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Cover image: embankments at the Danube waterfront of Regensburg "Donaumarkt" made of re-used Roman material, probably Carolingian (S. Codreanu-Windauer, BLfD 2014).

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Post - Classical Archaeologies

EDITORIAL

Rivers have always been a great opportunity for communication, commerce, sources of energy and resources. Around them real economic landscapes have developed, such as those in England analyzed with GIS techniques by Eljas Oksanen. A paper that shows – as many others in this volume – how well established today are spatial, temporal and statistical analyses among archaeologists, offering novel perspectives on traditional topics. At the same time rivers connect and divide, representing frontiers and obstacles, as well as a continuous threat for those living at the waterfront (as was the case with the River Trent in England analyzed by Richard Jones, Rebecca Gregory, Susan Kilby, Ben Pears), navigating or crossing them. In the drainage basin, more than elsewhere, it is possible to measure the ability to adapt and the resilience of the local communities, using remote sensing techniques and geoarchaeological surveys. These tools have been used to reconstruct ancient river paths, flow rate variations, and man-induced hydraulic modifications in the Lower Tiber valley (Antonia Arnoldus-Huyzendveld) and along the Tirso River near Oristano (Pier Giorgio Spanu).These techniques can also be used to investigate the evolution of agrarian landscapes near rivers, which in the low plain can be heavily transformed by the abandonment of agrarian landscapes, formation of marshy areas, and land reclamations (such as in the Lower Adige basin: Gian Pietro Brogiolo, Julia Sarabia). Furthermore, archaeological methods also can identify channels, such as the Fossa Carolina*, an excavated unfinished channel about 5 meters wide, with a minimum water depth of about 50 cm (Lukas Werther, Lars Kröger). Beyond channels, consolidation and precautionary measures, specific building techniques in wetlands, drainage systems in areas affected by stagnation or flooding hazards, and transports also can be analyzed.*

Rivers can tell many stories, sometimes being enemies and other times resource donors, but they are always incentives to create new social and political groups able to cope with them.

Cécile Rivals, winner of the 2017 PCA Award, proposes the use of the graph theory applied to urban landscape, to transform the fiscal appraisal notes, dated to the 15th century, into developmental planimetries of the blocks. New perspectives in the study of ceramics, especially for those still without conclusive chronology, are offered by the rehydroxylation dating method (RHX) for the dating of early medieval ceramics from southern Apulia in Italy (Paul Arthur, Alessandro Buccolieri, Marco Leo Imperiale). These methodological issues, as well as the paleopathological and anthropological analyses (here proposed by Jesús Herrerín, Lucía Muñoz, Natasa Sarkic, Rosa Dinarés on the necropolis of Viana de Duero in Spain), can be considered part of "traditional" archaeology. A different research line, with political implications, follows the archaeological study of English colonization in Ireland (imposed to punish a rebellion) between 1595 and 1643: an excellent paper describes a recent project developed by David Edwards and Colin Rynne.

Massimiliano Granieri's dossier about the legal framework of cultural heritage raises issues about political choices. Among the different countries, Italy stands out negatively, because of its elitist ideas on heritage, which result in restrictions and economic problems for researchers. A more open an democratic access to research is inspiring some of the recent projects developed in Padova, such as the participatory processes of research and heritage valorisation presented by Alexandra Chavarría, Francesca Benetti, Francesca Giannetti, Vito Santacesaria. The Council of Europe legislated these themes in different years with antithetic conventions: initially with the repressive Valletta Convention, which reaffirmed a bureaucratic idea of heritage management; later with the Faro Convention, inspired by the concept of a shared understanding and protection of heritage. This latter concept should be followed to give impulse to a discipline in crisis. A traditional understanding of archaeology (as Enrico Giannichedda highlighted) was used instead by the panel of the recent exam for archaeologists of the Italian Soprintendenza. In fact ignoring the real state of the art of a multidisciplinary and diachronic science, no trace of the methodological or transchronological aspects of archaeology appeared in the final oral exam used to discard 23 candidates out of the last 226.

A trend towards a focus on chronological specialisations and ignoring the real state of the art of a multidisciplinary and diachronic science that also reflects current programs in many Italian universities, condemning our academic and management systems to isolation from the exciting future perspectives which European archaeology is offering abroad.

The objective of PCA, now arrived to its 7th volume, is to open a window to this forward-looking international perspective.

PCA 7 (2017) ISSN: 2039-7895 (pp. 201-224)
Post - Classical Archaeologies

WINNER OF THE PCA AWARD 2017

The modeling of urban spatial dynamics in long time spans: the use of graph theory to study a block in Saint-Antonin-Noble-Val (Tarn-et-Garonne, France) from the 14th to the 19th centuries

CÉCILE RIVALS

Laboratoire TRACES, UMR 5608, CNRS, Université Toulouse 2 Jean Jaurès, Quartier Bouchet, 07120 Saint-Alban-Auriolles, France.
cecile.rivals@gmail.com

Medieval and modern tax sources (*compoix, terriers* and cadastres) are commonly employed for the study of landscapes, but the lack of map references hinders the possibility of using these data for location purposes. In order to study the plots' dynamics in a long-term perspective, it is necessary to move away from classical representations: the contiguity of plots is considered as a linked network. Thus, it is possible to retrieve the topological attributes from the documents and model the urban landscape using graph theory.
Keywords: graph theory, fiscal sources, spatial analysis, Middle Ages, modern period

Le fonti fiscali medievali e moderne (catasti, compoix, terriers) sono normalmente usate per lo studio del paesaggio, ma la mancanza di mappe nella documentazione più antica rende ardua la possibilità di utilizzarle per la localizzazione. Per studiare le dinamiche spaziali sul lungo periodo tramite queste fonti, è necessario discostarsi dalle classiche rappresentazioni, considerando la contiguità dei lotti come collegamento a una rete. In questo modo, è possibile usare gli attributi topologici del documento per creare un modello del paesaggio con l'aiuto della graph theory.
Parole chiave: *graph theory, fonti fiscali, analisi spaziale, medioevo, epoca moderna*

1. Introduction

The scarcity and heterogeneity of planimetric documents, before the systematic realization of the Napoleonic Cadastre in the 19th century, hampers the study of urban spatial dynamics. Fiscal sources, such as *terrier* and *compoix*, allow us to overcome these difficulties. These documents, considered ancestors to the Napoleonic Cadastre, appeared in France during the 13th century. There are tens of thousands of those in municipal and departmental archives and they have been in use until the 18th century. They identify the lands of a territory in order to levy taxes.

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Parcels are described and placed in space by the use of microtoponyms and surrounding features. The landscape exists in fiscal sources but in what form? *Compoix* and *terrier*'s writers didn't want to describe the landscape, whose notion didn't exist yet. The duty of historians consists of studying these data in order to give birth to a reconstructed landscape. The lack of map references complicates the use of *terrier* and *compoix*. The necessity of a strategy that oversteps these difficulties led to the application of graph theory in order to model spatial information.

In *compoix* and *terrier*, taxpayers' properties are identified, located and estimated. These documents are similar in matter and form. The purpose is to levy public or private tax in proportion to some value or use of parcels. *Terriers* come from lordly administration. They establish the nature of the fees due to the tenant's lord; instead, *compoix* come from public administration. It is prepared in order to fairly allocate the amount of the tax due to the king. What differentiates *compoix* from *terriers* is the lack of space continuity in the latter (Derruau 1946, p. 358). While the purpose of these fiscal documents is not to dealing with the landscape, the geographical information they contain can be used to reconstruct it. These documents consist of lists of parcels describing the owner, the nature, the location, the *confronts* (neighborhood's description), and the *allivrement* (coefficient to calculate the tax). Sometimes, some characteristics, such as surfaces, number of floors per house or agricultural quality of a plot, are mentioned. *Confronts* can be either other parcels or landscape elements (rivers, streets, public or religious buildings), which are called invariant *confronts*. The amount of *allivrement* is not the real price of the properties, but a theoretical evaluation used to distribute the annual tax.

