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From historical map to on-line 3D recreation: the 1861 cadastral map of Horta (Barcelona)

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Abstract

The recent study and classification of over 200 Catalan cadastral maps created in the 19th century has provided a valuable source of information about the rural landscape of the time. Moreover, it has been found that this cartographic information can be joined with data recorded in tax books known as *amillaramientos*, which provide statistics about land use, land ownership and quality of crops. By integrating both sources of information researchers from many disciplines can gain a better knowledge of 19th century Catalonia. If the information contained in the 1861 cadastral map of Horta and its corresponding amillaramiento is joined together, a planimetric map showing the distribution of land uses in the town can be created. However, by overlaying this new dataset on top of a DEM new 3D visualisations of the past can be created. The method described in this paper allows the systematic recreation of past Catalan landscapes by using cadastral maps of the 19th century, something which can be very useful to increase the scientific knowledge of the country. It also shows that the results can be distributed on-line, making them accessible to the public and multiplying the research impact of future findings.

1 19th century cadastral cartography in the Barcelona Province

One of the peculiarities of the Spanish tax system introduced in 1845 by the ruling Liberals was the lack of rural cadastre plots. This deficiency affected the Spanish tax system until well into the twentieth century. Thus, in 1846, the Spanish Government began to apply the Contribution of Properties, Cultivation and Livestock tax, which charged agricultural and livestock wealth of municipalities. The tax worked via a vertical spread quota system, with a certain element of arbitrariness, and was collected by the Spanish Treasury (Pro Ruiz 1992).

The quota system meant that the Treasury assigned to each of the different Spanish provinces –with some exceptions- a certain share of money to collect, the amount of which was defined by using vague and sometimes outdated information. Then the heads of the various provincial treasuries distributed the quota allocated to the province between the towns that were part of it. Finally, local authorities were responsible for distributing among local taxpayers a share of the land tax that had been assigned to their town (Vallejo Pousada 2010). Towns had, moreover, the obligation to deliver to the provincial fiscal authorities a document: the town's *amillaramiento* or tax assessment. The *amillaramiento* was a written document created by local authorities who numerically described the list of land and livestock taxpayers that lived in the town, both urban and rural (Llorente Roselló 2008). The information contained in these books allowed public servants to register the fiscal duties of each owner and town (Nadal et al. 2006). The management of this tax soon generated many fiscal conflicts. Firstly, they were created by councils that disagreed with the amount of land tax that had been assigned to them by the provincial Administration of Finance. Secondly, there were

those promoted by provincial Administrations of Finance in order to prevent tax evasion. And thirdly, those sponsored by private citizens who were unhappy with the amount of this tax assigned to them by the councils.

Due to all these conflicts, the government passed a law in 1847 whereby local councils that thought they had been unfairly overtaxed by at least 12% could file a claim before the authorities of the Treasury to adjust the amount allocated to the real amount of farming wealth and cattle the town had (Nadal et al. 2006). A year after the Ministry of Finance created provincial statistical committees nationwide, which were directed by public servants and composed by surveyors and agricultural experts. The function of these committees was to prevent tax fraud in the *amillaramientos* and to try to resolve tax disputes raised by the new fiscal law (Nadal, Urteaga & Muro 2006).

To resolve the generated conflicts, or just to avoid them, many municipalities decided when drawing up their *amillaramientos* to hire qualified surveyors –known as *agrimensores*- to measure the different plots in the existing rural municipality. As a result of their work, surveyors generated two different types of tax documents: the "Books of Measurements of Land" and a diverse and rich cartography of the rural composition of municipalities. The first type of documents informed about the number of the plot, the name of the taxpayer, the surface of the plot and the type of existing crop. In the province of Barcelona a total of 17 Books of Measurements of Land relevant to many municipalities were drawn between 1847 and 1852 (Nadal et al. 2006). The second type of documents contained the same type of information, but in this case expressed as a map. The preparation of land plot maps and atlases was mainly an

initiative of municipal nature, but also provincial authorities of the Treasury became involved. All this mapping activity generated three different types of cartographic documents: 1) parcel maps consist of a single sheet, usually of considerable size –like the Horta example- 2) atlas plots consisting of multiple pages, most of them presented bound, and 3) perimeter plans, in which were represented only the limits of the municipality. The latter was prepared by surveyors hired by provincial Administrations of Finance, as they were interested in knowing as fast as possible the exact surface of those municipalities which were thought to defraud the Treasury.

The elaboration all of this mapping activity was very expensive, which is why many councils only decided to carry it out in case of major conflicts with the provincial authorities or in situations of intense conflict between some of the prominent local taxpayers. In fact, the area most intensely mapped was Catalonia and the Balearic Islands (Nadal et al. 2006, Burgueño, NADAL 2011, Muro 2011, Rosselló, Rotger 2011). Between 1849 and 1883 163 rural plot maps of 105 different municipalities were drawn in the province of Barcelona. One area of the province that was the subject of many surveys during this period was the Barcelona plain, which in mid-nineteenth century was populated by a series of small towns like Horta, but nowadays is fully integrated within the current Barcelona city limits. Thus, between 1851 and 1872 seven plot maps of this area were drawn: Barcelona, 1851; Gràcia, 1851, 1872; Horta, 1861; Sant Martí de Provençals, 1853, 1871, and Vallvidrera, 1859 (Nadal et al. 2006).

