

## Evaluating the use of old cadastral maps

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### ABSTRACT

The old cadastral maps of the Spanish General Directorate for Cadastre (DGC) have always been in great demand. It was decided in 2012 to make an initial inventory of these maps with the type of information available, physical location, and condition. Subsequently, to evaluate their possible use, the inventory was examined to investigate whether these maps could be geographically referenced and made available on a geoportal. Several years later, it was determined that the inventory needed to be updated with a series of improvements (expanding the fields so that they become clearer, homogeneous, and more easily handled by software). A questionnaire was issued to technical specialists on property boundaries. As a principal conclusion we can highlight that the use of old cadastral maps in Spain is of great importance. The information on these maps is widely demanded by technical and legal experts who consider that an update and revision of the DGC inventory is essential. It is crucial that old cadastral maps are digitised and made available online, preferably free of charge and through an easy-to-use geoportal. The information on these maps helps to resolve property boundary disputes and has many other uses. Investment in the economic and human resources needed to preserve and publish these maps is essential given their great value.

### 1. Introduction

Regarding the preservation of old or historical maps worldwide, we can find old map services in Austria (Habsburg Empire) ([“Habsburg Empire-Cadastral maps \(XIX. century\), 2020](#)), Canada ([“Historic Cartography, 2020](#)), the United Kingdom ([“Historical map archives, 2020](#)), Russia ([“History, 2020](#)), and many other nations.

Old maps have various uses, the most common being the reconstruction of land use, analyses of changes in land cover and landscape ([Fuchs et al., 2015](#); [Kaim et al., 2016](#); [Pindoizzi et al., 2016](#)); and studies made in combination with aerial photography ([Forejt et al., 2017](#); [Claeys et al., 2019](#)). Old maps are also used when it is important to quantify the geometric and thematic precision of other sources ([Pindoizzi et al., 2016](#)).

At an international level in the cadastre, old cadastral maps (OCM) are used for many purposes ([Brumana et al., 2013](#); [Femenia-Ribera et al., 2013](#); [Follin et al., 2016](#); [Zaragozí et al., 2019](#)). These maps can be used for the reconstruction of past patterns of tilled fields using GIS for marking territorial boundaries ([Domaas, 2007](#)), for mapping non-forested areas using aerial photographs ([Skaloš and Engstová, 2010](#)), for analysing land-cover and structural changes in the cultural

landscape ([Hamre et al., 2007](#)), or for assessing the loss of wetlands ([Hesslerová et al., 2016](#)).

Old cadastral maps are valuable sources for historians when studying the social and economic background of changes in land use or ownership ([Kim et al., 2014](#)). Such maps offer great potential when digitised, geo-referenced, and combined with topographic surveys ([Wolfart, 2008](#); [Hamre et al., 2007](#)).

In Spain, the old cadastral maps of the Spanish General Directorate for Cadastre (DGC) have always been in great demand. Printed copies and/or digital information are kept in cadastre offices and historical archives. However, conservation is expensive and the need for further investment is being considered. The justification for such investment depends on the usefulness of the information in the maps.

The DGC defines old cadastral maps as: ‘all cadastral maps that are in use but no longer represent the current cadastral situation. The various territorial and regional offices have an excellent heritage of old maps with the associated alphanumeric information’ ([DGC, 2020b](#)).

Although the term ‘old’ ([International Cartographic Association, 1973](#); [Collier, 1975](#)) is the correct definition for this type of map, the Spanish language definition uses the word ‘*histórica*’. In the DGC, this type of map is usually termed ‘Cartografía Histórica Catastral’. Although

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the concept '*histórica*' is not strictly correct (Crespo Sanz and Fernández Wyttenbach, 2011; Crespo, 2014), it remains the most commonly used word for the concept of 'old'. Therefore, in Spanish the term '*histórica*' is used throughout the research, while the more exact term 'old' is used in this English translation for a better international understanding (as Crespo explains in his study).

Therefore, this study evaluates the use of old cadastral maps in Spain, mainly in matters related to property boundaries (although their usefulness in other areas is also considered).

For this, a brief introduction to the cadastre, cartography, property boundaries, and the old cadastral maps in Spain is first made. In 2012 an inventory was made of the old maps kept by the DGC; and a geoportal was developed in 2017 to facilitate the access to the inventory data. A questionnaire was issued in 2019 to professionals with extensive experience in property boundaries to assess the usefulness of these maps. Finally, a review and update of the inventory was made.

The usefulness of the old cadastral maps is mainly shown through the opinions of these technical specialists, and the main use is to help locate boundaries that are not apparent but exist on these maps. It is therefore necessary to establish policies for their archival and protection, and this leads to a study of how these maps can be published by the DGC.

## 2. Old cadastral maps (OCM) in Spain

Spain is a nation in south-western Europe and has been a member of the European Union since 1986. It has a total area of 505,944 km<sup>2</sup> (INE, 2018) with 1903 kilometres of land borders and 4964 kilometres of coastline. The population is approximately 46.5 million, and Spain ranks 15th in the world in terms of gross domestic product (International Monetary Fund (IMF), 2019). In addition to a central government, there are 17 regional states with their own powers in areas such as urbanism, health, and education. These regional states are divided into provinces (50 in total) and each province independently manages its own provincial historical archives (PHAs) that contain many old maps. Some municipalities have also archived local old maps.

### 2.1. Cadastre and old cartography

The Spanish Directorate General for Cadastre (DGC) manages the cadastre of 7603 of the 8124 municipalities in Spain (cadastrals in the regions of the Basque Country and Navarre are managed separately). The DGC is part of the Spanish finance ministry and its main function (although not its only function) is to collect property taxes (Lisec and Navratil, 2014). Its database contains some 92 million properties (DGC, 2020a). A digital cadastral database is a major investment for a jurisdiction tasked with the administration of land boundaries (Thompson, 2015). The DGC has provincial cadastre offices responsible for producing and maintaining provincial cadastral information. The management and coordination of work is handled in a centralised manner from the DGC in Madrid.

The land registries operate separately from the cadastre. The cadastre and land registries have always been independent from each other and pursue different objectives; the cadastre is based on maps and its basic aim is to levy tax. Its basic unit is the 'cadastral parcel'. The land registry (reporting to the ministry of justice) is a voluntary register of property rights. When it was founded, the land registry lacked any mapped records; and the basic unit was the 'land registry unit'. This unit often coincides with the cadastral parcel, but not always (Femenia-Ribera et al., 2021).

