Lana et al., 2003). Like altitude differences between new and old surfaces, where erosions and exposures are calculated in a cellular way in the raster. Changes in the elevation model can be represented by the following equation (01):

$$\mathrm{DoD} = \mathrm{DEMNew} - \mathrm{DEMolder} \quad (01)$$

There are several methods to estimate errors in a DEM, but usually, the mean square error (RMSE) is the most applied. Stage et al. (2016) reinforce the application of the RMSE; it is widely used in geosciences to measure the accuracy of continuous variables; it aims to make the quantitative analysis of control points. The RMSE performs the GCP calculations obtained by the GNSS receiver, to compare the position at the same point of the orthophoto. The equation for the Mean Square Error (Equation 02) is shown below:

$$\mathrm{RMSE} = \pm\, (n1 - n2)2N \quad (02)$$

Where:
n1=difference in the values of two parameters
n2=average difference
N=point sum

Results and discussion

The research was carried out in a 1.00 km section of Barreiro stream to verify the movements of the banks of the channel. From the images obtained with the RPAS DJI Phantom 4, DEMs were generated, by the same system used successfully by Angnuureng et al., (2020) where the distortions resulting from the camera's projection and the variation of the relief were corrected in the photographs, maintaining all on the same scale when the orthophoto was generated. Knowing the slope is fundamental to understanding the behavior of the site's geomorphology and hydrology. The stretches with higher slopes (Figure 1 and 2) influence the existing erosive processes.

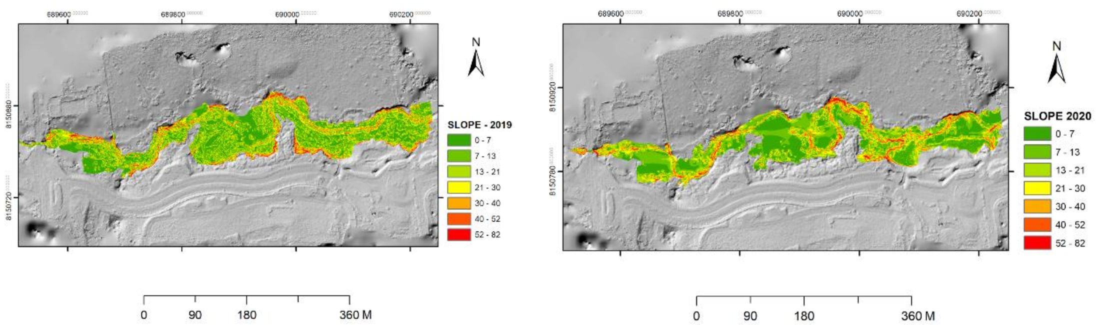

Figure 1: DEMs generated from flights in the study area: a) December 2018; b) September 2019.

The DoD processing occurred using the difference between September 2019 DEM and September 2020 DEM. DoD analysis shows the soil movement that occurred in the sample interval, having found values between 5.59 and -6.00, in a gradient ranging from blue (sediment deposition) to red (erosion). Whereas the values found for erosion and sediment deposition are influenced to different degrees by slope, vegetation, soil, and rocks.

Sediment deposition was throughout the monitored area, but in significant concentrations along the channel. It could be seen that the highest amount of deposition occurred in the sections removed from the concave banks. Due to the discharge flow and sediment input along the channel, a process called avulsion occurs in Barreiro Creek. Avulsion can be defined as the abandonment of a section of a watercourse that changes position, generating a new watercourse (SLINGERLAND & SMITH, 1998; VALENZA ET AL, 2020).

The erosive process obtained higher DoD values, having its distribution throughout the study area, with emphasis on the highest values found in the downstream section of the channel. The value found in the DoD for the erosive process shows coherence when comparing the result of the calculation of areas of the DEM.

In 2019 the area of the cutout was 57980.45m², and in 2020 the value found was 51274.02m². The values for the RMSE found were 0.037m in 2019 and 0.048m in 2020.
Considering the values found for erosion and deposition of sediments where influenced in different degrees by slope, vegetation, soil and rocks. Soil properties and precipitation characteristics have an interactive effect on erosive processes, leading to changes in the physical conditions of the surface, such as soil sealing and saturation, affecting the infiltration of water and its disaggregation WANG ET AL. (2014).

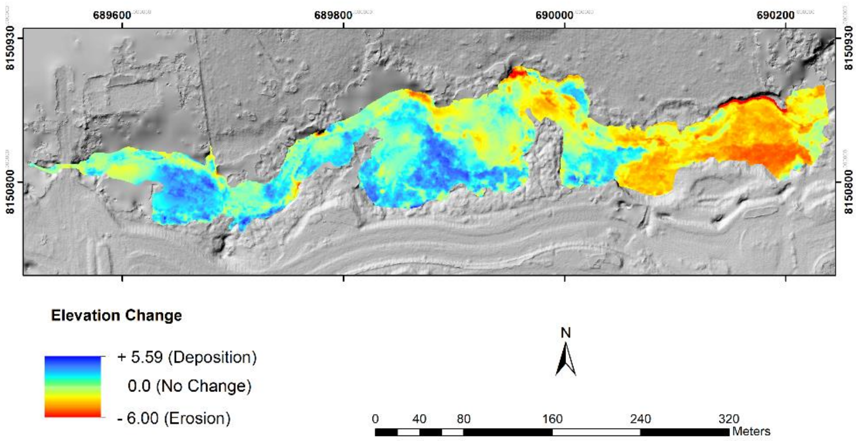

Figure 2: DoD map showing elevation changes in the study area.

Conclusions and future work

This research has shown that the DoD method with the application of RPAS is a precise approach for analyzing geomorphological changes and can be applied in other areas of study. The possibility of monitoring and obtaining continuous forms of digital terrain models and rapid data processing makes low-cost RPAS a necessary tool for the management of urban centers and water resources. The flights carried out in the study area follow one climatological periods: the drought season on winter.
The DoD results show the affected changes in the interval channel without analysis. It is necessary to emphasize that the results where executed in a relatively short time. Therefore it is essential to monitor events and detect flights between periods of drought and rainy season. The medium-term allows having a historical series of the evolution of the erosion while dimensioning the behavior of the fluvial geomorphology.

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