Because the information contained in tax documents from the 13th to the 18th century is remarkably rich and standardized, they are ideal for quantitative studies. By focusing on the nature of the plots or the amount of the *allivrement*, the economic and social history of a community can be analyzed (Claveirole, Pélaquier 2001). Toponymy and demography can also be used for the study of *compoix* and *terriers* (Le Pottier 1992). The mention of microtoponyms and especially the description of elements that are around the plot provide landmarks, thus allowing to pose questions on the organization of the territories. It is therefore possible to focus on the distribution of professions of owners and use of parcels. However, despite the multiplicity of possible approaches, historians face difficulties when they want to study space over time. These difficulties are due to the lack of map associated with registers. Nonetheless, fiscal documents, which describe over several centuries

the same space at small time intervals, are particularly helpful when studying spatial dynamics. Until now, the solution was to recreate the plot of small areas, based on the information included in the *confronts* (Catalo 1996, pp. 51-74; Mallorqui 2002, pp. 343-360; Hautefeuille 2006, pp. 523-552). This process is time consuming, and inevitably source of errors. Moreover, the parcels' shape is almost never mentioned in the registers, and this, therefore, represents a problem when trying to reconstruct a plot. The regressive method does not guarantee the accuracy of the reconstruction. Furthermore, registers not always provide information on parcels subject to taxation, and also homonymous owners can represent a problem of the reconstruction. Other solutions has been considered, but none has truly enabled the study of spatial dynamics (Claveirole, Pélaquier 2001; Brunel *et al.* 2002). Many researchers have shown these issues and insisted on the need of a new approaches (Conesa 2007; Leturcq 2007; Poirier 2010).

The Rome symposium in 1985 came to the same conclusion (Biget *et al.* 1989), but it also proposed new approaches through the use of a mathematical object, graph theory (Montpied, Rouault 1989, pp. 359-380). This method has remained at a draft stage because the technological possibilities did not allow them to carry it to term at the time. The advances in computer technology now make it possible to overcome these limitations.

In the context of the Modelespace project[1], we pursued the idea to apply graph theory to tax registers. The aim of this project was to provide a tool for analysing urban and rural spatial dynamics from *compoix*, *terriers* and cadastres (Le Couédic *et al.* 2012, pp. 71-84; Rivals 2013, pp. 190-196). This project, which relies on the collaboration of historians, archaeologists, geomatics and mathematicians, estimates that a plot can be conceived as a network and therefore modelled as a graph (Rodier *et al.* 2013, pp. 99-118). Thus, each parcel represented by a node is connected to the elements that are around and which it has a physical link (*confronts*) with, via edges (fig. 1). The components of the landscape (streets, rivers, public buildings) are also transcribed as nodes and connected to the plots. The aim of this approach is not just the recreation of the plot. We would like to distance ourselves from classical plot representation, in order to avoid problems encountered by histori-

[1] This program was founded by the *Agence Nationale de la Recherche* from 2010 to 2012. ANR-09-BLAN-0322-02 «Modélisation des espaces préindustriels». It was led by Florent Hautefeuille, Bertrand Jouve and Samuel Leturcq. The website is available at this address: http://modelespace.univ-tlse2.fr/.

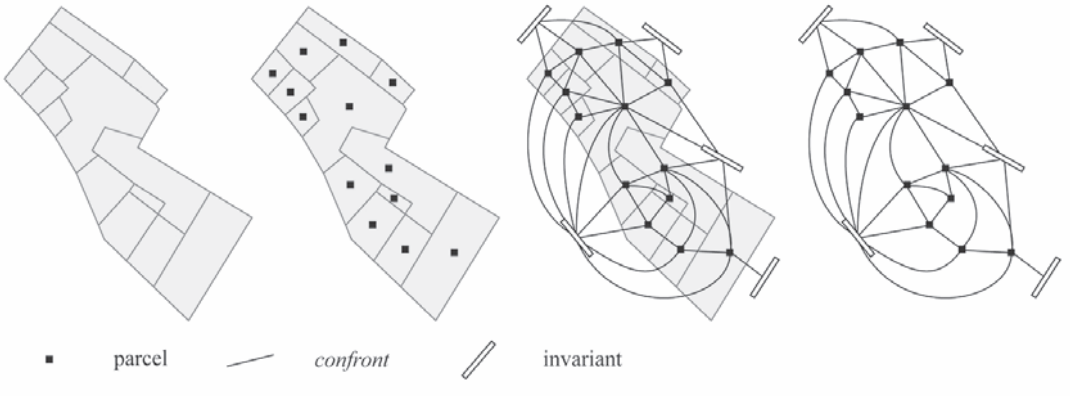

Fig. 1. Transcription of a plot from parcel's adjacency graph.

ans who attempted reconstructions. One of the main advantages to represent a plot as a graph, when trying to reconstructing it, is the minimization of errors. Indeed, when uncertainties remained about the relationship between two plots, the link is not created on the graph, while a plot representation involves making choices and can induce errors. Analyses carried out from graphs are made on an object which is more accurate than visual? reconstructions.

In this article, after the presentation of the methodology, the aim will be to show how to study spatial dynamics of a block in a small town in southern France, from the late Middle Ages to the pre-industrial era. The analysis of urban fabric requires the global understanding of traffic patterns and plots' access. It is also necessary to measure the impact of elements that shaped the landscape, such as streets, spaces for trading and fortifications, within the town development. By studying the spatial distribution of different social classes and professions across the town, it is possible to detect both fixity and dynamism across the urban landscape. The modeling of fiscal sources and the integration of historical and archaeological approaches/methods can answer these issues.

2. Methodology

Graph theory allows for a new approach to the urban landscape, which compares written and planimetric sources derived from fiscal sources over time. The first task is to transform the object of study into graphs. Fiscal registers without plan are directly extracted from a database, while graphs from cadastres come from GIS. Once each document

is converted into a graph, the comparison is not directly on the documents themselves but on their conversion to graphs of plot's adjacency.

2.1. The construction of adjacency graph plots

2.1.1. Based on written tax registers

The reconnection of adjoining links that can be established between plots based on mentions of *confronts* can hardly be done manually because the combinations are too numerous when the corpus grows. Today, the development of computer tools can overcome this problem. It is now possible to automatically link parcels from many scripts developed by Florent Hautefeuille[2]. For each parcel, these algorithms look for parcels or invariants that correspond to the *confronts*, in order to create an adjacency matrix of parcels. These automatic matching algorithms can process the links between parcels and invariants. References to localities and mention of the orientation of *confronts* (when they exist) are used to establish edges. While some cases remain insoluble, this method allows for the study of large corpora and the transition to a mathematical formalization.

