Flood risk and economic analysis of land choices: shape and nature of Bordeaux Metropole's land footprint in estuarien territories

F. Vergneau

Risque inondation et analyse économique des choix fonciers des individus: forme et nature de l'empreinte foncière de Bordeaux Métropole sur les territoires estuariens

Flood risk and economic analysis of the land choices of individuals: shape and nature of Bordeaux Metropole's land footprint in estuarine territories

AUTEUR Author

Florian Vergneau

CENTRE IRSTEA BORDEAUX, UNITE ETBX

ENCADRANTE Supervisor

Jeanne Dachary - Bernard

UNIVERSITE TOULOUSE 1 CAPITOLE / TOULOUSE SCHOOL OF ECONOMICS

RÉFÉRENT UNIVERSITAIRE Academic advisor

David Alary

PERIODE DE STAGE: DU 9 AVRIL AU 5 OCTOBRE

Period of internship: from april 9 to october 5

Stage en économie s'inscrivant dans le cadre du projet URBEST

Internship in economics as part of the URBEST project

RESUME

Nous développons un modèle de prix hédonique sur la Gironde avec pour objectif d'étudier l'impact du risque inondation sur le prix de l'immobilier, en particulier les appartements et les maisons, en utilisant la base de donnée DVF provenant de la DGFiP. L'impact du risque inondation est mesuré à travers deux mesures de zonage : le plan de prévention du risque inondation et littoral (respectivement PPRI et PPRL) et la réponse curative aux inondations consistant en des reconnaissances de catastrophes naturelles permettant d'initier une compensation financière pour les communes concernées. Notre analyse est conduite séparément pour les appartements et les maisons et nous nous attachons à décrire et inclure les facteurs d'attractivités et de risques pour expliquer le prix de l'immobilier. Nous utilisons un modèle SEM (spatial error model) avec lequel nous corrigeons l'autocorrélation spatiale. Nos principaux résultats indiquent que l'effet de zonage lié aux risques fluviaux a un impact négatif sur le prix mais de manière surprenante le zonage lié aux risques littoraux a un effet positif sur le prix. À l'inverse, la réponse étatique liée aux compensations financières entraine un effet inverse des effets de zonage. Nous discutons du caractère obsolète du PPRL et de l'effet destructeur sur les zonages du mécanisme de compensation étatique. En outre, nous cherchons à caractériser la stratégie foncière des communes girondines -mesures structurelles- en utilisant la base de donnée SAFER et discutons de la politique de gestion du risque inondation sur le département de la Gironde.

ABSTRACT

We develop a hedonic price model on the Gironde with the aim of studying the impact of flood risk on the price of real estate, especially apartments and houses, using the DVF database from the DGFiP. The impact of the flood risk is measured through two zoning measures: the flood and coastal risk prevention plan (respectively PPRI and PPRL) and the curative response to floods consisting of natural disaster reconnaissance to initiate financial compensation for the municipalities concerned. Our analysis is conducted separately for apartments and houses and we focus on describing and including the attractiveness and risk factors to explain the price of real estate. We use a SEM model (spatial error model) with which we correct spatial autocorrelation. Our main results indicate that the river risk zoning effect has a negative impact on price but surprisingly coastal risk zoning has a positive effect on price. In contrast, the state response to initiate financial compensation has the opposite effect of zoning effects. We discuss the obsolete nature of the PPRL and the destructive effect on zoning of the state compensation mechanism. In addition, we seek to characterize the land strategy of the Gironde municipalities - structural measures - by using the SAFER database and discuss the flood risk management policy for the Gironde.

SUMMARY

I. INTRODUCTION

A. Presentation of IRSTEA - National Research Institute of Science and Technology for Environment and Agriculture

IRSTEA is a public institution in science and technology (French: Établissement Public à caractère Scientifique et Technologique) under the dual supervision of the Ministries in charge of research and agriculture. Multidisciplinary, action-oriented and supporting public policies, its research and expertise activities involve strong partnerships with French and European universities and research organizations, economic actors and public policy-makers. IRSTEA is also a founding member of the French National Alliance for Environmental Research (AllEnvi) and the European network Peer. It has held the "Institut Carnot" since 2006.

Environmental sciences embrace the study of environments and natural resources, biodiversity, ecosystems, and more generally the impact of human activities on the environment as well as global change. The "environmental shock" of the Kyoto Protocol raises complex and multi-scale challenges for the planet. Research questions approach the economic and societal challenges of climate change and the invention of ecological growth patterns (or "green growth"), be they related to energy performance, renewable energies, access to water resources, food production, risk management and restoration of natural environments.

Since the last environmental summit, France has been involved in a major process of "ecological transition" of its economy and society. The 2009-2013 National Sustainable Development Strategy developed by the Ministry in charge of Ecology laid down nine objectives for adaptation to global change. The Land 2020 objective of the Ministry of Agriculture highlights the need to reconcile our production methods with ecological efficiency. Formulated in autumn 2008, the concept of "green growth" is based on the virtuous circle of economic competitiveness based on respect for the environment and eco-systems in a logic of sustainable economic performance. This new form of growth is expected to generate thousands of "green" jobs across all industries.

Technological research and innovation for the environment is at the forefront of this ecological transition process. They are among the 5 scientific priorities selected in 2009 as part of the "National Strategy for Research and Innovation" (SNRI). Environmental research covers a broad range of scientific disciplines, due to the diversity and complexity of the systems studied, the need to understand the phenomena that characterize them, and the challenging scientific questions arising within it.

The skillsets required range from experimentation to the human and social sciences. Environmental research is multidisciplinaryby definition. In the face of environmental challenges, policy makers, along with economic and societal stakeholders, need help to to better understand the changes and mechanisms involved in implementing innovative solutions. They need useful scientific knowledge, be it in the form of expertise or innovation.

IRSTEA has it headquarters in Antony, with a network of nine regional centers, spread across France. These local offices are at the heart of Irstea's research programs, and allow researchers to gain a clear insight into the issues affecting local stakeholders. Local centers are subdivided into a number of research units. In Bordeaux, there are two main teams, one focused on "environment, territory and infrastructure", and the other concentrating on "aquatic infrastructure and global changes". My internship took place in the former of these two teams, as part of the URBEST project, financed by Labex COTE.

B. Context of the internship: the URBEST project

The aim of the URBEST research project is to examine growing adaptive governance in estuarine cities, in a context of continuing global change. The URBEST project will aim to identify the extent to which the arrival of climate change adaptation on the agenda of estuarine cities leads to a paradigm shift in urban, land-use planning, environmental, and risk governance policies.

Many major cities are located on estuaries, including ten of the largest ones in Western Europe. Estuarine and coastal areas are at risk both from changes to the impacts of climate change and from the anthropogenic effects of metropolisation. This calls for extensive adaptation governance to preserve the ecological services provided by the interaction between cities and estuaries, and to protect against flooding, low flow, biodiversity degradation and other extreme events. New "borderless" adaptive governance is especially suited to the wide range of multi-scale interdependencies affecting estuarine areas. Climate change adaptation needs a new, more forward-looking approach to crafting cities and territories. URBEST will aim to examine the on-going governance of territorial, cognitive and political interdependencies adopted by estuarine cities faced with the issues of climate and global change. This shift from examining urban estuaries to studying estuarine cities is motivated by recent laws in France reinforcing the political influence of cities over territories situated outside their limits, and by a re-emergence of the urban-rural divide in matters relating to environmental and climate change.

URBEST will deal with this issue from three theoretical perspectives: analyzing territorial geopolitical reconfiguration linked to climate change multilevel governance, analyzing the various forms of "visibilisation" of climate change as a public problem, and analyzing analyzing strategies and tension between stakeholders, ranging from discreet compromise to public debate. A number of empirical studies will examine climate change governance in the "Bordeaux Metropole" area as well as the outlying peri-urban, rural, and estuarine areas. Three case studies will be carried out: the governance of flood and submersion risks in Gironde estuary, the governance of estuarine biodiversity by Bordeaux Metropole and the drinking water governance in Bordeaux Metropole.

The Bordeaux agglomeration (map of the Gironde in appendix 1 p.55) is subject both to the influence of the rivers (Garonne and Dordogne) and their main tributaries and to that of the ocean during a storm episode: it is a river-sea regime. The 17 municipalities of Bordeaux Metropole are thus subject, in whole or in part, to this risk. A third of the territory is located below the high water of the Garonne and more than 40 000 people live in the flood zone. Since 1 January 2016, Bordeaux Metropole has assumed full responsibility for managing aquatic environments and flood prevention (GEMAPI). It is within this framework that it has defined three levels of priority in this area: flood prevention and the management of dikes and containment systems, the management of major watercourses and the valuation of wetlands. However, almost the entire Gironde is subject to flood risk either because of the river or the sea and so present an original and interesting study arena.

In this economics thesis, we focus exclusively on the first case study: the governance of flood and submersion risks in the Gironde estuary. More specifically, we will study territorial interdependencies in the context of land. Today, it can be said that land is a political (JARRIGE, et al., 2015) and strategic territorial resource (JOUVE, VIANEY, 2012) given the different social and political expectations and the competition it generates. In the Bordeaux-Metropole area, land resources are in demand among public stakeholders as part of their respective strategies. One good example of this is flood risk management, where cities need to effectively site flood expansion zones: special areas designed to protect densely populated metropolitan areas.