Since this cartographic project did not respond to any official mapping instruction, the scale and format of the produced maps varies from one province to another. For

example, the scale adopted in the majority of cadastral maps of the province of Barcelona was 1:5 000, while in the province of Girona it was 1:2 500. Moreover, in Barcelona 19 atlases were created, while only two of them have been found in Girona. All the maps which have been found are manuscripts and polychrome. In general, only a manuscript copy of each map has been preserved, but there are some exceptions such as the cadastral map of Barcelona drawn by the architect Juan Soler i Mestres in the year 1851, of which three copies have survived. Most plans contain graphic scales which follow the metric system; although in the early years many of these scales were expressed in measures such as traditional Catalan cana or the Barcelonese span. With the exception of city perimeters maps, most of these charts have all plots numbered. They also contain abundant and valuable local geographic information, which means that, among other features, the hydrographical network, roads, settlements, the limits of the municipality or cultural elements such as spas and shrines can be identified. In addition, most of these maps are accompanied by a book or books which record information for each plot such as surface, agricultural use, the taxpayer's name, soil quality or the tax levy.

All this mapping was done by a small army of 46 private cartographers, some of which, like the mathematician Llorenç Preses i Puig or the surveyor Pedro Moreno Ramirez, managed to create and manage enterprises which specialised in carrying out territorial municipal surveys. All these cartographers were not a homogeneous professional group, as they came from different backgrounds, with surveyors being the largest group with 29 members, followed by master builders and architects with ten and four members respectively. Finally, there were three cartographers who belonged to other professional bodies.

Since all these series of maps were not systematically produced the current location of the finished product can be found scattered in multiple archives and map collections both of public and private ownership. Even if many maps are preserved in local public archives –like Horta's map- there are several map collections that are located in regional or national map libraries. Moreover, there are many which have never been located even after finding evidence of their existence. The reader can get an idea of the situation and geographical spread of this Catalan cartographic documentation by accessing the up to date on-line catalogue of all cadastral maps which have been discovered (Montaner, Nobajas 2011).

2 Integration of a cadastral map with GIS: Horta's map from 1861

Nowadays Horta is a composing part of the city of Barcelona and one of its neighbourhoods, but until 1904 it was an independent rural town (Díez i Quijano, Arxiu Municipal de Barcelona & Barcelona 2005). Its once independent city council commissioned the surveyor Joan Serra and Bonet, a recent graduate from the School of Fine Arts in Barcelona, to make the necessary measurements and drawings to elaborate a cadastral map of the fields which lay within Horta's town limits (Montaner, Nobajas 2011). In the year 1861 he delivered a map entitled "Plano geométrico del pueblo y término de San Juan de Horta" (Nadal et al. 2006), which is the map is the only cadastral plan known of Horta in the 19th century. It is a manuscript map, polychromic, drawn on a scale of 1:5 000 and has a size of 105 x 136 cm, of which several copies exist (Díez i Quijano 1982). The surface within the town limits is divided into five

sections, which are subsequently divided using the cadastral boundaries, which means that each agricultural plot is assigned to its legal owner. If more than a crop was grown in a single parcel of land, agricultural plots are further divided. Apart from the agricultural plots, the map also has the name of the owner of each parcel and it represents the municipal road network, the streams and rivers, human settlements and several place names as well (Montaner, Nobajas 2011). Surface measurements in the map are not represented using the International System of Units but in 'mujades' and 'mundinas', local units of measurement nowadays deprecated. A last singular characteristic of the map is that it is not oriented to the north, but to the NW, following the traditional system used in the Barcelona shire by which the Mediterranean Sea is represented at the bottom of the map.

Since the map is a 150 years old manuscript, obtaining a digital copy of it is a delicate matter as the original map could be damaged in the process. This is the reason why it was considered to be more suitable to take a high resolution picture of it than the traditional scanning approach. The problem when using a picture is that there is a risk of distortion in the scale of the points furthest from the centre of the map. In some cases, as it is the case with aerial photographs, this phenomenon requires performing a photogrammetric restitution to minimize this effect (Imhof 2007). For the map at hand, however, it was not considered necessary to rectify the image since the map itself occupied the central portion of the picture and it was far away from the margins, greatly reducing the levels of distortion within the area of interest.

Integration between historical cartography and modern digital cartographical tools like GIS software is not as straight forward as it is with modern maps or data. The process of georeferencing the digitised historical map is critical when displaying historical information within a GIS. There are a series of challenges that can render a historical map as unsuitable for georeferencing like the lack of common reference points between old and new maps, lack of geometrical consistency or lack of geographical accuracy. If the georeferenced historical map does not comply with those minimum qualities the image may be dramatically warped (Orciani et al. 2007), making it unsuitable for a GIS unless major adaptations are undertaken.

The old town of Horta is nowadays an integrant part of the city of Barcelona, but 150 years ago it was a rural town which relied heavily in farming to sustain its inhabitants. Since then, changes in land use have been radical, making it a difficult place to georeference since there are not many common points with other maps whose coordinates are known accurately. In this case, the document used as a cartographic base to georeference the historical map was the 2008 edition of the 1:10 000 topographic map of the Cartographic Institute of Catalonia (Institut Cartogràfic de Catalunya 2008a, Institut Cartogràfic de Catalunya 2008b, Institut Cartogràfic de Catalunya 2008d, Institut Cartogràfic de Catalunya 2008c). Fortunately, some common points were identified; the country house of Cal Mariné, the chapel of St. Cyprian and the corner between the current Tajo Street and Torrent de Can Mariné Street, represented as rivers on the map. Those points, in addition to other topographical control points as the top of the Tibidabo Mountain or the Collserola ridge, helped to georeference the map. The overlap between the old map of Horta and a slope map generated from a DEM of the area (Institut Cartogràfic de Catalunya 2011) shown in

Figure 1 proves that the final result has been quite positive, as the municipal boundary north of the old town of Horta matches the crest of the Collserola Mountains, which was what defined the administrative divide. Also, rivers digitised from the original map follow almost in a seamless way the lower part of valleys, where streams flow nowadays.