In the database developed within the Modelespace project, the automatic pairing scripts create an adjacency matrix of parcels, which can be exported to a graph visualization software, as *yEd Graph Editor* or *Gephi*. The obtained graph considers also the plot-to-plot pairing and the pairing of plot to invariants that are identified and localised. Other invariants are not considered. For example, it is not possible to manage unnamed streets, as they are not distinguishable. The last task, that need to be done manually[3], consists of completing the edges between parcels that are not identified automatically and to create some invariants that are identified but not localisable. For instance, some streets are named but the name has changed and it is impossible to assign them to a specific geographical location. However, it is necessary to include the unnamed streets in the graph as they can be used to integrate different parts of the graph itself and thus increase its overall connectivity. The pairing procedure is in the process of being increasingly automated.

[2] Florent Hautefeuille has developed these scripts in the program Modelespace «Modélisation des espaces préindustriels» (http://modelespace.univ-tlse2.fr/).

[3] Yves Truel made the same observation when he built the plot graph of a *terrier* realised in 1770 (Truel 2013, pp. 563-596). He sought to automate this task by creating a graph of certain edges and by using tools (like degree and planarity) in order to eliminate the problematic edges.

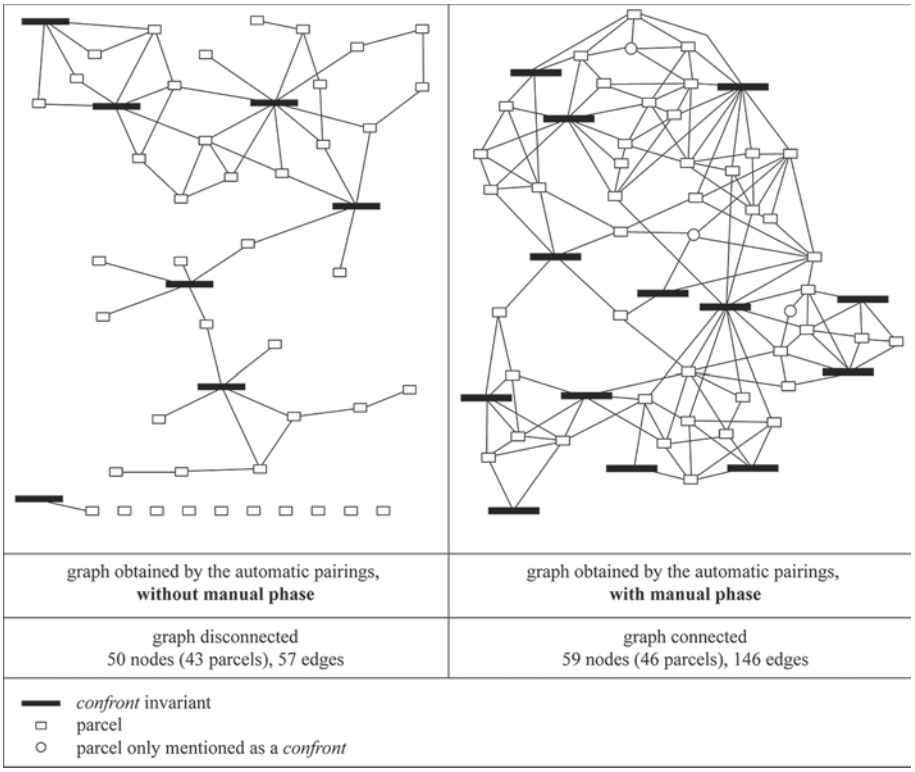

Fig. 2. Necessity of a manual task for the creation of plot's adjacency graph from fiscal registers.

In automatic procedures, reciprocal *confronts* are the only ones considered: a link is created only if "*A confronts B*" and "*B confronts A*". In some cases, especially for registers without the mention of all the *confronts*, the restriction based on reciprocity severely limits the number of matches. That is why the choice was made to add some edges, even when there is no reciprocity. To avoid the risk of error, this task should not be automatic. For example, when there is a strong inconsistency with other neighbours, the link is not established. This step greatly increases the connectivity of the graph (fig. 2). Some parcels which are not reported in *terrier* or *compoix* are sometimes mentioned as a *confront*. In those cases, they are added in the graph to reflect the entire area. They are distinguished from the other parcels by the node's shape. The same fiscal source can produce two different landscapes depending on the selected prism (Conesa 2007, pp. 108-109). The landscape of

declared parcels only may be different from that provided by the study of *confronts* which may reveal other parcels undeclared. It is essential to combine these two landscapes.

The orientation of *confronts*, when specified in the source, is useful to construct graphs. Indeed, sometimes streets are not linear but form right angles while carrying the same name. In that case the automatic procedure creates only one node, which must be cut into sections with different orientation. That information is also useful to distribute nodes on both sides of an invariant when it passes through the area in question.

2.1.2. From cadastres

Le Couédic *et al.* propose a new method of generating a graph from plot maps that has been developed within the Modelspace project (Le Couédic *et al.* 2012, pp. 71-84).

The first task is to digitize the plan as a topological structure[4], thus obtaining a topological planar graph (fig. 3). In this graph, nodes are points of intersection of parcels and edges are the boundaries. Then we extract the dual graph, in which nodes are parcels and edges are the neighbourhood links. The last task is to associate to each node attributes such as the nature, the owner's name and profession, the locality, the surface and the amount of *allivrement*. The adjacency matrix can then be imported into a graph visualization software.

Some questions were raised about the treatment of linear invariants (such as rivers and streets). Several solutions have been envisaged in order to incorporate them into graphs: removing and integrating them directly to the parcels, splitting them into as many sections as parcels, cutting them at each intersection and representing them as nodes connected to all the surrounding plots. The latter solution is the most relevant to compare parcel plans to fiscal registers without plan, as this representation corresponds to the structure described in the sources.

2.2. Graph analysis

The comparison of different states of the same landscape is not done at the parcel level. Indeed, it is not possible, with few exceptions, to identify a parcel from one register to another. The comparison over time is

[4] It is essential that the plan forms a complete paving without empty spaces or overlaps between parcels. The ArcInfo software has effective topology tools.