The DGC makes digital maps available for all the territory in vectorial format. Public lands appear as blank spaces as they do not pay property taxes and were therefore excluded. Public lands were indirectly delimited as blank polygons on the old maps. However, current legislation now requires the inclusion of public lands in cadastral maps. Paper maps were originally published at rural scales of 1/2000 and 1/5000; or at urban scales of 1/500 and 1/1000.

A major project was completed in the 1990s to vectorise all the cadastral paper maps (using various techniques). Through the website of the Cadastre Electronic Office (SEC in Spanish) (Fig. 1), the public can freely access all the information (except for protected data). This website has been available since 2005. More than 1,160,000 online queries were received by the electronic office in 2019, and most queries were about cadastral maps. The following formats can be downloaded from the electronic office: xml, dxf, gml, u gml, shp; and the office also offers Inspire Cadastral Cartography Services (DGC, 2021a).

The cadastre was originally the responsibility of the Instituto Geográfico y Catastral (IGC), now known as the Instituto Geográfico Nacional (IGN). However, in the 1980s an independent organisation – currently called the DGC – was created for all cadastral activities. For this reason, most of this cartography was published by the IGC, with some copies in digital format published by the IGN.

All cadastral maps (rural and urban) have been available since 2003, and much of the information was derived from the digitisation of the original paper maps (Ignjatić et al., 2018; Walford, 2005). The old maps were made using a variety of techniques and the oldest date from the '*advances cadastral*' series is 1895 (Pro-Ruíz, 1992). After the cadastral maps were vectorised, they were updated over time. The physical condition of the old paper maps depended on where and how they were stored. Some are stored in paper format in provincial cadastre offices in varying states of preservation, while others have been digitised in tiff (Fig. 2), pdf, jpg, or ecw formats. Some have also been lost. A lack of resources has caused many provincial cadastre offices to pass the task of conserving maps that are no longer in use to the provincial governments and their provincial historical archives (PHAs). The PHAs conserve a wide variety of historical documents regarding the province, and since they have started conserving old cadastral maps, they report that these maps have become one of the most consulted sources in their archives.

In Spain there is legislation regarding archives and documentary heritage (BOE, 2021) and the documents and maps found in historical archives are considered heritage. The 1985 Historical Cultural Heritage Act requires holders of cultural heritage documents to preserve the documents and allow access to researchers.

### 2.2. History of cadastral mapping in Spain

The Instituto Geográfico y Catastral (IGC) was created in 1870 to carry out a cadastre of the whole of Spain and for this purpose the national geodetic network had first to be created (IGN, 2021). Previously, there were literal cadastral documents called '*amillaramientos*' in which each citizen described the properties he or she owned. But as this information was used for the payment of taxes, the areas were often under-declared and fraud was common. There were isolated cadastral maps in some areas – but these were very few given the technical difficulties in mapping at the time. To prevent fraud, the government carried out the cadastral mapping of the whole of Spain. The 1906 Cadastre Act marked the beginning of the cadastre as we know it today (Pro-Ruíz, 1992) and this legislation was most recently revised in 2004.

The first steps at the end of the nineteenth century were to mark the boundaries of the municipalities with the agreement of the town councils. These were measured using classical surveying techniques (topographical survey made on the area with a tachometer, total station, and so on). The municipalities were then divided into polygons, and cadastral plots were measured. All cadastral plots in Spain are now measured, but this has been done over many years and using a variety of techniques, according to the legislation of the day. Measurements were made by municipalities using their own approaches. The cadastral parcels of the polygons (cadastral maps) were measured by various means including: freehand sketches; classical surveying; photogrammetry; aerial photography; and orthophotography (Berné Valero and Femenia-Ribera, 2000).

The best maps were those measured by classical surveying, but these were no longer made after the 1980s, when the IGC became the Instituto





Fig. 1. Example of a cadastre electronic office map for printing based on orthophotography from the National Aerial Orthophotography Plan (PNOA), 2020. Source: DGC

Geográfico Nacional (IGN) and the responsibility for the cadastre passed to the current DGC. These high-quality classical maps are known as topographical cadastral maps (TCMs) (Fig. 2). Although they are no longer produced, they remain the most widely used maps for the delimitation of property and, above all, for defining boundaries. They are also used in land registries (Femenia-Ribera et al., 2016). Unfortunately, these maps were not produced for all municipalities.

### 2.3. Demarcation of property in Spain

This study assesses the use of the old maps in solving problems related to property boundaries, such as: identification of cadastral parcels; definition of boundaries; area size calculations; existence or otherwise of buildings and/or year of construction; corrections to the cadastre; and so on.

Concepts that relate to property boundaries in Spain involve the definition of the boundaries of a series of rights on parcels of land belonging to one or several owners (private individuals or public administrations). This topic includes everything related to the identification of cadastral parcels and/or land registry units (and/or boundary markers) in cases where their location is approximately known or completely unknown. These may be boundaries between land owned by individuals or administrations (public lands: livestock migration routes, coastlines, mountains, rivers, public roads, mines, and so on); administration-administration boundaries (municipal boundaries, and international borders). Also included are metric calculations of distances, volumes, and areas; easements (more commonly those of passage, although they can be of light and views, party walls, and water access) between individuals or public lands; locations and existence or

otherwise of buildings and/or infrastructure; boundaries of administrative concessions, and so on. This is also complemented by all the steps that lead to, or help in, the resolution of a dispute; cadastral corrections; inscriptions, or rectifications in the land registry; communications with administrations; and court reports about property demarcation. It is often necessary to indicate the boundaries of land owned by individuals or administrations, and recent legislation now obliges the registration of public land in both cadastre and land registry.

There is currently no specialist profession in Spain with exclusive skills in these areas or in the legislation that deals with these issues. The generic concept of a 'competent specialist' is usually used. See for example, Act 13/2015 of 24 June on the Reform of Mortgage Legislation approved by Decree of 8 February 1946, and the consolidated text of the Cadastre Act, approved by Royal Legislative Decree 1/2004, of 5 March 2015.

