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Cover image: vectorialised cadastre of Borgo Rudena, Padova (F. Giacomello).

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research

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Rudena in Padova: sources and data integration for an analysis of a late medieval district

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This article summarizes a study about medieval Padua in which the GIS was used to perform the analysis of urban napoleonic cadastre and to relate the results with archaeological and architectural evidence and written sources. After an introduction dedicated to the Roman city and the hydrographic environment, the study focuses on a single urban district, Borgo Rudena, born as a predominantly monastic settlement outside the early medieval town and then incorporated by the city walls during the late Middle Ages, becoming an integral part of the city.
Keywords: GIS, urban landscape, urban topography, Padua, late Middle Ages

Questo articolo riassume uno studio riguardante Padova medievale, in cui il GIS è stato utilizzato per analizzare il catasto urbano di età napoleonica in relazione ai dati archeologici e architettonici e alle fonti scritte. Dopo una introduzione dedicata alla città romana e l'ambiente idrografico, lo studio si focalizza su un singolo distretto urbano, Borgo Rudena, nato preminentemente come insediamento monastico e successivamente incorporato all'interno delle mura cittadine durante il basso medioevo, diventando così parte integrante della città.
Parole chiave: *GIS, paesaggio urbano, topografia urbana, Padova, basso medioevo*

1. Continuity with the ARMEP project

For the ARMEP project (Padua's medieval architectures), Padua University's medieval archaeology team extended GIS analysis significantly to encompass the study of Padua's medieval town centre, with first-rate results particularly relative to the analysis of the relationship between buildings and the urban fabric, as well as in data management (Valente 2011).

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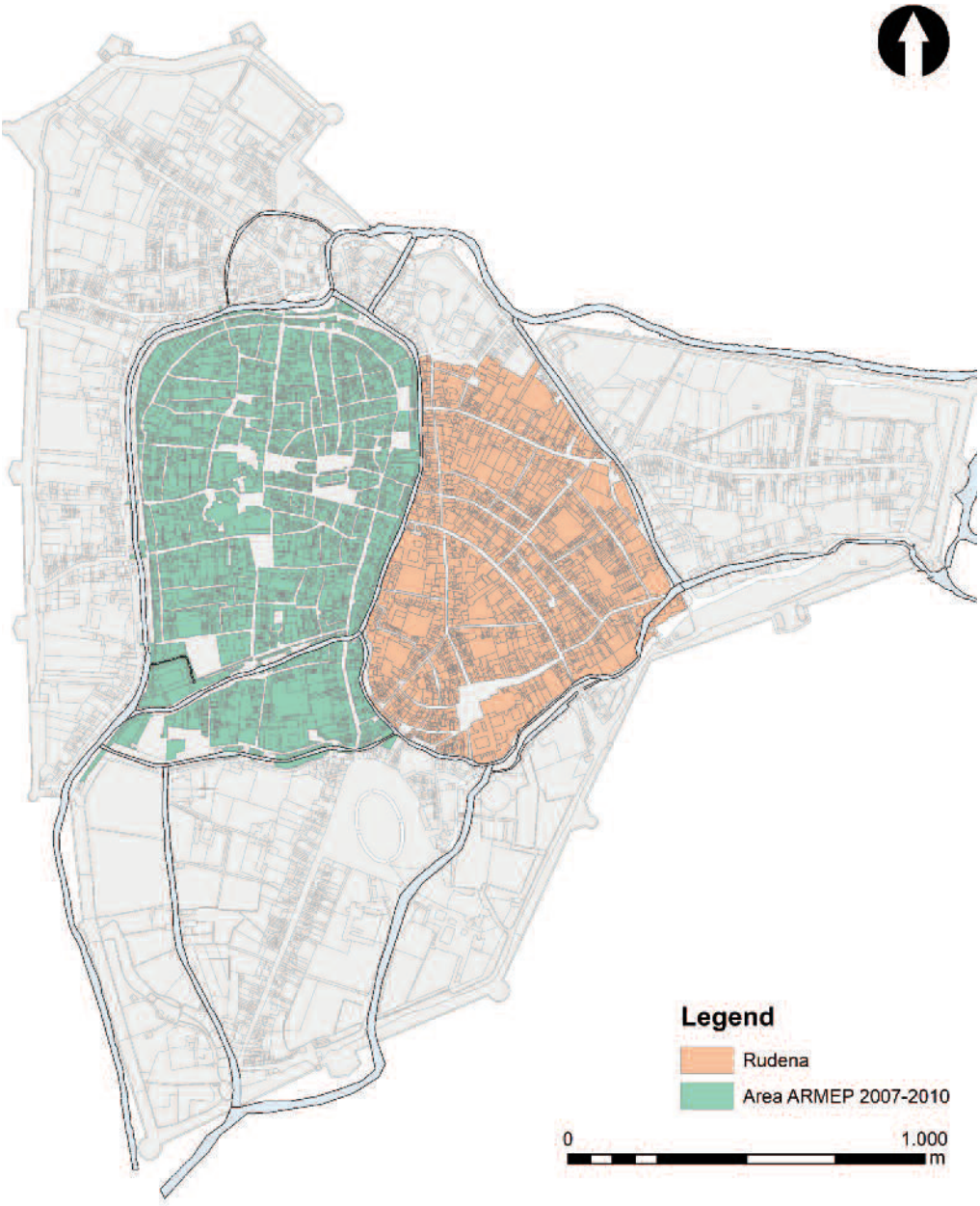

Fig. 1. Padova. Study area of the first phase of ARMEP Project and the Rudena district.

While the project's first phase, which ended in 2010, focused on the town centre, the second phase also looked at the urban districts outside the loop of the River Bacchiglione and outside the oldest town walls, referred to as its first circle. These districts developed in the town's suburban area, along its communication routes with its country hinterland, and were fully developed in urban and architectural terms by the end of the 14th century when the Carrara walls were built around them and they were effectively swallowed up into the town. One of these districts, Rudena (fig. 1), was the focus of special interest for its importance in the town context, as it comprises the Basilica di Sant'Antonio and other important religious buildings and complexes (fig. 2). A second determinant characteristic is its age and the historic events which took place there. Previously part of the Roman city, it was subsequently abandoned and reverted to a rural state from late antiquity to the late Middle Age, with urban and architectural redevelopment taking place only from the 13th century onwards and continuing to the 14th century. Lastly, the state of conservation of its urban characteristics was a factor in the choice. Like the rest of Padua, Rudena's urban fabric remained virtually unaltered from the 16th to the 19th centuries, while in the 20th century significant work modified its identity and that of the town in general, covering over its urban canals, demolishing its ring of town walls, disrupting the relationship between the town and its rivers and other water courses as well as eliminating the hydraulic and architectural borders which divided up the town internally.

2. *Patavium*: Roman city and hydrographic context

Starting with an in-depth study of the Roman town's urban and hydrographic context was essential for the study of Rudena. *Patavium* was founded as a Paleo-Veneto port town on the banks of the River Bacchiglione. Livy's and Pliny the Elder's accounts long led scholars to believe that the Brenta was Padua's river, at least until the early Middle Ages, but recent geomorphology studies by Padua University and Soprintendenza Archeologica del Veneto have demonstrated that it was only the pre-second Millennium river sediments which came from the River Brenta, while later sediments were attributable to the River Bacchiglione (Mozzi *et al.* 2010). Thus, the Bacchiglione occupied the river bed carved out and abandoned by the River Brenta well before Padua was founded. While the geomorphological framework of the hydrographic situation has finally been clarified, the debate relating to interpreting the ancient sources has not yet reached definitive conclusions.

