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ULTRA-HIGH RESOLUTION MAPS AND MODELS AS TOOLS FOR MANAGING AND MONITORING ENVIRONMENTALLY SENSITIVE GEOSITES (ESTRELA UNESCO GLOBAL GEOPARK, PORTUGAL)

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ABSTRACT:

This paper focuses on the interpretation of the natural components presents at different geosites in the Estrela UNESCO Global Geopark and on the analysis of soil erosion dynamics associated with trampling events in recent years. Three areas were evaluated: Salgadeiras - Covão da Clareza, Lagoa Seca and Covão do Boi. On there, UAV photogrammetry surveys were applied to obtain orthomosaics and dense clouds that then were used like background at the successive steps of the analysis. The high resolution of the point cloud and orthomosaics allowed us to identify and cartography the geology, hydrography, and vegetation features presents in each place. Besides all trampling sectors were mapped, establishing thus areas potentially vulnerable to environmental degradation because of walk-induced erosion. The analysis presented at this work evidenced an increase in the trampling areas in all the geosites considered, evidencing the potential of this tool like support for future sustainable management of protected areas.

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1. INTRODUCTION

An accurate knowledge of the natural components of the territory is essential to implement geoconservation strategies and tools. This also allows for assessing the risks and evaluating the conservation of geological heritage. In the Estrela UNESCO Global Geopark, a granitic and metasedimentary mountainous region in Central Portugal (Figure 1), unmanned aerial systems (UAS) are used for mapping and monitoring sensitive geosites, and to develop sustainable management plans. Using visible and multispectral sensors, we produce high-precision terrain models and orthomosaics, resulting in very high resolution geological and geomorphological maps, including infrastructure. Surveys in different dates allow for quantifying the impacts, particularly in terms of walk-induced erosion.

1.1. STUDY AREAS

This research focuses on three geosites with high scientific and international relevance: Salgadeiras - Covão da Clareza, Lagoa Seca and Covão do Boi.

Salgadeiras - Lakes of Covão da Clareza geosite is located at c. 1800 m.a.s.l., and has high scenic, ecological, scientific, cultural and touristic values. Its landscape is composed of glacially polished rock surfaces, showing grooves and striations in a landscape of knob and basin morphology (Vieira et al., 2020).

Figure 1. Location of the Estrela UNESCO Global Geopark on the Iberian Peninsula.

It shows several permanent and temporary lakes, as well high-altitude peat bogs of high ecological value. Glacier erosion has been responsible for the removal of the granitic weathering mantle.

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The Covão do Boi geosite is located at c. 1840 m.a.s.l. and several granite columns promoted by occurrence of vertical and sub-horizontal joints that promoted deep chemical weathering are found. The column tops lie at similar altitude revealing the razing action of the Late Pleistocene glacier. Following deglaciation, the weathering mantle preserved among the columns and having survived glacial erosion was eroded by fluvioglacial processes and subsequently by water erosion (Vieira et al., 2020).

The Lagoa Seca geosite is a wide col at 1420 m.a.s.l. dividing the Zêzere valley and the headwaters of the Beijames valley. The area represents the boundary between the glaciated and non-glaciated areas of Serra da Estrela. In the westernmost sector of this geosite there is a large accumulation of moraine boulders, showing the presence of several arcuate ridges. These accumulations are lateral moraines, deposited by the Zêzere glacier when it overflowed the valley and witness more than 300 meters of ice thickness in the Zêzere valley. Vieira et al. (2021) have shown that the moraine ridges show evidence of two glaciations peaking at c. 140 and 30 ka BP.

2. METHODS

This research was carried out in three phases: i. aerial surveying and modelling, ii. Database creation and mapping and iii. Spatial analysis and geoconservation proposals (Figure 2).