Cadastral maps have no legal significance, but Act 13/2015 facilitates mapping coordination between cadastre and land registry. Cadastral parcels coordinated with land registered properties acquire legal validity (Femenia-Ribera and Mora-Navarro, 2018; Femenia-Ribera et al., 2021). Although OCMs have no legal significance, they are used in many cases as reliable evidence in conflicts, in the absence of other evidence (since the land registry at that time did not use maps). This approach, based on detailed technical reports, has been upheld in several court cases.

### 2.4. Example of old cadastral maps used in a boundary demarcation

This section presents a practical case in which the aim is to stake out a boundary that does not currently exist, but which nevertheless appears

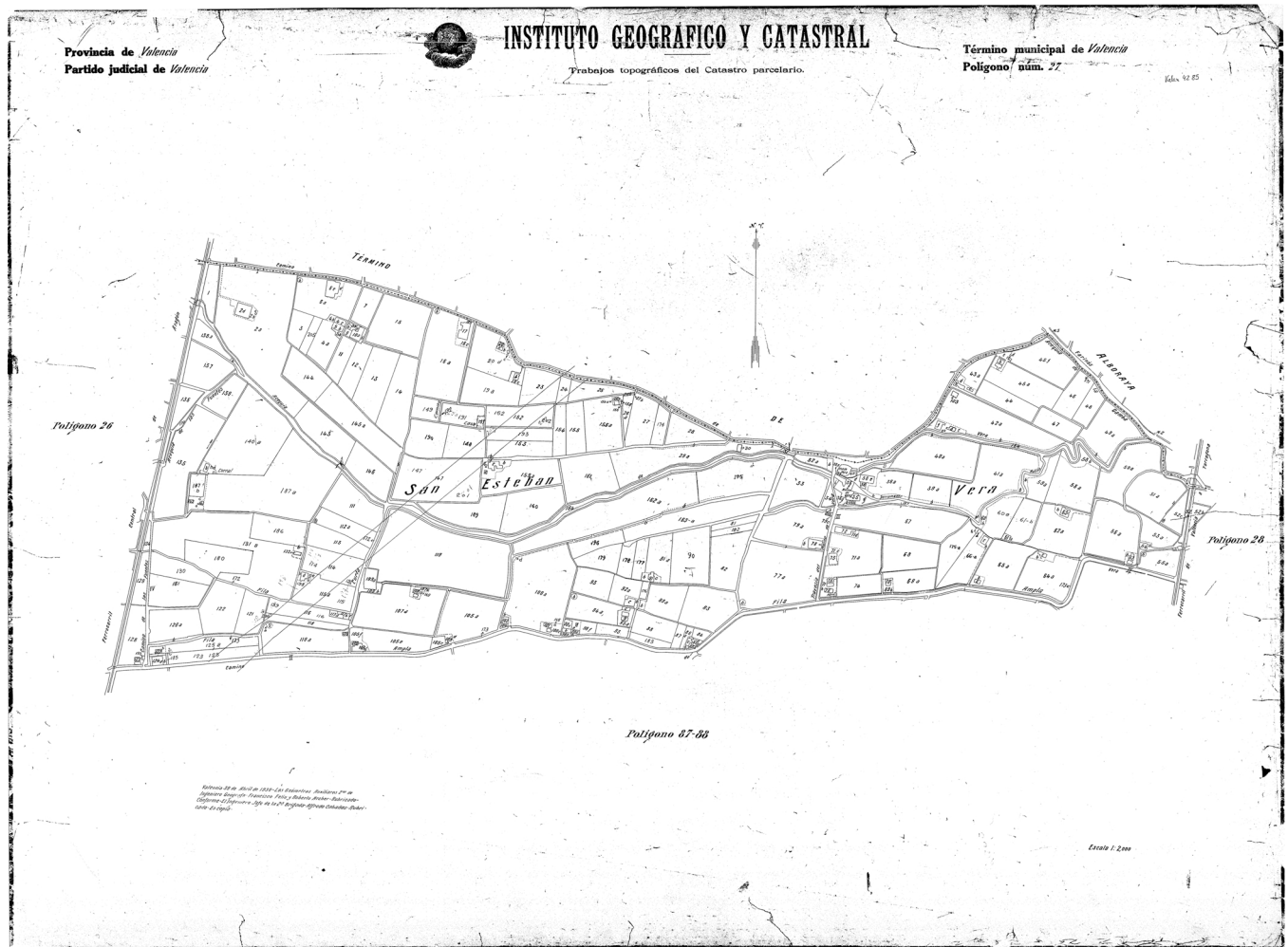


Fig. 2. Old cadastral map: topographical cadastral maps (TCM), 1930.  
Source: DGC

mapped on a topographical cadastral map (TCM) from 1960. The map is at a scale of 1/5000. Fig. 3 shows the map with current cadastral cartography superimposed. The objective is to stake out the former parcel 113 on the TCM. It should be noted that the map had deteriorated in the parts where it was folded due to continuous use, and care was taken to protect the map.

The TCM uses relative and planar coordinates, and the current cadastre uses the EPSG 25830 coordinate system (UTM projection, zone 30, ETRS 89 ellipsoid). To obtain the TCM in the EPSG 25830 coordinate system, at least two homologous points are necessary – although it is advisable to use at least four or more to obtain an over-abundance of data and so obtain estimations of errors in the fit. The homologous points should surround the study area. It is often difficult to find homologous points in two mappings made 60 years apart as roads, parcel boundaries, and buildings change over time. A Helmert coordinate transformation is made once the homologous points have been located. There are other types of transformations, such as projective or polynomials. These transformations deform the original OCM image by areas to match the control points. These transformations can only be used when the original image map has internal deformations. The OCM must have no internal deformations nor differing X and Y axis scales. For this reason, a Helmert transformation with one scale factor is commonly used.

A least squares fit is made in search of the displacement, rotation, and scale factor that minimises the differences between the common point coordinates: the original coordinates being obtained from the

current cadastre (although they could also be obtained by other means) and the transformed coordinates of the TCM. Table 1 shows the result of the fit.

