PRELIMINARY ESTIMATION OF AUBETA DEBRIS FLOW DEPOSITION AND EROSION VOLUMES USING LIDAR DATA.

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During the 17th and 18th June 2013 catastrophic rainfall event, a significant debris flow occurred in a torrent of the Pyrenees. Ortophotos and digital terrain models made periodically by the Cartographic and Geological Survey of Catalonia (ICGC) together work field have been used to map the debris flow area and calculate the sediment budget. The analysis of the mass balance showed that approximately 104.000 m^3 was mobilized in the debris flow area, of which 71.000 m^3 settled there. This implies that 33.000 m^3 of sediments were incorporated into the river Valarties.

Keywords: Debris flow, LiDAR, Volumetric Sediment Budget

INTRODUCTION

In Catalonia, torrential flows are a frequent process mainly presents in two areas: the Pyrenees and the Pyrenean foothills, and the coast and the pre-coastal area of Catalonia. In the past, many significant rainfall episodes with catastrophic consequences have been inventoried. During the 20th century the most important, due to their catastrophic effect, occurred in 1907, 1937 and 1982, causing floods, deposition of sediments and damages in the infrastructures (Balasch et al., 2008). More recently, at the beginning of this century, intense rainfalls have also caused significant damage. Of note are the episodes of August 2008 in the Runer river located on the Andorra-Catalonia border (Hürlimann et al., 2011), and the recent intense torrential activity presented between 2006 and 2015 in Port-Ainé torrent (Pinyol et. al., 2017).

In 2013, during the 17th and 18th of June there were a significant rainfall in the Central Pyrenees, which caused an exceptional flood of the Garonne and Noguera Pallaresa river (Oller et al., 2013). These events produced significant alterations to the river area, as well as important damage in different infrastructures. The material losses insured were estimated at 19,60 million euros according to the Insurance Compensation Consortium (2013). The causes of the flood of the Garonne were due to the coincidence of two exceptional events, a severe rainfall (124,7 mm, 101,2 mm of which corresponds to June 18) and important meltwater, due to an exceptional snow thickness. On 17th of June the flow of the Garonne river was also very high due to snow melting (125 m^3/s) and suddenly the peak value increase until 280 m^3/s, in Bossost, the highest value since 1937 (Pineda et al., 2013).

One of the most important events inventoried by its dimensions and its effects on the environment and in the infrastructure has been the debris flow in Aubeta torrent. In this paper we present a mobilized material preliminary estimation made by space-time comparison of Digital Terrain Models (DTM) obtained from data LiDAR (Light Detection and Ranging).

STUDY SITE

The Aubeta torrent (ETRS89: 42.6587 N/ 0.8585 E) is located in the Central Pyrenees at the north side of the Aigüestortes and Estany de Sant Maurici National Park (Val d'Aran County, Spain). The Aubeta basin covers a total drainage area of 2,08 km^2 and its altitude ranges from 1375 m to 2502,5 m. a.s.l. (Pujalbo peak). The basin drains towards the East and ends in the Valarties River. The Melton ratio is 0,50 and the Relief ratio 1,05. The analysis of the morphometric parameters of the catchment indicates that the Aubeta basin is susceptible of generating hyperconcentrated flows (Wilford et al. 2004). From a geological point of view, the Aubeta stream is located in the Pyrenean Axial Zone, and is part of a Hercynian WNW-ESE oriented trust fault structure. The bedrock is formed by Paleozoic materials, Cambro-Ordovician sandstone, Siluric metapelite and black shales and Devonian and Corboniferous limestones. The bedrock is in a great part covered by Quaternary glacial deposits.

DATA SET

Analyses were performed on aerial images and airborne LiDAR datasets obtained before and after the debris flow event. For the geomorphological cartography 3 sets of aerial images (ortophotos) have been used: 2011, 2013 (a month after the event) and 2015. For the quantitative analyses, the work method consists in the space-time comparison of DTMs obtained from data LiDAR, acquired in 2011 and 2016.