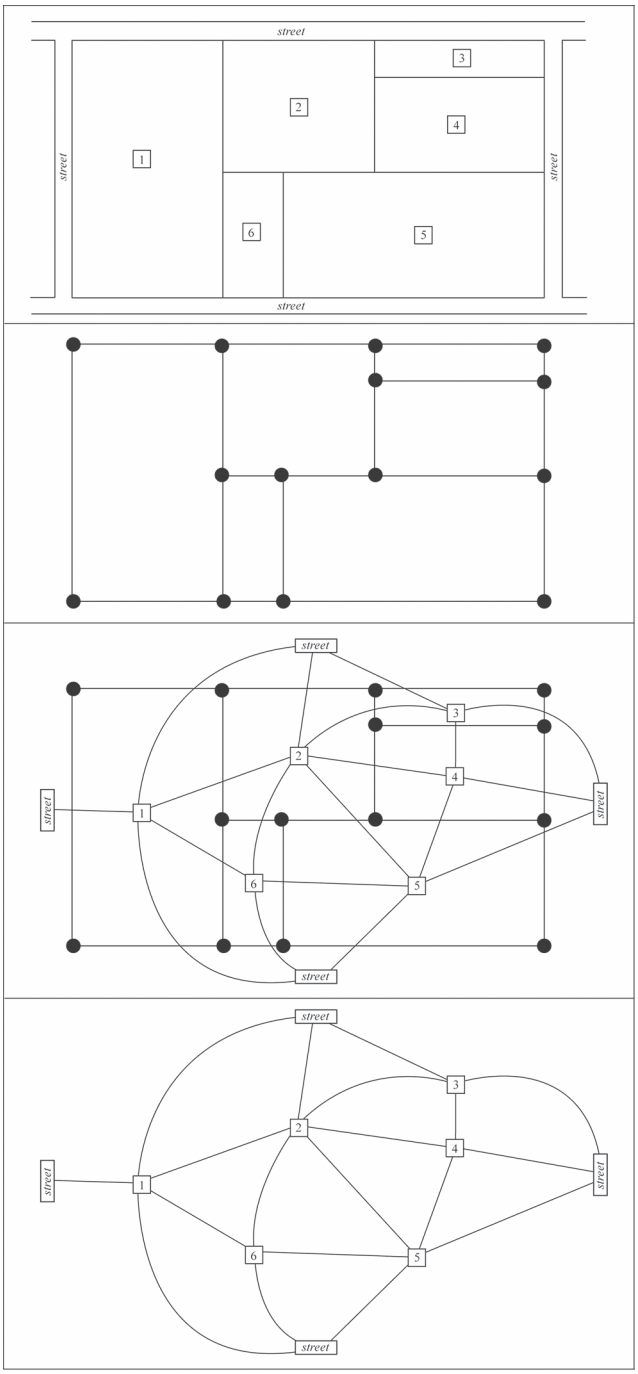

Fig. 3. Principle of the creation of a plot's adjacency graph from a plan.

carried out on groups of parcels, identified by invariants surrounding them. The aim is a global understanding of an area and not the evolution of each parcel taken separately. These comparisons are conducted from two main angles. The first one is based on visual comparisons with node's attributes and the distribution of nodes around an invariant. The second one is to identify paths and cycles in which length is significant.

2.2.1. The graph as representation tool

Information is associated to each node of the graph. According to register's precision, this information is the nature, surface, *allivrement* per m^2 and owner's profession. This information allows various displays: colour, shape and size of nodes reflect the attributes. With regards to the edges, the attributes are related to the orientation of adjacent links (north/south or east/west) and the degree of reliability when there is a doubt. From these displays, we can make observations on node's distribution. For example, we can observe the increase of gardens along a river, or an *allivrement* per m^2 higher for parcels on a street with a lot of shops. The distribution of owners' professions shows the specificity of an area. Using this method, it is possible to study the landscape of a single time period as well as visually compare the graphs of diverse periods. The distribution of parcel's nature in an area evolves over time and this change may be symptomatic of urban restructuring, as well as of the evolution of a dominant profession in a specific zone.

It is not easy or wise to compare directly parcel's surface or amount of *allivrement* per m^2, as units and values have changed over time. Nevertheless, it is possible to speculate on proportions. For each parcel, the amount of *allivrement* per m^2 is compared to the average of the city or the neighbourhood. Thus, if from one period to another, the *allivrement* per m^2 of an area is below average and then above, the value of the area increased. The procedure is the same for surface. It is possible to know if there was a major reorganization of space. Although these phenomena can be identified on graphs, they still have to be interpreted. For instance, we have to explain why an area becomes more commercial or residential, increases or decreases value. The moving of an activity (market or butchery for example) may explain these developments.

2.2.2. Paths of length 2 between two invariants

In a graph, a path is a sequence of nodes so that two consecutive nodes are connected by an edge. The path length is counted as the number of its edges. the distance of two nodes is considered as Euclidean.

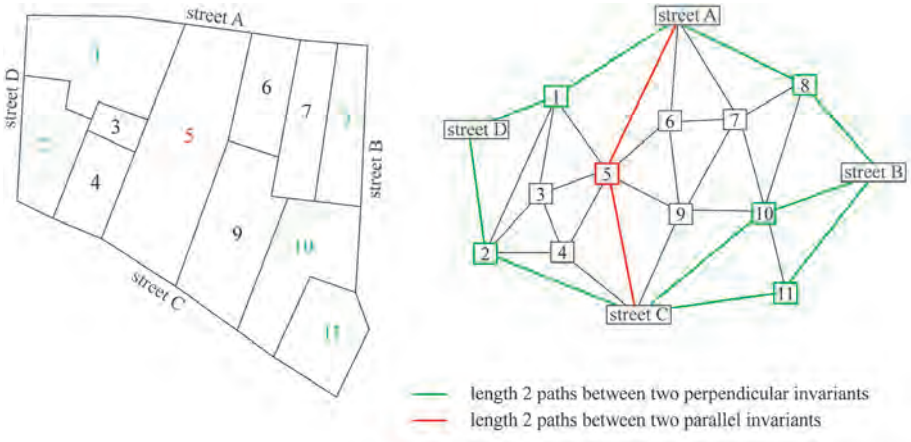

Fig. 4. Interpretation of length 2 paths between two invariants.

A path of length 2 between two invariants corresponds to the presence of only one node between them. These paths provide two types of information. If the invariants are perpendicular streets, and there is only one path of length 2, then the node is a corner parcel (fig. 4). If more than one path of length 2 exists, then one node corresponds to the corner parcel while the others are L-shaped parcels. If the invariants are not perpendicular, then the node is a traversing parcel (fig. 4). Obviously, all the reciprocal are true.

The identification of paths of length 2 presents several advantages. For instance, the accumulation of length 2 paths, between two non-perpendicular invariants, actually corresponds to a lanyard parcel. The identification of this kind of cutting is important, both in urban and rural territory, as it reflects a specific spatial? organization and shows the influence of the invariants to this organization. For example, in Saint-Antonin-Noble-Val, the modelling of adjacencies of a *compoix* made in 1670[5] allowed identifying a lanyard plot near the Aveyron river (fig. 5). This area is constituted by lanyard parcels between streets *de l'Escolo Vielo* and *du Bourdel* to the north and the wall along the river to the south. On the graph of a plots plan made in 1782[6], despite some plots limits changed, the organisation is similar. On the map itself, there are several lanyard

[5] Archives communales de Saint-Antonin-Noble-Val, CC7-10.

[6] Archives communales de Saint-Antonin-Noble-Val, JJ13.