Fig. 2. The Rudena districts hosted many religious buildings and complexes: the most important are Sant'Antonio, the Monastery of Santo Stefano and the Hospital of San Francesco.

The Roman city spread out within a loop of the river and across its eastern banks (Braccesi, Coppola 2002, pp. 18-19), occupying the space of the river's counter loop, as the distributional *domus* map shows (TESS, http://tess.beniculturali.unipd.it/web/ricerca/ricerca-geografica/), complementing that of the suburban necropolis (Rossi 2014). The city's structure, especially of its public spaces, has not, however, been conclusively clarified, particularly with regard to the forum and the civil and religious buildings around it, which were perhaps located in the Caffè Pedrocchi area. Only fragmentary remains have been identified, relating to dated and non-stratigraphic excavations.

Excavations carried out on the Riviera dei Ponti Romani have unearthed its river port and a *horreum* on the eastern side. A temple to Juno has also been hypothesised in this location. Other monumental buildings were situated along Via Altinate, where San Gaetano is located today. The still partially conserved amphitheatre was located in the town's northern sector, on the river's east bank, while the theatre whose foundations are visible when the Prato della Valle canal dries up was at its southern edge. (The most up-to-date publication relating to the vestiges of the Roman city is a small educational volume published on the occasion of the two thousandth anniversary of Livy's death: Bonetto, Pettenò, Veronese 2017).

The characteristics of the road network are unclear and have been long debated. Lately, but using hypotheses formulated in the past, Robin Brigand has used GIS based morphological analysis to demonstrate the survival of the Paleo-Veneto layout, which was the basis for later Roman architectural development without a prior urban reset (Brigand 2010): as theorised in earlier studies, Roman *Patavium* was not a castrum in layout with orthogonal *cardines* and *decumani* (Bosio 1981, p. 235).

East-west communications between the two banks of the river were supplied by at least two stone bridges, now called Ponte Altinate and Ponte di San Lorenzo, the starting points for the roads to the eastern suburbs and then onwards to Aquileia (Via Altinate - Via Annia) and south-eastwards in the direction of Saccisica and Chioggia (Via San Francesco).

In late antiquity, the religious centre of the Christian town was its cathedral; its central position, on the exact site of the current cathedral, has been confirmed thanks to definitive excavations and after a lengthy debate (Chavarría Arnau 2017). The event which sealed the fate of the city of late antiquity was, in all likelihood, the Lombard conquest followed by the bishop's abandonment of the city and the transfer of public power

to Monselice, leading to Padua's political and social decline. This state of affairs continued until the breakup of the Monselice council in the late 10th century (Brogiolo 2017, p. 399). Early medieval documentary and archaeological testimony depicts a smaller and ruralised town, encompassed between the area of the episcopal complex and the castle (Torlonga), whereas the whole eastern sector had been abandoned. Further mentions appear in the late 10th century and onwards, in relation to fields and vineyards belonging to the Canons of the Cathedral and the Santo Stefano and Santa Giustina monasteries (diplomas mentioning Rudena are shown in Giacomello 2018, p. 92).

3. Analysis of the district

The district was studied in a GIS environment with morphological and dimension analysis of the Napoleonic cadastral parcel plan as well as of the primary orientations and road network in relation to elements in the urban landscape.

One of the most important elements in Padua's urban landscape is its 16th century walls, despite the fact that these had only limited impact on the districts' formation, since these were not only older but never expanded up to the wall limits. The relative density of the medieval settlement is, thus, to be attributed to the walls built by the Carrara family and the Comune, very little of which are still extant, and the presence of canals, many of which were filled in in the 20th century.

Padua's medieval hydrographic situation is worthy of further study because the archaeological and geomorphological evidence demonstrates that it is markedly similar to its Bronze Age paleo-hydrography (Mozzi *et al.* 2017) and, to an even greater extent, to that of the Iron Age (Balista, Gamba 2004) (fig. 3). This leads to significant questions on the effective genesis of its medieval canal network which would, thus, have resulted from the recovery of unused paleo canals, rather than new 13th century excavations, as the historical sources and historians in general have argued.

The real genesis of the late medieval canals is obviously of importance in understanding the road network as well: in Rudena, a close relationship between the form of certain sections of the road network and that of the canals surrounding the district on its south, west and east sides can be observed. Of particular note is the concentric shape of the district to the south, a legacy of Canale di Santa Chiara's morphology, a 13th century element which was evidently built by reactivating water flow

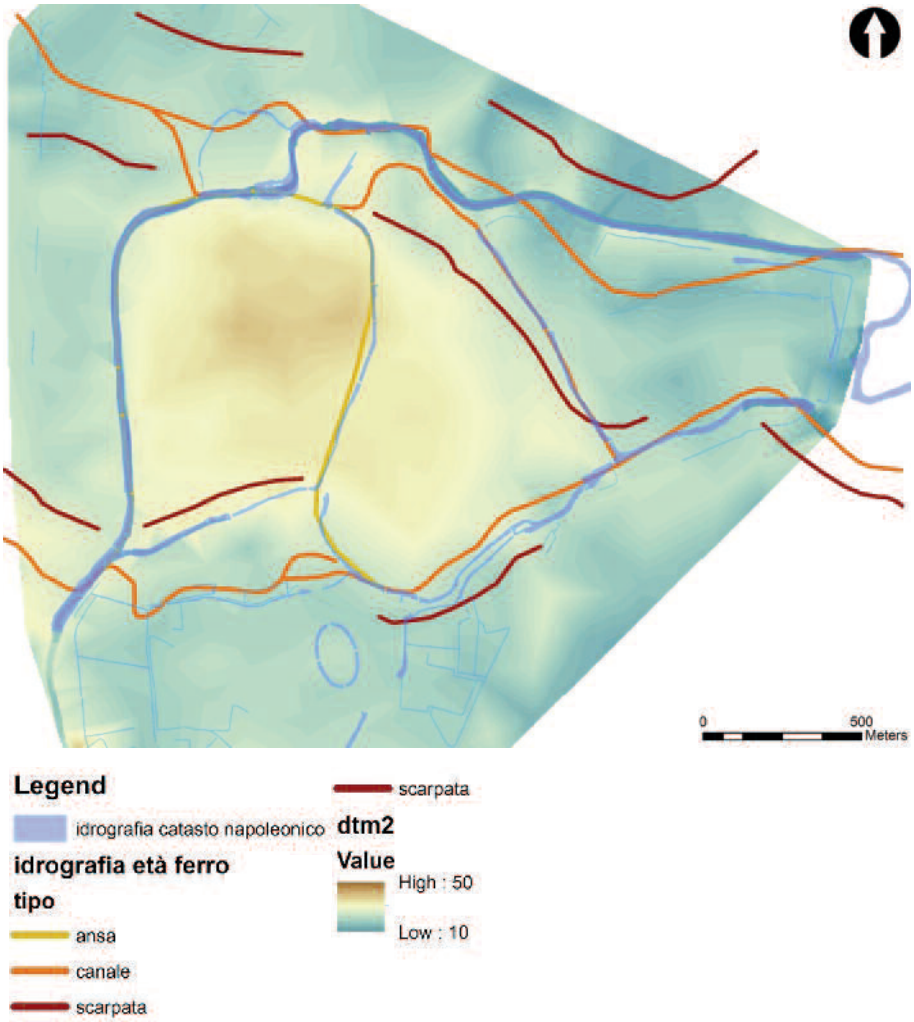

Fig. 3. Map of Iron Age Hydrography (da Balista, Gamba 2004) combined with 19th century hydrography, derived from medieval hydrography. It can be observed that the 19th century\medieval hydrography reflects the protohistoric one, contradicting the thirteenth century Paduan sources that document the excavation of the canals.

within the river's counter loop (fig. 4). It is also important to reiterate that the main gates from the town and the suburbs to the district have remained unchanged since Roman times and that the principal east-west roads, as link roads between the Roman bridges, are historic or, at least, influenced by historic elements.