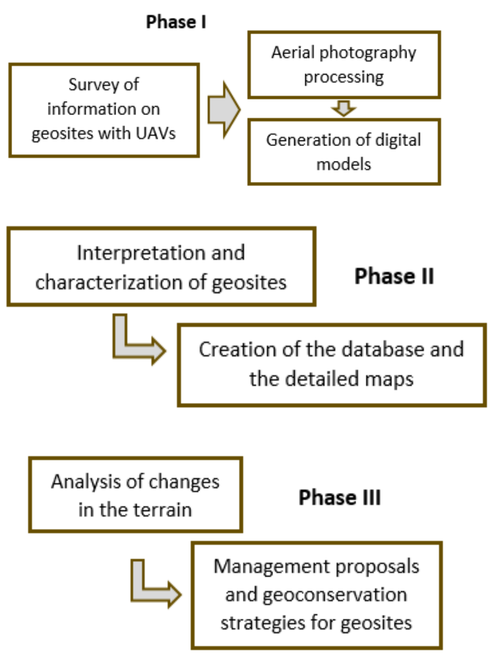

Figure 2. Methodological framework from aerial surveying to the management proposals.

In the phase I, the image acquisition of each geosite with UAS were developed. Due to the long time span, we have used different UAS models (eBee standard and DJI Phantom 3 Advanced) with optical cameras. Surveys were conducted in 2014, 2015, 2017 and 2019, but not all geosites had similar repeat dates (Table 1). Aerial photographs were processed using Pix4D Mapper for generating the georeferenced point clouds, the digital surface models (DSM), the orthomosaics and the 3D mesh files. The models were all co-registered to allow for accurate comparisons.

Geosites	2014	2015	2017	2019
Covão do Boi			November 20	August 29
Salgadeiras		July 29		August 30
Lagoa Seca	May 31			August 31

Table 1. Dates of the aerial surveys of the geosites.

Phase II included the interpretation and characterization of the geosites, with the creation of a detailed map of each geosite, as well as the preparation of a spatial database, used as support for the analytical stage and for the management proposals. Four classes groups were defined with the elements to be identified at the three geosites: geology, hydrography (lakes and streams), vegetation and anthropogenic features (infrastructures and trampling areas). The ultra-high resolution of the orthomosaics and DSM allowed for a detailed characterization of these components. Slope and shading models were also built and used as visualization support for the mapping (Figure 3). The results were validated in the terrain.

Phase III consisted on the monitoring through the comparison of the orthomosaics and DSMs from the 2019 survey, and the orthomosaics from previous campaigns.

3. RESULTS AND DISCUSSION

The ultra- high resolution of the digital models allowed the generation of cartography maps with very high level of detail, where was possible identify different components such as trampling zones, vegetation, sets of ponds of different sizes, areas of bare soil and deposits.

During the interpretation and characterization steps the orthomosaics were used as an editing support, and the 3D densified point clouds, the DSMs and its derived slope and shading models were used as support and consultation sources.

The surface cover in *the Salgadeiras - Covão da Clareza geosite* is not dominated by a particular component, being shared between granitic outcrops (35%), shrub areas (36%) and herbaceous communities (17%).

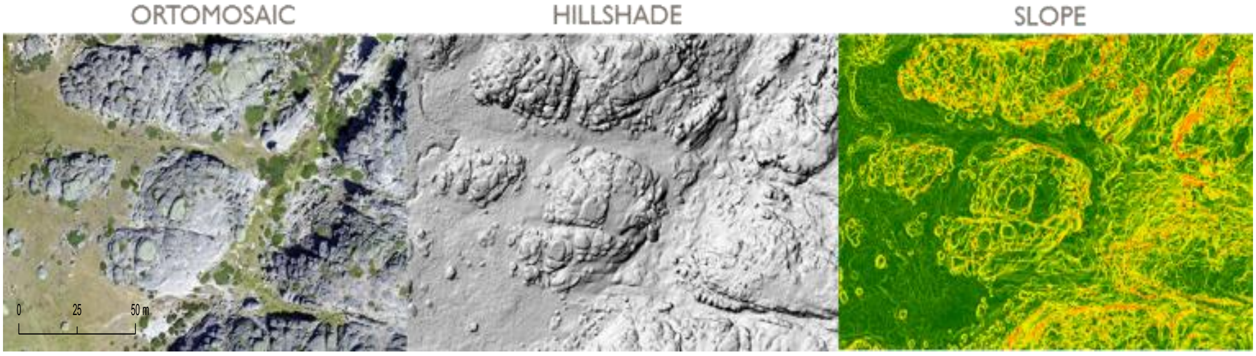

Figure 3. Models used to support the geosite analysis: orthomosaic, shadow and slope. Example from the Covão do Boi geosite.