Furthermore, the deformation of the map after its georefencing is minimal, with a root mean square error (RMS) very close to zero. Therefore the geometric quality of the map drawn by the surveyor Joan Serra in 1861, even if it lacks a projection system, is remarkable. The overlap of the old map of Horta with modern base maps, like Google Maps or the Catalan Cartographical Institute topographic maps has attested that the outcome of the georeferencing is almost entirely coincidental, mainly thanks to the drawing and technical abilities of Joan Serra.

The next step in the GIS integration process was to manually digitise the map into different layers to allow performing spatial analysis as Figure 2 shows. Once created, the layer containing the plots was linked with information obtained from the correspondent *amillaramiento*. Inconsistencies between the original map and the *amillaramiento* were found, some of them understandable because the *amillaramiento* is a year older than the map, some due to typing errors, and some arbitrary (Nobajas 2011). Once the map had been linked with the information of the *amillaramiento*, it was ready to be integrated with an elevation model and to perform analyses. It should be noted that while the map was created in 1861, the information gathered in the associated *amillaramiento* was written the following year (Ministerio de Hacienda. Delegación

Provincial de Barcelona 1862), so even if the map dates from 1861, the information relating to owners or land use corresponds to 1862, a fact which has led to some minor discrepancies between both works (Nobajas 2011).

3 Combining 19th century Catalan historical cadastral data and DEMs

The integration of Catalan cadastral maps with geographical information systems is quite novel as the discovery and classification of the series of maps has mostly occurred in recent years (Nadal et al. 2006). Some of the first experiences in integrating Catalan historical cadastral maps and GIS were carried out to explain landscape evolution by comparing them with more current cadastral maps (Parcerisas 2008). The first studied area was the Maresme shire, a region which has experienced dramatic changes in the last 150 years as it has evolved from being a mainly rural area to becoming densely populated and one of the Catalan tourist hot spots (Parcerisas i Benedé, Vilassar de Mar 2010). The area which nowadays falls within the Barcelona city limits has also been studied in search of landscape changes (Font Casaseca 2008). The methods followed by all these existing studies are similar to the one previously described in this paper, which consisted in digitising the land parcels and then linking them to the information located in the *amillaramientos* to obtain spatial land use and property data. What previous work had not done was linking the newly created data with Digital Elevation Models and, in many cases; they did not georeference the maps, greatly limiting their analysis, visualisation and distribution potential.

The original map from 1861, as all Catalan historical cadastral maps, is planimetric so it does not provide information about the terrain's altimetry. However, when linked with the appropriate data, the newly created layer can be visualised in 3D representing the relief of the mapped area (Orciani et al. 2007). To graphically represent the altitudinal distribution of Horta's land use a DEM was utilised. Since the scale of Horta's map is quite large, a highly detailed DEM was used with a resolution of 15x15 meters and an altitudinal average quadratic error of 0.9m (Institut Cartogràfic de Catalunya 2011), provided by the Cartographic Institute of Catalonia (Institut Cartogràfic de Catalunya 2010).

It is when combining the DEM, which in this case was provided by an ancillary institution, with the primary data created from the historic map that its georeferencing quality is put to the test. If either the geometrical or geographical quality of the original map is low, or the precision of the georefencing is not good enough, the overlay of both layers will show it. However, in this case, both the original map and the georeferencing process were of an adequate quality, as the adequate overlay between physical features present in the DEM and the digitised in the map shows (Figure 1). Another issue when overlaying historic cartography with a current DEM is that the relief of the area may have changed. While it is unlikely that large structural geomorphologic changes have taken place in the 150 years which have passed since these maps were drawn, there is a chance that smaller modifications of the landscape have occurred. However, the most noticeable changes can be produced by human activity, especially in an area as densely populated as the Barcelona plain. For example, the DEM clearly shows a trench which corresponds to the B-20 urban motorway (Figure 3), which was completed by the 1992 Olympics (Waldheim 2006). Nevertheless, apart from the motorway, the area covered

by Joan Serra's map has not suffered big changes which could change the 3D recreation of Horta's past.

Once the geometric and geographic appropriateness of the historical map and the suitability of the DEM have been assessed, both layers can be put together to convert a planimetric map into one with relief, so historical three-dimensional reconstructions can be created. These representations can be made directly with the DEM raster layer or by converting it into a TIN (Triangulated Irregular Network). In this study case, both ways of representing relief have been used to compare the visual results, and while there are advantages and inconvenient when working with one type of data or the other, the final visual result does not change greatly.

4 The influence of elevation in past environments

While digitising agricultural plots and linking them to their corresponding land uses from the information contained in the *amillaramientos* on a two dimensional environment is already an achievement which can be used to improve the knowledge of the past, adding a third dimension greatly increases the level of understanding of how past environments were. Scholars from many different fields can use the information contained in these 3D recreations as they can be a window to the past, allowing studying how landscapes have evolved in the last 150 years and giving a deeper knowledge of how these areas were like in the past.

In Horta's case, the influence elevation had in the land use distribution can be quickly observed by presenting a series of short examples. Firstly, it shows that the former municipality of Horta had two differentiated parts; one corresponded to the basin of the Horta brook, and it was where the town of Horta *sensu stricto* was located. The second area corresponded to the left side of the Vallcarca brook basin, and the main settlement there was the Vallcarca hamlet. The area covered by the Horta brook basin was the largest and it held the main settlement within the city limits, together with many isolated country houses. On the other hand, the Vallcarca zone was on the other side of a small mountain ridge and had a quite smaller area, so it only held one hamlet and a few isolated houses. As figure 4 shows, the division between both basins and population areas was so significant that when the town of Horta became a part the city of Barcelona it was included in the Horta-Guinardó district, while the Vallcarca zone was annexed to the district of Gràcia which historically had been a completely different town. A second piece of information which can be extracted from figure 4 is that the distribution of the population follows a clear altitudinal pattern, both in the Horta and Vallcarca sectors. Largest settlements were located on the lowest parts of the town, where streams crossed the old town limits, while isolated country houses could be found in higher areas usually near waterways. However, the highest parts within the city limits did not have any buildings whatsoever.