The urban economy has long studied the relations that govern the structuring of cities, the shape of cities and their relations to neighboring territories (Muth – 1969, Alonso - 1964). However, the new challenges facing estuarine metropolises confront this analytical framework: what are the socio-economic mechanisms that govern the spatial organization of land? What factors influence land prices? Does the influence of the city on its peripheral territories express itself through accessibility alone or can its footprint be exerted through other channels?

We therefore propose a descriptive analysis of the land market, seeking to highlight and characterize certain forms of intra-metropolitan interdependence (between municipalities of Bordeaux-Metropole) and extra-metropolitan areas (between Bordeaux-Metropole and neighboring rural communes). More precisely, we will seek to identify the shape of the land footprint of the metropolis in the estuarine territories (intra- metropolitan or extra-metropolitan) and the nature of this footprint (II), by characterizing the destination of the acquired land to better highlight the land conversion required for residential dynamic, in perspective of the flood risk prevention plan[1] in which the areas of flood expansion would be located a priori. Finally, we will develop a hedonic price model in order to test the impact of vulnerability to flooding on land prices (III). We relies on distinguishing the respective impact of two non-structural measures on land prices: the preventive strategy consisting in a flood hazard zoning and the curative response to flood events consisting in orders for natural disaster to initiate financial compensation (known as the CatNat system).

I. REVIEW OF LITERATURE

To analyze the land market of Bordeaux metropole in the face of flood risk and adaptation to climate change issues, we decided to study land price and the main factors that influence it. We will first present our hedonic price method. We will then apply it to flood risks, particularly in the context of zoning and CatNat responses, before defining an adapted econometric-spatial model (C).

A. The composition of the land price by the hedonic price method

1. Theoretical background : The hedonic price method

Real estate can be considered as an aggregation of attributes whose only known market value is the total price of the property but, since the real estate transaction deals with this aggregate, we cannot decompose the price for each of them. Based on this this observation, Rosen (1974) proposed a founding model for the valuation of these implicit prices known as the hedonic valuation method. This model is placed in the context of a market in pure and perfect competition in which consumers and producers are dealing with a good described by a finite number of characteristics, with each value estimated in two stages. As a first step, the consumer determines the total price he is willing to pay for a combination of quantities of each attribute to obtain the hedonic auction function. By describing this function by each characteristic, we obtain in a second time the marginal willingness to pay by an individual for each attribute of the good.

Formally, we consider N housing compounds of $K\ (k = 1, \dots, K)$ characteristics. Each property $j\ (j = 1, \dots, N)$ offers a combination of quantities $x\ (x = x_1, \dots, x_k)$ of K characteristics, such as a property j is represented as a list describing the combination of the quantities of each characteristic ($x_1^j, x_2^j, \dots, x_{kj}^j$). All agents have a perfect knowledge of the features offered by each proporties and quantities of each of them. Knowing this combination, each housing j is given a market price

[1] *In french PPRI: Plan de Prévention du Risque Inondation) zoning*

$p_j = h(x_1^j, x_2^j, \ldots, x_{kj}^j)$. The function h is the hedonic price function that associates with any combination of characteristics, the bid price that the individual must offer to acquire this combination (Gravel - 2000). It is therefore the price of housing and, depending on the competitive nature of the real estate market, the agents have no influence on the price level: p_j is a market price. By describing this function in relation to one of the characteristics, we obtain the implicit price attributed to this one:

$$p_{x_1^j} = \frac{\partial p_j}{\partial x_1^j} \text{ (i)}$$

More specifically, it is the marginal consent to pay for a marginal variation of a given characteristic. The hedonic price method therefore makes it possible, from the total price of a good, to estimate the willingness to pay for each attribute of the dwelling or the implicit value they grant to each of them.

2. The composition of the land price in the literature

Starting from the urban standard model developed by Alonso (1964), the individual residential choice is above all a tradeoff between the distance to the center of the city and the size of the house: the intensity of occupation of the space decreases with the distance to the urban center. However, this spatial characteristic differentiating locations is not unique since space is not homogeneous (Brueckner et al. - 1999). Indeed, we can consider the case of a city with a main center and secondary centers and, in this case, as the distance to the main urban center increases, the level of rent and human occupation decreases, until near a new secondary center. The multicentric structuring of the urban space would therefore induce a discontinuous distribution of populations and buildings (Papageorgiou et al. - 1971). In the case of a mono-centric city, the distance to the business center or the distance to the city center is sufficient to measure accessibility. The distance to the various centers of the city as well as the access to the means of transport (the highway, the station or the airport) would make it possible to characterize the location of the goods (McMillen and McDonald - 1998). However, other measures of accessibility and location can be used such as travel time instead of distance or distance and time used to move to the center (Des Rosiers and *al.* - 2000). Hoesli and al. (1997) consider an indicator measuring both location quality and accessibility by examining the existence of nearby services (school, commerce, transportation, noise) weighted by the distance to the city of Bordeaux. The weighted localization quality has a positive impact on the rent of apartments in Bordeaux. On the other hand, the accessibility indicator, the distance or the location indicator, cannot fully take into account the influence of location on housing prices, as there is an indeterminate number of externalities which affect the price of a property located at a given location (Fik and *al.* - 2003). Indeed, spatial characteristics would influence the value of real estate prices at two levels: through adjacency effects and neighborhood effects (Can - 1992). The prices of neighboring houses would then be similar only because they share the same location characteristics (Can - 1990).

There is a large body of huge literature on land value, land price and property prices. Basu and Thibodeau (1998) detail characteristics that contribute to estimating the price of a residential detail characteristics that contribute to an estimate of the price of a residential property: building characteristics, physical characteristics of properties, neighborhood characteristics, accessibility variables, labor market variables, externality, the zoning variables and the date of the transaction. Moreover, assuming that similar individuals make similar residential choices (Cavailhès - 2009), then space also has socio-economic characteristics that can be likened to an endogenous spatial attribute (Brueckner et al. - 1999). For Dubin and Sung (1990), the neighborhood socio-professional category appears to be more important than the quality of municipal services in determining property values. Indeed, it seems that the presence and concentration of highly qualified individuals and standard of living leads to the establishment of cultural and recreational services, increasing the level of amenities

(Brueckner et al. - 1999). In fact, a socio-spatial segregation is established, on the one hand by the competitive sorting done by the land market, and on the other hand by the repulsion or attraction effects that act between the different populations (Selod - 2004). The socio-professional and demographic categories of the buyer also appear as one of the important characteristics (Adair et al. - 2009)

Urban space is not simply a blank canvas (Goux - 1981), but is rather first shaped by the natural and topographical elements that constitute it. All these natural amenities are attractive or repulsive characteristics for individuals, inducing the organization of space around them (Girard - 2016). Consequently, dense areas with valued spatial attributes are created in the neighborhood (Girard - 2016). In addition, exogenous amenities combining natural and historical amenities as well as modern amenities, are transcribed directly into the utility function of individuals (Fujita - 1989). Individuals express a preference for natural and "open" spaces, too much urbanization would reduce the level of proposed auction rent (Wu et al. - 2004). This same phenomenon is also reflected in a substitutability effect between amenities and the size of housing: individuals are willing to sacrifice residential space for a better residential environment, especially since the benefit derived from the spatial attribute is large and very localized (Wu - 2001, Fujita - 1989). Evaluating the implicit price attributed to urban amenities in the city of Angers, Larue et al. (2013) mobilize variables capable of transcribing the value given to the intrinsic and extrinsic attributes of housing. The valuation of urban amenities is approximated by indicators relating to urban "green" amenities and land use (distance to green spaces) and indicators for other urban elements (distance to the center or to the traffic lanes).

Literature show the importance of different factors in explaining land and property prices, among which the intrinsic characteristics of the good, the accessibility to jobs and services or the proximity of amenities. But what about negative externalities such as the flood risk?

B. The impact of the flood hazard in the land price on the literature

Risk can be defined as the result of the combination of a source of danger (probability of occurrence of an event and intensity of that event) with issues at risk from hazards (number and vulnerability of populations, housing and facilities) (Grislain and al. - 2012). Some authors compare the decision to locate in a safe zone with an auto-insurance decision (Brookshire et al. - 1985). We can therefore expect that security has a price and that, all things being equal, non-floodable housing is more expensive than another one located in flood zone. Thus, it would result from that a price differential between the house located in a safe zone and that situated in the risk zone equal to the expected value of the damage, plus a risk premium reflecting the risk aversion of households (Mauroux - 2015).

A price differential higher than expected would support the hypothesis that households are risk averse. A price differential below the damage would be a sign of under-capitalization of risk by the markets. In Charleville Mézières, before 1995, risk was not capitalized in real estate prices: the price discount for houses located in the flood zone was not significant and was much lower than the average cost of damage sustained. After 1995, when the Meuse burst its banks, the price differential exceeded the average cost of insurable damages (Terra - 2006), reinforcing the hypothesis emitted by Mauroux. The lack of data after these events does not allow the author to conclude on the persistence of this effect. However, while the risks should be reflected in the price of housing, local real estate markets are nonetheless subject to a very large number of determinants (quality of housing, location, tension between supply and demand, etc.) and exposure to natural risks is most often the undesirable side of an environment that is often attractive (view of a lake, a river, proximity to the coast and its beaches, etc.), which tends to confuse the price signal (Mauroux - 2015). The negative effect of exposure risk on price can more than be made up for by the positive effect of proximity to a watercourse or shoreline. In the Basse Vallée de la Canche, the price of housing located within 150 meters of the rivers but outside the flood zone is 13.7% higher than the average value in this valley. The price of a house close to the Canche and in a flood zone has, on average, a slight gain of 1.1% (Longuépée and Zuindeau - 2001).

