GEODETIC DATUMS OF THE ITALIAN CADASTRAL SYSTEMS

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ABSTRACT:
The geodetic datum, and its possible descriptions, of the Italian cadastral networks are analyzed, in order to provide a solution to fit the cadastral sheets to modern map contents and grids, using just their corner crosshair data. Analyzing the extension of the Genova 1902 datum to the whole Italian territory, it occured that the transformation error is acceptable only in the original survey area of the respective triangulation net. For Souther Italy and Sicily (Sicilia), the errors exceed the 20 meters. The Molodensky-type transformation parameters of the Castanea della Furie 1910 and the Guardia Vecchia (Sardinia) datums are provided using only their fundamental point coordinates, without error estimation. While these datums are not correctly checked at their whole application are, we suggest to define local datums of the Bessel ellipsoid, using the Bessel and WGS84 coordinates of the respective cadastral grid origins and use them for geo-reference as a basis of the local Cassini grids.

Keywords: *cadastre, Italy, geodetic datums, map grids, geoinformation.*

1. INTRODUCTION

Cadastral maps represent the result of the highest scale survey of any region. They are not topographic maps. Their goal is to show the property system of the mapped area, so any topographic element that is important for this aspect, is shown, while others often omitted. Historical cadastral sheets provide valuable information about not only the natural and built environment but also about some aspects of the society of the time of the survey.

Because of their high scale, their creation is extremely expensive. Even the updating of the cadastre claim considerable funds from the state budgets. That’s why the coordinate system, the geodetic basis of a cadastral work is rarely changed. Re-ambulation is often made on the basis of the older version, following their geodetic and topographic ’skeleton’.

The main period of the cadastral works in Europe was the first two thirds of the nineteenth century. Countries that gained their independency after this period, have quite complicated cadastral systems, more or less preserving the political distribution of their lands of the time of cadastral mapping. Besides Germany, Italy provides the best example to this.

Concerning Italy, the complete unification of the country was in 1870. To this time, large parts of the Appennien Peninsula was covered by cadastral surveys, mainly carried out by Piedmont, the Kingdom of Naples and the Papal State (*Frazzica et al., 2009*). After the WWI, territorial gains from the former Habsburg Empire resulted three new cadastral systems to be incorporated (one of them ’lost’ after WWII). Together with them, nowaday Italy has 31 major („grandi origini”) and more than 800 smaller, local („piccoli origini”) cadastral systems, all of them have its on projection origin. (**Fig. 1**).

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At some smaller parts of the country, the modern national map grid system was later introduced and applied (*Moncada, 1948; Bonifacino, 1953; Giucucci, 1953*). Fortunately, the story of the related geodetic datums were simplified prior to nowadays. Of course, the above mentioned systems had several trigonomentric networks as geodetic bases. In the first decades of the twentieth century, however, the Italian Institute of Military Geography (Istituto Geografico Militare; I.G.M) developped four geodetic network, all on the Bessel 1841 ellipsoid; the Genova 1902 (**Fig. 2**), the old Monte Mario (**Fig. 3**), the Castanea delle Furie 1910 and the Guardia Vecchia (**Fig. 4**) datums, for northern, central and southern Italy and Sardinia, respectively (*Mori, 1922*). However these systems were independent ones, nowadays one of them the Genova 1902 datum is more or less used for all parts of the country. Outside of northern Italy, the original area of this datum, the coordinates of the basepoints as well as the cadastral system origins were transformed from the locally valid network to Genova 1902 datum.