If land use is analysed together with a 3D model, it can be easily observed that there was a clear altitudinal distribution of crops. As figure 5 shows, in 1861 Horta's land use followed a traditional three ring pattern, as it was common in the ancient regime's

European rural areas. Orchards were located near the village, cereals and vineyards were a bit furthest away and forest and land were in the areas further away from the town or where access was difficult (Ruiz Montejo 1998). As the visualisation of the cadastral map shows, the areas within immediate reach from the town mainly had orchards, and fruit trees, while cereals were predominantly located on the flat areas of the town. Vineyards, on the other hand, were located on steeper slopes but at an intermediate distance from the village. The highest and steeper areas within the city limits were predominantly forests and uncultivated land. This land use distribution, which still followed the preindustrial scheme, was therefore greatly influenced by altimetry, so a relief representation greatly helps to identify this trend. It should be mentioned that those lower areas which are represented as uncultivated land were presumably former vineyards which had perished due to the powdery mildew (*Uncinula necator*) outbreak which ravaged Catalonia during the years previous to the drawing of the map (Nadal, Urteaga González 2008).

The last chosen example to illustrate the importance and usefulness of combining historical cadastral cartography with elevation models is that allows observing trends in the evolution of land use and the influence elevation and slope has had on them. Between 1862 and 2003 the area which was included within Horta's town limits has experienced dramatic changes. As figure 6 shows, in 1862 the populated area represented a very small portion of the available land and was circumscribed to small areas at the bottom of valleys, while at the beginning of the 21st century all low and flat areas have been colonised by the urban fabric. This change of land use has meant that all agricultural land has disappeared under a layer of tarmac and buildings. On the other hand, higher and steeper areas have remained almost untouched by the urban sprawl.

Those parts are still forested, while some of the land classified as barren has become either forested or shrubland.

Even if just descriptive examples, the cases shown here prove that elevation is a factor which must be taken into account when studying past landscapes. It is therefore clear that giving a third dimension to the digitalised cadastral map can help identifying previously unknown trends and patterns, providing a deeper knowledge of the area covered by the cadastral map. However, all the methods described up to this point have been designed to run on local GIS systems, which greatly limit the access to the results to people which have experience with digital cartography. If results could be distributed on-line members of the public would have access to the information and even perform their own analyses.

5 Distribution of historical geographical information on-line

With the advent and popularisation of distributed cartography (Ormeling 2010), internet based maps have become ubiquitous and the user base is virtually anyone with an internet connection (Peterson 2013). The increasing ease in the use of digital cartography allows distributing research results on-line so society can benefit from academic studies. When distributing planar cadastral cartography using an on-line mapping service, the amount of options available is very broad. There are several proprietary providers of distributed cartographic services like Google Maps, Bing Maps, Yahoo Maps or Apple Maps, volunteered open source projects such as OpenStreetMaps

or OpenLayers and WMS, all of which can be used as a way to display the cadastral data. However, when dealing with distributed 3D visualisations the available options shrink. While there are products such as NASA's World Wind or Marble which could also be used, it was decided that the best option was to use Google Earth for two reasons, its high popularity (Yu, Gong 2012) and its web browser plug-in (Google 2013). The plug-in allows accessing the information in a customised and easy way, as it is not necessary to install the software, while keeping all the rendering and interaction capabilities Google Earth has. Also, it allows working with KML files, which are an OGC standard (Open Geospatial Consortium 2008).

Distributed GIS allows sharing historical findings with users worldwide and overlaying them with current aerial imagery. To achieve this purpose, an interactive web application that allows the virtual reconstruction of Horta in 1862 was created and made public on the Internet (Nobajas 2012). The application uses the Google Earth web browser plug in to disseminate the results of the work described throughout the paper. It allows not only navigating the 3D recreation, but it also permits adding or removing layers to see, for example, past streams or paths overlaid with current imagery of the area (figure 7). Since the potential audience to these kind of recreations is virtually anyone, a clearer visual representation is needed. This is why on top of the choropleth map representing variables; 3D models were added, allowing an easier interpretation of the results (figure 8). These 3D models were created within a desktop GIS and exported as a KML file which could be opened within Google Earth, but they were also added to the web browser service.

6 Limitations and future research

The methodology and results described are quite successful in extracting and distributing historical cadastral information, but they have a series of limitations which should be noted and improved in future research. The main limitation the method has is that it is extremely time consuming, as all the digitalisation of the old map has been done manually. This has meant digitising over agricultural 300 plots and all the features present in the map like roads, streams or settlements, a process which due to the manuscript nature of the map requires a lot of attention to detail and limits the possibilities of automation. If the process was replicated with other Catalan cadastral maps the amount of time required to achieve it would be vast. The fact that the creation of those maps was not centrally planned meant that as many as 46 different cartographers authored cadastral maps in Catalonia (Montaner, Nobajas 2011), each one using a different technique and symbology to create their maps. This heterodoxy in the map characteristics means that designing and creating an automated algorithm which extracts the cadastral map features is very difficult to attain, a challenge that would be increased due to the bad condition some of the maps have and which would require them being restored. However, even if a method to automate the digitising process was found and all maps were successfully restored, in order to provide information about the land use it is necessary to link them to the information contained in the *amillaramientos*, which are also manuscript. It would be therefore necessary to digitise all *amillaramientos* as well, a task which should be endeavoured by public institutions, since they are kept in public archives and they contain public fiscal information. Digitising all the information contained in the *amillaramientos* would not be only useful

to people working in mapping and GIS, but also to many researchers from a wide array of disciplines who would benefit if they were made easily accessible.