Areas with temporary ponds occupy 5% of the surface, leaving 7% for areas with bare soil and scattered rock assemblages. 20 temporary lakes were identified which concentrate water in winter and are practically dry in summer.

The resolution of the orthomosaic allowed us to locate the sectors with granitic outcrops, representing diaclases following the surface fractures of the outcrops, mapping their orientation. The largest area of the temporary lakes identified was 1690 m^2, located in the western sector of the geosite, only 60 meters from the main road. Another lake of 1350 m^2 was also delimited, located to the east of the first lake, only 20 meters away. The other 18 lakes have an area between 20 and 250 m^2, all of them without water at the time of the photographic capture, however, they were identified by characteristics such as soil moisture, distinctive vegetation and rocky delimitation. Trampling zones were also identified in the accessible areas of the geosite, being categorized by trampling zones in bare soil and by trampling zones in vegetation, particularly in grasses. This trampling network is located mainly in the northern sector of the geosite, in a west-east direction, linking the EN339 road to the lakes. The extensions of the trampling zones in bare soil were 1810 meters, and the trampling zones with vegetation were 1550 meters.

The Lagoa Seca geosite was characterized by a dense shrub cover. Also, large granitic blocks (larger and smaller than one meter), were identified and their disposition on the terrain was useful for the definition of 5 glacial moraine ridges. This identification has a high scientific value because the previous works mention the presence of only four ridges in the area (Vieira, 2004). Here, the surface cover is dominated by shrub communities occupying 85% of the terrain, meanwhile herbaceous species represent the 3.5% and 9% is represented by scattered granitic rock clusters. The temporary lake area covers 2% of the total surface, leaving less than 1% for areas with bare soil.

The very high resolution of the orthomosaic also allowed us to identify and map the locations of pockets in the granitic rock boulders (Figure 4). These weathering pits are result from post-glacial chemical dissolution processes. A total of 69 weathering pits were identified in granitic boulders, with a diameter of between 10 cm and 90 cm approximately.

Figure 4. Individualization of weathering pits in granitic rock boulders - the Lagoa Seca geosite.

Covão do Boi is the geosite with a miscellany of impressive granite outcrops and endemic grasslands (Figure 5). The surface cover is dominated by granitic outcrops, occupying 49% of the area meanwhile shrub species and herbaceous species represents 21% and 20%, respectively. Granitic rock assemblages occupy 7% of the surveyed area, and 3% correspond to bare soil. No water bodies are identifying at this geosite and the water lines observed are seasonal.

Here, the high resolution of the mosaic also allowed us to characterize for the first time the set of Granitic Columns. The identified columns present heights between 0.5 and 9 meters, and diameters between 1 and 5 meters. A total of 58 columns were mapped and they can be classified in four categories: Incipient, isolated, grouped and prolonged isolated columns (Figure 6).

In the phase III, the cartography made at the phase II was used like starting point to make a comparison of the strategic components to be monitored: trampling zones, bare soil sectors and sectors with herbaceous vegetation communities.

