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Quantification of gully volume using very high resolution DSM generated through 3D reconstruction from airborne and field digital imagery

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1. INTRODUCTION

NEW REMOTE SENSING TECHNIQUES FOR GULLY EROSION ASSESSMENT

- Provide high resolution DEMs → centimeter accuracy
- Reduce the time and cost of the measurements
- Allow a more precise evaluation of the geomorphological processes
- Remain a challenge in improving the accuracy, evaluating the associated errors and increasing the spatial scale
- 3D photo-reconstruction has been already validated for gully erosion assessment purposes at reach scale (several meters length)

Definitions:

- **Airborne photo-reconstruction: automatic aerial triangulation (AAT) and camera calibration (CC) method to generate georeferenced orthomosaics and a georeferenced Digital Surface Model (DSM) from imagery collected by a camera mounted on an airborne platform.**
- **Field photo-reconstruction: 3D photo-reconstruction technique using uncalibrated and non-metric cameras based in automated "structure-from-motion" algorithms from imagery collected in the field. DiffGPS is required for georeferencing.**

OBJECTIVES:

The aim of this work is to compare the performance of two innovative remote sensing techniques based on image acquisition with uncalibrated and non-metric digital cameras: an airborne platform conducted with a manned aircraft and 3D field photo-reconstruction.

Fig. 1. View of the aircraft employed for the collection of the digital imagery in the airborne survey.

Fig. 2. View of the image collection for the field photo-reconstruction technique with deployed ground control points (GCPs).

2. MATERIALS AND METHODS

2.1. Study site.

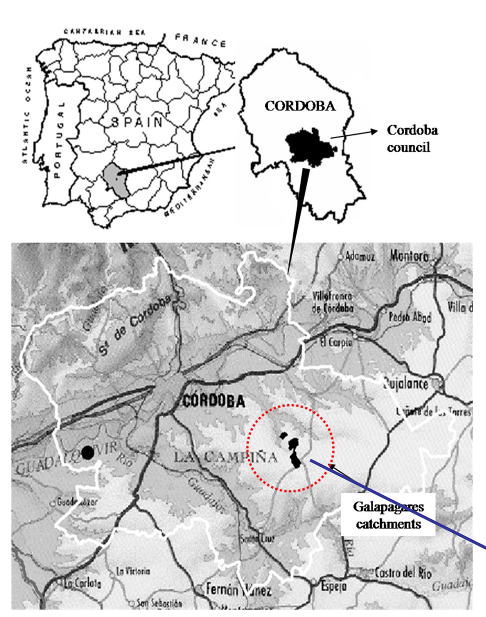

Fig. 3. Study site.

Galapagares catchment

Area: 80 km2

Campiña´s rolling landscape

Vertic soils on miocene marls

Annual crops (wheat, sunflower) under intensive agricultural practices

Figure 4. Plan view of the studied gully from the airborne imagery (Color-infrared).

2.2. Methodology

Single survey in December 2012

	Airborne photo-reconstruction	Field photo-reconstruction (Reference method)
Equipment	Panasonic Lumix DMC-GF1 camera (4000 x 3000 pixels) mounted on manned aircraft CIR camera GPS Trimble Copernicus	Nikon D60 (4000 x 2600 pixels) diffGPS Trimble R7 for georeferenciation and perimeter (2 cm centimeter accuracy)
Data acquisition	978 pictures Covered area 390 ha 20 reference points outside the gully	2,600 pictures Covered area 0.5 ha (gully surface) 70 Control points deployed at the gully perimeter measured with diffGPS
3D model and georeferencing	Pix4D	Photoscan (Agisoft)

3. RESULTS AND DISCUSSION

3.1. 3D Model accuracy

Airborne (AR)	3D photoreconstruction (PR)
6.6 cm pixel 1,440,187 key points for 3D bundle block adjustment Gully limits defined by change of slope criterium Elevation offset as a consequence of the lack of ground control points in the vicinity of the gully RMS Elevation error ~ 0.35 m	6.6 cm pixel from 158,267,135 points after dense reconstruction Thirty ~15 m-long gully chunks for independent reconstruction Gully limits defined visually by diffGPS operator