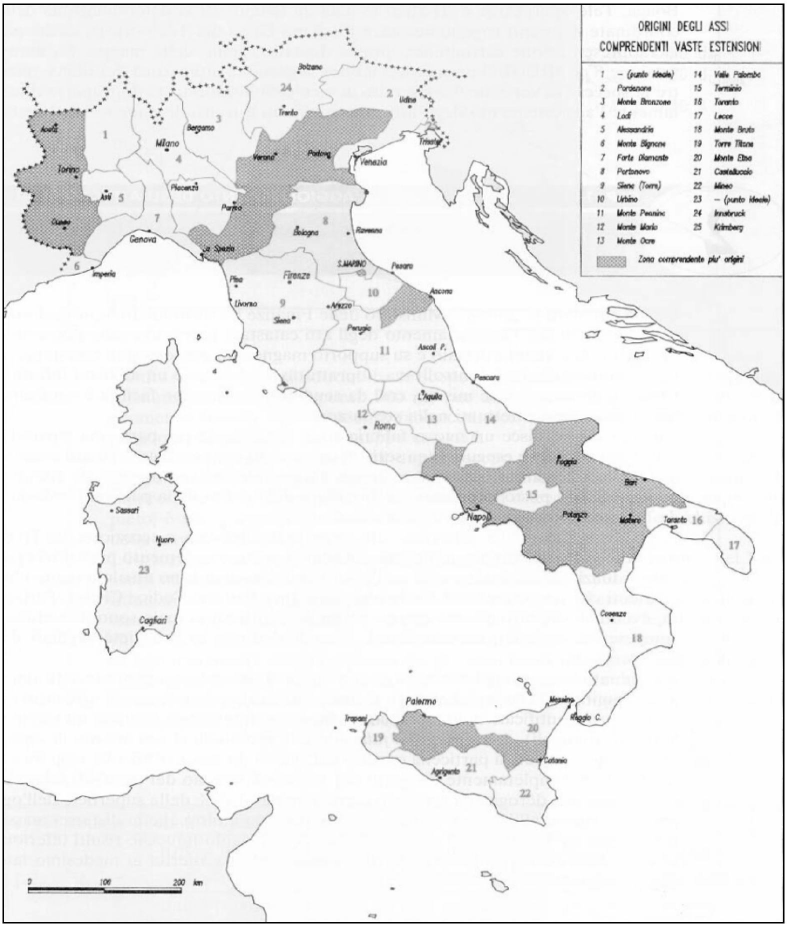

Fig. 1 The extents of the Italian cadastral regions (*Pigato, 1999*).
Dark shade indicate the territory of minor (small) systems.

Fig. 2 The Istituto Idrografico della Marina in Genova, with the fundamental point of the Genova1902 datum on the roof terrace of it (Panoramio).

Fig. 3 The tower of Monte Mario, fundamental point of the old and the 1940 Monte Mario datum (photo of G. Timár)

Fig. 4 The Guardia Vecchia near La Maddalena, Isola Maddalena at the northeast coast of Sardinia, the fundamental point of the Sardinian triangulation (photo of Antonio Balzani, Panoramio).

The present paper aims to estimate to error of this extension of that system, and to describe the parameters of the other systems for GIS applications, thus offering a tool for future, higher-accuracy methods to fit the cadastral maps of souther Italy and Sardinia to modern grids.

2. DATA AND PROCESSING

Cadastral system origins and geodetic basepoint data were obtained from the Italian geodetic data portal [1], which provides a free access to all geodetic base data of the country, according to the Open Access strategy (*cf. Crăciunescu et al., 2008*). List of the origins of major system were partially obtained from *Trevisani (2003)*. For all points, the original or transformed coordinates on Genova 1902 datum were provided, as well as their location on global WGS84 datum. Of course, the coordinates on the (new) Monte Mario 1940 datum and the national Gauss-Boaga system (*Boaga, 1943*) were also presented but we acknowledged its parameters well known (*Antongiovanni and Ghetti, 1985; Paggi et al., 1994; DMA, 1990*), so their analysis was beyond our present scope. Additional historical geodetic data were provided by *Mori (1922)* and *Mugnier (2005)*.

Using the Genova1902 and WGS84 geodetic coordinates of the cadastral origins, the seven parameters of the Burša-Wolf type transformation (*Burša, 1962*) were estimated (*Ádám, 1982*), omitting the most erroneous points – while the places of these blunder data characterize well the overall accuracy of the general usage of the Genova1902 datum. We also provide the three abridging Molodensky parameters (*Molodensky, 1960*) between these datums, providing the best horizontal accuracy (*Molnár and Timár, 2004*). Besides, the simple abridging Molodensky parameters are given for the old Monte Mario, the Castanea delle Furie and the Sardinian Guardia Vecchia datums. Unfortunately, we had no access to original coordinates in these latter systems but the ones of the fundamental points. Taking them into account, higher accuracy transformations could be provided.