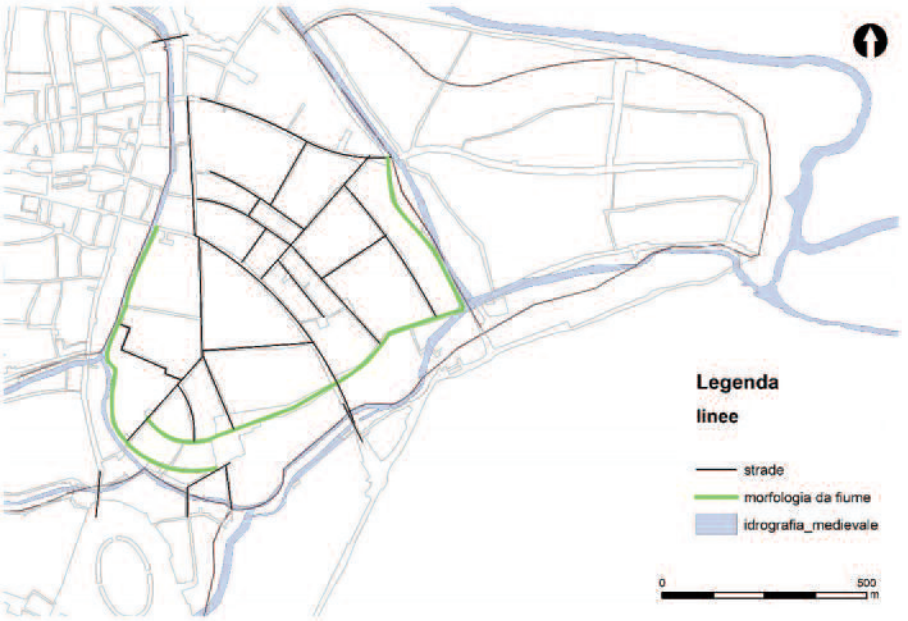

Fig. 4. The morphology of the viability of the Rudena district is closely correlated with that of hydrography, being surrounded by canals on the East, West and South sides. The southern sector is most influenced by the shape of the river counter-loop and the roads have a direction parallel to that of the canal.

3.1. Analysis of the orientation of the segments making up the cadastral parcel plan

Orientation analysis was performed on the Napoleonic land survey geo-referenced and digitalised in segments. North-related orientation was calculated for each of these and expressed in sexagesimal degrees using the *ArcMap bearing* tool. The 360 degrees expressed by the bearing depended on the orientation used to edit the segments; therefore, to maintain the direction alone, all corners were simplified to flat angles (180°). The use of this simplification allowed a colour palette to be established which enabled orientations to be observed with substantially raw data on the map. To highlight perpendicular elements, the angle range was further simplified from 0° to 89,° with this simplification being functional to observing iso-oriented plots (fig. 5) and to visualising any pre-eminent orientations with a histogram.

The 'raw' map shows the differences between the arched layout of the cadastral parcel plan, which opens up in a north-west to south-east fan following the form of Via San Francesco, incorporating the axis

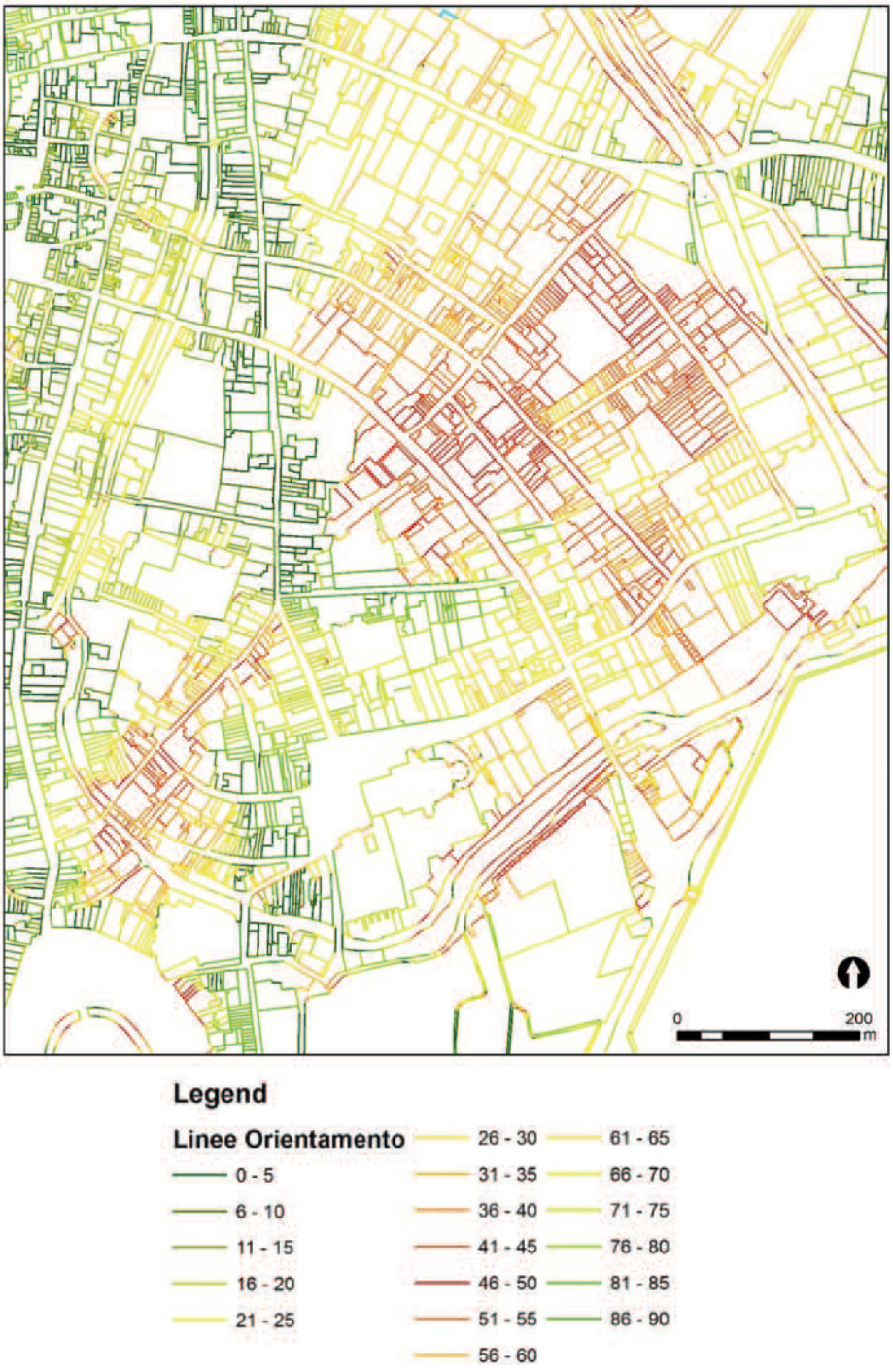

Fig. 5. Analysis of the orientations of the segments of the Napoleonic parcels.