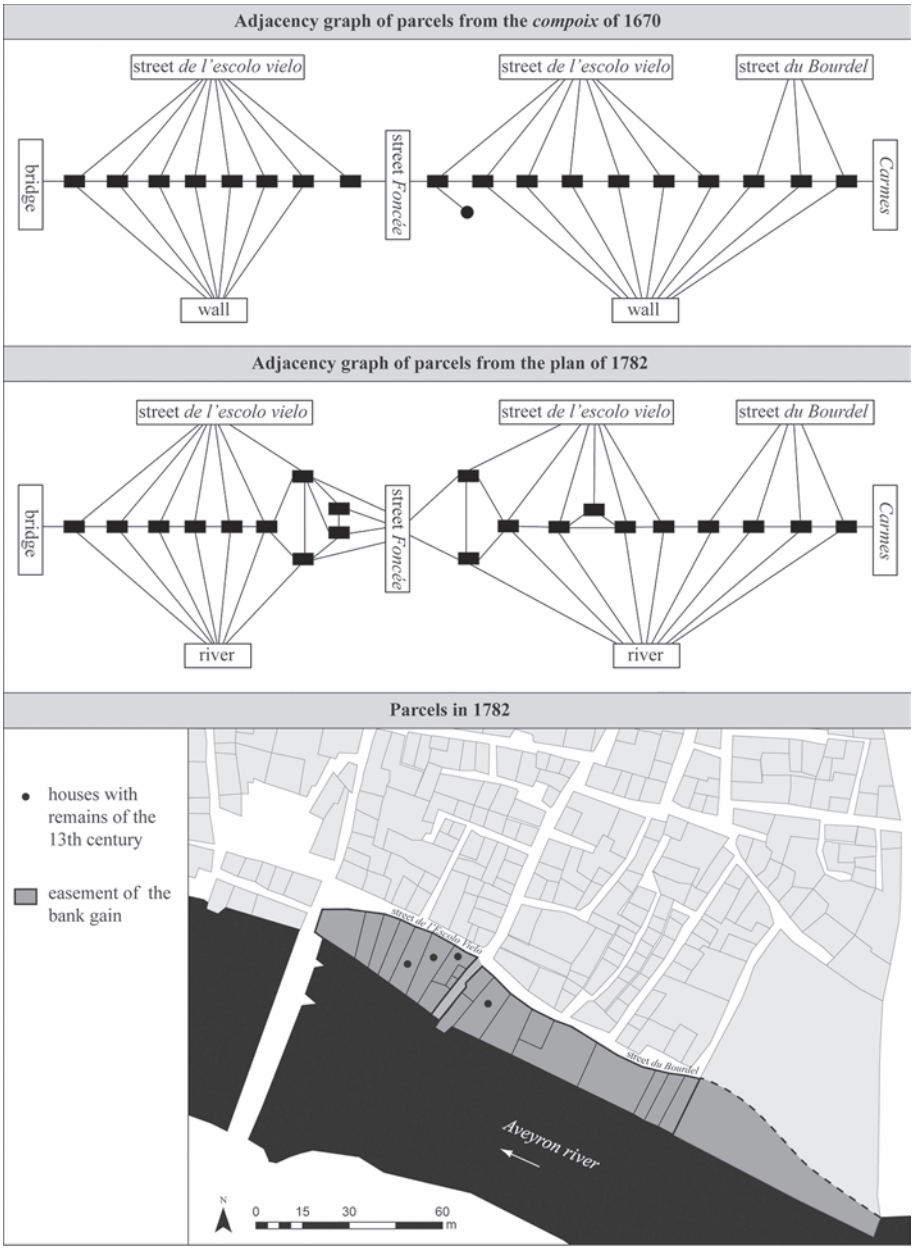

Fig. 5. Identification of a lanyard plot which is the result of a 13th century planning in Saint-Antonin-Noble-Val.

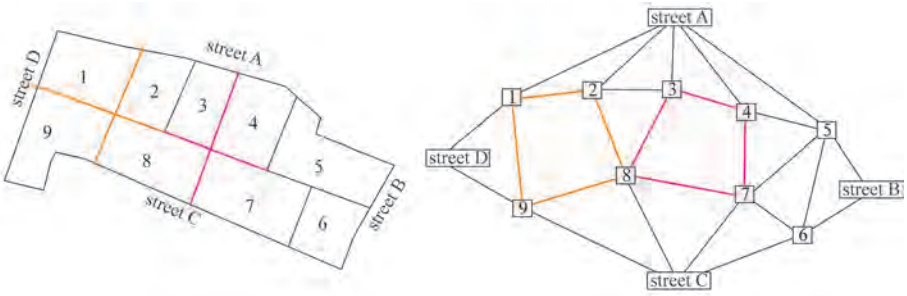

Fig. 6. Cycles of length 4, translation of cross-shape boundary.

parcels between streets and the river. The regularity of this plot and the winding streets indicate that this area resulted from the riverbank encroachment. The streets aligned along the former riverbank. The riverbed has been reduced in its northern part by an extension of the habitat on the riverbanks. This spatial organisation is the result of a formal planning of the area. The use of archaeological data enables to specify the *terminus ante quem* gave by the 1670 *compoix*. Indeed, remains of the 13th century have been identified on some facades in this area (fig. 5). Overall, with the crossing of many approaches, it is possible to identify a particular spatial planning and then propose a date.

The identification of corner parcels provides topographic landmarks. They help to stall the graph and make it more readable. Through the modelling using graphs, it is indeed easier to identify in the registers and maps a house at the corner of two streets. Once the parcel is identified, it is possible to use any figurative data as well as archaeology. Historical, mathematical and archaeological approaches are then complementary.

2.2.3. Long cycles

A cycle is a list of closed consecutive edges. The cycle length is the number of its edges. The most common length of cycles in adjacency parcels graphs is 3 (fig. 6). The presence of length greater than 3 cycle signifies a cross-shaped boundary (cycle of length 4) or more rarely star-shaped boundary (cycle of length greater than 4). Indeed, the contact between two parcels in the angle is never described in fiscal documents. A repetition of length 4 cycles can often reveal a regular plot which may be resulted from a subdivision process. This phenomenon can also be explained by the presence of an undescribed parcel in the register.

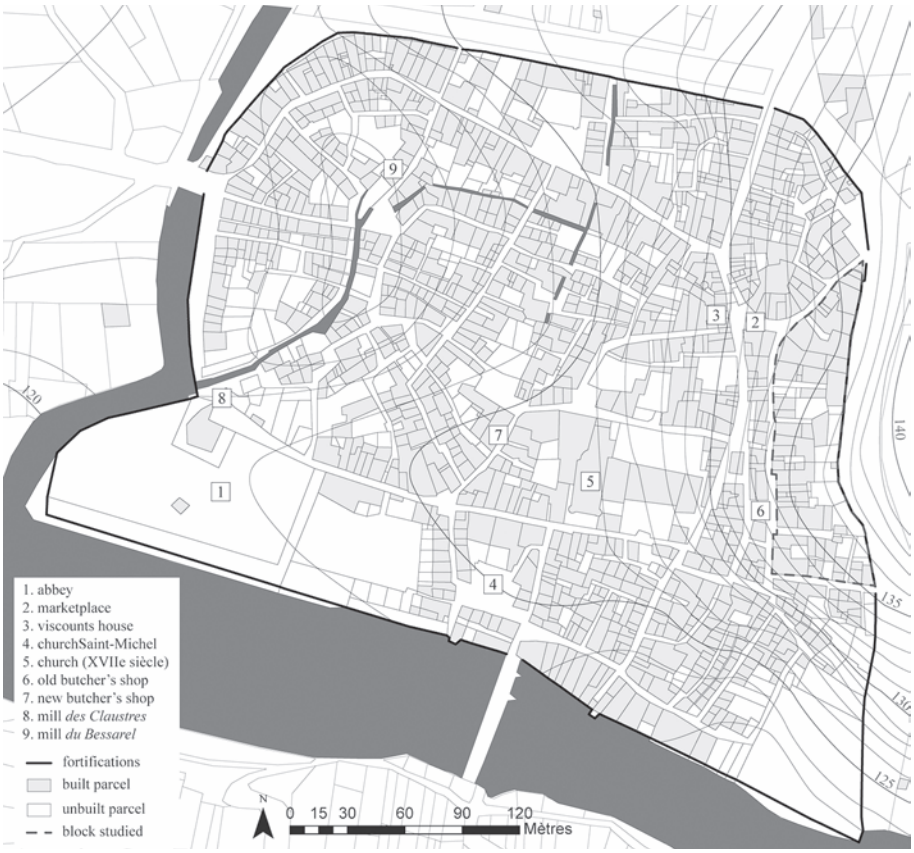

Fig. 7. The modern plot of Saint-Antonin-Noble-Val from the Napoleonic cadastre.