3. RESULTS AND ITS DISCUSSION

According to *Trevisani (2003)*, these are the fundamental points of the major Italian cadastral grids, completed with some coordinates, downloaded from [1]:

Table 1. ***The fundamental points of the major Italian cadastral systems. Genova1902 longitude of Point 23 is taken from [1], however it is an obvious blunder. PI at Points 1 & 23 indicates 'Punto Ideale', defined by coordinates instead of any terrain object.***

Nr.	Name	Genova1902		WGS84	
		Lat	Long	Lat	Long
1	Vercelli PI	45.45	8.204363	45.450433	8.205047
2	Pordenone	45.954150	12.660401	45.954554	12.660503
3	Monte Bronzone	45.708633	9.990309	45.709048	9.990771
4	Lodi	45.313672	9.502465	45.314130	9.502994
5	Alessandria	44.914226	8.610709	44.914720	8.611350
6	Monte Bignone	43.872907	7.732943	43.873513	7.733709
7	Forte Diamante	44.460561	8.938858	44.461114	8.939474
8	Portonovo	44.531880	11.753116	44.532469	11.753367
9	Siena (T. del Mangia)	43.317535	11.331871	43.318285	11.332211
10	Urbino	43.724425	12.636111	43.725135	12.636264
11	Monte Pennino	43.100577	12.888616	43.101383	12.888754
12	Roma (Monte Mario)	41.923444	12.451900	41.924405	12.452135
13	Monte Ocre	42.255529	13.443024	42.256464	13.443123
14	Valle Palombo	41.650375	14.259624	41.651030	14.259638
15	Monte Terminio	40.840440	14.937349	40.841579	14.937321
16	Taranto	40.474949	17.228763	40.476222	17.228541

Table 1 (continued)

Nr.	Name	Genova1902		WGS84	
		Lat	**Long**	**Lat**	**Long**
17	Lecce	40.350682	18.169618	40.352009	18.169302
18	Monte Brutto	39.139509	16.421972	39.140896	16.421881
19	Torre Titone	37.847500	12.539363	37.849035	12.539843
20	Monte Etna (P. Lucia)	37.763122	14.985233	37.764674	14.985380
21	Monte Castelluccio	37.414518	13.779165	37.416115	13.779475
22	Mineo	37.265472	14.692406	37.267086	14.692592
23	Sardegna PI	40.00000	8.638581	40.000409	9.116896
24	Innsbruck	47.270276	11.393789	47.270495	11.394035
25	Krimberg	45.929041	14.471915	45.929449	14.471782
26	Monte Cairo	41.540496	13.760462	41.541532	13.760545
27	Francolise	41.181580	14.063770	41.182662	14.063830
28	Cancello	40.992680	14.430113	40.993799	14.430148
29	Miradois, Napoli	40.862511	14.255439	40.863634	14.255497
30	Monte Petrella	41.321142	13.665475	41.322197	13.665572
31	Marigliano	40.924113	14.456006	40.925236	14.456036

Points 1-23 are the classic fundamental points of the country. Points 1 and 23 are the so called ideal points (defined by their coordinates, not by a given terrain object). Points 24 & 25 are the origins of the territories of the former Austria and Austrian coastal zone. Point 24 is the Pfarrturm in Innsbruck (*Buffoni et al., 2003; Timár, 2009a*), cadastral center of Tyrol, while Point 25 is the former Krimberg, now Krim (*Timár, 2009b*), south of Ljubljana, Slovenia, the cadastral center of the former Coastal Zone (Küstenland) of Austria. Between the two world wars, the town of Zara (now Zadar in Croatia) was part of the country, its cadastral sheets are centered at Stephansdom, Vienna (*Timár, 2009b*). The points 26-31 are around of Naples, and they are ofter characterized as 'minor systems'.

According to the data found, the simply abridging Molodensky parameters of the four Italian cadastral datums to the WGS84 are the following, using the EGM96 geoid model (*NIMA-NASA, 1997*), that can be further refined by local geoid solutions (*Barzaghi et al., 2008*):

Table 2. ***Abridging Molodensky parameters between the Italian Bessel (cadastral) datums to the WGS84, computed from the fundamental point coordinates and the geoid undulation at the points. Note that the Monte Mario point has different coordinates on the Bessel ellipsoid that the ones on the Hayford ellipsoid (used later).***

Datum	dX (m)	dY (m)	dZ (m)
Genova1902	516	127	528
old Monte Mario (Bessel)	544	135	511
Castanea 1910	535	106	534
Guardia Vecchia	593	48	473

While the Bessel-ellipsoidal coordinates of Genova and Monte Mario are well-known, it is worth to give the old and modern coordinates of Canstanea della Furie and Guardia Vecchia:

Table 3. ***Old and modern coodinates of two fundamental points, and their sources.***
([a]: Mori, 1922; [b]: calculated from Trevisani, 2003; [c]: Mugnier, 2005; [d]: [1])

Point	Datum	Latitude			Longitude		
Castanea delle Furie	local	38	15	53.637[a]	15	31	14.555[b]
	local	38	15	53.38[c]	15	31	18.436[c]
	WGS84	38	15	58.404942[d]	15	31	12.87132[d]
Guardia Vecchia	local	41	13	21.15[c]	9	23	59.21[c]
	WGS84	41	13	22.117557[d]	9	23	57.51512[d]