The second limitation which could be improved in future models is increasing the visual appeal of the 3D recreations. In order to reduce the visual angularity and crudeness of the final results, more detailed elevation models should be used. In this paper a 15m resolution DEM was used (Institut Cartogràfic de Catalunya 2011), but more detailed elevation models for Catalonia exist and could be used to smooth the generated 3D surface (Instituto Geográfico Nacional 2013). Together with the increase of the coverage quality, more detailed and historically accurate 3D models could be used to improve the recreation of the past. Even if the buildings rendered in 3D which have been used to improve the quality of the visualisation are very similar to stereotypical 19th century Catalan edifications (figure 9), no research has been carried out to precisely recreate the urban fabric of Horta. In order to have a full recreation of that area it would be necessary to create 3D models of all existing buildings which in 1861 already existed and fill the empty spaces with data from archaeological and archival research. This way the urban fabric of Horta would be correctly represented and the visualisation quality would greatly improve.

7 Conclusions

There are many well preserved maps from before the Digital Revolution, but many of them have yet to be digitised and georeferenced. Once the information they contain has

been extracted in a format compatible with GIS, spatial analysis, past representations or land use evolution analysis can be carried out. However, the process is full of challenges; historical maps have to have a minim degree of geometrical correction to avoid unbearable map deformation. There must also be common recognisable points with modern cartography to achieve a proper integration within GIS. In addition, unless an automation system can be used –for example if maps from the same series are digitised-, it is a time consuming process since each layer has to be digitised by hand.

Nevertheless, once a historic map has been successfully integrated within a GIS, it can be used to perform spatial analysis of past periods, to visualise historical data in a non-planar way or to distribute it on-line. The potential for geographers, historians, economists or anthropologists when using GIS together with historical data is almost unlimited (Knowles 2002). The Horta case presented in this paper shows that integrating Catalan cadastral maps from the 19th century with a GIS is possible due to the high geometrical quality of the maps created by the agrimensores. If a systematic digitalisation, georeferencing and digitalisation of all the 19th century cadastral maps found in Catalonia was carried out, a magnificent source of information would be made available to researchers of many fields.

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Figure 1 City limits (green) and streams (blue) overlaid over a slope surface.

Figure 2 Layers digitised from the cadastral map

Figure 3 Surface changes due to human activity. The trench between the blue lines is the B-20 motorway, which did not exist when the 1861 map was drawn.

Figure 4 Old town limits of Horta, current Barcelona districts and built areas. The Vallcarca basin has been annexed to a different district, in part due to its orographic characteristics. River layer created from the current DEM.

Figure 5 Recreation of the altitudinal change of land uses in Horta (1861). Legend: Blue-Orchards, Orange-Fruit trees, Yellow-Cereals, Purple-Vineyards, Brown-Uncultivated, Green-Forest, Black lines-Roads, Blue lines-Rivers

Figure 6 Land use change in Horta (1861-2003). Legend: Pink-Urban, Yellow-Agriculture, Grey-Barren, Light Green-Shrubland, Dark Green-Forest, Red-Roads

Figure 7 Old Horta perimeter and streams on top of a current aerial photography within Google Earth's plug-in

Figure 8 On-line recreation of the old town of Horta in 1862.

Figure 9 The proposed recreation uses a generic house model for the urban part of the recreation which could be improved by using historically accurate 3D models.

From historical map to on-line 3D recreation: the 1861 cadastral map of Horta (Barcelona)

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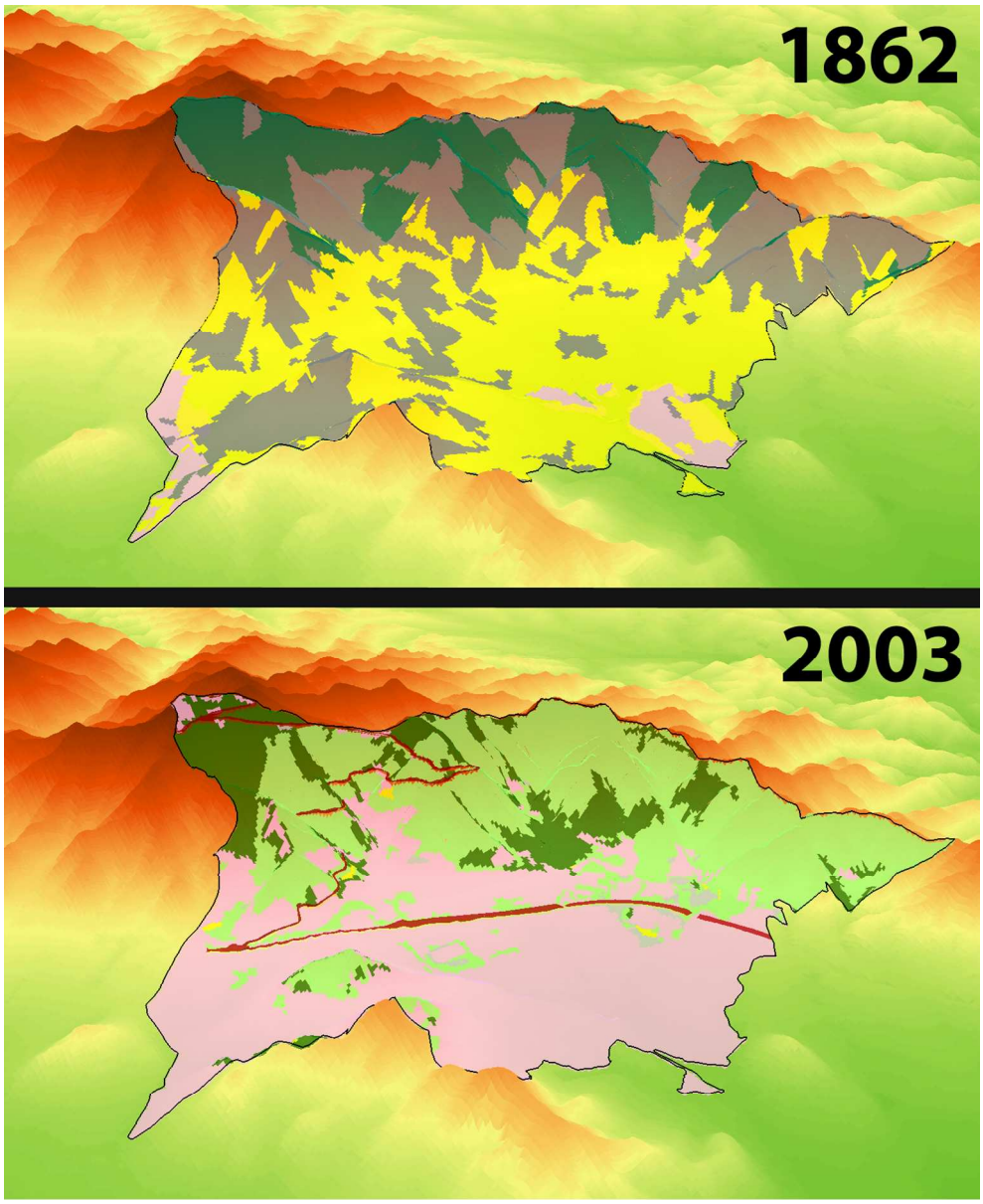
Running head: From historical map to on-line 3D recreation