Data collection was carried out with the CARAVAN aircraft, owned by the ICGC, and the topographical LiDAR sensor Leica ALS50-II. The average density obtained per block is 1,928 pt/m^2 for 2011 and 1,577 pt/m^2 for 2016. For the orientation, the 3D coordinates of the laser points were obtained from the calculation of the trajectory of the airplane in the ETRS89 reference system and with point cloud adjustment obtained the dz, roll, pitch and heading corrections. The altimetry requires control points measured directly in the field with GPS. After the adjustment, an automatic points ground classification was obtained and after that it was reviewed by an expert operator. The altitudes are referred to geoid EGM08D595. For the filtering, the TerraScan module of TerraSolid software has been used. The altimetric accuracy is estimated between 15 and 50 cm depending on the slope.

For the comparative analysis between the data of 2011 and 2016, two DTM of both years were obtained from the points classified as terrain. These were obtained by the linear triangulation interpolation method, establishing a cell size of 2 x 2m. Through the subtraction between the two MDTs a difference model has been made, which allows the detection of preferential erosion and accumulation zones. The calculation of volumes of eroded and accumulated material was done with the "Cut Fill" tools of ArcGIS, which consists of a cut and fill operation and calculation of the difference in surface elevation of the MDT for each cell. With these results we obtained the sediment balance between the total volume of material loss (erosion) and increase of material (accumulation).

GEOMORPHOLOGICAL CARTOGRAPHY

Mapping of debris flow (see Fig. 1) was carried out from the helicopter inspection on 20th June 2013, from the ortophotos taken by ICGC, especially the july 2013 ortophoto, and from

the 2016 field observations. From the erosive point of view, the debris flow started in the channel itself, at the 2080 m. a.s.l. Nevertheless, a significant lateral scar of 5.250 m^2 was identified at 1907 m. a.s.l., which undoubtedly incorporated a great amount of sediments to flow. The debris flow traveled 1.960 meters to the Valarties river, eroding importantly the bed and lateral margins, but also depositing in elevated areas, waters behind the dike of the 1539 m. a.s.l. and above all, in the cone of dejection. From all these observations, the cartography of the area affected by the debris flow was carried out. This area was used as an area of analysis for the comparison of MDTs.

Fig. 1 Ortophotos before and after the debris flow. At top, 2011 ortophoto shows the parking in the dejection cone. At bottom, 2013 ortophoto with delimited debris flow area (in red).

VOLUME CALCULATION RESULTS

By comparing the MDTs, accumulations of up to 8,6 meters and erosions of up to 14,7 meters have been observed (see Fig 2). The maximum accumulations have occurred in the dejection cone, in the area that was lowered for use as parking. The maximum erosions have occurred in the lateral scar. The total debris flow mass balance calculation showed that 104.000 m^3 was mobilized in the debris flow area, of which 71.000 m^3 settled there. This implies that 33.000 m^3 of sediments were incorporated into the river Valarties. It is worth noting that the MDT of 2016 includes several anthropic modifications made in the dejection cone due to tourist interest. However, it has been considered that the sediment was not transported outside the study area.

CONCLUSIONS

This paper presented a methodology for analyses of debris flow using space-time comparison of Digital Terrain Models (DTM) obtained from data LiDAR (Light Detection and Ranging), acquired in 2011 and 2016. The following summarizes the conclusions:

The Aubeta catchment basin is characterized by the following morphometric parameters: its area are 2,08 km^2, the Melton ratio is 0,50 and the Relief ratio 1,05. The analysis of these parameters indicates that the Aubeta basin is susceptible of generating hyperconcentrated flows.

The maximum accumulations have occurred in the dejection cone, in the area that was lowered for use as parking. The maximum erosions have occurred in the lateral scar. The total debris flow mass balance calculation showed that 104.000 m^3 was mobilised in the debris flow area, of which 71.000 m^3 settled there. This implies that 33.000 m^3 of sediments were incorporated into the river Valarties.

The methods proposed are recommended for quickly and accurately estimation of the mobilized material. Nevertheless, we would like recommend the importance of carrying out the LiDAR flight immediately after of the occurrence of the event, before that anthropic action modified the mobilized material.