Concerning **Table 3**, we have to draw the attention that the point at Castanea has been measured twice, first in 1875 (*Mori, 1922: p. 310*) and in 1910 (*Mori, 1922: p. 318*). The latitude in the first line of **Tabel 3** concerns to the 1910 while the second one does to 1875 measurement, the latter one was used in *Mugnier (2005)*. Longitude in first line was simply calculated from the latitude of Monte Mario on Bessel ellipsoid using the difference between Monte Mario and Castanea (*Trevisani, 2003*). Data in line 1 was used to compute the datum transformation parameters in **Table 2**.

As a unified cadastral datum, the Genova1902 was extended to the whole territory of Italy. Using the 30 fundamental points (Sardinia Punte Ideale is excluded as an obvious blunder), the abridging Molodensky parameters are the following, optimized to best horizontal fit:

dX= +541 m; dY=+140 m; dZ=+558 m
(average horizontal error: 10 m; max. horizontal error: 22 m);

and the Bursa-Wolf type parameters from Genova1902 datum to the WGS84 are:

dX= +656.5 m; dY= +138.2 m; dZ= +506.5 m; rotX= –5.187 arc sec; rotY= +2.540 arc sec; rotZ= –5.256 arc sec; scale factor= –12.61 ppm (according to ‘coordinate frame rotation’; average horizontal error, except Sicilia and Southern Italy: 2.5 m; maximum horizontal error: 5.6 m.)

We have to mention, that the remaining errors (inner distortion of the system) is up to 20-22 meters in Sicilia, around 20 meters in Southern Italy and around 4-5 meters at the auxiliary origins (Innsbruck and Krimberg), indicating that the extension of Genova1902 datum beyond its original survey territory is not precise enough it these regions. That’s why the quasi-official Italian coordinate conversion utility CartLab2 does not provide cadastral transformations to these territories. Using the original geodetic bases could improve this situation.

However, in GIS applications, we can set up local solutions. We need to describe the fundamental points (to which the cadastral sheets are geo-referred, see **Fig. 5**) as origins of local Cassini projections, as well as the local datum connected to them. dX, dY and dZ parameters for the locally defined Bessel datums can be computed from data in **Table 1** (completed by undulation data from a geoid model, in order to have a spatially correct result).

Using these parameters, the cadastral sheets can be fit to modern databases (e.g. to Google Earth, **Fig. 6** and **Fig. 7**) with acceptable accuracy using only the corner crosshairs (**Fig. 5**).

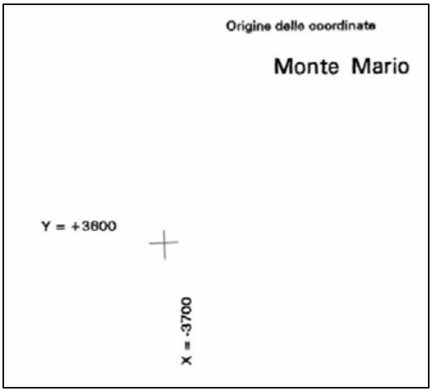

Fig. 5 Corner of an Italian cadastral sheet – see the information of the projection origin and the crosshair showing the coordinates in meters from the origin. If the coordinate system is given correctly in GIS environment, the georeference can be done using only the four corner crosshairs as control points.

Fig. 6 Result of the fitting of the cadastral sheet on Google Earth. Colosseo and the adjacent blocks fit well.

Fig. 7 Higher scale magnification of the fitted sheet: block outlines fit well at the ground level.

As a final word, we have to underline again that the datum name ’Monte Mario’ is referring to two different datums: the one of Bessel ellipsoid, used for cadastral use (’old’ Monte Mario) and the modern Monte Mario 1940 datum of the International (Hayford) ellipsoid, used for the modern national Gauss-Boaga grid (*Baiocchi et al., 2002; Baiocchi and Lelo, 2010a; 2010b*).

CONCLUSIONS

We computed datum transformation parameters for the four Italian cadastral datum to WGS84 (**Table 2**).

We analysed the accuracy of the extended Genova1902 datum on the territory of Italy and obtained acceptable errors in its original survey area but errors up to 5 meters at auxiliary points (Innsbruck, Krimberg) and errors up to 20 meters in southern Italy, Sicilia and Sardinia.

We proposed local solutions to geo-reference cadastral sheets even in these regions, with acceptable accuracy, by using local datum definition to each cadastral regions.

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