Keywords: Historical cartography, cadastral maps, distributed GIS, visualisation, Horta, amillaramiento.



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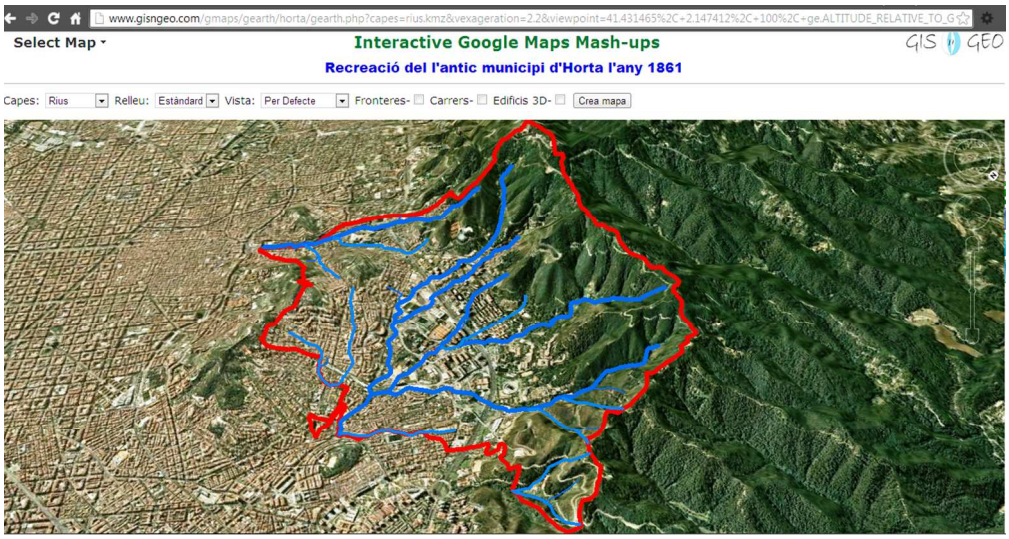

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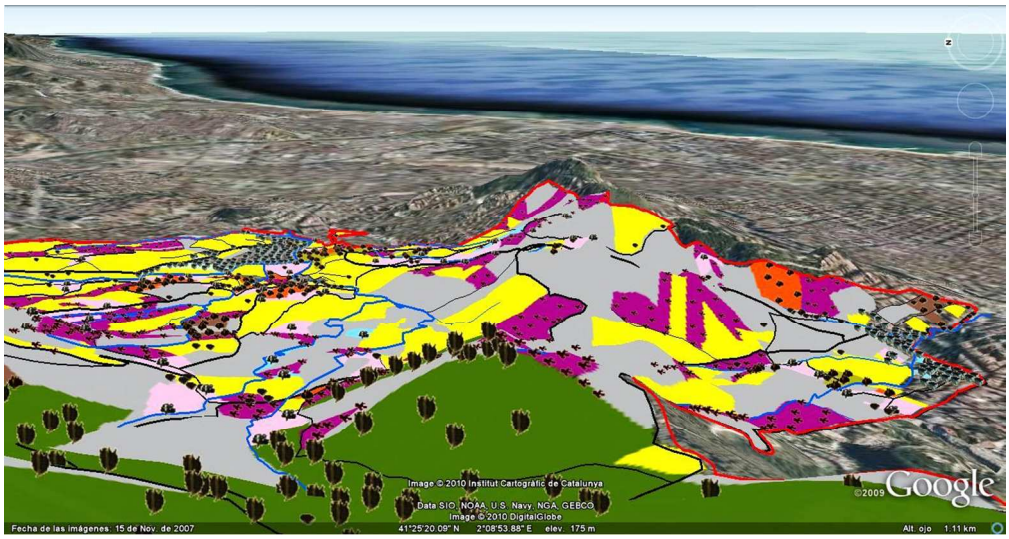