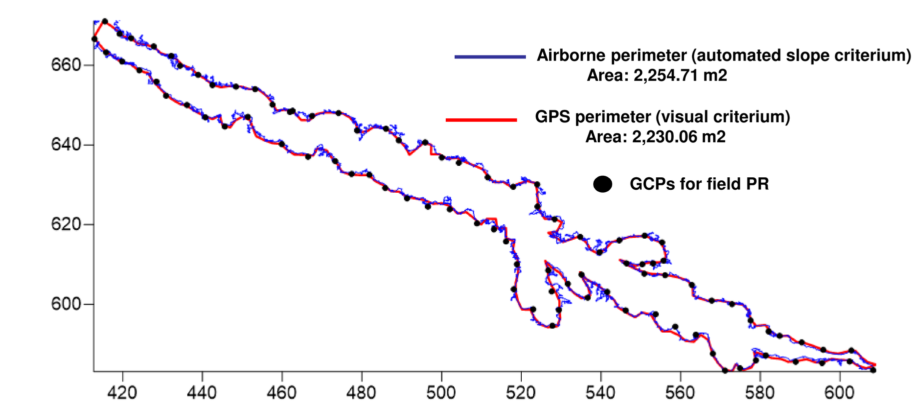

Figure 5. Plan view of the gully perimeter for both AR (automated slope criterium through DEM analysis) and PR (visual criterium from field GPS operator).

Both criteria produced similar results for the gully perimeter determination.

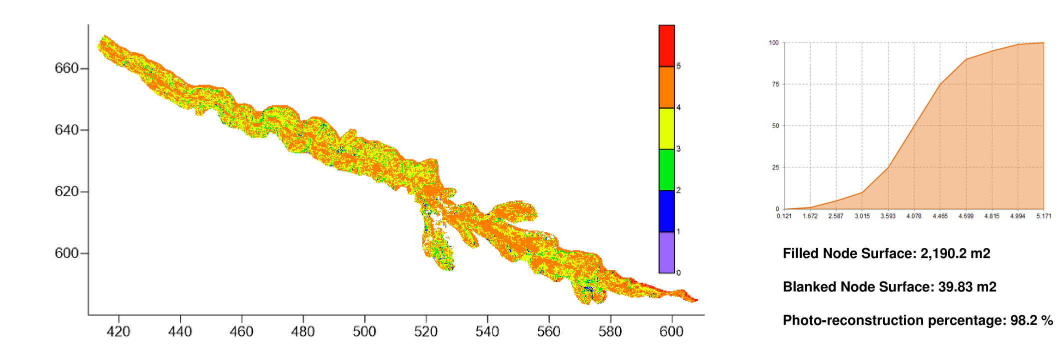

Figure 6. Point density map and point density accumulated frecuency for field photo-reconstruction method (PR) .

PR method showed a high level of reconstruction (> 98%) and a high and spatially uniform point density (4 points/cm^2 in average), being suitable to be considered as the reference method.

3.2. Comparison between techniques

Volume estimations

For AR y PR methods, the volume calculations were performed by substracting the upper gully surface and the gully DEM. The upper gully surface was estimated by interpolation of the elevation of the gully perimeter points obtained by the slope and visual criterium, respectively.

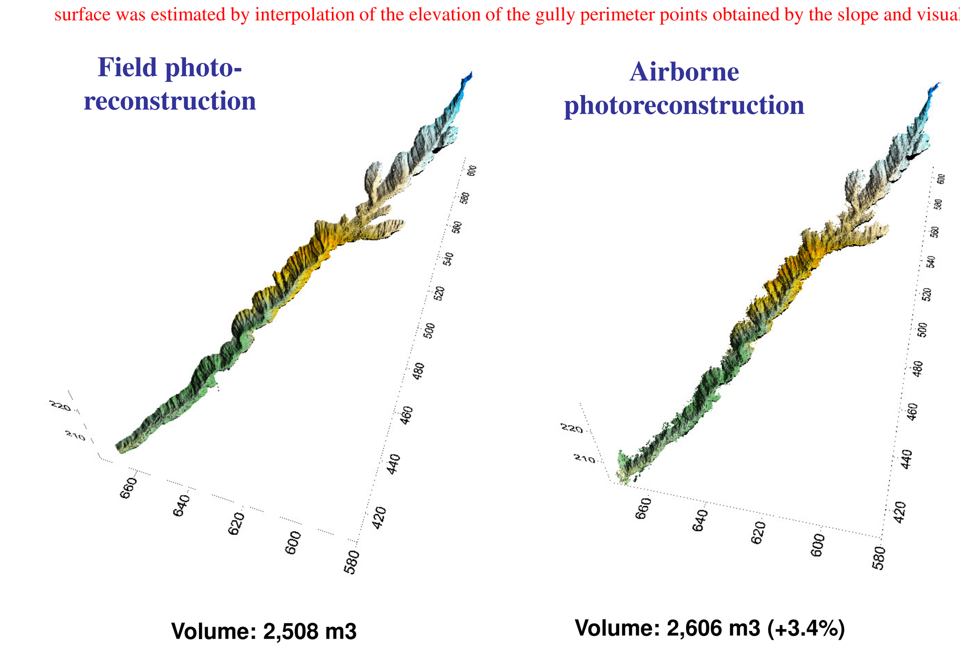

Figure 7. 3D view of the elevation models for both techniques.