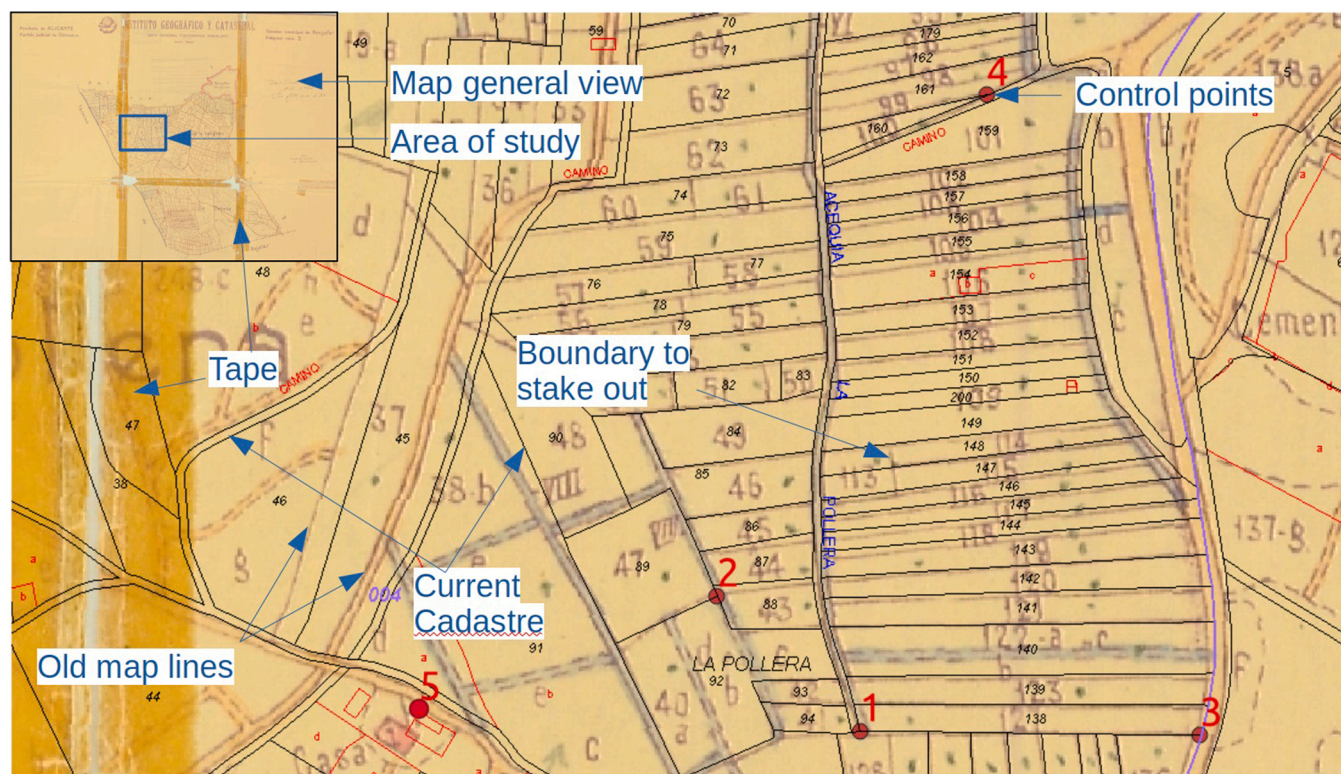
In Table 1, the column:

- ‘Number’ is the number of the homologous point,
- ‘Enable’ indicates if the point is used for the fit.
- ‘Pixel X’ and ‘Pixel Y’ are the pixel coordinates before the transformation.
- ‘Map X’ and ‘Map Y’ are the coordinates of the homologous points in the target coordinate system (in this case EPSG 25830)
- ‘dX’ and ‘dY’ are the differences found between the transformed pixel coordinates and the coordinates of the homologous points.

As can be seen, both maps have errors and so there is no exact solution as the transformation depends on the points chosen for the fit. Differences can exist between the coordinates of the current map and the coordinates of the old map once adjusted for various reasons: erroneous identification of homologous points; errors in the current cadastre; errors in the old maps; deformations; tears; and dilations in the paper of the old map.

Once the best fit is obtained, the stakeout coordinates can be obtained from the old map as it is georeferenced in a current coordinate system. The reliability of these stakeout coordinates is obtained from the results of the fit, and in the example, the stakeout coordinates would be considered to have a standard deviation of 3.2 m in the X-coordinate and





**Fig. 3.** Geo-referencing a TCM from 1960 with the current cadastral map to obtain stakeout coordinates. Source: authors

**Table 1**  
Table of control points. Image and map coordinates and differences between the adjusted coordinates and map coordinates.

| Number                    | Enable | Pixel X | Pixel Y  | Map X      | Map Y        | dX          | dY          |
|---------------------------|--------|---------|----------|------------|--------------|-------------|-------------|
| 1                         | true   | 1876.42 | -1752.89 | 697,527.09 | 4,216,434.82 | 4.31        | -1.59       |
| 2                         | true   | 1799.23 | -1686.64 | 697,467.94 | 4,216,490.73 | -1.81       | 0.62        |
| 3                         | true   | 2032.98 | -1750.39 | 697,668.89 | 4,216,432.80 | -2.96       | 0.14        |
| 4                         | true   | 1927.83 | -1441.64 | 697,579.96 | 4,216,698.97 | 0.46        | 0.83        |
| 5                         | false  | 1642.28 | -1749.53 | 697,344.63 | 4,216,443.68 | -14.31      | -3.90       |
| <b>Standard deviation</b> |        |         |          |            |              | <b>3.21</b> | <b>1.10</b> |

Source: authors.

1.1 m in the Y-coordinate.

### 3. General methodology

As an initial step, the DGC wanted to exactly quantify the inventory of existing OCMs in the various management units (in 2012). An analysis of the data revealed that a considerable investment is needed due to the large number of existing documents, many of which had not been digitised. At that time, various alternatives were studied, but they were not feasible due to the high cost of digitising documents. The inventory is available on the DGC website to help users discover which maps are available and where they can be obtained, as many of the queries are about existence of certain documents and their location. Many of the OCMs are in provincial historical archives (PHAs) that do not report to the DGC.

Research continues on possible methods of publishing, through bibliographic studies, and on the use of OCMs by specialists and citizens. To facilitate access to inventory data, the development of a geoportal is being considered, which will also enable an evaluation of the coherence of the data obtained and geospatial analyses (2017).