Logics of land use in the context of urban expansion are the product of a number of variables. Among them, it is important to mention the different institutional and normative frameworks defining a culture of relationships with land and its mobilization for different uses, and which consequently induces the practices and rules that influence them (Ghorra Gobin - 2004). In terms of flood risk management, this may be an appropriate balance between structural and non-structural risk management options. Examples of non-structural measures include land use controls, regulation of flood risk zones through zoning mechanisms and compensation for damage, corresponding to a certain form of state-sponsored insurance scheme. However, acceptance by the general public of non-structural measures is clearly not achieved despite the fact that it is the subject of a strong consensus between the actors of the water policy (Hartmann and Driessen - 2013). Indeed, the establishment of zoning and the communication around risk exposure often raise serious concerns, and even blockages, on the part of residents and local actors about the risk of a depreciation effect on the value of their houses that are in exposed areas (Chabbal - 2005). Empirically confirming this concern, the result of the study of land transactions in Alachua County, Florida suggests that properties located in a flood zone, and legally defined as such, have a price, all else being equal, lower than those located outside of this area. Interestingly, the price differential is less than the present value of future insurance premiums (Harrison and others - 2001). Similarly, the PPRI flood risk zone (one of the french legal zones with regard to flood risk prevention) seems to have a negative impact on the price of land in the Gironde estuary (Dachary-Bernard et al. - 2014). The same authors created a variable that underlines the institutional effectiveness to respond to flood events that gives the number of times where these events have been considered as natural disaster (As allowed by the French CatNat system), made possible from the moment the local authority asks the State to recognize the event as such. They found that such a response from municipalities to flood events is some sort of a guarantee that financial risks are lowered. This effect does not compensate for the zoning effect, but rather reduces it. However, the process by which the different actors involved in flood risk prevention determine the flood zoning reveals local political struggles, to be put in parallel with the obvious competition of the land use and the different policies of attractiveness of the townships. Similarly, one could criticize the state insurance scheme that covers, at least in part, the cost of floods. In fact, the knowledge that a city will be compensated in any case would reduce the advantages of prevention and consequently the sensitivity of policyholders, municipalities and other local actors, to the preventive measures that the State would like to put in place (Dubourdeau - 2012).

We can specify different models in order to estimate the relationship between price and its factors. Knowing that the location of land or properties is of huge importance, it is necessary to consider how to integrate the spatial dimension into our modeling approach.

C. Some technical spatial econometric backgrounds

Spatial autocorrelation can be defined as the relationship of independence that exists between two observations and is due to their relative location (Griffith - 1992). First, all objects are related to each other in a space, but close spatial objects are more related to each other than objects that are distant because they share a similar environment (Tobler - 1970). Secondly, the characteristics of a spatialized observation impact the characteristics of its neighbors and vice versa: there is then a phenomenon of spatial diffusion (Lesage and Pace - 2009). These two spatial processes lead to the observation of similar values in the same location (Anselin - 1988). Spatial autocorrelation is when we observe a spatial grouping of similar values but can also translate the multiplicity and intensity of spatial structures within a city (Dubé et al. - 2011). In addition, the presence of a strong spatial dependence in the residuals of a regression makes it possible to account for the bad specification of a model and in particular the omission of explanatory variables as well as the biases caused by administrative or statistical divisions. Le Gallo (2002) explains that hedonic regression in case of presence of spatial autocorrelation can be modeled in two ways: either in the part of the dependent variables (the autocorrelation of prices is caused by the evaluation process) or in the terms of error if the autocorrelation of prices is caused by externalities. Bowen, Mikelbank and Prestegaard (2001) cite the problem of spatial correlation between real estate prices and they find that the spatial impact on real estate prices can be divided into two components: the impact at city level that can be measured by the indicator of the city, neighborhood or region and the local impact to be measured by the spatial autocorrelation variable. Just as the parameters of hedonic estimation vary by location, they can also vary temporally. Can and Megbolugbe (1997) indicate that the reliability of the real estate price index is a function of the specification of the hedonic model. They therefore construct a real estate index by applying a spatial econometric model that integrates both the spatial dependence between the prices of neighboring properties and the temporal dependence between the current transaction value and that of past sales.

Pace, Barry and Sirmans (1998) explain that there are two approaches to analyze spatial autocorrelation: either by modeling the weight matrix in order to re-estimate the model of the spatial econometric approach or by estimating the covariogram used in the geostatistical approach.
The publication by Gillen, Thibodeau and Wachter (2001) differs from previous studies in the assumption that spatial autocorrelation does not depend solely on the distance between observations but also direction (anisotropy hypothesis). They find that real estate prices are more correlated in the direction of downtown.

Spatial heterogeneity can be defined as "instability in the space of economic relations" (Le Gallo - 2004). More precisely, in the case of residential choices, this heterogeneity results in the fact that according to the area under concern, individuals will not value the same attribute in the same way. In practice, this heterogeneity manifests itself through the spatial variability of the estimated coefficients and a heteroscedasticity phenomenon of the residues (spatial variability of the variance of the residues). The presence of spatial heterogeneity then raises the question of the existence of sub-markets (Anselin - 1988) and can therefore be taken into account via the segmentation of the real estate market according to the different spatial contexts identified.

When an individual chooses his residence, he proposes a global price for a vector of characteristics. Thus, the residential choice has an endogenous character: the individual simultaneously chooses the attributes of the dwelling and the implicit price that he is willing to pay to acquire the use as well as the quantity of these attributes (Dantas - 2010). This simultaneity generates dependence between the explanatory variables of the price and the residuals of the estimate, resulting in estimated coefficients that are biased and non-convergent. This methodological bias is generally treated by the instrumental variables method, which consists of replacing the endogenous explanatory variables with auxiliary variables, correlated with these explanatory variables but not with the residuals.

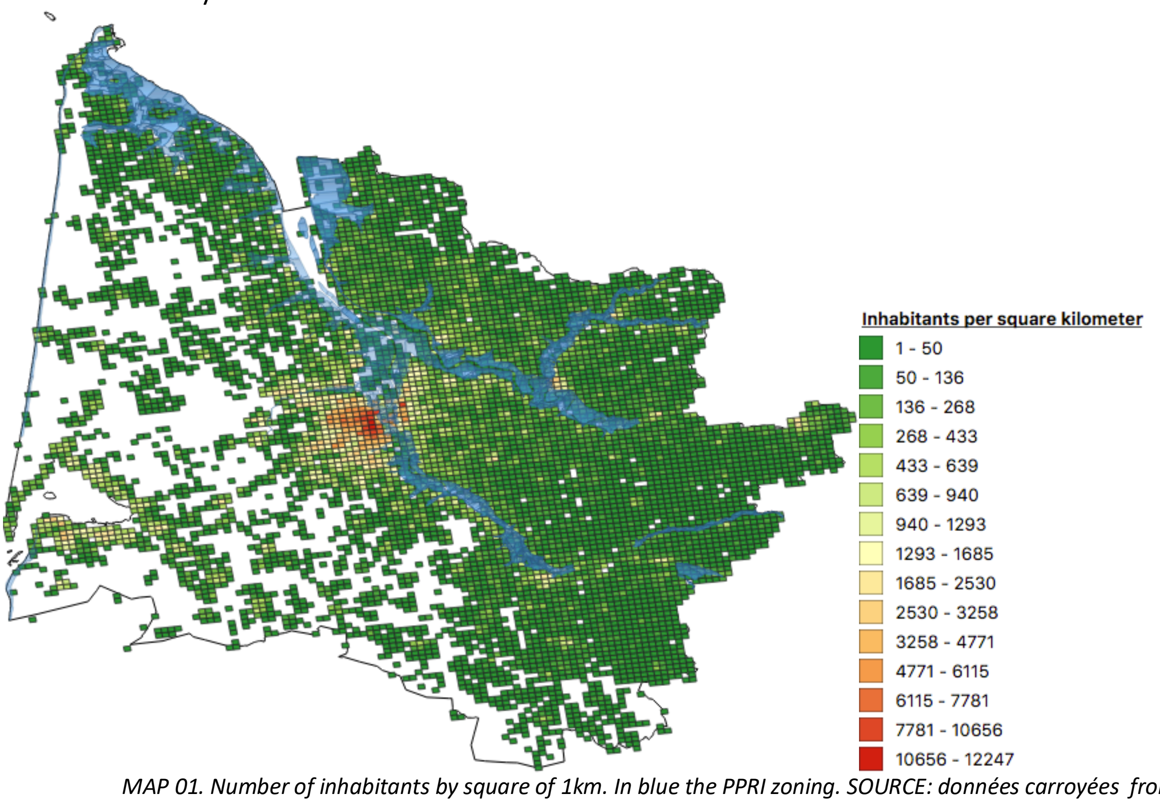
II. INTERDEPENDENCY AND LAND STRATEGY OF THE GIRONDE MUNICIPALITIES WHEN FACED WITH FLOOD RISKS

We describe at first the county of Gironde which represents our study area (A) by the repartition of its population, the use of land, the mobility flows and the economic activities. This choice of area is motivated by the fact that Bordeaux Metropole has a very strong impact on the surrounding territories and also because there is a strong interdependency links between them. Then, we present the flood risk in Gironde (B) and we try to highlight the presence of a strategy regarding this hazard from cities and with a particular to Bordeaux Metropole (C).

