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Availability and characteristics of the historical and recent aerial photographs and orthophotographs in Spain for the analysis of rill and gully erosion

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Abstract: Several kinds of methodologies and techniques have been used indeed in order to monitor rill and gully erosion processes. In this paper authors provide a guidance regarding the available aerial photographs and orthophotographs for rill and gully erosion studies in Spain and covering the whole country. A set of 8 different series of aerial photographs and orthophotographs were located in Spain. Their characteristics were quite diverse, differing in scales, formats and resolution. Most of the photographs and orthophotographs proved, at least, to be suitable for their use in studies of permanent gullies, allowing the monitoring of medium and long-term erosion rates since 1945.

Keywords: rill and gully erosion, aerial photographs and orthophotographs, Spain

Introduction

Erosion produced by concentrated water flow has been highlighted as an important soil degradation phenomenon in the Mediterranean catchment. As a consequence, many works have been developed in Mediterranean countries during the last years related with the erosion caused by rills (e.g. Torri et al. 1987), ephemeral gullies (e.g. Capra et al. 2009) and permanent gullies (e.g. Vandekerckhove et al. 2000).

In Spain, many works have been carried out which reflects the increasing concern about rill and gully erosion processes, rates, consequences and thresholds: Benito et al. (1991), Faulkner (1995), Casalí et al. (1999), Nogueras et al. (2000), Martínez-Casasnovas et al. (2003a), Valcárcel et al. (2003), Santisteban et al. (2005), Gómez Gutiérrez et al. (2009) etc. Several kinds of methodologies and techniques have been used indeed in order to monitor rill and gully erosion processes, mainly involving sedimentological and botanical evidences (e.g. Vandekerckhove et al. 2001), historical sources (e.g. Stankoviansky 2003) and topographical surveys and resurveys with different equipments: erosion pins (e.g. Crouch 1990) or traditional theodolite to differential Global Positioning Systems (GPS; Wu & Cheng 2005).

Different spatial schemes have been also used during the topographical surveys such as repeated cross-profiling (Schnabel & Gómez Amelia 1993) or headcut retreat monitoring (Vandekerckhove et al. 2003). A few works on gully erosion studies using terrestrial and aerial photogrammetry (e.g. Marzolff & Poesen 2009) and Airbone Laser Scanning (i.e. LIDAR; James et al. 2007) have been published during the last years.

Nowadays, data acquisition is focused in new technologies and probably articles including data acquired by Terrestrial Laser Scanning (known as TLS) will be published during the next months. However the time scale of the studies based exclusively on modern techniques is constrained by the date of appearance of those techniques. Therefore, some historical sources are still necessary in gully erosion studies. To this respect, the existence of historical and more recent aerial photographs and orthophotographs is of great scientific value. In addition, aerial photographs and orthophotographs allow us to know the appearance and configuration of the landscape when they were taken, helping us to establish relationships between the characteristics of the erosional features (area, length, volume, morphology etc.) and land use and vegetation cover. The availability of this material and the development of modern spatial information technologies (remote sensing, geographical information systems, photogrammetry, GPS, LIDAR, LTS etc.) gave rise to their use in erosion studies and particularly in gully erosion (Martínez-Casasnovas 2003).

Rills, ephemeral and permanent gullies are linear elements in the landscape, commonly comprising vertical walls and material at the channel bottom which differs in texture and color from that of the contiguous areas. Therefore, a gully is easily recognizable from the air. These characteristics allow mapping on an orthophotograph the area affected by erosional processes of concentrated flow. Sometimes, it is also possible to rebuild a tridimensional model of the channel by photogrammetric techniques and therefore to calculate the volume of material evacuated by the flow. Furthermore, the use of aerial photographs is an alternative to expensive field work campaigns (Watson & Evans 1991).

There is a wide availability of literature describing the use of multi-temporal series of aerial photographs to estimate the spatio-temporal dynamics of gullying: Watson & Evans (1991), Nachtergaele & Poesen (1999), Martínez-Casasnovas (2003), Martínez-Casasnovas et al. (2003a), Ries & Marzolff (2003), De Luna et al. (2004), Parkner et al. (2006), Campo et al. (2007) and Gómez Gutiérrez et al. (2009). Digital elevation models derived from aerial photographs have also been used in gully erosion studies: Thorne (1986), Desmet & Govers (1996), Betts & DeRose (1999), Betts et al. (2003) and Martínez-Casasnovas et al. (2003b). All these works evidence the convenience and confidence of using aerial photographs and orthophotographs in gully erosion studies.

Sometimes, however, finding these documents is laborious and tedious, being the researchers forced to spend a lot of time in localizing and acquiring it. In fact, this article is the result of an intense search and documentation work developed in the last years by the Geoenvironmental Research Group of the University of Extremadura regarding historical and recent aerial photographs and orthophotographs in Spain.