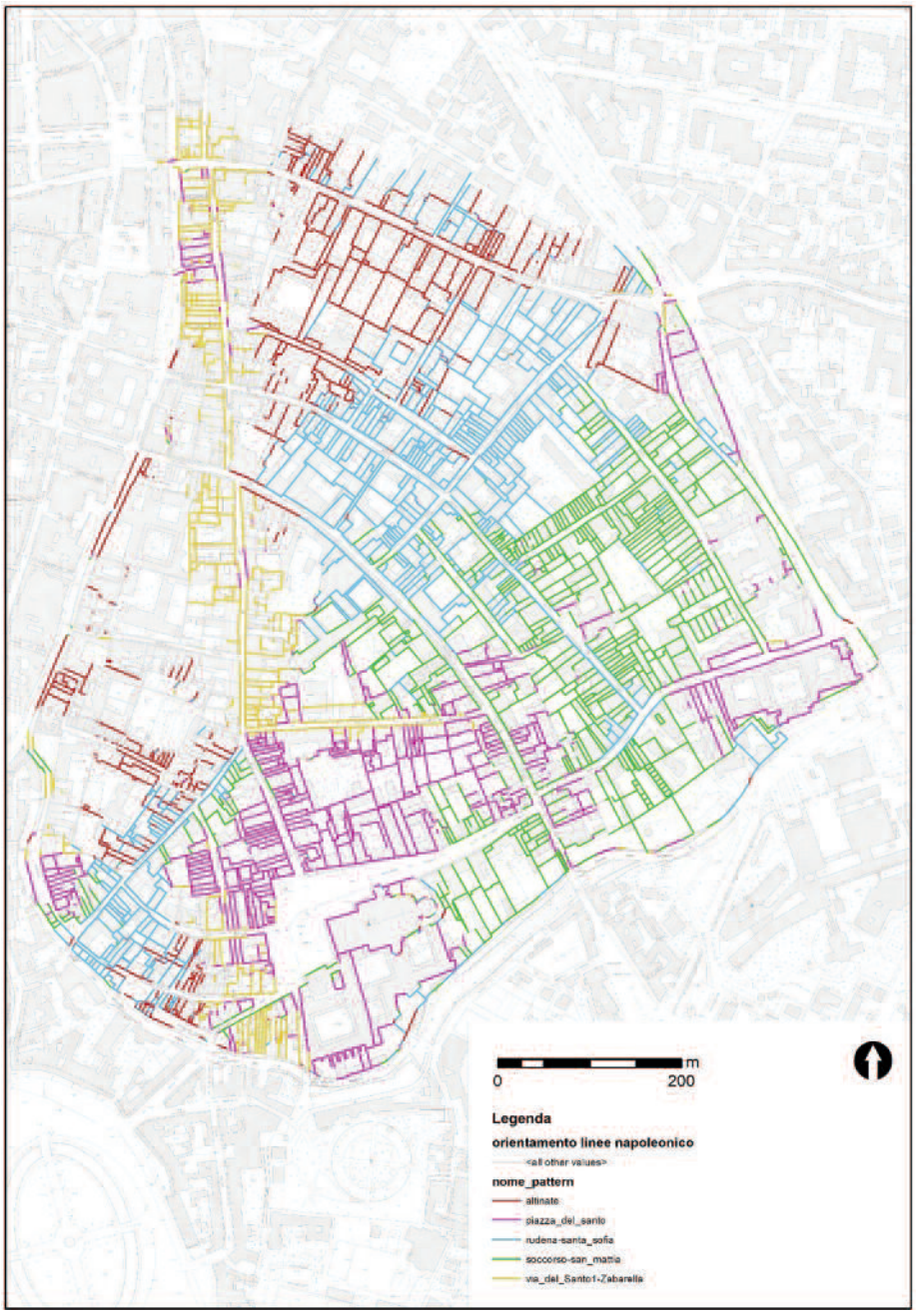

Fig. 6. Selections of segment orientation classes based on pre-eminent elements of the urban landscape.

formed by the Via Rudena-Via Santa Sofia arch spectrum. Lastly, the vertical Via Zabarella-Via del Santo axis makes up an orthogonal system with Via Stampa and Via Galilei.

For a better understanding of the district's composition and the relationships between the various patterns and elements in the urban landscape, a 'reasoned' map was drawn up, presenting orientations on the basis of the road axes or of the most important buildings (fig. 6):

- in blue, the land map and the roads surrounding Via Santa Sofia, together with its continuation on Via Rudena and separate from the hospital complex on Via San Francesco;
- in green, the eastern side of the district between Soccorso (in Via San Francesco) and Via San Mattia, also with long and narrow land plots. This system comprises 16th century Cà Lando;
- in yellow, the north-south axis consisting of Via Eremitani and Zabarella and the first section of Via del Santo, with its orthogonal east to west;
- in purple, Piazza del Santo with the Basilica, the last section of Via del Santo, from Crosara to the square, and the Borgo Nuovo district behind Via Rudena;
- finally, red is used to highlight all land plots on Via Altinate, which are generally larger than those of the rest of the district and form a pattern strictly tied to the road they look out onto, without extending much inwards within the block.

3.2. The road network

An analysis of the district's road system in relation to the outside world, to the rest of city and to its inner blocks is of fundamental importance to an understanding of its urban fabric. Functional to highlighting integration and separation between the district's areas is the analytical tool *spacesynthax* (Hillier, Hanson 1988), carried out using *Depthmap*, a software developed by UCL University College London and available at http://www.spacesyntax.net/software/. A polygonal road system map is transformed into *Axialmap* (fig.7), in which the road system is represented by segments that intersect or are oriented by the morphology of the roads. A district sector's integration or segregation is calculated via the number and type of each road's intersections with the rest of the network. The best-connected roads, shown in red or green, are generally the preferential routes, even if they are not always the shortest or quickest ones. The more segregated roads, in blue or purple, are reachable via mandatory itineraries or dead-end roads. In the Rudena district, the main axes are clearly:

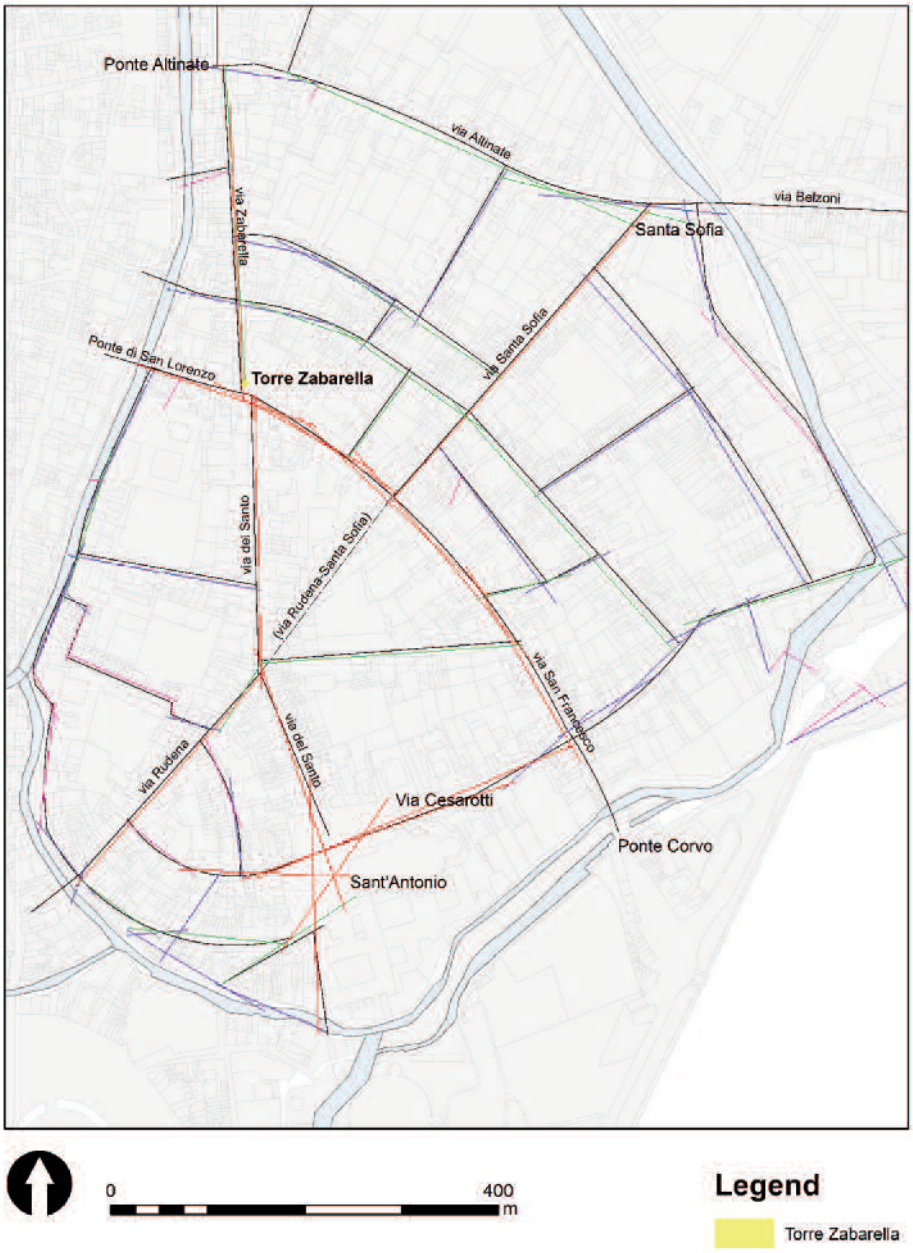

Fig. 7. Viability inside the Rudena district designed with axial map. Highlighted the Zabarella Tower that breaks the North-South axis of Via del Santo-Via Zabarella.

- Via San Francesco, leading from Ponte San Lorenzo out of town in an arched trajectory, which impacts on the morphology of the whole southern sector, up to Via Altinate. It intersects with the north-south axis made up of Via Santo-Via Zabarella and, diagonally, with Via Santa Sofia;
- Via Santa Sofia, which crosses the whole north-eastern sector in a south-west to north-east direction, intersecting concentric roads to Via San Francesco;
- Via Zabarella and Via del Santo, the only axis which crosses the whole district from north to south. From its intersection with Via Rudena, Via del Santo bends eastwards to Piazza del Santo;
- Via Rudena, which crosses the district's southern sector from north-east to south-west and intersects almost all the minor *contrade* (city quarters) districts which make it up;
- Via Cesarotti, which links Ponte Corvo to Piazza del Santo.

The most segregated sectors comprise the south-western districts and the river banks in their formation prior to the covering of the river.

The Via San Francesco mandatory route between the Roman bridge at San Lorenzo and Ponte Corvo, anotherRoman bridge, is probably the district's oldest and it impacts on the morphology of all the northern blocks up to Via Altinate, which is equally ancient but does not impact on the morphology of the blocks looking out onto it. Rudena's orientation, from San Daniele to Via del Santo, is also a feature of Via Santa Sofia; yet, between the two road sections is located the Ospedale di San Francesco block. The presence of a link between the two roads across the San Francesco block has been hypothesised in other studies but no archaeological traces exist; it is simply a supposition reinforced by the presence of two important and old churches, San Daniele and Santa Sofia, at its northern and southern ends.

Via Zabarella is another axis, which must have already existed in the 11th century: this road is linked to the toponym 'braido', a word of Lombard origin indicating a suburban field. Furthermore, at either end of this street are the early medieval monasteries of San Bartolomeo, to the north, and Santo Stefano, to the south, and lastly Zabarella tower. This latter is situated at the intersection between Via San Francesco and Via Zabarella, strategically positioned to guard over the city's gate. Torre dei Dalesmanini, located to the north between Via Altinate and Via Eremitani, is similarly placed.

The northernmost section of Via del Santo was probably built later than Torre Zabarella, dated to the late 11th century: the Via Zabarella-Via del Santo route, at its intersection with Via San Francesco, is an anomaly

called 'baionnette' in morphological analysis, i.e. a deviation in the road itinerary caused by an older element (in this case Torre Zabarella).

The Via del Santo segment which starts at Crosara, i.e. from the intersection, and continues to the square, is lined up with Basilica del Santo and was probably built to link the square with the best of the district, following the construction of the basilica.

3.3 Cadastral parcel density

Areas with the highest cadastral parcel density were identified on the Napoleonic land survey, corresponding to smaller concentrations of cadastral parcels linked to the presence of smaller sized buildings, greater space fragmentation and higher settlement densities. This parameter serves to highlight and observe the district's structure and should be considered in conjunction with other features such as the road system and the main buildings.

Cadastral parcel density assessment was obtained by achieving a punctiform layer in GIS, extracting the localisation point for each unit from the Napoleonic land survey and thereby creating a raster image, which expresses the density of the points in an arbitrarily set spectrum

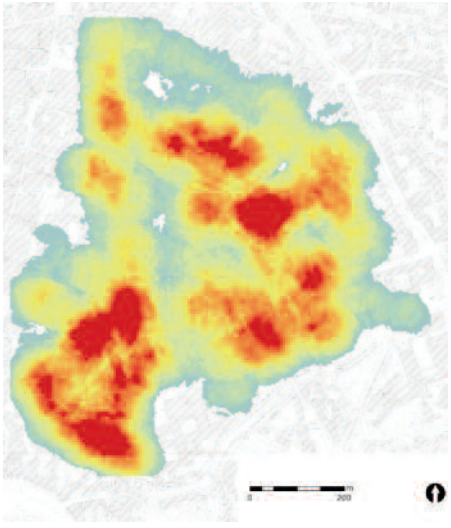

Fig. 8. Rudena, cadastral parcels density obtained with a radius of 50 m from the centroid of each parcel.