A. Interdependency between Bordeaux Metropole and the Gironde municipalities

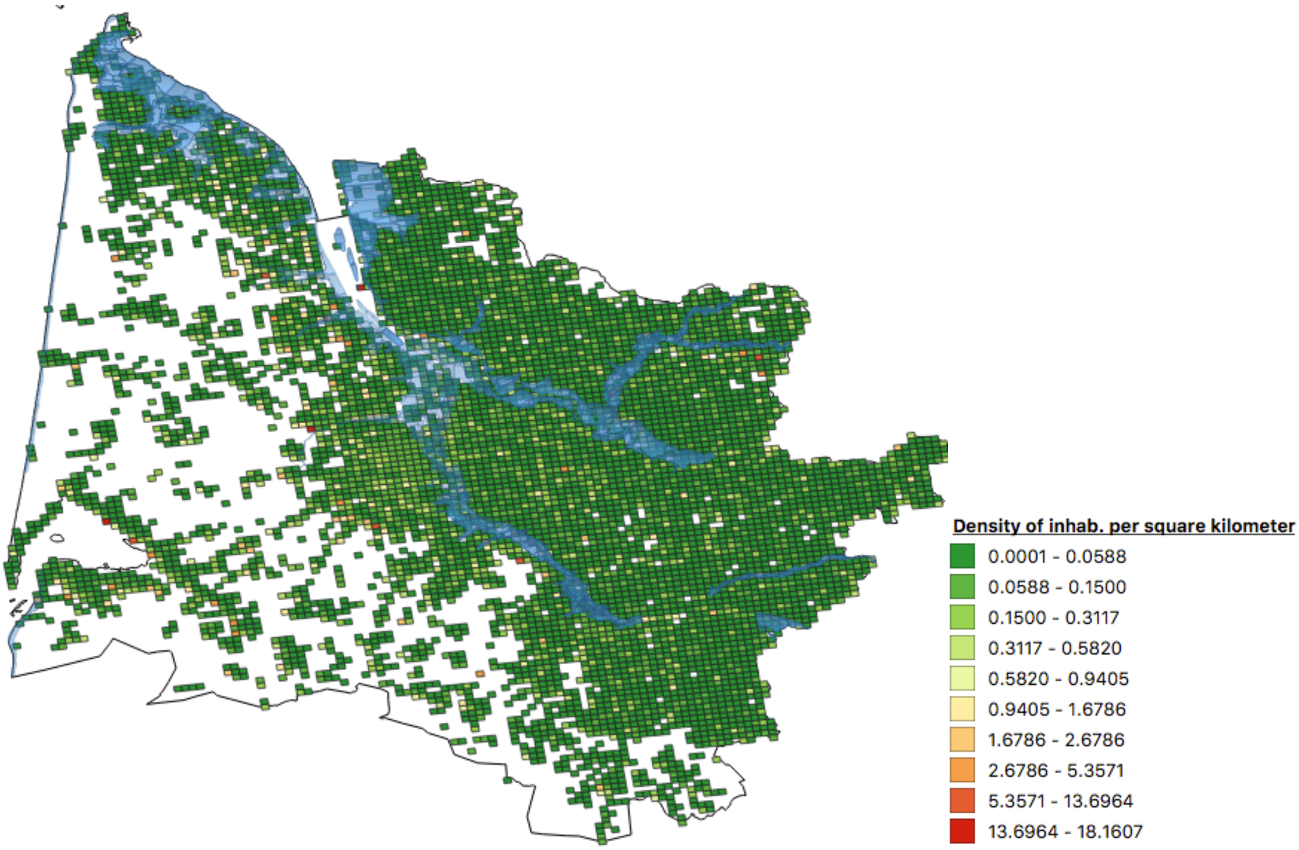
1. Demography of the Gironde

As of January 1, 2015, the Gironde has 1,543,000 inhabitants with an average of 154 inhabitants per square kilometer which is twice the regional density. Between 2008 and 2015, the Gironde population grew by 1.2% per year on average, even though this variation is differentiated between the 538 municipalities. It is the department of the region where the natural balance (birth minus death) contributes the most to this increase (+ 0.3%). The migratory flow remains however the essential vector of the demographic growth (Source: INSEE). The population of the department presents a structure similar to that of France in ages and a slight difference in distribution by sexes. The rate of people over the age of 60 is 21.3% in 2007 compared to 21.5% nationally (source: INSEE). In 2007, the department had 47.9% of men, lower than the national rate (48.4%). However, socio-professional structuring is similar to that of the national level. No category represents any overrepresentation. We represent on the map 01 below the distribution of the population per square kilometer square using the INSEE squared data. The absence of a square means the absence of data, in particular because of the secrecy of statistics



MAP 01. Number of inhabitants by square of 1km. In blue the PPRI zoning. SOURCE: données carroyées from INSEE. METHOD: Natural breaks at 10 classes

The population density of the Gironde, 154 inhabitants per square kilometer in 2015, is 35% higher than that of France which was 103.6 in 2011. As of January 1, 2012, the Gironde has more than 780 000 homes. With almost two-thirds of the park composed of houses, individual housing predominates, but less than in the region as a whole (71% of houses). Main residences make up 85% of the park, secondary residences 8% and vacant ones 6%. Nearly half of the main residences were built between 1946 and 1990 and just over a quarter before 1946. Households are mostly owners of their principal residence (56%), but the Gironde, highly urbanized, stands out with the highest share of tenants (42%) in the region (source: INSEE). Population density is measured in the Gironde department (number of inhabitants per square kilometer). The map 02 below represent the densities per 1 square kilometer tile. We use INSEE's squared data and cross-reference them with the BD Topo database of the IGN, using the layer of the habitable structure that give us the living space of each homes that we sum up for every tiles.

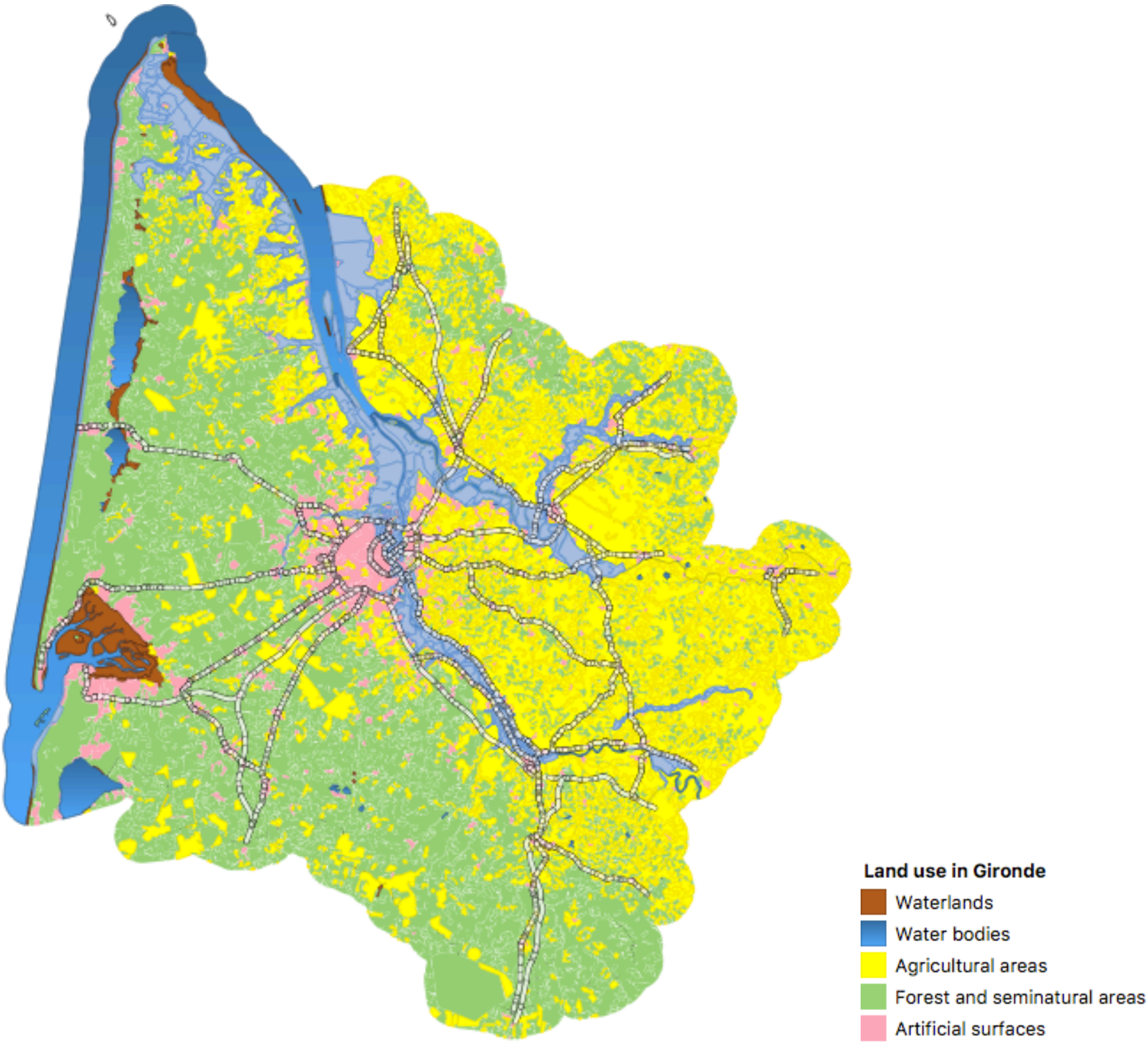


MAP 02. Density of population by 1km square. In blue the PPRI zoning. SOURCE: data carroyées of INSEE, BD Topo IGN and georisque.gouv.fr. METHOD: Natural rupture at 10 classes