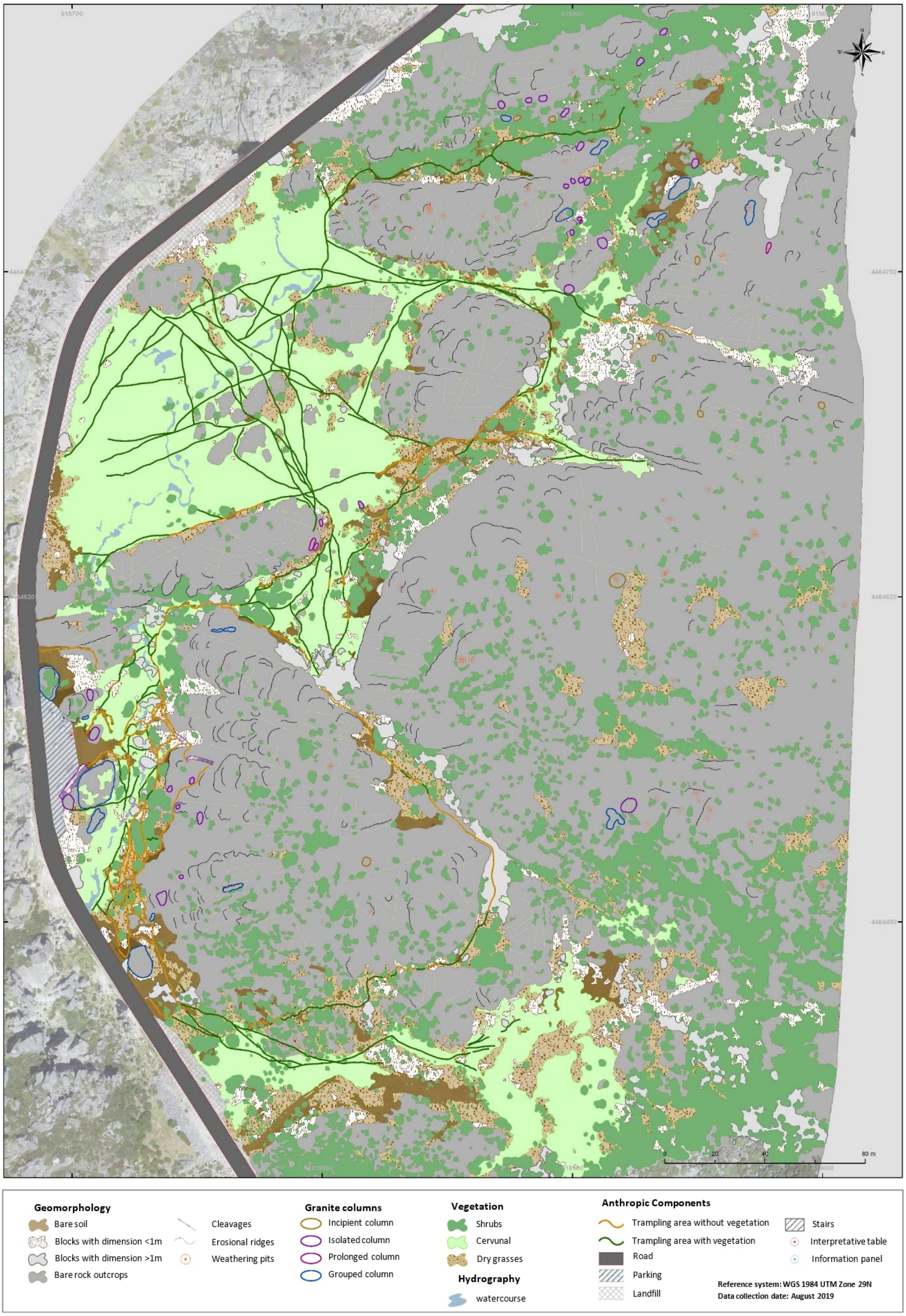

Figure 5. Ultra-high resolution map of the Covão do Boi geosite.

The monitoring phase showed an increase in the trampling areas between 2017 and 2019 in the Covão do Boi and Salgadeiras geosites.

New trampling areas also were identified in the Salgadeiras - Covão da Clareza geosite, specifically in its the eastern sector, on herbaceous vegetation. In 2015, well-defined trampling trajectories were observed, differentiated in some sectors by being in areas of bedrocks and bare soil. For the 2019 year, the trajectories increased, growing from 104 to 111 sections and showing a 13% of increase in trampling on vegetated ground and a 5% of increase in trampling on bare ground. The high resolution of the maps generated allowed us to establish the sectors more vulnerable or damaged (Figure 7).