3. An application on a block of Saint-Antonin-Noble-Val

One of the areas selected for the application of the modelling of fiscal sources is located in the eastern part of the city of Saint-Antonin-Noble-Val, France (fig. 7). This block, of about 6000 m², is bounded on the east by the *boulevard du docteur Adrien Contans* which was created in place of the medieval fortifications. Currently, it contains about 70 parcels (fig. 8). Fiscal sources available for the study are three royal *terriers*[7] (1397, 1459 and 1609), one *compoix*[8] (1670), one plot plan[9] (1782) and the Napoleonic cadastre[10] (1814).

[7] Archives départementales du Tarn-et-Garonne, A120, A121 and C370.

[8] Archives communales de Saint-Antonin-Noble-Val, CC7-10.

[9] Archives communales de Saint-Antonin-Noble-Val, JJ13.

[10] Archives départementales du Tarn-et-Garonne, 3P2457.

Fig. 8. The plot of the block between 1782 and 2003, from cadastres.

3.1. Parcel's nature

According to the graphs of the 1397 and 1459 *terriers*, the block was mainly occupied by houses (fig. 9). From the 17th century, the proportion of gardens increased. Then, barns and courtyards have multiplied between the end of the 18th and the start of the 19th. This tendency is representative of the global evolution of the city during the modern era. The population has reduced during the 17th century, especially because

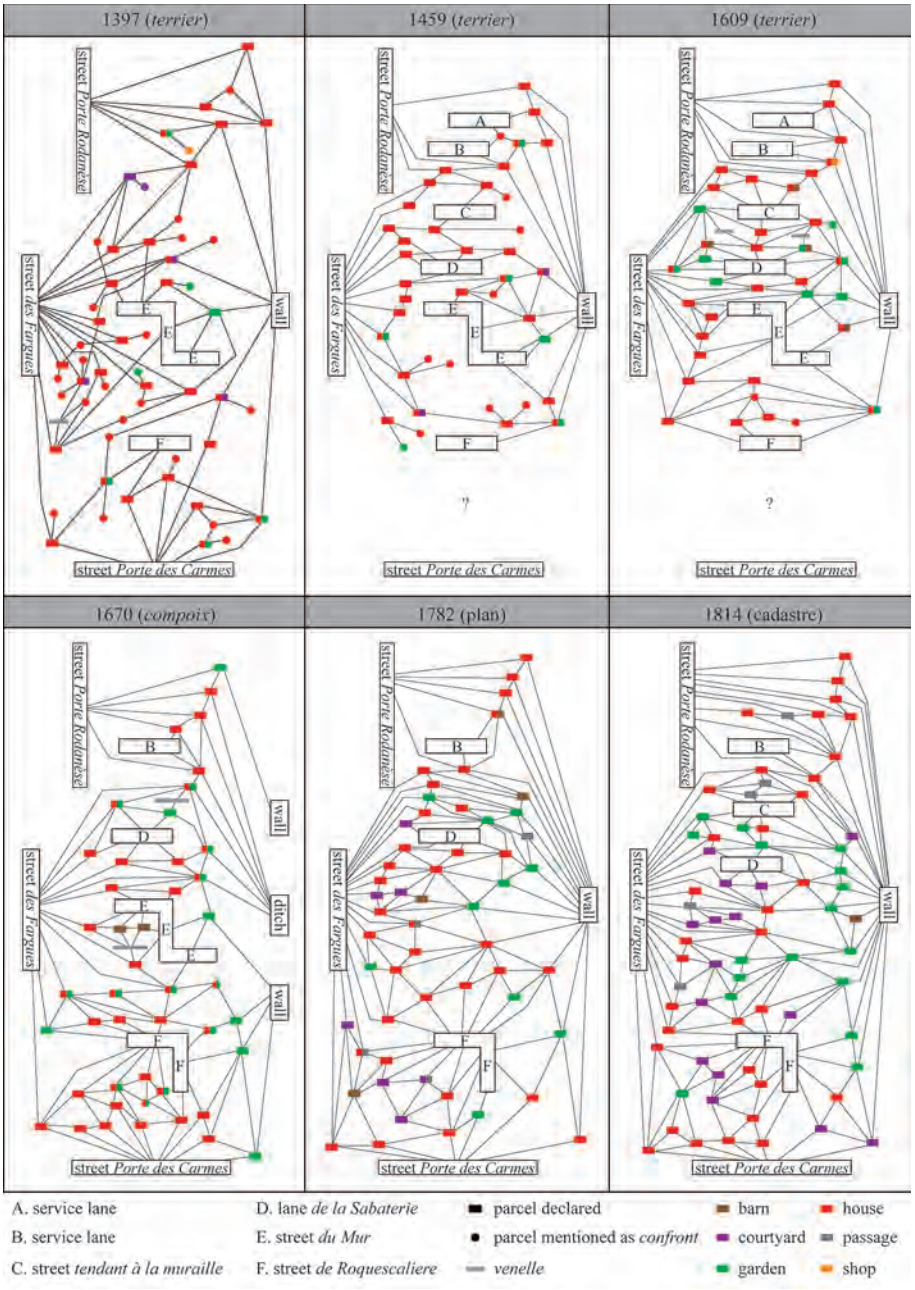

Fig. 9. Parcel's nature of the block between 1397 and 1814 from graphs.