We observe on the map 01 the concentration of population around two main areas: Bordeaux Metropole and Arcachon bay. Our study area present the originality to have a big metropolis (773 542 inhabitants in 2015 – INSEE), facing flood hazard, and an attractive coastal tourist area (almost 370 000 tourists during summer – syndicat intercommunal d'Arcachon), facing a specific flood hazard from the sea. However, we observe on the map 02 that the density of inhabitant per square kilometer as we measure it does not show any specific spatial feature

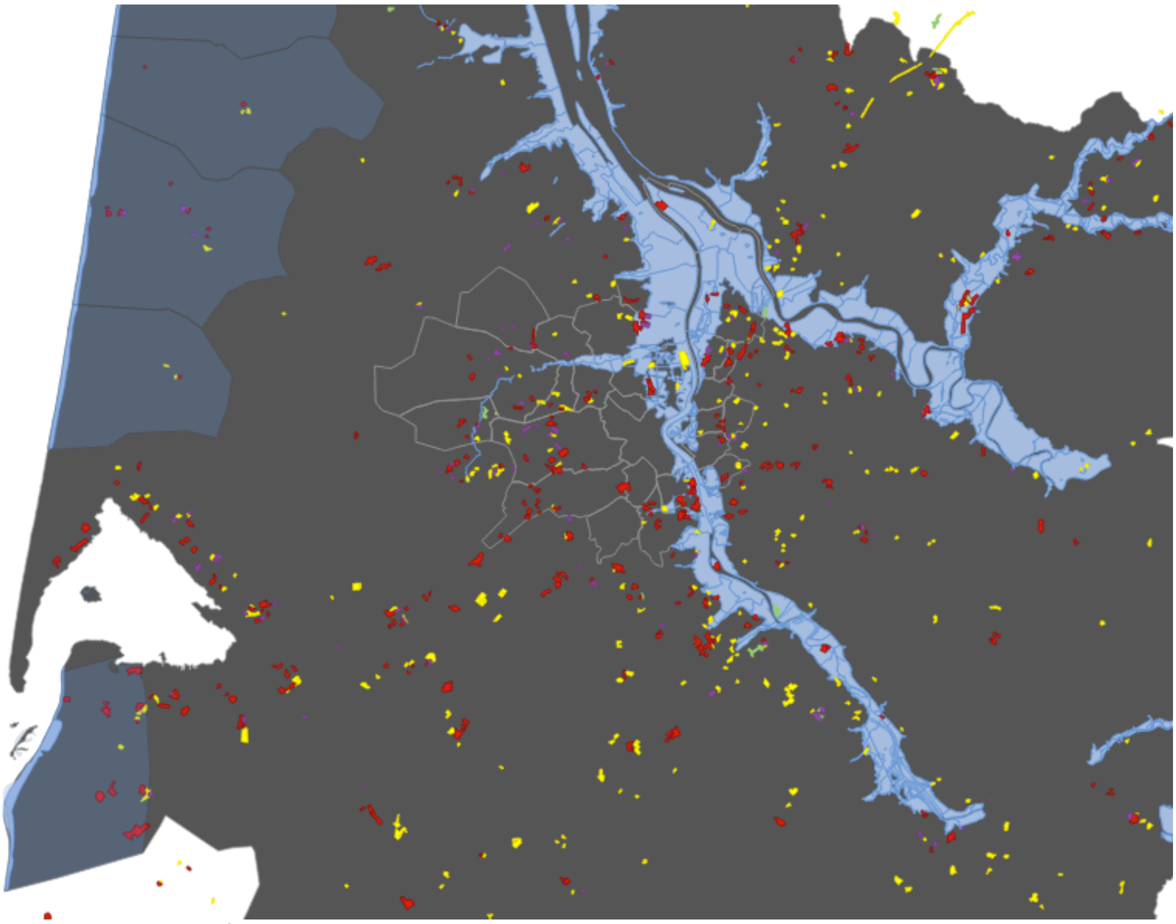
2. Use and change of land use in Gironde

With more than one million hectares, the Gironde is positioned as the largest metropolitan department. In comparison with the rest of France, the share of agricultural soils is lower due to a greater presence of natural soils (forests, etc.). It should be noted that artificialized soils are also more present. With 130,000 hectares of artificial land, which is superior to the Bordeaux vineyards, the Gironde is the leading department in terms of artificial surface area (source: DRAAF).However, it should be noted that the Gironde is the largest county in terms of area in square kilometer. We represent on map 03 below the use of the soil in Gironde in 2012 by using the data Coline Land Cover, from the website of the Ministry of ecology.



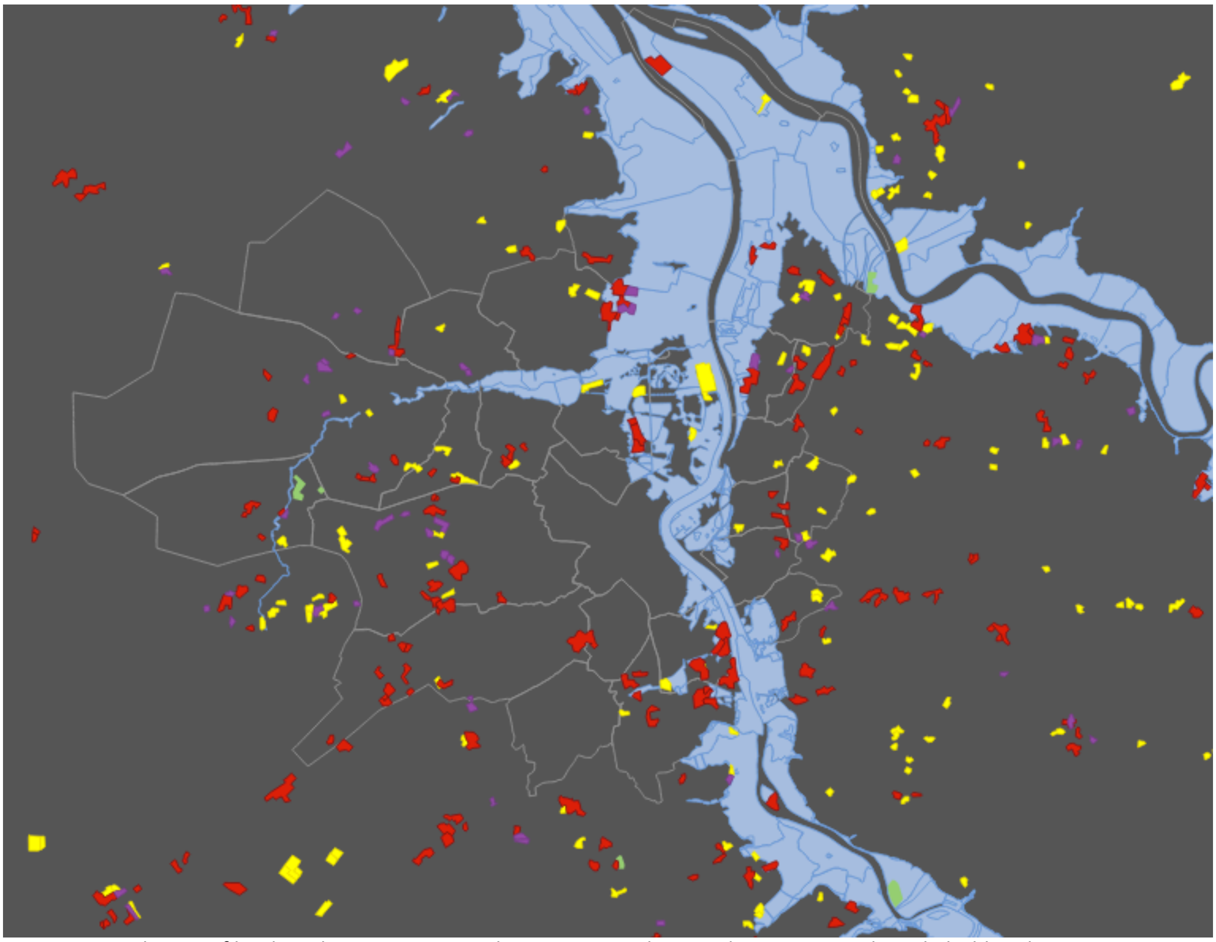
MAP 03. Land use in Gironde in 2012. In light blue, PPRI zoning.In grey, the main roads. SOURCE: Coline Land Cover 201, BD Topo IGN

During the period 2006 - 2014, land use in the Gironde differed from the general trend across France. While natural land use developed roughly in line with the national average, artificialization increased twice as fast as in the rest of France. This led to greater decline in agricultural. Covering 590,000 hectares, natural land use was the most common, made up primarily of wooded soils (84%). Heathlands and wastelands (9%) were the next largest, followed by wetlands and submerged land at 6% (due to the presence of large Medoc lakes). In eight years, the proportion of natural land use shrunk by 16,500 hectares. Between 2006 and 2014, in the Gironde, artificial land use increased by 17%, or 19,000 hectares more than in 2006. This increase was driven by increased construction (+ 28%), which today covers nearly 26% 000 hectares. "Roads, roads, car parks, etc." increased by 24% to reach 49,000 hectares in 2014. The artificialization progresses on the outskirts of some agglomerations, as in the case of the Bordeaux Metropole, Arcachon or along the lines of communication (source: DRAAF). Maps 04 and 05 below the change of use of the soil in Gironde over the period 1990 to 2012. In yellow, the artificialization between 2006 and 2012, in purple, the artificialization between 2000 and 2006 and in red the artificialization between 1990 and 2000. In green, the passage of ground urbanized in ground vegetated.