To assess how the maps are used by specialists, the qualitative methodology used in the survey technique was aimed at specialists in

property delimitation (through contacts and professional associations). PHA staff who also receive many property delimitation queries were also surveyed. The initial survey questions are about the profile of the respondent, and this information enables a classification according to profiles. To assess the importance of various aspects, respondents are asked to rate importance from 0 to 10 (from no importance to great importance).

Following the results of the first inventory regarding the geoportal, the investment that needs to be made in OCM can be determined. To this end, the DGC sent the provincial cadastre offices a new questionnaire that enabled gathering more up to date data. This time a questionnaire structure was designed to avoid possible inconsistencies in entered data (2019–2020).

### 4. Old cadastral map inventory

Increasing numbers of professionals and individuals are requesting old maps from the DGC for a variety of uses. Due to the large volume of requests, the DGC decided to make a detailed inventory of all the types of maps existing in the cadastre offices and provincial historical archives (Santos Pérez, 2012). This inventory was prepared following a survey that was finished in 2012.

For this survey, a questionnaire was prepared and sent to each of the 33 territorial and 15 regional management offices and the data had to be returned within four months. The questions were related in two blocks, questions about rural and urban maps (depending on the type of land shown). Each block of questions was in an independent questionnaire. The territorial and regional offices are divided into rural and urban departments and this division dates back to the antecedents of current maps. In each office, these questionnaires may have been completed by several individuals. For this inventory, information was requested on: map product type (name depending on the measurement technique used); publication date; map type (paper, polyester, photographic paper, format tiff, and so on); scale; area shown; location; and whether it was in raster digital format (yes or no) (DGC, 2021b) (Table 2). The state of conservation of the maps depended on the conditions in each office and results varied across the country.

This information was returned to the DGC by the provincial cadastre offices and added to a database (MS Access) with information showing the maps held by the provincial cadastre offices, and whether the maps were in rural or urban scales, and the information was listed in alphabetic order by municipalities. The outcome of questionnaire-based survey is available on the DGC website in the ‘cadastral products’ section in compressed zip files (DGC, 2020b).

The inventory can be seen on the DGC website.<sup>1</sup> An extract from this inventory can be seen in Table 1 for the municipality of Pego in the province of Alicante.

Some 25,000 downloads of the inventory were made from 2015 to 2021. A story in a specialised blog in 2012 about the publication of the inventory has been the most visited entry for the blog from 2010 to 2021 (Femenia-Ribera, 2012). This was the first inventory to reveal what documentation existed. However, over time the use of this information by those who requested it has meant that the location of some cadastral maps has changed, some documents have been subsequently digitised, and others have been lost. Many users of the portal expect to find every map available in digital format but are informed that they must request the maps directly from each provincial cadastre office. The most demanded information is regarding the topographical cadastral maps: the year of their publication; the place where they are stored (the provincial historical archives or provincial cadastre offices); and whether they are available in digital format.

### 5. Geoportal development

The format of the inventory of 2012 was inappropriate for inexpert users of databases as it was available as a mdb file that had to be downloaded from the web, and the maps needed to be manually searched by municipality. To improve accessibility (Brovelli et al., 2012) and usefulness (Cuca et al., 2013) an initial geoportal with this information was designed and developed in 2017 as part of an academic project (Fig. 4). Thanks to the growth of geoportal products and online cartographic platforms, access to spatial data has never been so easy for so many people (Panchaud et al., 2017).

The geoportal was created with open source software because such software is increasingly stable, sophisticated, and competitive (Brovelli et al., 2017). Geoserver was chosen as the map server as it is open-source and designed for interoperability, data discovery, and dissemination of spatial data using open standards (Jankovic et al., 2018).

The main objective of the geoportal was to facilitate the location of old maps by municipality, according to the inventory carried out in 2012. It is possible to see the maps kept by each municipality by clicking on a municipality on the map. To locate a municipality, start with the region and province, and the geoportal then zooms in. It is also possible to discover which municipalities contain certain types of maps. The

<sup>1</sup> DGC website / Productos: <http://www.catastro.meh.es/esp/productos.asp> (in ‘Consulta de Cartografía Histórica Catastral’)

**Table 2** Extract from OCM inventory of DGC, DGC provincial cadastre offices, Valencia region, 2012: Municipality of Pego, Alicante. Codification in Spanish.

| URBAN id | Province code | Province name | Scanned              | DGC prov office code | Municipality code | Municipality            | Product type                | Year                    | Map type        | Scale | Area           | Number of maps | Location                            | Digital format | Observations |
|----------|---------------|---------------|----------------------|----------------------|-------------------|-------------------------|-----------------------------|-------------------------|-----------------|-------|----------------|----------------|-------------------------------------|----------------|--------------|
| 387      | 03            | ALICANTE      | No                   | 032                  | 032102            | Pego                    | Implantacion (50-60)        |                         | polyester       | 1000  |                | 5              | PHA (provincial historical archive) | No             |              |
| 388      | 03            | ALICANTE      | No                   | 032                  | 032102            | Pego                    | Implantacion (50-60)        |                         | polyester       | 5000  |                | 1              | PHA                                 | No             |              |
| 389      | 03            | ALICANTE      | No                   | 032                  | 032102            | Pego                    | Primeras revisiones (80-90) | 1989                    | polyester       | 1000  | 326            | 21             | DGC PO (DGC prov office)            | No             |              |
| 390      | 03            | ALICANTE      | Yes                  | 032                  | 032102            | Pego                    | Primeras revisiones (80-90) | 1989                    | Vegetable paper | 5000  | 5280           | 11             | DGC PO                              | No             |              |
| RURAL id | Province name | Scanned       | DGC prov office code | Municipality code    | Municipality      | Product type            | Year                        | Map type                | Scale           | Area  | Number of maps | Location       | Digital format                      | Observations   |              |
| 328      | ALICANTE      | No            | 032                  | 032102               | Pego              | Avance catastral        | 1916                        | opaque paper            |                 |       |                | PHA            | No                                  |                |              |
| 329      | ALICANTE      | No            | 032                  | 032102               | Pego              | Cadastral on orthophoto | 2004                        | opaque paper /polyester | 5000            | 5280  |                | DGC PO         | No                                  |                |              |

Source: DGC.