Therefore, the main objectives of this work are i) to provide a guidance regarding the available aerial photographs and orthophotographs for rill and gully erosion studies in Spain and covering the whole country, ii) to summarize the main characteristics of these materials and iii) to analyze the suitability of using the different photographs and orthophotographs for soil loss monitoring and assessment, produced by rills, ephemeral and permanent gullies.

Available photographs and orthophotographs and their characteristics

Available aerial photographs and orthophotographs cover a time period of 61 years, involving 8 different flights in Spain, which means an average interval between two consecutive photographs of almost 8 years (Table 1). Two available sources of ma-

Table 1. Main characteristics of the available aerial photographs and orthophotographs in Spain

Flight	Date	Scale (aprox.) or pixel size	Format and type	Distributor
American flight A	1945	1:45,000	Digital copy (Grey scale photograph)	Spanish army (CECAF)
American flight B	1956–1957	1:30,000 – 1:35,000	Digital copy (Grey scale photograph)	Spanish army (CECAF)
IRYDA flight	1977–1983	1:18,000	Analogical or digital aerial photographs (Grey scale)	National Center for Geographical Information (CNIG)
Tragsa national flight	1983–1985	1:30,000	Analogical or digital aerial photographs (Grey scale)	National Center for Geographical Information (CNIG)
Cadastral flight	1987–1989	1:20,000	Analogical or digital aerial photographs (Grey scale)	Spanish government
Olive tree GIS	1997–1998	1.0 m	Orthophotograph (Grey scale)	Spanish government
PAC GIS	2002	0.5 m	Orthophotograph (RGB)	Spanish government
PNOA	2006	0.5 m	Orthophotograph (RGB)	National Center for Geographical Information (CNIG)

terial are known in Spain as the American Flight versions A and B. The first one was carried out in 1945 by the United States Army with an approximated spatial scale of 1:45,000. The American Flight B was also carried out by the United States Army showing a larger scale (varying from 1:30,000 to 1:35,000).

Materials of both flights can be acquired from the Photographic and Cartographic Center of the Spanish Air Army (known as CECAF). Later in time (1977–1983), the IRYDA (spanish acronym of the Institute for Agricultural Reform and Development) promoted the execution of a flight with the largest scale among all the available materials (approximately 1:18,000). Two later flights two cartographic purposes were carried out in 1983–1985 and 1987–1989 at scales of 1:30,000 and 1:20,000 respectively. In 2002, promoted by the Spanish government, orthophotographs were made as part of a SIGPAC, GIS for the monitoring and management of agricultural grants of the European Union (EU). It was created as a record of the agricultural reality in Spain. The origin of this initiative was another GIS developed in 1998–1999 to monitor olive tree orchards in agricultural plots and to manage the grants of the EU to this agricultural sector (known as "*SIG Oleícola*"). Both last-mentioned sources were the first public services providing orthophotographs based on Wep Map Services (WMS) technologies, i.e. on-line, in digital format and orthorectified. More recently, as part of the development in Spain of European laws regarding the Spatial Information in Europe (INSPIRE), the Spanish National Geographic Institute (IGN) created the National Plan of Aerial Orthophotograph, also known as PNOA.

Suitability of available photographs and orthophotographs to monitor and cuantify erosion caused by concentrated flow

The positional error in geospatial datasets is well known (Chrisman 1991). Errors in orthophotographs are usually related with the quality and amount of the ground control points used during the orthorectification process, scale of the flight, topography of the study area, and technical characteristics of the materials. Traditionally, cartographers assume that the spatial errors in maps can be assumed as 0.2 mm multiplied by the map scale.

This hypothesis is based on the minimum visible discrimination capacity of the human eye. Following this criterion, the accuracy of the abovementioned photographs and orthophotographs will vary from 3.6 m to 9.0 m. However, this error can be reduced to 0.02 mm multiplied by the scale when optical zoom instruments are used, resulting to accuracies varying from 0.36 m to 0.90 m. According to these values, the photographs presented here would be only suitable for their application in large permanent gullies or badland areas. Sometimes, however, the location is not the characteristic that soil erosion researches analyzes, alternatively, the length, area or volume of the erosional features are also of great interest. In this line, Gómez Gutiérrez et al. (2009) tested the geometric quality of 6 out 8 orthophotographs.