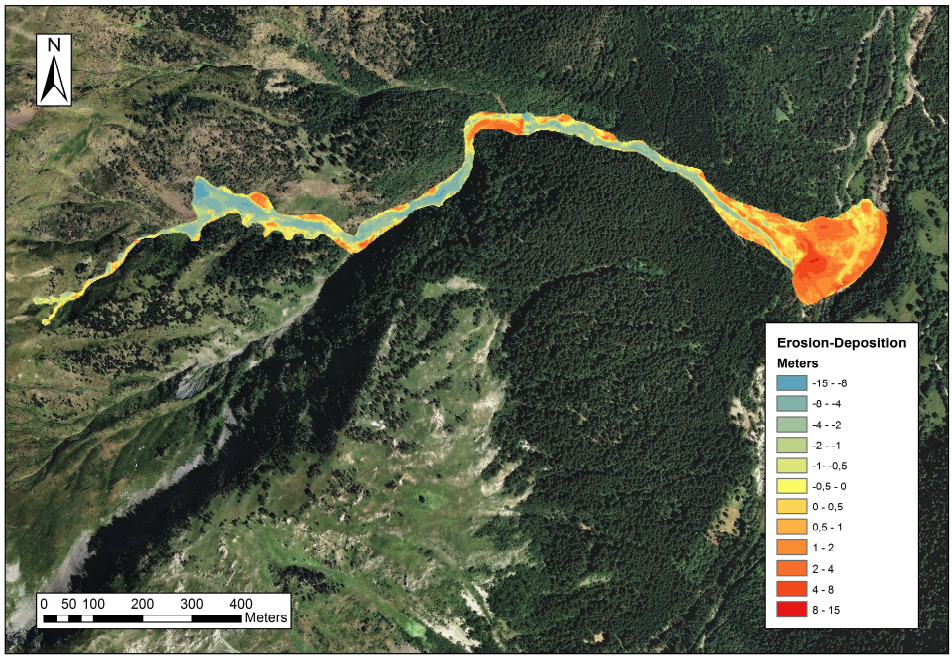

Fig. 2 Results of the difference model between the two MDTs (2011-2016).

REFERENCES

Balasch C, Becat J, Marugán CM, Nadal A, Rapalino V & Remacha R (2008) Les riuades del segle XX al Pallars Sobirà: 1907, 1937 i 1982. Arxius i societat, Quaderns de divulgació històrica, Núm 2. Departament de Cultura i Mitjans de comunicació, Generalitat de Catalunya. 239p.

Hürlimann M, Abancó C, Moya J, Raïmat, C & Luis-Fonseca R (2011) Debris-flow monitoring stations in the eastern Pyrenees. Description of instrumentation, first experiences and preliminary results. Italian Journal of Engineering Geology and Environment - Book. Casa Editrice Università La Sapienza , 2011. DOI: 10.4408/IJEGE.2011-03.B-061, pp. 553-562.

Oller P, Pinyol J, González M, Ripoll J & Micheo MªJ (2013) Efectes geomorfològics de l'aiguat i riuada del 18 de juny de 2013. *Proceedings of the conferences La gestió de les inundacions*, November 27 and 28, 2013.

Pineda N, Prohom M, Serra A, Martí G, Garcia C, Velasco E & Gracia A (2013) Efectes geomorfològics de l'aiguat i riuada del 18 de juny de 2013. *Proceedings of the conferences La gestió de les inundacions*, November 27 and 28, 2013.

Pinyol J, Hürlimann M, Furdada G, Moysset M, Palau RMª, Victoriano A, Gonzalez M, Moya J, Guinau M, Raïmat C & Fañanás C (2017) El barranco de Portainé (Pirineo Central): Un laboratorio in situ completo para el estudio de la actividad torrencial. Abstract accepted in IX Simposio Nacional sobre Taludes y Laderas Inestables, June 27-30, 2017.

Wilford DJ, Sakals ME, Innes JL, Sidle RC & Bergerud WA (2004) Recognition of debris flow, debris flood and flood hazard through watershed morphometrics. *Landslides (2004)* 1: DOI 10.1007/s10346-003-0002-0. Published online: 5 March 2004, Springer-Verlag, pp. 61-66.