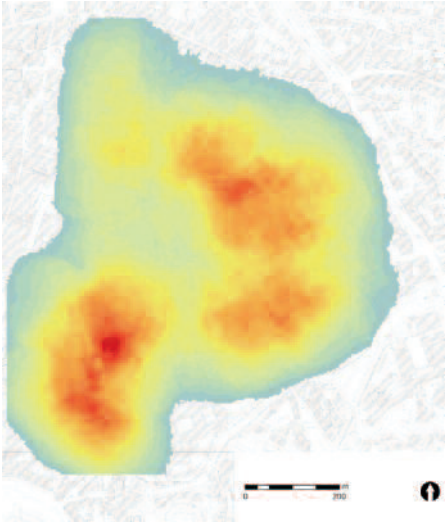

Fig. 9. Rudena, cadastral parcels density obtained with a radius of 100 m from the centroid of each parcel.

(in fig. 8 and 9 see the results obtained by setting a 50m and 100m spectrum). The images obtained show that the greatest cadastral parcel density is located around modern day Via Rudena and in the eastern part of the district along the south-west to north-east axis, defined hypothetically by Via Rudena and Via Santa Sofia. A further medium-high density area is the southern edge of Via San Francesco.

While in the town centre the squares, and thus the commercial area, exert a powerful magnetic force over the cadastral parcel plan and determine high fragmentation, in Rudena there are no commercial, religious or public elements performing the same role. Its monasteries are certainly the district's most important buildings, yet these do not generate notable building densities (fig. 10). Density in sectors 'free' of important buildings indicate residential areas made up of properties of limited size, corresponding predominantly to porticoed terraced houses.

3.4 Cadastral parcel morphology

For a morphological analysis of the cadastral parcels, multiple indexes were applied to express numerically the form of the polygons representing properties.

The first index applied was thickness, which defines a polygon's degree of elongation calculated with the *GIS tool* supplied by *Easy Calculate*: value 1 corresponded to a circular form, while values close to 0 represented long, narrow forms. Figure 11 shows the arrangement of cadastral parcels with a very low thickness index, indicating a long, narrow shape. The next stage was a DSR index (Robert *et al.* 2013, p. 213), generated by the relationship between the polygon area and the minimum circumscribed rectangle.This conveys the regularity of the cadastral parcels: an irregular units appear as a concave or convex forms, whereas forms resembling a square or rectangle are considered regular. The result was the prevalence of very regular cadastral parcels with DSR indexes between 1 and 1.2. This type of characterisation allows the properties of the cadastral parcels to be further visualised, depending on the choice of further analysis with more interpretational relevance. The presence of a great many regular shaped units enabled the ArcMap *minimum bounding geometry* tool to be applied (Giacomello, Parisi, Schivo 2018, p. 138) to extract the maximum unity width and length, with the certainty of obtaining significant results (see what follows and the next section).

In addition to form, the dimensions of the Napoleonic cadastral parcels were analysed based both on linear vectorialisation and polygonal vectorialisation.

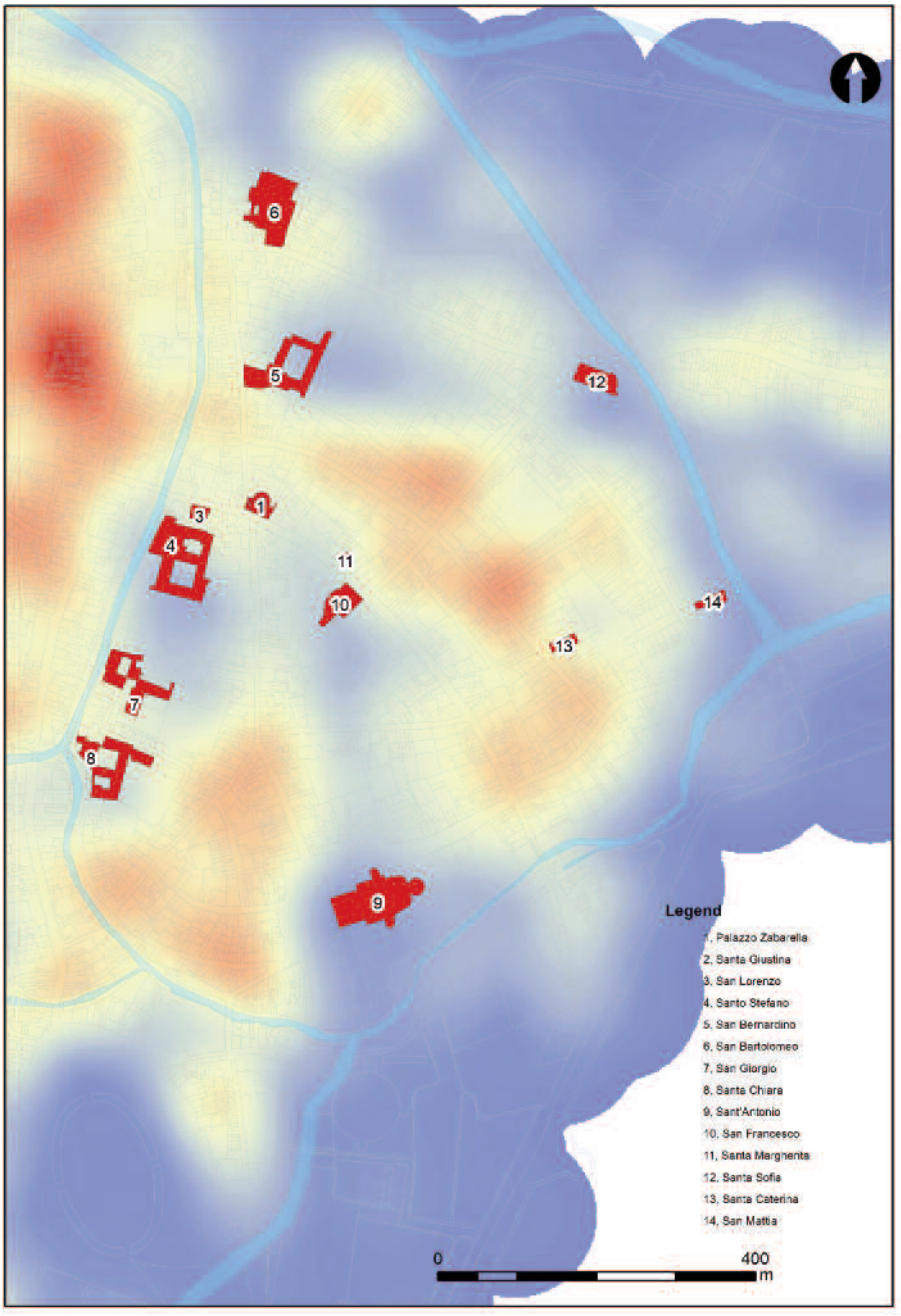

Fig. 10. Rudena, kernel density on the centroids of the Napoleonic parcels. The limits of the higher density areas appear even clearer. The red polygons represent the most important buildings of the district.

Fig. 11. Rudena, chromatism of parcels based on the thickness parameter.

The analysis of unit area dimensions showed that the majority of units are 30 to 150 square metres in size, with the most frequent being approximately 100 square metres in size. The district's main streets, such as Via del Santo, Via Altinate and Via San Francesco, present large units, whereas properties set back from the main areas, such as the southern and eastern ones, were smaller (fig. 12).

Dimensional analysis of street fronts showed that most were from 4 to 6 metres wide, dimensions which are linked to terraced house layouts (Boaretto, Valente 2011).

4. From GIS to historic data

The historic data used to interpret dimensional analysis derived from both written sources and archaeological evidence.