MAP 04. Change of land use between 1990 and 2012. In light blue the PPRI zoning. SOURCE: Coline Land Cover

We observe on the map 04 (and on the map 05 centered on Bordeaux Metropole) a strong artificialization during the period 1990 – 2000 (in red) and 2006 – 2012 (in yellow) in all territory and near or in the PPRI/PPRL. However, and surprisingly, we observe, in comparison, a weaker artificialization during the period 2000 – 2006 (in purple). Finally, the passage of ground urbanized in ground vegetated (in green) is very marginal.


MAP 05. Change of land use between 1990 and 2012, centered on Bordeaux Metropole. In light blue the PPRI zoning. SOURCE: Coline Land Cover

3. Economic activity in Gironde

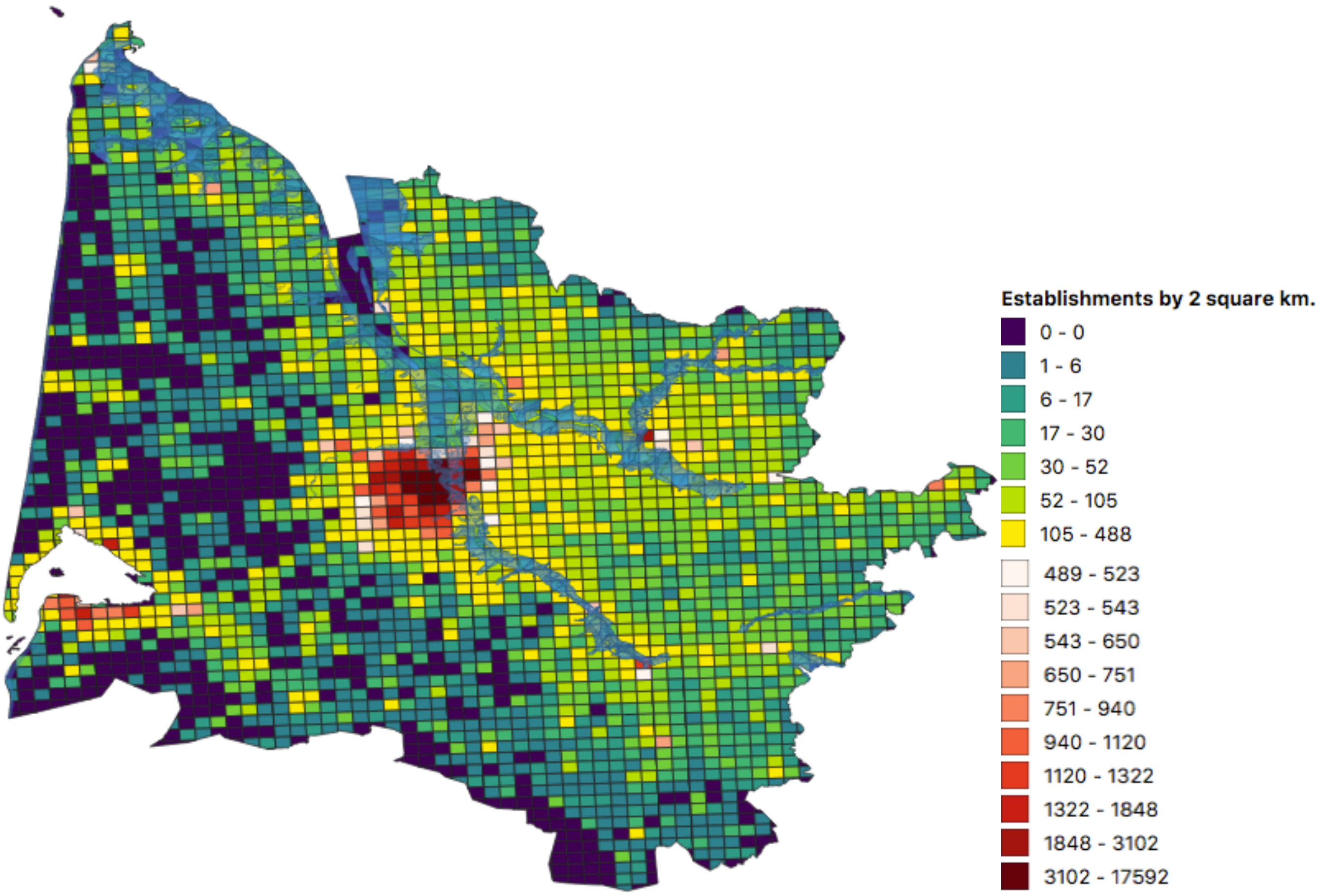
At the end of 2013, the Gironde has 157,000 active establishments outside the defense sector, 71% of which do not employ employees and 23.5% of which employ less than 10. Nearly two-thirds carry out a trade, transport or business activity. various services. The Girondin productive fabric is dynamic with a creation rate of 17%, the highest in the region. Institutions in the non-farm merchant sector are mainly small-scale enterprises: 86% belong to micro-enterprises, 5% to small and medium-sized enterprises, 4% to medium-sized enterprises and 4% to large enterprises. One-third of employees work in large companies (source: INSEE).

The agriculture sector accounts for 4.2% of total employment in the Gironde. The agricultural area used covers one quarter of the departmental territory. Half of this area is dedicated to viticulture, making it the largest vineyard in France, almost all of which has a protected designation of origin. In addition, fishing activities are not negligible, the Gironde being bordered on the north by the estuary and on the west by the Atlantic (source: INSEE).

In Gironde, at the end of 2013, the industry employs nearly 60,000 employees, i.e one in ten employees. There are both high-tech industries and traditional industries and three sectors predominate: the manufacture of transportation equipment, mainly aeronautics, the manufacture of food, beverages and tobacco products and woodworking, paper and printing industries. They provide for them three 40% of industrial employment. Construction accounts for 6.6% of total employment in Gironde, while commerce accounts for 13% of the department's employees (source: INSEE).

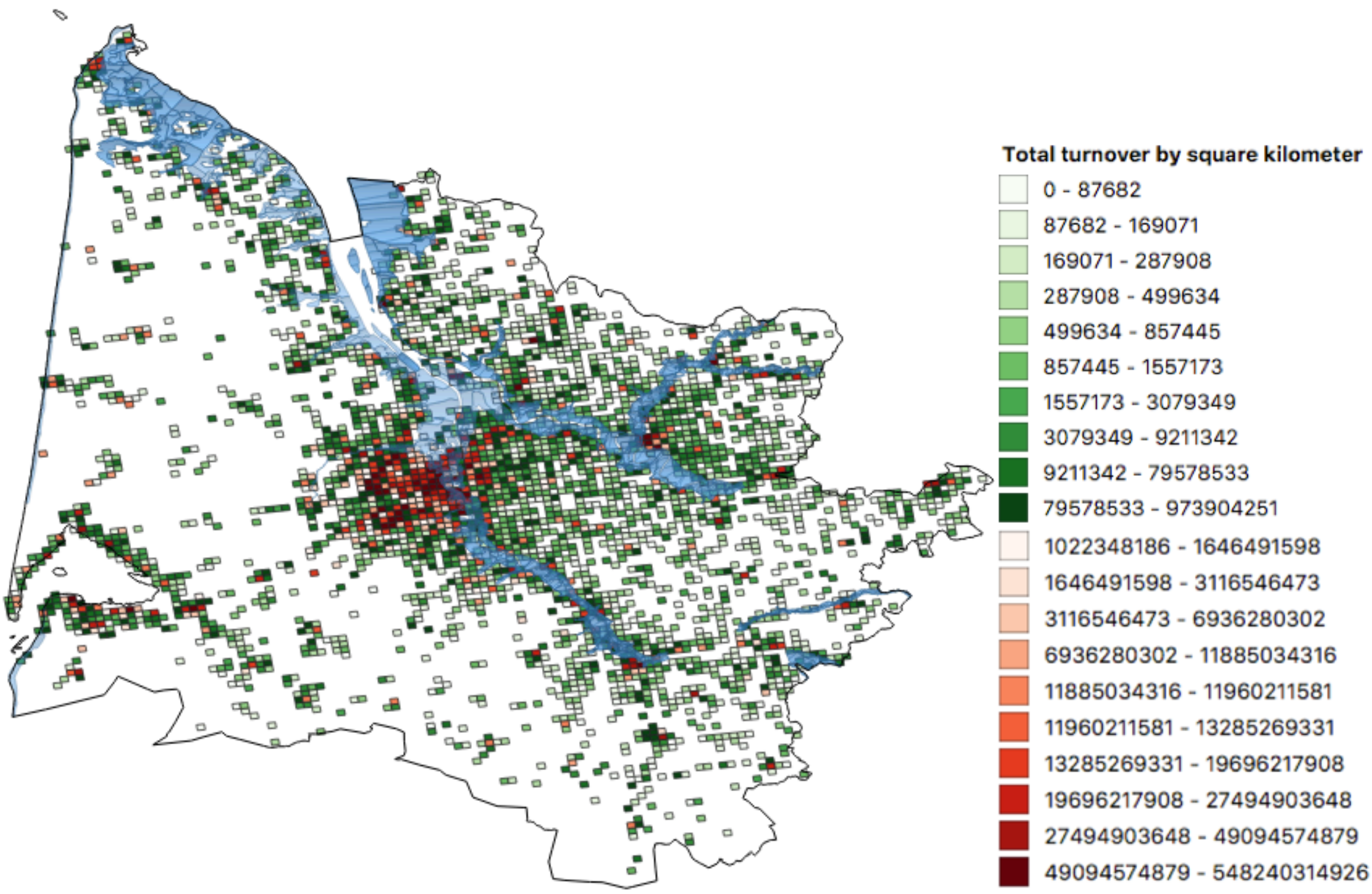
More than two-thirds of employees are in the service sector. Public administration, education, human health and social work account for half of this. The civil service has 140,000 employees, 47% in the state civil service, 35% in the territorial and 18% in the hospital. This high proportion is in line with a concentration of decentralized administrative headquarters in the regional capital and the establishment of major hospitals. The teaching hospital of Bordeaux is also the largest employer in the department and the region with more than 16,000 employees spread over its various institutions (source: INSEE).