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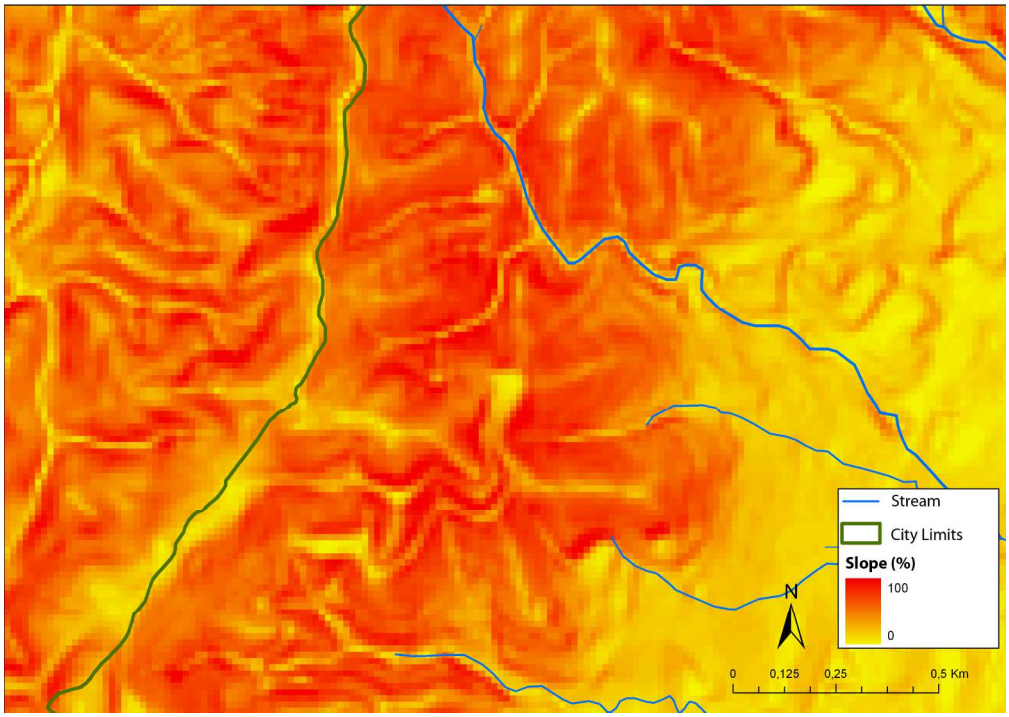

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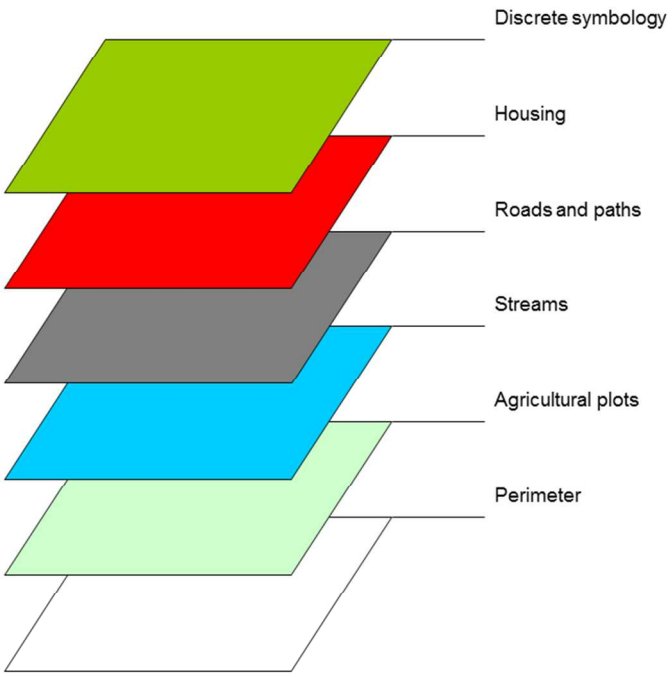

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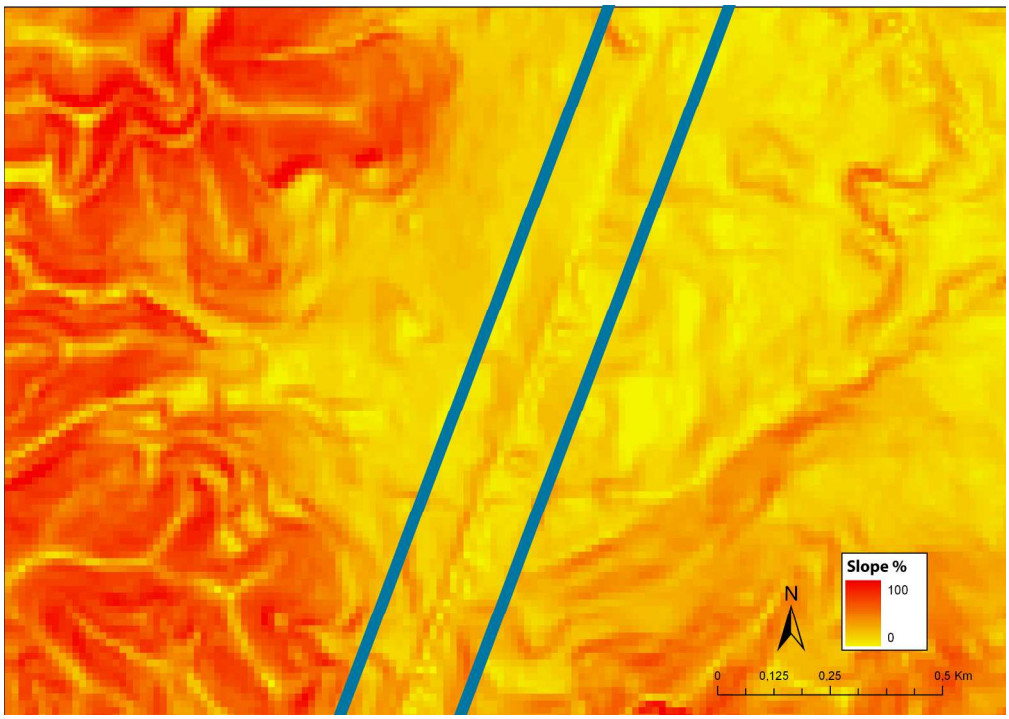