Source analysis showed that the property dimensions documented from the 12th to the 15th centuries ranged from 4 to 7 metres on their short sides, while their long sides ranged from 20 to 35 metres. The two oldest documents supplying information relating to property dimensions in Borgo Rudena date to the late 12th century and are deeds from the Benedictine monastery of Santo Stefano. The documents cite properties located in *hora Ruthena* and other areas of the district such as San Bartolomeo, Santa Sofia and San Lorenzo (Giacomello 2018, pp. 126-130).

Other information was sourced from archaeological evidence: the Ospedale di San Francesco excavations unearthed some residential buildings, lined up along the road side (Tuzzato 2015). The dating of these buildings has a definite end date prior to 1383, when the hospital's founders bought the land. The dimensions of these residential plots, drawn from the 2015 archaeological findings, range from 10.8 to 12.8 metres or 5 perticas and half a foot, and 6 perticas.

Analysing the dimensional data and integrating it with morphological data enabled areas to be identified which presented (in the 1815 survey, obviously) further plot sequences with characteristics attributable to the late Middle Ages, the 13th to 14th centuries in particular. It is noticeable that this type of cadastral parcel is very frequent in the district and, above all, that in many cases it forms compact blocks and sequences of homogeneous plots lined up along the road side. This pattern is to be found in Via Santa Sofia, Via Gabelli, Via Battisti, Via Agnus Dei, Via San Francesco, Via Rudena, Via del Santo, Via Cappelli and Via Bellano.

Without professing to date plots with any degree of certainty on a morphological-dimensional basis alone, in the absence of archaeological or architectural confirmation, this analysis highlights the presence in the

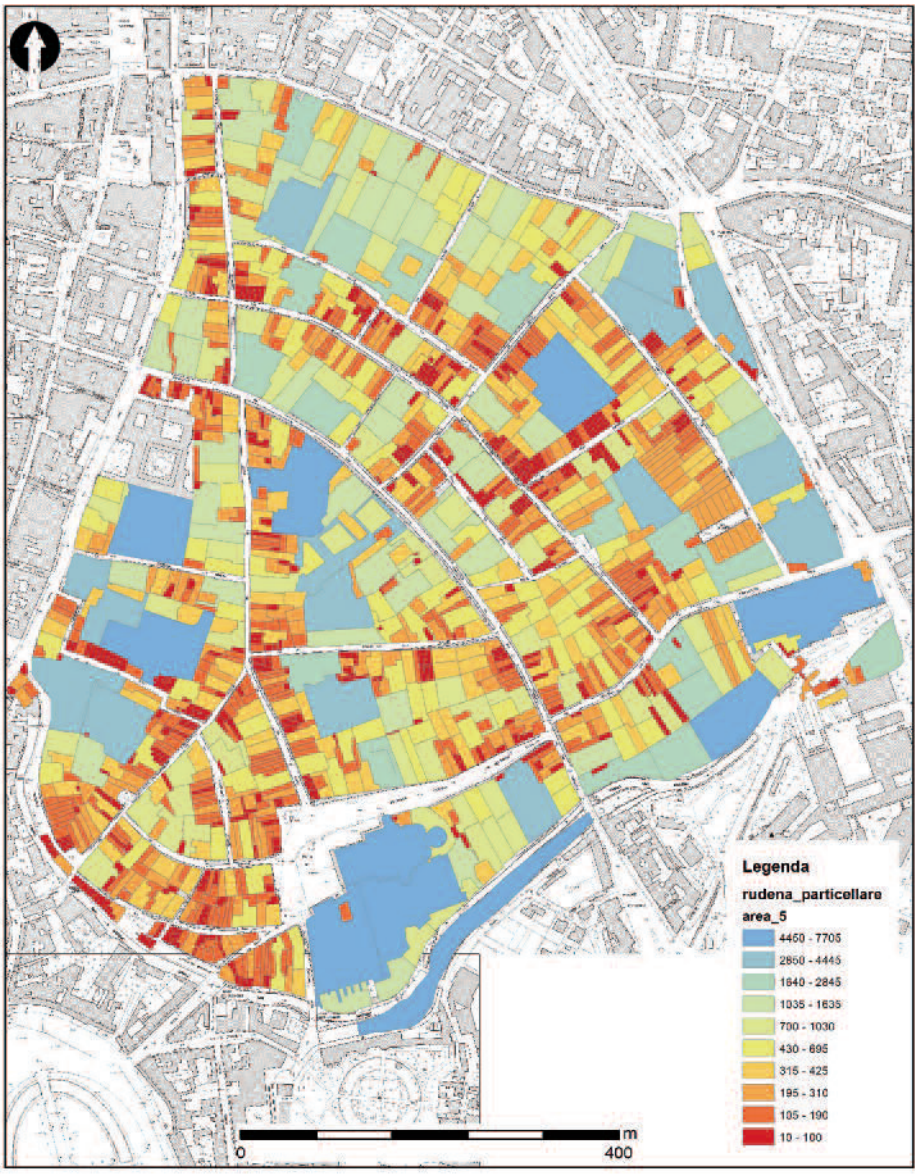

Fig. 12. Rudena, chromatism based on the area size of the individual Napoleonic parcels.