By using the SIRENE database on the establishments, we can geolocate to the address all the establishments of Gironde, including the companies and the public services, by using the database of address of the IGN and the BANO (address database from Open Street Map). We make a grid with 2x2 km tiles then we count the number of establishments per square. We present the number of establishments on map 06 below. In addition, we extracted by web scrapping (from the website verif.com) all the financial data, when they were available, which concerned 10% of all the establishments from the Gironde establishments. We represent the cumulative turnover per square kilometer on map 07 below.



MAP 06. Number of establishments per 2x2km tile. In blue: PPRI area. SOURCE: SIREN database

We observe on the map 06 a similar spatial scheme than the one from the number of inhabitants per one square kilometer: two main areas around Bordeaux Metropole and Arcachon bay which clearly concentrate the economic activity. We also observe to the east of Bordeaux Metropole a certain number of establishments, mainly agricultural, which is consistent with the land use in Gironde. The map 07 below on the total turnover per square kilometer show similar results.



MAP 07. Total turnover per square kilometer. In blue: PPRI area. SOURCE: SIREN database, verif.com

4. Mobility flows in Gironde

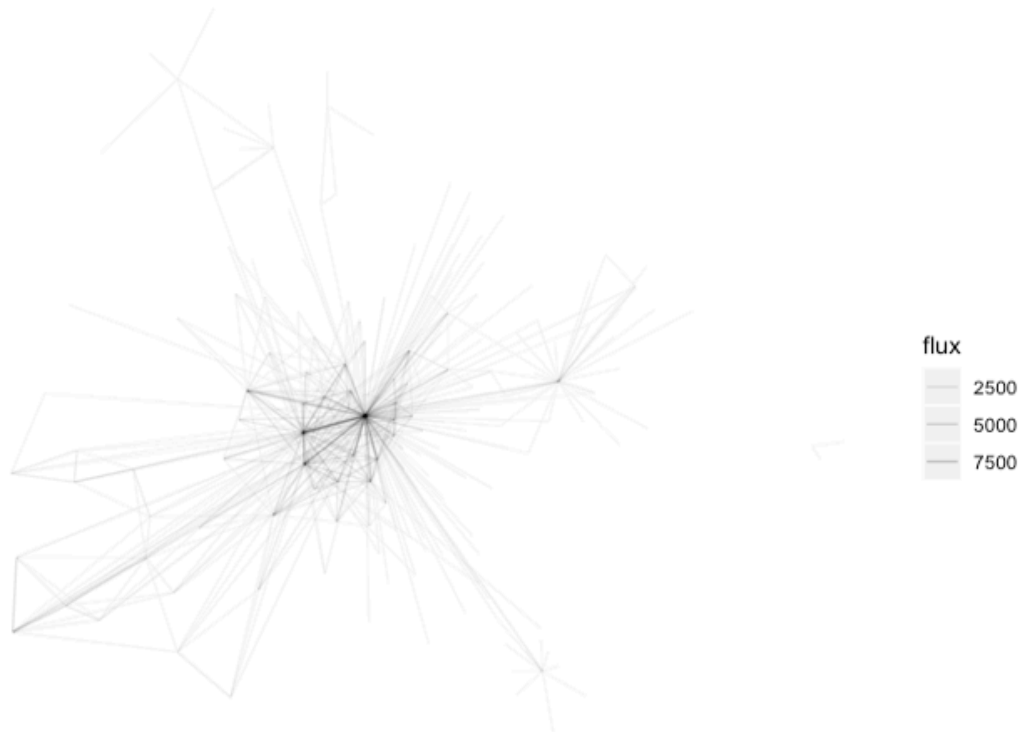
Every day, the Girondins achieve nearly 4.7 million trips. Half of these trips are concentrated in the territory of Bordeaux Metropole (called BM after), 30% are outside the agglomeration. Exchanges between large territories are relatively small (only 12% of trips). The car is by far the most used mode since it provides 7 trips out of 10 but the attractiveness of other modes is progressing. The modal share of the car has declined over the last decade while that of all other modes has increased. However, outside the BM, the use of public transport (ensuring 12% of Bordeaux Metropole residents' trips) remains low since 85% of the displacements of the inhabitants of the agglomeration except BM are by car (source: agence d’urbanisme Bordeaux Métropole called a’urba).

"Home-shopping", "home-leisure" and "home-care" trips represent roughly as many trips as those between "home" and "work" which represents 21% of trips. The most important travel distances are recorded for the reason "work": 12.4 km on average on the Gironde (8.5 km for the inhabitants of the BM, 14 km for the inhabitants of the agglomeration except BM and 16.1km for people living outside built-up areas). The average distance of a movement (all modes, all patterns) of a resident of the department is 7.7 km but this distance varies significantly depending on the area of residence: 5.2 km for a BM inhabitant; 10.6 km for a person living outside the agglomeration (source: a’urba).

The inhabitants of the out-of-town sectors make 25% less trips than those of the BM but they make 53% more kilometers. The average daily time spent traveling by Girondin is almost the same regardless of his place of residence. However, the average distance traveled on a day by an inhabitant of the BM is half that of a Girondin non BM (20 km BM side for about 40 km on the rest of the territory).

Here we must see the combined effects on the territory of the BM of greater individual mobility, greater use of alternative modes to the private car and greater congestion networks (source: a'urba).

We are interested here in the flows of mobility in the Gironde department and particularly in home-work and home-school flows. We use the INSEE databases "professional mobility in 2014" and "school mobility in 2014" and in particular the table concerning the 100 most important flows. Rather than using only a map representing flows between municipalities, we choose to adopt a "network" approach by considering communes as nodes. The goal is to bring out the predominant nodes on R using the "igraph" package. We then display a ranking of municipalities according to the criterion of "in degree of vertex" which represents the number of edges of other individuals.

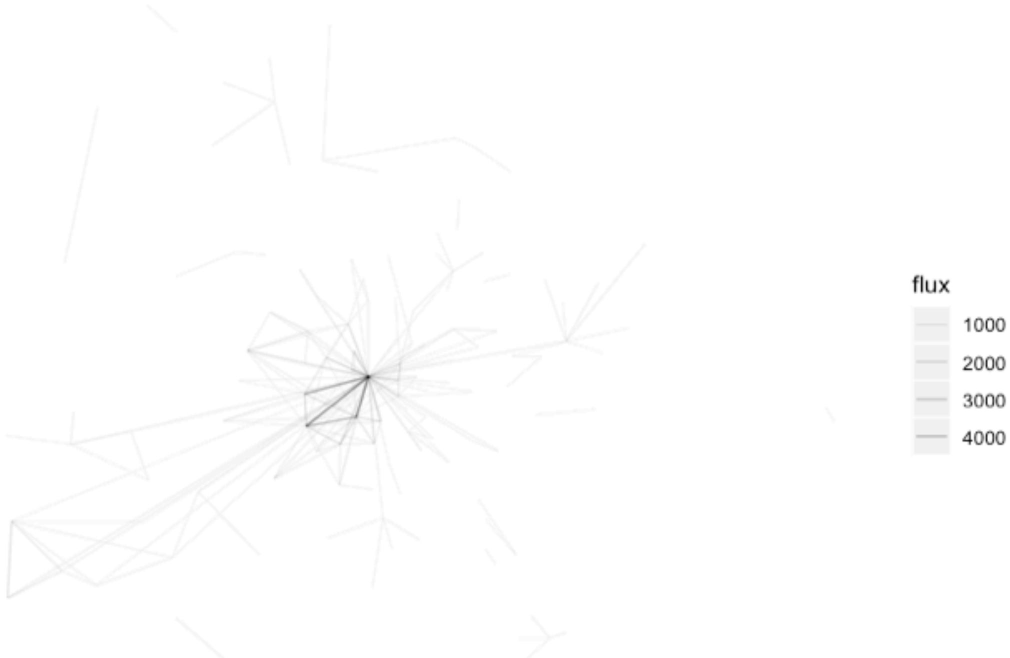


MAP 08. Stylized map of home - work flows. Central node corresponds to Bordeaux. SOURCE: INSEE

COMMUNE	IN-DEGREE	BORDEAUX METROPOLE ?
Bordeaux	172	Yes
Mérignac	77	Yes
Pessac	57	Yes
Libourne	32	No
Saint Médard en Jalles	30	Yes

TABLE 01. Main in-degree nodes of home – work flows

We observe on the stylized map 08 a coherent spatial scheme regarding the home – work flow: the five central nodes belong either to Bordeaux Metropole or Libourne (the ninth largest city in Gironde) where the economic activity is concentrated. However, the home – place of schooling flows are less important but also concentrated to Bordeaux Metropole. It is not surprising as schools (except for universities) are more homogeneous across the Gironde and their implantation take into account the density of inhabitants.