The test was applied to the orthophotographs of the years 1998, 2002 and 2006 and to orthophotographs corresponding to 1945, 1956 and 1989 obtained by orthorectifying the photographs showed in Table 1. The test consisted in comparing length and area measures of different elements (enclosures, walls, buildings, etc.) with true field data obtained by using a laser meter. The average Root Mean Square error for Length measures (RMS_L) was 0.75 m with a maximum of 1.20 m for the orthophotographs of 1998, while the average Root Mean Square error for Area measures (RMS_A) was 4.67 m^2 with a maximum of 15.82 m^2 for the orthophotograph of 1945 (Fig. 1).

Table 2 shows the results of an analysis carried out by comparing the average size of different erosive forms related with concentrated flow and the scale, i.e. the pixel size, time interval between consecutive photographs (as compared with the temporal scale of the process, e.g. several rainfall events or weeks for rills and several centuries for badlands), the radiometric resolution (Grey scale or RGB) and previous results obtained by Gómez Gutiérrez et al. (2009) about the availability of aerial photographs and orthophotographs in Spain.

According to the analysis none of the documents were suitable for estimating the surface affected by rills or other rill-related variables as soil erosion caused by rills (length or volume).

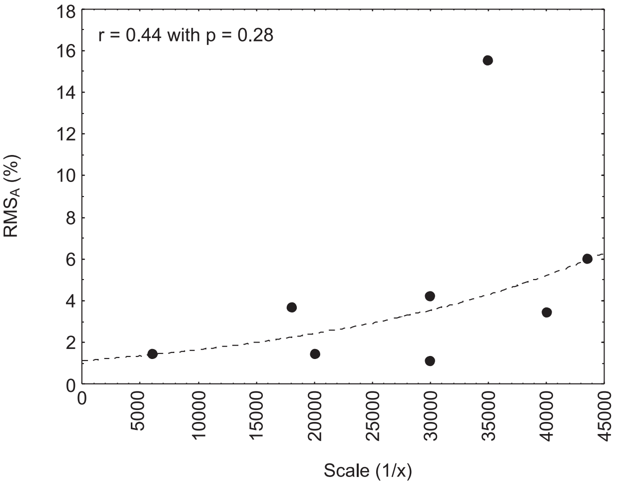

Fig. 1. Relationship between scale and Root Mean Square error for Area measures (RMS_A) for the orthophotographs of the years 1945, 1956, 1982, 1984, 1989, 1998, 2002 and 2006 (Since Gómez Gutiérrez et al. 2009)

Table 2. Suitability of available photographs-orthophotographs for the study and quantification of several types of erosion caused by concentrated flow

Flight	Date	Rills	Ephemeral gullies	Permanent gullies	Badlands
American flight A	1945	Inappropriate	Inappropriate	Inappropriate	Suitable
American flight B	1956–1957	Inappropriate	Inappropriate	Suitable	Good
Ministerial flight	1977–1983	Inappropriate	Inappropriate	Good	Excellent
Tragsa national flight	1983–1985	Inappropriate	Inappropriate	Suitable	Good
Cadastral flight	1987–1989	Inappropriate	Inappropriate	Good	Excellent
Olive tree orchards GIS	1997–1998	Inappropriate	Inappropriate	Suitable	Good
PAC GIS	2002	Inappropriate	Inappropriate	Good	Excellent
PNOA	2006	Inappropriate	Inappropriate	Good	Excellent

In addition, the time steps between consecutive photographs or orthophotographs overcome that of the temporal scale needed for the occurrence and development of rills. As regards to the ephemeral gullies, only the more recent orthophotographs (2002 and 2006) seems to be suitable of use.

Nevertheless, the long time gap between these two orthophotographs dissuades from their application in ephemeral gully erosion studies. Most of the orthophotographs would be, at least, suitable for the monitoring of permanent gullies, mainly those with the largest scales or the minimum pixel size in the case of orthophotographs (i.e. photographs and orthophotographs of the years 1977–1983, 2002 and 2006).

Conclusions

A set of 8 different series of aerial photographs or orthophotographs were located in Spain covering the whole country. Their characteristics were quite diverse, differing in scales, formats and resolution. Photographs are delivered by different departments of the Spanish Public Administration: the Photographic and Cartographic Center of the Spanish Air Army (CECAF: http://www.ejercitodelaire.mde.es/ea/pag), the National Center for Geographical Information (CNIG: http://www.cnig.es/) and other public agencies related with spatial information (such as the cadaster or Agricultural Ministry: http://www.catastro.meh.es/ and http://www.marm.es/ respectively).

None of the orthophotographs proved to be suitable for the monitoring and analysis of rills or ephemeral gullies. In addition, the temporal resolution generally used in rill and ephemeral gully erosion studies is lower than the time intervals between consecutive photographs or orthophotographs. Most of the photographs and orthophotographs proved, at least, to be suitable for their use in studies of permanent gullies, allowing the monitoring of medium and long-term erosion rates since 1945.

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