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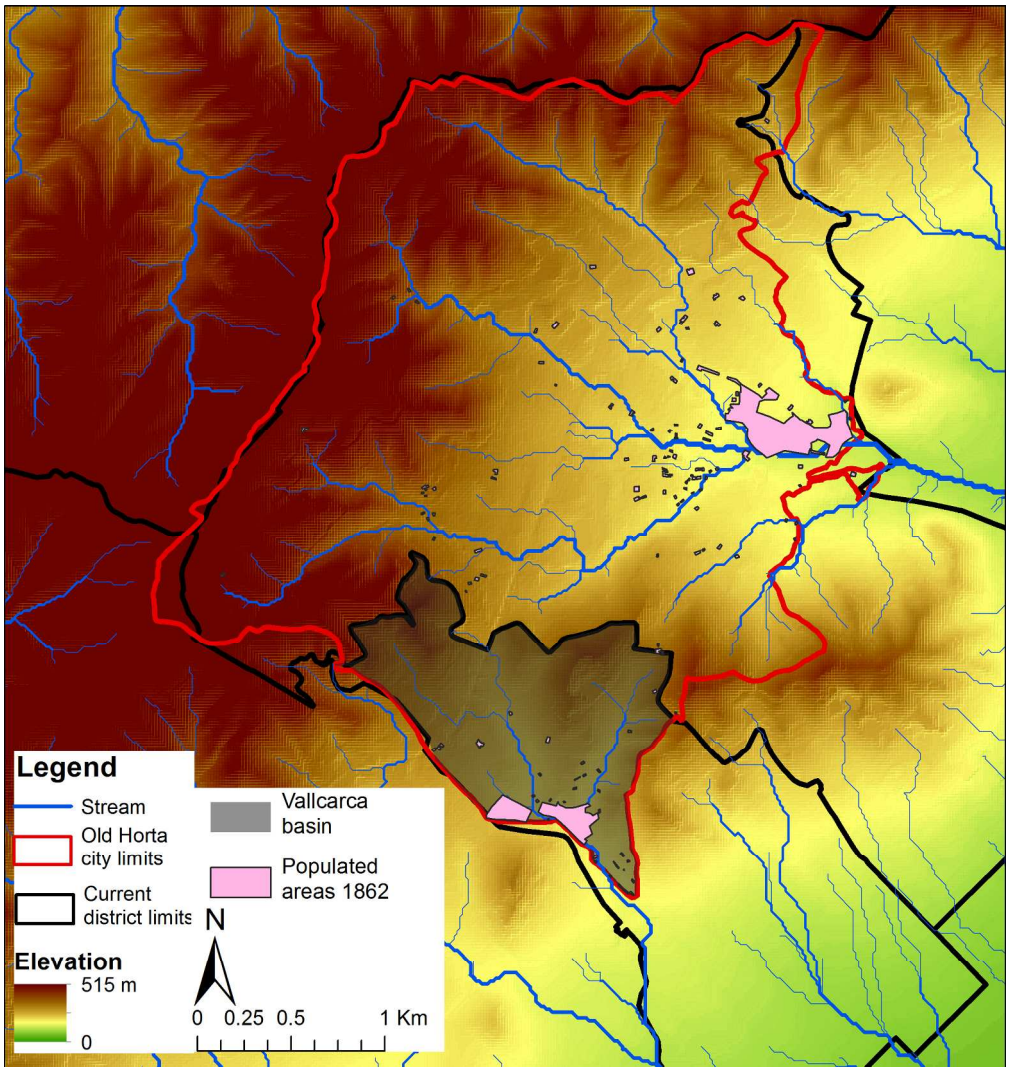

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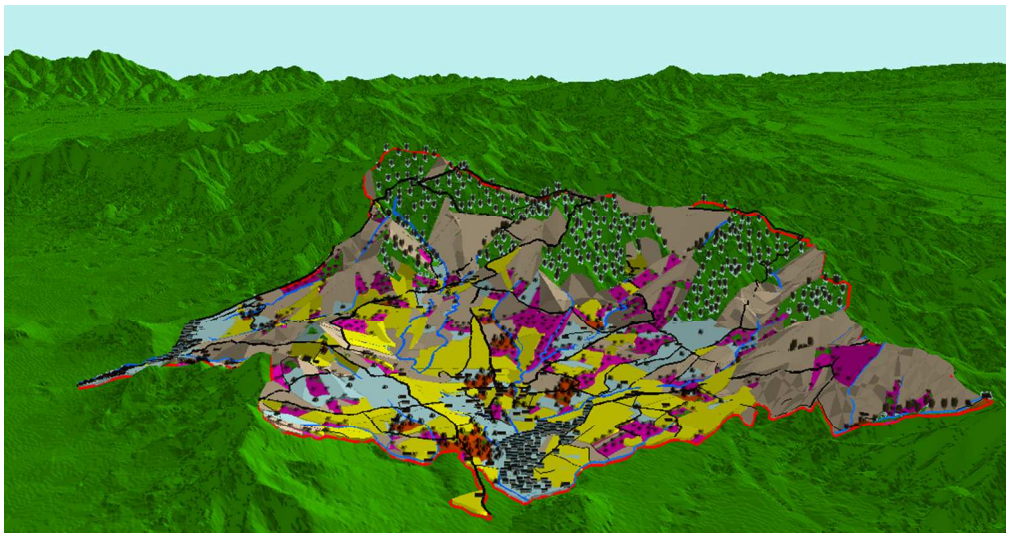

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