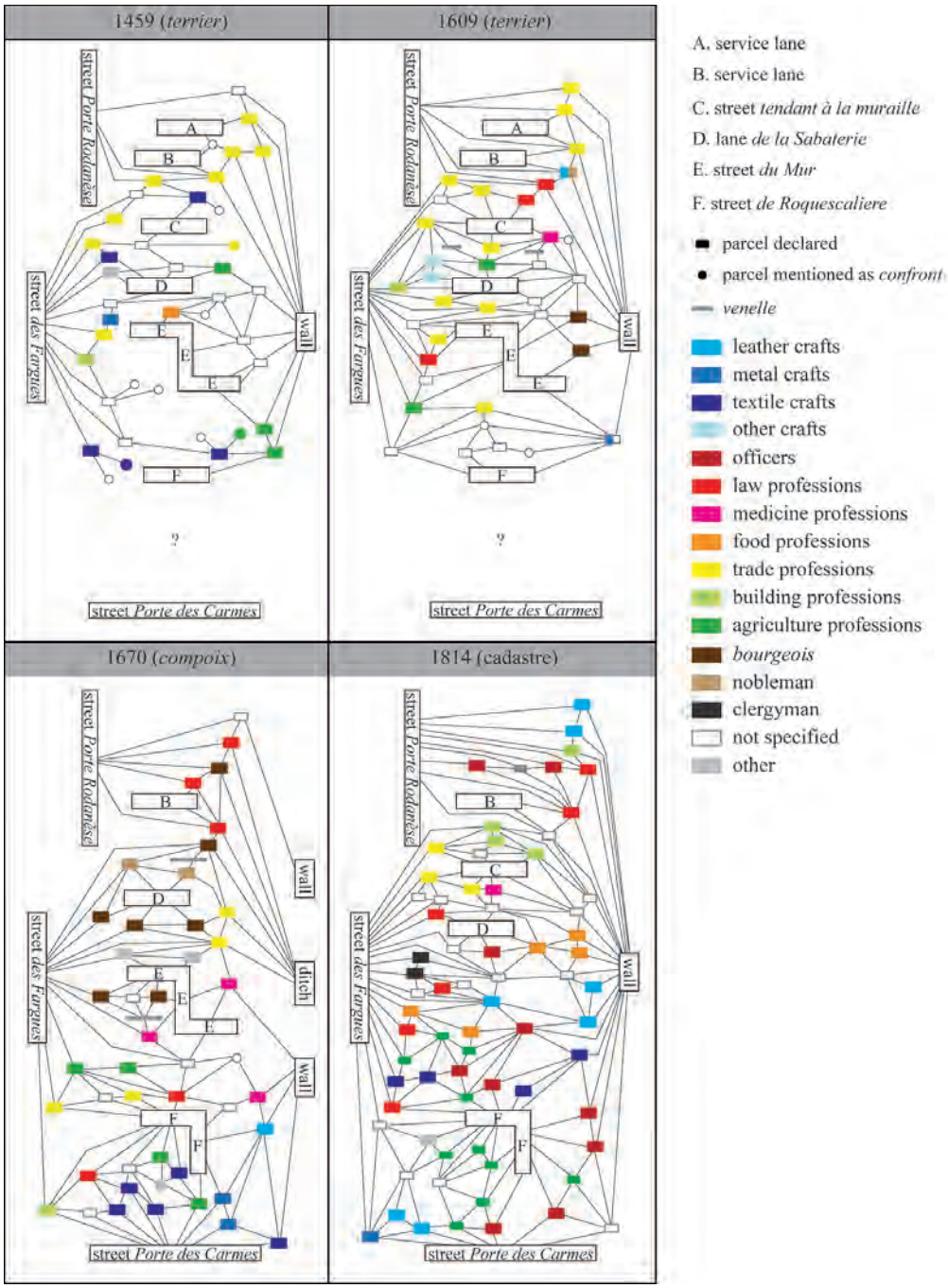

Fig. 10. The profession of parcel's owners in the block between 1459 and 1814 from graphs.

of two plague epidemics. Rural exodus has caused gradual desertion of urban parcels. Then the attractiveness of the city has lowered when the new road between Paris and Montauban was built, avoiding Saint-Antonin-Noble-Val.

3.2. Socio-professional distribution

Some registers mention the owner's profession. This information can be displayed on the graph in order to study the socio-professional distribution in the block, at a very small scale (fig. 10). According to the *terrier* of 1459, traders used to gather in the north of the block. There were no lawyers, no noblemen or *bourgeois*. The distribution was different in 1609. A *bourgeois* and a nobleman had properties in this block, nearby the wall. Law and medicine professions were present in the centre of the block. Parcels owned by traders were connected to the main street. In 1670, members of the elite (nobleman, *bourgeois*, lawyer) were located in the north. Textile and metal crafts were represented by some parcels in the south, between the street *Roquescalière* (F) and the street *Porte des Carmes*. In conclusion, it can be argued that, in two centuries, a strong evolution in owner's professions occurred, despite the separation between north and south continued. The members of the elite gathered in the north, while the south was dedicated to a working class represented by crafts, building jobs and farming. The Napoleonic cadastre shows a distribution organized in three areas. In 1814, law professions were located in the north, along with building professions. Textile and leather craftsmen were clustered in the centre, while farmers were in the south.

The modelling of the data included in the 1670 *compoix* can also be based on the amount of *allivrement* for each plot (fig. 11). Although it's difficult to think at a small scale without a comparison with other blocks, it appears that the most taxed houses were located in the north part of the block.

We noticed a distinction in the block between north and south. The street *du Mur* (E) can be considered as a boundary. The differences observed are linked to the position of the marketplace and the viscounts house, to the east of the street *Roquescalière* (fig. 7).

3.3. Influence of walls

The modelling of fiscal sources of this block, provide information on the fortification's organization in this area. In fiscal registers, the *confront invariant* on the east is the wall, which is today the *Adrien Con-*

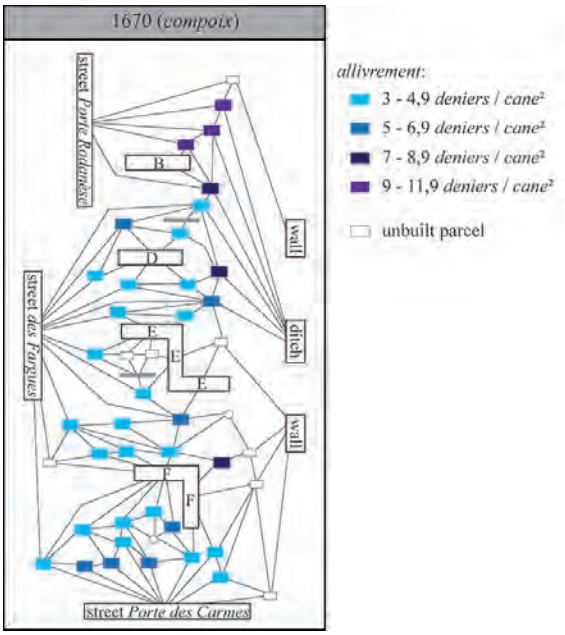

Fig. 11. The amount of *allivrement* in the block from the 1670 *compoix*.

stans boulevard (figs. 8-9). In 1670, the oriental *confront* was either the ditch or the wall. The study of the graph reveals that the ditch was marked out by houses or combined plots (house and garden), whereas the wall was adjacent only to gardens. Further to this observation, the first hypothesis is that the wall was incompletely demolished at the time of the realization of the register and houses were adjoined to the ditch. The second hypothesis is that houses were enlarged to the wall by reusing it, which explains that the *confront* is not the wall but the ditch.

In 1397, only the wall was mentioned as the eastern *confront* (fig. 9). It is bordered by built and unbuilt spaces (garden and courtyard). The lack of mention of the ditch demonstrates on one hand that the wall had a defensive role since it was there the entire route, and on the other hand, that houses were not used as fortifications. When houses have the wall as *confront*, it probably means that some small free spaces undescribed in registers were inserted.

This example reconsiders, at least for this part of the city, the idea that houses formed the fortification (Rivals Rossi 2015, 95-99). Through the modeling of tax registers, we have facts that allow us to say that the wall and the houses were separated by unbuilt spaces. From now on, we know the layout of fortifications and their impact on the environment, just after two conflict phases, the Hundred Years War and the Religion Wars, which had impacted deeply the urban landscape.

3.4. The internal circulation patterns in the block

This area also reveals the transformations of access to the parcels inside the block. Access to the parcels could only be gained through the streets *des Fargues* to the west, *Porte Rodanèse* to the north, and *Porte des Carmes* to the south (fig. 8). Today, only two streets cross the block, from the west to the east: the streets *de Roquescaliere* (F) and *du Vallon* (C). This one was extended to the east in 1844. The 1814 cadastre reveals two additional lanes: a service lane (B) and the lane *de la Sabaterie* (D). It also shows that the street *de Roquescaliere* (F) is in an L-shape. The 1782 plan does not show the street *du Vallon* (C) but it can be identified in the unbuilt parcel n° 129. Thus, from a simple regressive analysis, we note that streets and lanes have evolved between the late 18th and the early 19th.

The study of fiscal registers reveals the existence of other streets and lanes. They provided access to parcels that do not have a street front. They also allow the access to the wall, as shown by names of two of them: *rue du Mur* (the Wall street) and *rue tendant à la muraille* (the street tending to the wall). The graph of 1670 *compoix*[11] (fig. 9) shows that lanes (B) and (D) already existed on that date, as well as the street *de Roquescaliere* (F), still in L-shape. These three streets were also represented on the 1782 plan. A new street with a special shape appears in the 1670 *compoix* graph, the street *du Mur* (E). There are four length 2 paths between the perpendicular invariant *rue des Fargues* and *rue du Mur* (E). This fact can be caused by two situations. In both cases, two parcels are located at the corner of these streets, one north, one south. The other two parcels can be L-shaped parcels, which could explain why they are limited by two streets. This kind of shape is relatively rare in Saint-Antonin-Noble-Val. Another situation is possible; one of the two streets can have a non-rectilinear shape. The mention of the *confronts* orientation allows to infer that the *rue du Mur* (E) had a bayonet-shape. The current plot, as the 1782 and 1814 plot, contain no trace of this street. In the 1670 *compoix* graph, the location of invariants known by plans provides a geographical coherence to the graph, since the nodes connected to those invariants move with them. Thus, the *rue du Mur* (E) is located between the lane *de la Sabaterie* (D) and the street *de Roquescaliere* (F), the only possible location for a connected graph.