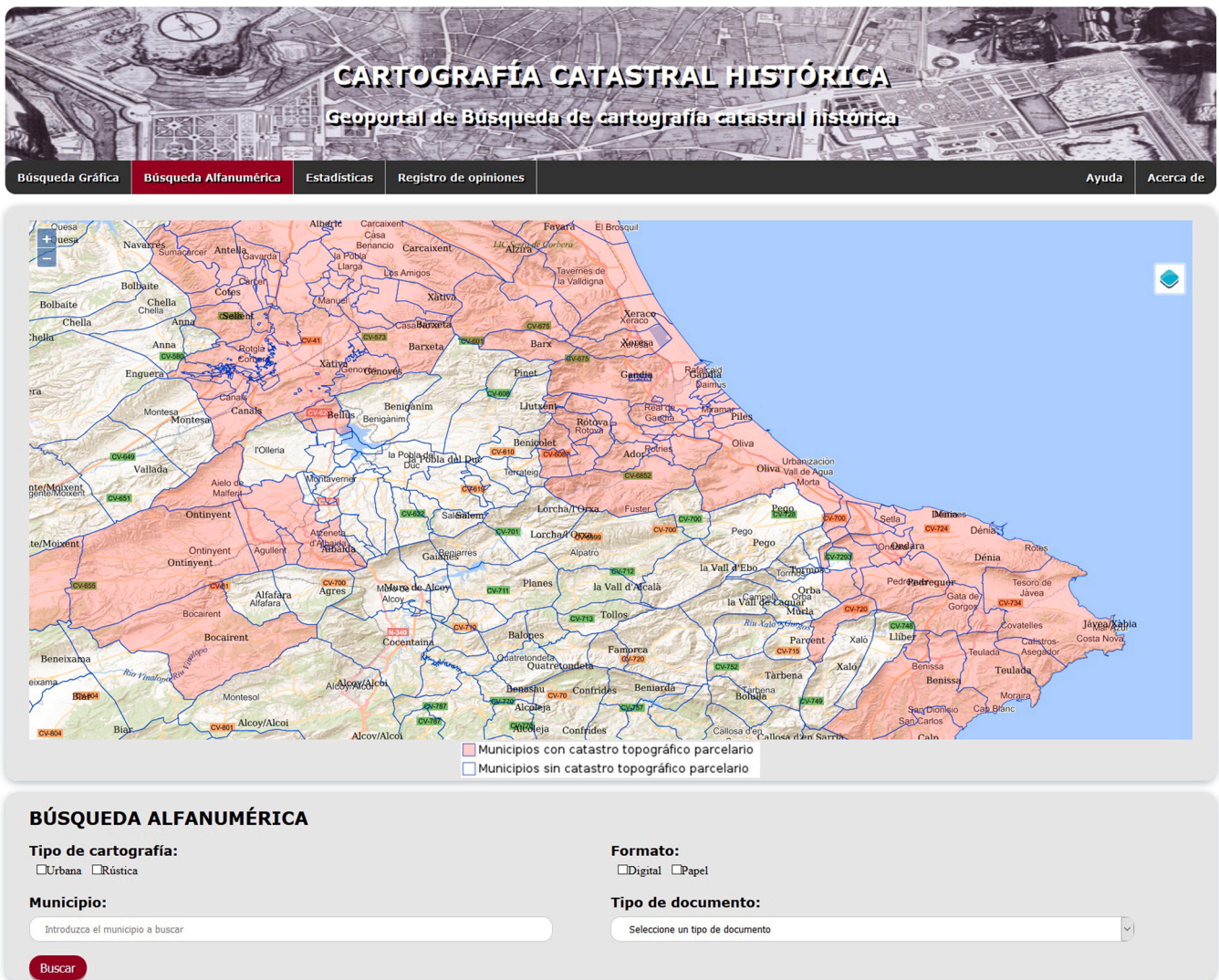


Fig. 4. Draft geoportal OCM.  
Source: authors

geoportal displays a list with the selected municipalities that contain a specified type of map. A municipality is zoomed in on by clicking and the old maps available for that municipality are displayed.

Two inventory tables were used to achieve the above objectives, one for rural maps and another for urban maps. To enable graphic searching and zooming into municipalities, three more tables with geometry were added: region, provinces, and municipalities. Thanks to the fact that the inventory tables contained the region, province, and municipality codes, it was possible to link these new tables to make spatial operations possible.

A data model had not been made for the DGC's old map geoportal inventory database, as the original plan was to make an approximate inventory rather than a geoportal. For this reason, the data showed inconsistencies, especially as fields contained a multitude of values that meant the same thing in different words. For example, for the scale field, the following values can be found: '1/5000', '1:5000', '1: 5000', '5000', while the province field shows 'Alicante', 'Alacant' or 'ALICANTE', and so on. This makes analysis difficult.

Due to the inconsistencies in the database values, a homogenisation of the data was made. For this, an update of the database was carried out, assigning the same value to records that clearly showed the same information but with differently written values.

The geoportal also asked users if the geoportal is useful to them and

some 75% of those who completed this section considered it very useful.

### 5.1. Inventory and geoportal conclusions

The DGC 2012 inventory, the geoportal, and the multitude of requests for maps stored by the DGC and the provincial archives suggested that it was time to update the inventory by changing and expanding the fields so that the information would be clearer, homogeneous, unambiguous, and more easily handled by software.

The suggestion that the provincial cadastre offices should update their inventories was proposed in 2018. It was also considered worthwhile asking whether all the old maps should be gathered, digitised, and made available at the cadastre electronic office. After analysing the inventory, the economic and human investment needed can be quantified. Before deciding to move forward, an evaluation of their use was planned for 2019.

## 6. Survey on the use of old maps in the evaluation of property boundaries

### 6.1. Methodology: design, testing, distribution

A preliminary study was made to propose the best survey

questionnaire design in terms of the number of questions, response time, type of questions, and so on (Casas Anguita et al., 2003a, 2003b; Sandoval Girón, 2015). Before distribution, testing was performed with several collaborators to check the questionnaire for possible errors and make improvements. Survey questionnaires were distributed and answered on the internet.

To carry out the survey, various tools were reviewed, especially those that were free of charge and where data collection would enable further analysis (we finally used Google Forms). A total of 20 questions took some seven minutes to answer and a total of 382 respondents participated. The survey questionnaire was completely open and designed for Spain.