Airborne technique produced a low error for volume estimation. See the more irregular gully perimeter derived from the automated slope criterium.

Cross-sectional area estimations

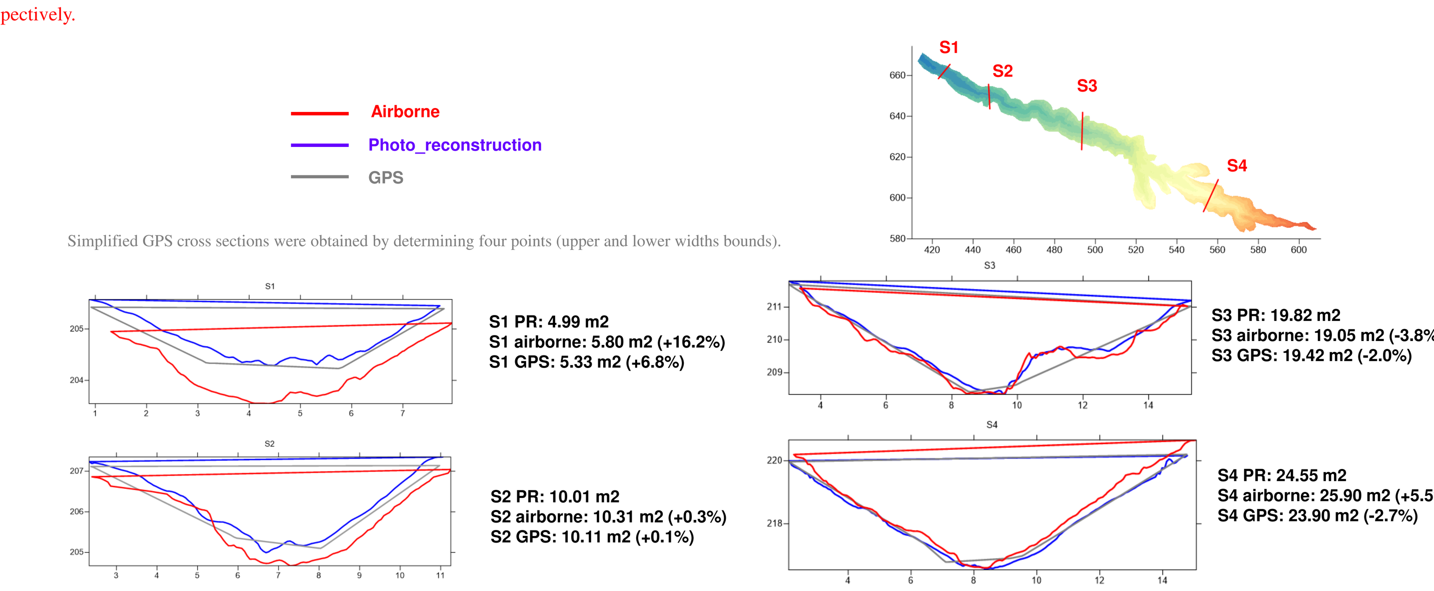

Figure 8. Comparison of four cross sections for both remote sensing methods (airborne and field photo-reconstruction) and GPS measurements.

Airborne cross-sectional area estimations produced errors beneath 17%. Significant elevation offset is observed in sections 1 and 2.

4. CONCLUSIONS

- Field photo-reconstruction along with diffGPS georefencing proved successful as the reference method due to its dense and relatively uniform reconstruction results, within the same order of magnitude of terrestrial LiDAR measurements carried out in soil erosion studies. Moreover, it proved useful for the reconstruction of entire gullies (several hundred meters long), though improvements on the optimization of the image collection and processing may be accomplished.
- The airborne 3D model, when obtained without deploying ground control points (GCP) in the vicinity of the gully, produced elevation errors of several tens of centimeters. Therefore, with the present methodology, its use for the detailed evaluation of gully changes at small spatial or temporal scales is not advisable. However, it provided close approximations for gully volume and cross-sectional areas and represents a powerful tool for gully erosion assessment over medium scales (several hundred hectares) where field PR technique is not cost-efficient. In addition, the deployment of GCPs is recommended in further airborne surveys since improvement on the accuracy of the model is expected.

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5. REFERENCES

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