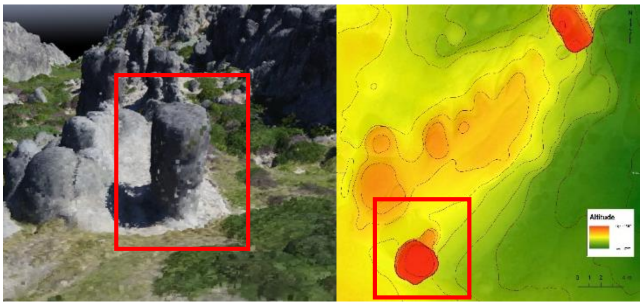

Figure 6. 3D representation of an isolated column - Covão do Boi geosite.

In the Covao do boi geosite, differences in the network of trampling areas on the cervunal grass meadow were identified, to the northwest sector, close to the main road. The new trampling areas for 2019 on vegetation show a growth of 6% (154 m). In areas on bare soil, the same 1,150 m in length were identified. At the Lagoa Seca geosite, only a 4% of increase in trampling areas over vegetation and a 10% decrease over bare ground was identified.

4. CONCLUSIONS

The use of UAV as a photogrammetry tool provided a very detailed baseline information for management and monitoring of the geosites.

The very high-resolution images derived from it allowed elaborate very detailed land cover maps, characterize some geomorphological elements, such as weathering pits and granitic columns, and identify a new moraine ridge in Lagoa Seca. Besides they allowed quantify the evolution of the walk-erosion processes in recent years.

The current context has brought to the forefront the issues of conservation and valuation of the geographical landscape, particularly geological heritage, generating various methods and criteria that can be used in the processes of inventory, understanding, conservation and protection of sites of geological interest.

High-resolution mapping, obtained using UAVs, has provided effective and accurate information that contributes to these processes, making this technique an important tool for the planning and management of natural areas.

This research demonstrates the importance of high-resolution territorial diagnostics in the planning and management process, identifying the main components involved in the natural dynamics of geosites. The resolution of the aerial surveys allowed a very detailed analysis of the geosites, enabling a management proposal to be made to counteract the vulnerabilities identified.

Finally, we consider that all products produced with a high level of cartographic detail can play a relevant role in conservation studies of the Estrela Geopark.

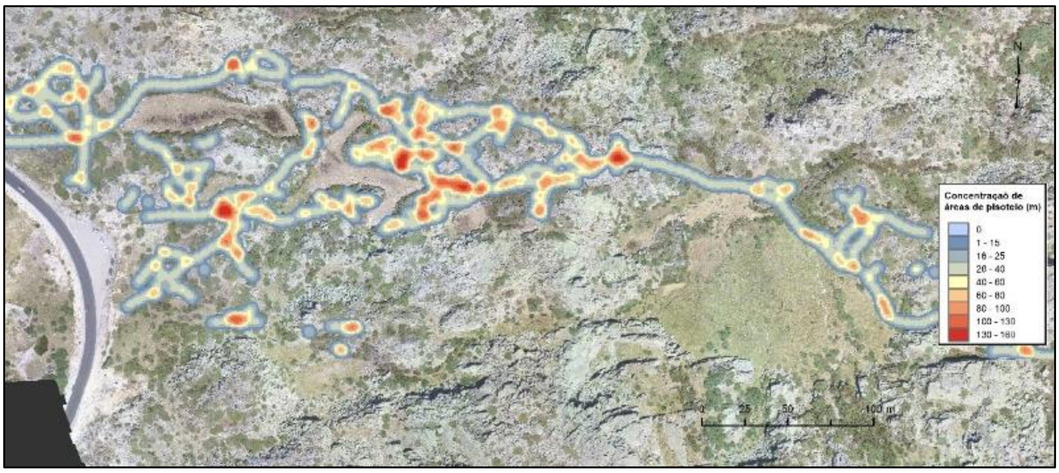

Figure 7. Map of density of trampling areas in the Salgadeiras - Covão da Clareza geosite.

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