The questionnaire was made available during February, March, and April 2019. It was distributed mainly through personal contacts working in fields related to property boundaries, as well as national and regional professional associations (mostly in the provinces of Valencia and Alicante) and with emailings to various provincial historical archives.

After data collection and debugging, a data analysis was made, and the results were compiled in a report.

After the deadline to complete the survey, the data was collected in Excel format. A similar format was sought so that it would be possible to differentiate and analyse certain questions based on specific profiles of the respondents. Although the questionnaire was initially open to any profile, it was mostly completed by technical specialists with experience in property boundary issues. These professionals have the best understanding of cadastral mapping and can best evaluate its use; and their opinion is therefore considered especially important.

## 6.2. Analysis of the recompiled information and results

The 382 initial surveys were generally reviewed, and 379 were selected as containing reliable data for analysing the environment in Spain after an initial filtering. Each of the answers and profiles of the respondents were analysed to see if the data were coherent, and the chronological order of the answers was consistent. Incomplete or repeated surveys were eliminated. The observations section provided a great deal of information about the subject knowledge of the specialists. The distribution of the survey through groups and professional contacts was adequate. Given the uniform profile of the respondents, it was decided to analyse all the results together, while not ruling out any pre-selections in the future.

Closed questions were alternated with multiple choice and open questions. Examples:

- Did you know that the DGC carried out an inventory of its old cadastral maps in 2012?
- Indicate from 0 to 10 how important you consider old cadastral maps to be in assisting you to resolve property delimitation conflicts. With 0 being of no importance and 10 being of great importance.
- Indicate, in addition property delimitation, other purposes (maximum three) for which you consider old cadastral maps to be important.

Due to the limitations of Google Forms, the formats of some of the open questions and answers were unified. In the closed questions, some respondents commented as if they were open-style questions. Space was also left at the end of each question for an open-ended response. The final question was left for remarks, suggestions, or comments, and was widely used by respondents (22% of the total). Observations were also made about the absence of certain professions and work environments that were not initially considered. This information is useful for future surveys.

Various pie charts or histograms were made with the data of the 379 evaluated questionnaires. Although the draft questionnaire was checked by a group of people with various profiles, there were some sections that were overlooked. In some open questions this caused a multitude of answers and instead of producing confusing graphics for analysis, we

grouped these answers by subject with a limit of ten contributions.

We can highlight as results:

- Most respondents were professional technical specialists with extensive experience in issues of property boundaries; 1 in 4 respondents were women. A question was included to discover the gender of the specialists and this information was needed help promote technological studies for women. The number of women choosing this type of degree is decreasing.<sup>2</sup>
- A large proportion of the respondents come from the provinces of Valencia (18%), Alicante (11%), Madrid (8%), and Barcelona (8%). The majority age range was 40–49 (42.4%), followed by 50–59 (23%), and then 30–39 (22.2%). The vast majority had university studies (93.6%) and had experience working on issues related to property boundaries (72%). The respondents were engineers specialised in topography, geomatics, and map-making, followed by professionals working in architecture/surveying and geography, as well as legal specialists and agricultural/agronomic engineers. Some 38.3% were self-employed, 35.6% worked in the public administration, 21.9% in private companies, 10.3% in education, and 5.5% in research.
- Most of the respondents had experience in topics related to property boundaries (92.1%), while 61.5% of the respondents had ten or more years of experience. The vast majority had around 15–20 years of experience (Fig. 5). In this latter case, the number of women drops to 1 in 5.
- More than half of the respondents (52.8%) are aware of the existence of the DGC inventory of old cadastral maps.
- 57% of the responses give the highest importance to updating and reviewing the inventory (Fig. 6). Some 73.1% attach the utmost importance to making the old cadastral maps available in an online digital format. Some 53.8% gave the highest importance to the social and economic value of the old cadastral maps being readily available online. Some 56.6% gave great importance to the fact that the maps help them resolve property boundary conflicts. Some 63.2% gave the utmost importance to creating a geoportal with reliable and detailed information on the old map inventory, and 51.2% attach great importance to investing the economic and human resources necessary for the preservation and publication of the heritage contained within old cadastral maps.
- Some 59.9% estimate the time spent obtaining a map at ten or fewer hours; however, 12.7% estimate spending 100 or more hours. Some 45.6% estimate the cost saved by obtaining a map to be €50 or less each time; 17.5% estimate the cost at €200 or more. Regarding cost, the vast majority (83.9%) consider that the maps should be free. There were many general comments about the costs, not of the maps themselves, but of the time spent on travel, making requests, and completing paperwork.
- The following are the other uses for old cadastral maps considered in order of importance: surveying plots; spatial planning; protection of public lands; research; urban planning; recognition of the legal existence of a building due to its proven age; environmental impact studies; and risk assessments. Other uses have also been suggested, such as: preservation of ancient placenames as a historical and linguistic source; establishment of municipal boundaries; landscape studies; mining; expropriations; socioeconomic purposes; detection of mass war graves; landowner identification; location of old hydraulic elements such as water wheels and waterfalls, lime kilns, mills, and so on.
- Observations, suggestions, or comments were often made by the respondents (82 comments were received from 21.6% of the total number of respondents). Comments ranged from congratulations for

<sup>2</sup> Ministry of Education. STEAM Women: <https://www.educacionyfp.gob.es/mc/intercambia/mujeres-steam/estrategia-steam-mefp.html>



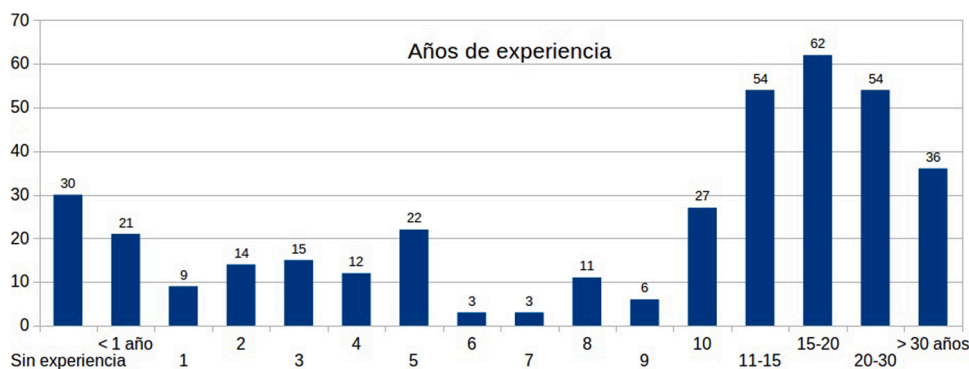


Fig. 5. Histogram showing years of experience in relation to topics on property boundaries.  
Source: authors