Older fiscal registers, although less complete and less accurate, also provide information on the organisation of access to parcels. For the

[11] Archives communales de Saint-Antonin-Noble-Val, CC7-10.

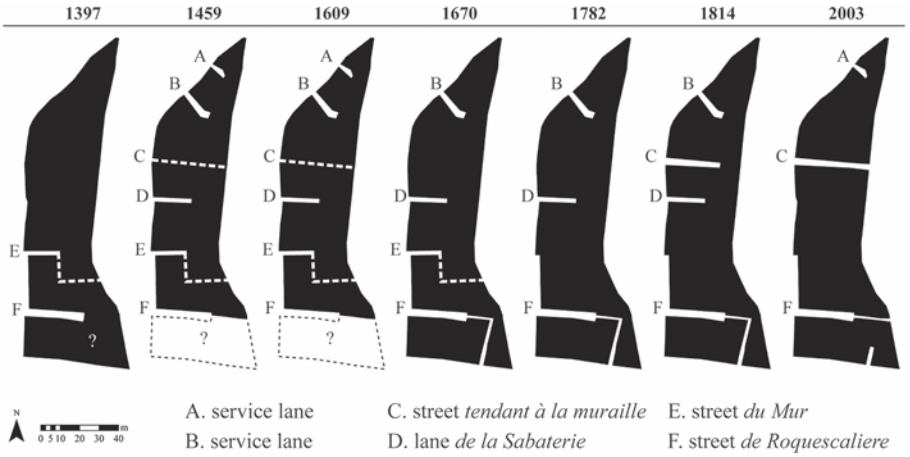

Fig. 12. Changes of access in the block from the modelling of fiscal registers.

1609[12] and 1459[13] royal *terriers*, it was not possible to identify parcels located between the streets *de Roquescaliere* (F) and *Porte des Carmes*[14] (fig. 9). The graphs of these two registers reveal the presence of an additional lane to the north (A) and a lane *tendant à la muraille* (C). It actually corresponds to the *rue du Vallon*. The 1397 royal *terrier*[15] graph shows the presence of the streets *du Mur* (E) and *de Roquescaliere* (F). The lack of precision and the low number of parcels declared does not allow us to state whether these streets were the only ones to be used to access the inside of the block. Similarly, it is not possible to know the shape of the street *de Roquescaliere* (F), particularly because there is no mention of the orientation of the *confronts*. Inconsistencies remain in the graphs of 1609, 1459 and 1397 registers. They are mostly due to the fact that several parcels belong to the same owner and to the lack of precision in *confronts* description, or even perhaps to errors in registers. But some of them are simply caused by the fact that sometimes streets pass under houses.

Graphs allow for the visualization of how many parcels were served by only internal lanes. They reveal the importance of secondary streets in the connectivity of the street network. To analyse this, we had to iden-

12 Archives départementales du Tarn-et-Garonne, C370.

13 Archives départementales du Tarn-et-Garonne, A121.

14 It does not mean that this space was unbuilt, as evidenced by the presence of two houses of the 13th century and the modelling of the 1397 *terrier*.

15 Archives départementales du Tarn-et-Garonne, A120.

tify parcels which have these lanes as a *confront* but not another main street. For instance, in 1459, the lane (A) served two parcels, the street *tendant à la muraille* (C) gave access to two houses, the lane *de la Sabaterie* (D) also served two houses and the *rue du Mur* (E) provided access to three houses and one garden, at least. Several parcels which were not declared, known by their mention as a *confront*, could also have been in the same situation.

All of these observations are synthesized as an evolutionary diagram (fig. 12). Some of these representations are from plans (1782, 1814 and 2003), while others are built from fiscal registers through their modelling as graphs (1397, 1459, 1609 and 1670). This diagram provides an image of the evolution dynamics of internal access to parcels of the block between late 14th century and today. Before the 18th century, two streets served the wall. The first one (C) disappeared between 1609 and 1670, the second one (E) between 1670 and 1782. This occurred at the time when fortifications were dismantled after the 1622 siege (Rivals 2015, pp. 205-223). These streets lost one of their roles: to serve the wall. The destruction of the wall was probably followed thereafter by the filling of the ditch. Thus, the second role of those two lanes, to serve parcels which were inaccessible by the main streets, also became unnecessary because the access could be done by the east, over the ditch.

This modelling also provides information on the way that public spaces were considered, as the case of service lanes which gave access to few parcels. Unlike streets, they were sometimes incorporated into private spaces in the fiscal registers. The case of the lane (A) is enlightening (fig. 12). It was mentioned as a lane in 1459 and 1609, then disappeared from the plot before reappearing on the current cadastre. It is obvious that it was not removed then reopened, but it was considered as part of the plot that was served during a moment. The lane (B) invisible on the current cadastre is still visible on site (fig. 13). Considered public since 1459, it was privatized in the 19th or 20th century. The street *tendant à la muraille* (C) is present in the 1459 and 1609 registers, as well as the 1814 plan, before becoming the street *du Vallon* in the middle of the 19th century. It was not mentioned in the 1670 *compoix* and the 1782 plan. However, it is possible that it was privatized during a moment, before being made again available to all residents.

If streets and lanes identified on graphs are not always detectable on ancients maps, they are however present in buildings. Both service lanes (A) and (B) are accessible from the street *de la Porte Rodanèse* (fig. 13). The *rue du Mur* (E) which now belonged to a house in the street

Fig. 13. Physical reality of streets and internal narrow streets of the block.

des Fargues, measuring 2.64 m in width. It is still hardly observable on the facade but perfectly visible on the rear, in heart of the block. The lane *de la Sabaterie* (D) is now privatized, but does not disappear from the urban landscape. The openings which provided access to the south and the north are still visible.

4. Conclusion

The transcription of tax registers without plan under graphs provides an overview of parcels adjacency, from which it is possible to study spatial dynamics. This method is fully involved in the renewal of the research on urban development. In the case of the block studied in Saint-Antonin-Noble-Val, the distribution of socio-professional classes, relying on the mention of owner's profession and on the amount of the *allivrement* in relation to the surface, reveals a distinction in the occupation linked to the proximity with trade and power places. By examining not only the plots but also the landscape, we can measure the influence of components such as fortifications, which were surrounded by unbuilt spaces. Finally, the modelling of the circulation patterns shows a real dynamic of the urban fabric in the long-term.

The research based on the modelling with graphs is only at its beginning. This method needs to be applied to other spaces, urban and rural, to reveal other mechanisms of spatial dynamics. The next development in this type of research will involve the analysis of fiscal documents through the use of optical character recognition software. If we improve automatic pairing, limiting the manual phase to a minimum, the data acquisition for spatial dynamics analysis can be done very quickly. Moreover, it will allow for the study of larger corpora. By modelling all the tax data of a city, it will be possible to detect the existence of lots that have gone before the first maps were produced.

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