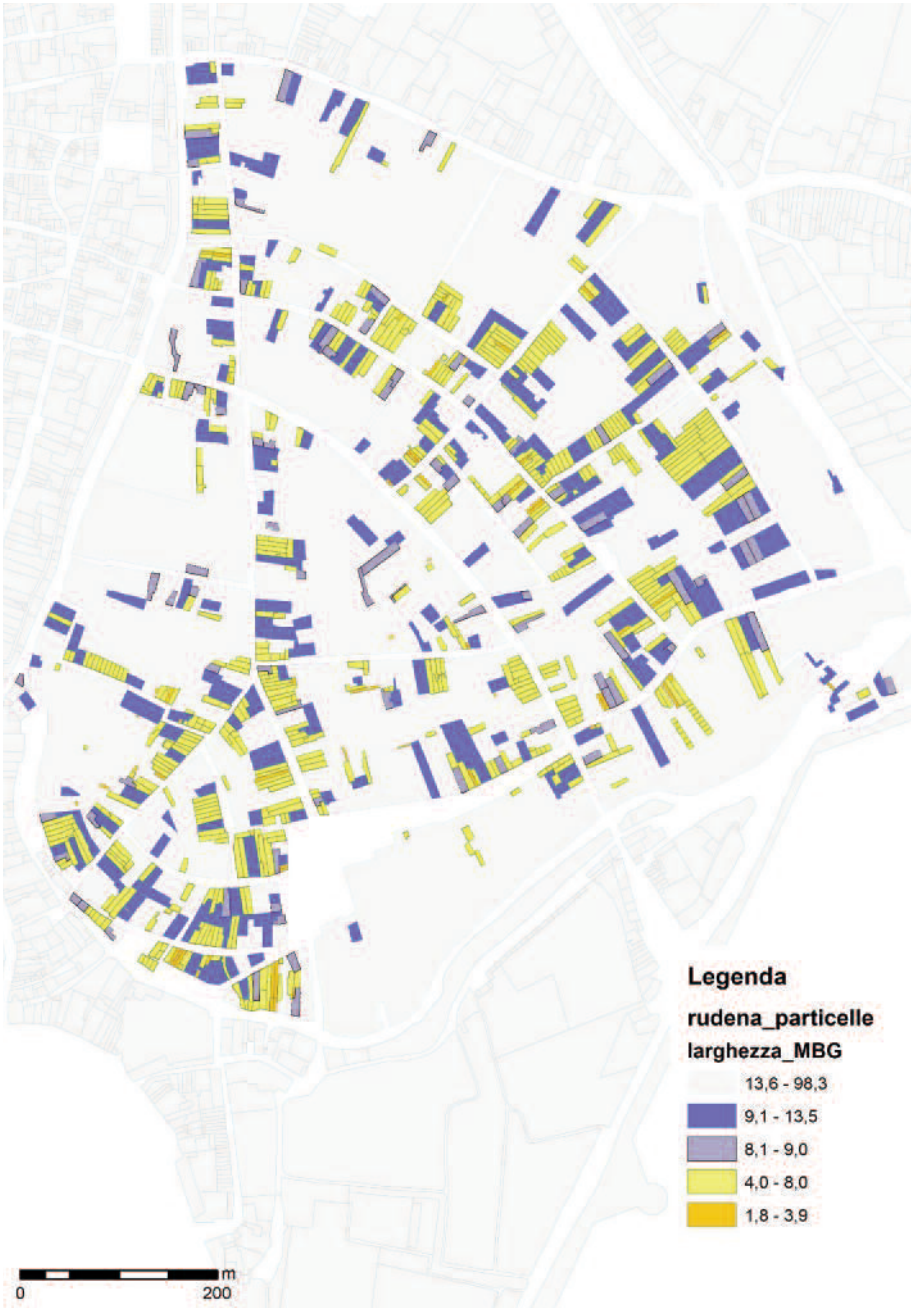

Fig. 13. Rudena, chromatism based on the width of the parcels: in yellow the parcels with dimensions compatible with those obtained from written sources, in blue those with dimensions compatible with those obtained from archaeological data.

district of a considerable quantity of units with early medieval size characteristics (fig. 13). The most significant data is, however, perhaps their distribution across the district, indicating that this type of plot was reused over the centuries with minimal variations or that the bulk of the area had already been portioned up in the 13th and 14th centuries.

Yet, based on (a) the historical context and references in Rolandino's *Chronica* (second half of the 13th century), in which the author affirms that Borgo Rudena was one of the town's most beautiful districts in 1256 (*Rolandinus Cronica* VIII, 12), thus implying an already well-developed architecture, (b) the 14th century building of the Marsilio da Carrara walls, (c) the early 14th century documents that already list almost all of the toponyms later rediscovered in the 18th century survey and, more specifically, in the Napoleonic survey, it can reasonably be hypothesised that the urban fabric had already formed in the 14th century.

5. Conclusions

The current state of the district's buildings makes the assessment of the state of conservation of the residential architectural heritage impossible without resorting to invasive methods, due to the plaster and restoration work covering wall facings.

Fig. 14. Catastic of the Properties of Sant'Antonio, sheet 6. Representation of the eastern front of the second part of Via del Santo.

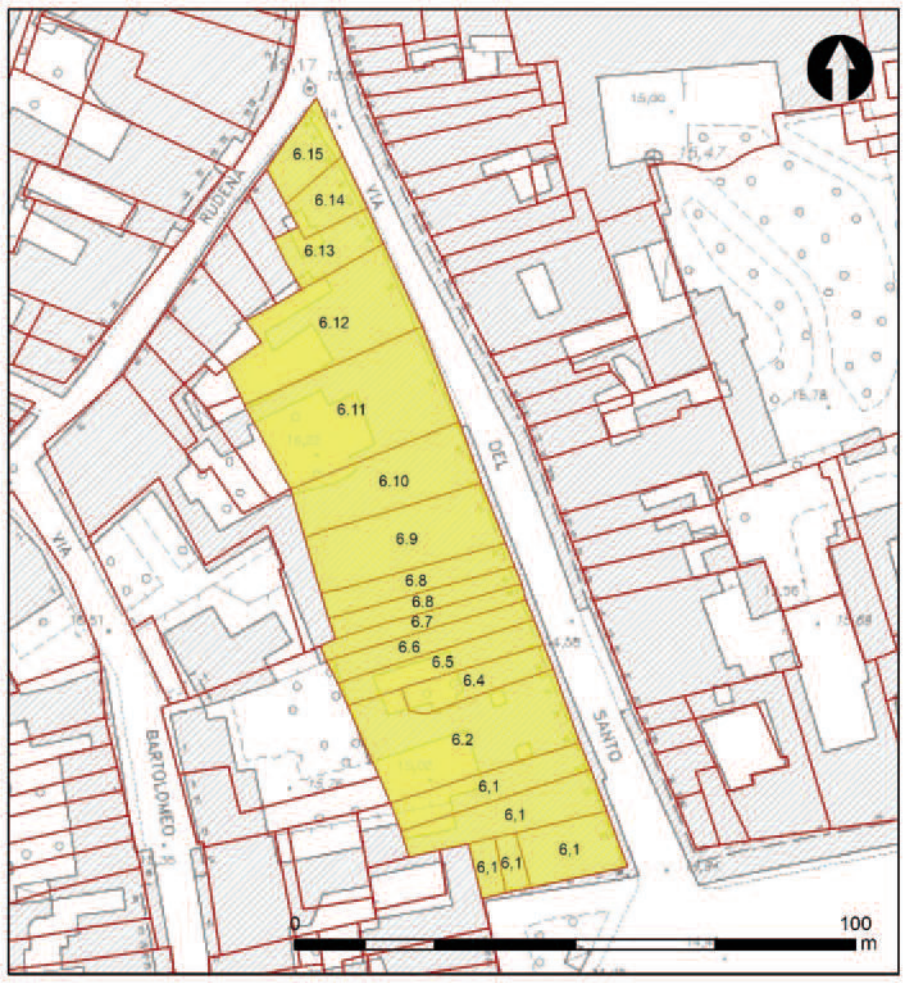

Fig. 15. 19th-century cadastral parcels corresponding to the buildings represented in the Catastic, sheet 6 (fig. 14).

To side step these obstacles, at least partially, iconographical sources were used, the Catastico delle Proprietà di Sant'Antonio drawn up by Lorenzo Mazzi in 1735 (housed at Archivio di Stato di Padova, Aspd-S. Antonio 320). These depict the façades of dozens of buildings, both residential and otherwise, many of which are still extant in the Rudena area; although shown without a scale, they offer a significant quantity of details: numbers of portico arches, presence of decorated capitals, windows with Gothic or Venetian arches, balconies, chimneys.

After systematic comparison between the 18th century building sequence and that shown in the 19th survey (e.g. figs. 14 and 15), limited changes to the building sequence are visible in the century which passed between the Catastico and the Napoleonic survey, a sign that little had changed since the early 18th century. A last comparison was carried out between current buildings and those shown on Mazzi's Catastico. In many cases, current façades clearly point to the same layout of floors, windows and doors shown in the 18th century. This simple comparison enabled many still existing buildings, 'concealed' by modern homes, to be dated prior to 1735, at least. The temptation to arm ourselves with chisels and chip away at the centimetres of modern plaster sealing off the history of these buildings is, thus, a legitimate and powerful one. With the hope of soon uncovering new data from archaeological excavations and architectural restoration projects, the certainty remains that this sector of the historic centre encompasses an urban and architectural heritage far greater than is generally perceived.

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