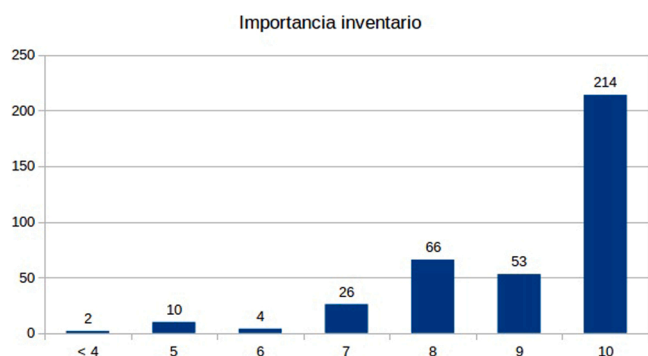


Fig. 6. Histogram showing the importance given for an update and review of the DGC inventory. No importance being 0 and great importance being 10.  
Source: authors

the initiative, remarks about the importance of these maps, specific explanations about the situation of old maps in each area. There were also some criticisms and requests – such as having geo-referenced old maps and alphanumeric data for owners (which would be extremely useful). This leads us to underline the high level of interest among respondents.

- In the survey, archives and professional associations were asked several questions related to opinions and requests for this type of information. The Spanish Engineering in Geomatics and Land Surveying Association (in Spanish: COIGT) has acquired OCM to facilitate access due to the large number of OCM requests related to demarcation of property.

## 7. Updated inventory

For the above-mentioned points, there is a need to update and improve the inventory with a prepared data model as part of the DGC's objectives plan. An instruction manual was created with a total of 22 fields to improve the inventory by incorporating a clear data model (generally for rural properties). The current survey is an improvement on the previous survey, and questionnaires were sent to provincial cadastre offices in May 2019 and returned by December 2019.

Once the inventory update survey was completed (Santos Pérez et al., 2019), it was calculated that there are some 650,000 documents stored in provincial cadastre offices, of which some 350,000 were digitised and some 70,000 geo-referenced for easier use (Burt et al., 2019). In addition, there were some 340,000 documents in the provincial historical archives. Some old maps were moved to the historical archives because of storage problems in some provincial cadastre offices.

## 8. Conclusions

The study has made it possible to verify the usefulness of making the old cadastral maps easily available on the internet. For this reason, the cadastre electronic office has already begun freely publishing all the old cadastral maps, starting in March 2021 with maps from the Madrid and Valencia provincial cadastre offices. Gradually, the rest of the provincial cadastre offices will be added as the digitisation process progresses. A digital certificate of identification is required to download these maps (DGC, 2021c).

The next step in the project, once the new database has been refined, will be to contract a specialised company to scan all the documents that are not yet digitised in the provincial cadastre offices. A study will be made as to whether it is possible to geo-reference the maps in the same process for a reasonable price. Communication with provincial historical archives is fluid and attempts will be made to digitise the cadastral maps they are holding. The final step will be to ensure that all the information can be freely downloaded on the internet.

As general conclusions we can highlight:

- Designing a geoportal requires considerable effort in the design of the data model, data collection, and the programming of the front and back ends. But the result is a tool accessible to all users, who only need a browser to view, analyse, or download the data. A good initial design is essential to avoid repeating the same work.
- In terms of the information we analysed from the survey, we can say that the use of old cadastral maps is of great importance for indicating properties and there are many other uses. On a scale of 10, almost all respondents gave a score greater than or equal to 5 (99.3%) for aspects such as updating and reviewing the DGC inventory; that old cadastral maps should be available in a digital online format; the social and economic value of easily available access; the usefulness of old maps in resolving property boundary disputes; the value of a geoportal for the inventory; and the importance of investing the economic and human resources needed to preserve and publish old maps online. A large majority (around 60%) gave these tasks the greatest importance. Moreover, those surveyed who had ten or more years of experience were slightly more likely than average to give these tasks the highest priority.
- The responses regarding the time needed to obtain a map and its cost are heterogeneous, and reflect a multitude of factors (location, local provincial cadastre office, scale, type of map, and so on). Although the cost of the map itself is often remarked on, in most cases an attempt is made to assess the time spent obtaining maps (including hours of work, travel time, and paperwork) and this is the greatest problem posed by the respondents. Although the vast majority believe that the maps should be free; many would be willing to pay a minimal symbolic price to cover costs.

- For recovering boundaries, the specialists use in most cases the OCMs, and above all those maps made by classic topography, such as the TCMS.
- It is considered of great importance that old cadastral maps are easily accessible in digital formats online – such as through a geoportal. OCMs should be completely digitised and geo-referenced. The results of geo-referencing must also be published, as this metadata defines the possible uses: such as control points and errors. All the information must be presented in the same way – as in the Cadastre Electronic Office (in the case of Spain).
- This study shows something that may seem obvious for professionals involved in the demarcation of property but is not so obvious for non-specialist users: the usefulness of OCM. This research verifies and quantifies how the preservation and publication of old cadastral maps on the internet is a valuable public service.
- It is considered that investment in the financial and human resources needed for the preservation and publication of old cadastral maps is critical. Therefore, the allocation of human and economic resources should be considered a priority. A business model should be developed with basic cost recovery calculations.
- For these reasons, the DGC is already starting to follow the steps recommended by the UN to protect its digital heritage (ONU, 2012).

### Declaration of Competing Interest

We, Carmen Femenia-Ribera, Gaspar Mora-Navarro and Luis J. Santos Pérez are the authors of this original paper and we certify that the submission is original work and it is not under review at any other publication. No conflict of interest was reported by the authors

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### Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.landusepol.2022.105984](https://doi.org/10.1016/j.landusepol.2022.105984).

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