MAP 09. Stylized map of home - place of schooling flow. Central node corresponds to Bordeaux. SOURCE: INSEE

COMMUNE	IN-DEGREE	BORDEAUX METROPOLE ?
Bordeaux	70	Yes
Talence	21	Yes
Pessac	19	Yes
Lormont	12	Yes
Mérignac	11	Yes

TABLE 02. Main in-degree nodes of home – place of schooling flows

B. The flood risk in Gironde

1. Economic and environmental issues

The Gironde Estuary (see map 19 in appendix 1 p. 55), the largest estuary in Europe, represents an important socio-economic territory of the French coastline and concentrates multiple issues. The cities of Bordeaux (220,000 people) and Royan (22,000 main residents, 300,000 people in summer season) are the main demographic poles of the estuary. In particular, 17 communes of Bordeaux Métropole are thus subject, in whole or in part, to the flood risk, representing 1/3 of the territory below the highest waters of the Garonne and 40 000 people living in flood zone. At the level of the department of Gironde, the departmental file of Major Hazards of Gironde of 2005 considered that the risk flood is a major risk in 229 communes located along the Garonne, the Dordogne, the Isle, the Dronne, Dropt, Ciron and the Gironde Estuary. The studies carried out since then lead to increase this figure by integrating in particular 11 additional communes around the Arcachon basin subject to the risk of marine submersion as well as 42 other communes located in the major bed of the main secondary watercourses of the department. A total of 267 out of 542 communes are subject to flood risk (source: SMIDDEST).

Headquartered for a maritime activity operated from and to industrial ports, the estuary has an annual traffic of 8 million tonnes of chemicals and agri-food mainly. In addition, it houses on its right bank the Nuclear Production Center of Blaye which provides about 8% of the national electricity production. Many industrial activities including high SEVESO exist on the peninsula of Ambes. The Médoc and Haute Gironde, known worldwide for their vineyards, are also home to a rich agricultural activity linked to cereals and livestock. Finally, the Gironde Estuary benefits from an important cultural heritage, marked by remarkable sites (Cordouan lighthouse, village of Talmont, citadel of Blaye, quays of Bordeaux). Landscapes are generally preserved and traditions still present thanks to hunting and fishing (source: SMIDDEST).

2. Historicity of flood in Gironde

In recent years, the Gironde Estuary has been severely affected twice: during the storm Martin in December 1999 and during the storm Xynthia in February 2010. Regarding the storm Martin, it blew from 27 to 28 December 1999 for more than seven hours, with wind gusts accompanied by heavy rains causing significant overflows of rivers. This phenomenon has its origin in the strong rise in sea level (+ 1.55 m compared to the level forecast in the Verdon, + 2.22 m in Ambes and + 2.25 m in Bordeaux) and in the strong winds that have blown in the axis of the estuary (194 km / h), which increases the amplitude of the tides. The tidal coefficient was average as was the flow of the river. This exceptional event has a return period of more than 200 years. Overflows, ruptures of dikes or malfunctioning of the drainage networks have generated significant flooding in many municipalities around the estuary, resulting in death and multiple damages (roads and tracks cut, trees torn off, houses flooded, damaged or destroyed, homes without electricity ...). Storm Xynthia struck the Atlantic coast during the night of February 27-28, 2010. Exceptionally violent, the storm Xynthia strongly impacted the departments of Vendée and Charente-Maritime, causing numerous human casualties and generating very important material damage. In the Gironde, the floods did not reach the exceptional character of the storm Martin of December 1999 nor that of Klaus of January 2009. Although the strong coefficient of tide (113) associated with a very strong wind (points with 137km / h) resulted in a 98 cm increase in the Verdon, from the center of the estuary the level in lit minor became again lower than that recorded during the storm of 1999. The return time associated with this storm is greater than 100 years.

Event	Outflow	Tide	Wind	Storm surge
28-02-2010	Average	Strong	Very strong	Very strong
30-03-2006	Weak	Strong	Average	None
12-03-2006	Average	Weak	Weak	None
5-05-2004	Weak	Strong	Average	Average
6-02-2003	Strong	Weak	Weak	-
27-12-1999	Weak	Average	Very strong	Very strong
29-04-1998	Average	Strong	Average	-
7-02-1996	Weak	Average	Very strong	Average
23-12-1995	Weak	Strong	Strong	Average
18-03-1988	Strong	Strong	Very strong	None
17-12-1981	Strong	Weak	Weak	Average
13-12-1981	Average	Strong	Strong	Strong

TABLE 03. Historicity of floods in Gironde. SOURCE: SMIDDEST

3. Flood protection in Gironde

From the 17th century the littoral zones of the estuary, which were former marshes, have historically been able to develop thanks to the construction by man of a protection system composed of concrete or earth dikes and docks. These facilities were designed to prevent water from entering the land during high tides. This system, which today extends over a linear distance of nearly 350 km, has never been thought of or managed in a homogeneous way.

Many works are poorly maintained for lack of technical and financial means, so they are today subject to a high risk of rupture. Moreover their height is not homogeneous nor thought in a coherent way. The current problem of the dikes of the estuary is then complex both in terms of the height and the state of protections as compared to the managers who maintain them. Complementary to the dike and embankment protection system, water management in the marshes is ensured by a complex system of hydraulic structures (gates, shovels, valves, valves) to retain or drain the water. Here again, the works are often in bad working order and the managers are not always identified..

4. Land strategy, legal provisions and public actors in the face of flood risk

Flood protection consists in structural measures such as dikes, but also in non-structural measures (or soft measures) such as policy instruments. Since the mid-1990s, flood risk zoning has been renewed with the creation of Flood Risk Prevention Plans (PPR in French) that we represent in map 20 and map 21 in appendix 3 p.55. Their development is based in principle on two key concepts of risk, the hazard (ie the so-called reference flood, usually the 100-year flood) and the vulnerability (of people, properties and activities exposed at risk). However, the vulnerability is not integrated into the PPR map, only the hazard is retained (Tricot - 2008). In addition, from one department to another, the construction of zonings varies according to the choice of the reference flood hazard[2] and consequently leads to different boundaries, but also to a classification of distinct zonings (Douvinet and al - 2012) and talk about the race to multiply zoning, which reflects the various negotiations at the local level and can also be seen as a real political struggle. In the end, their implementation is not without difficulties (Beucher, Rode, 2009). To mitigate these, the State strives as of 2002 to put in coherence all the devices of prevention of the floods, by instituting the Programs of actions of prevention of the floods (PAPI). They illustrate the transition from a concerted display to the consideration of municipal projects by developing a partnership relationship between the State and local actors (municipalities, communities of communes, sanitation unions ...).

The PAPI prefigure the "Flood Directive" which aims to ensure greater efficiency of national and territorial public actions following the floods that have occurred in Europe for a decade (Vinet - 2010). The Flood Directive prompts the government to evaluate (Preliminary Flood Risk Assessment - EPRI) and identify flood risk areas (TRI), with a view to develop a Flood Risk Management Plan (RMMP). Note also the existence of marine submersion plan (PSR) to encourage the various concerned territories to build projects to prevent the risks associated with marine submersions, floods by runoff or flash floods and breaks in river or sea dikes

The PLU (local planning plan) is the urban planning document on which the mayor and the state rely to issue urban planning authorizations. It is also the document referred to by design, construction and urban planning professionals as well as individuals. It is therefore a particularly important document from the point of view of taking into account the risks of flooding in the spatial planning of a municipality or an intermunicipal community. As for the development of SCOT (the tool for designing and implementing intercommunal planning), the consideration of flood risks is imposed by the urban planning code.

The system called 'CatNat' established by the Act of 13 July 1982 organizes the procedure for compensation for damage resulting from natural disasters. This system involves both insurance companies and public authorities and is based on a procedure derogating from the common law of

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[2] *See map 16 p. 37 for a simulation of flood hazard in Gironde, which is the closest approximation of the "real" flooding risk that we found*

insurance. Thus, with regard to the recognition procedure, upon the occurrence of a disaster (that we represent in map 22 in appendix 3 p.57), the citizens must contact the mayor of their municipality, so that the procedure for recognizing the state of natural disaster is committed. The mayor gathers the demands of the victims and constitutes a file which includes the communal request which specifies the date of occurrence and the nature of the disaster, the preventive measures taken and the previous recognition which benefited the commune. The file is then sent to the prefecture which gathers all the communal demands for the same phenomenon and orders various technical reports. After investigation, requests are examined by the interministerial commission responsible for deciding on the abnormal intensity of the disaster.

In general, the community wishing to control the land must identify the tools and the actors to be mobilized according to the objectives and the territorial and institutional contexts and in particular with regard to the flood risk. The tools of land control are rarely specific to the management of natural environments and even less to the management of water resources and aquatic environments. Project leaders are not always the ones who master the tools, needing to build land control strategies to mobilize and articulate between them different procedures and actors. In this sense, it can be considered that flood risk management is fragmented. We provide below an overview of the actors and legal tools that can be mobilized to face flood hazards. Note that the SMIDDEST play a central role as it is the supporting structure of the PAPI.

Land acquisition tools	**Amicable acquisition**	
	Acquisition through the right of first refusal	**Right of pre-emption urban, in terms of natural areas, in terms of agricultural areas (SAFER)**
	Expropriation procedure	
Acquired land management tools	**Management Agreement**	
	Rural lease with environmental clauses	
	Lease SAFER	
Urban Planning Tools	**PLU, SCoT, SAGE,SDAGE**	
Easements	**Servitude of temporary retention of waters / zones of mobility**	
	Strategic Area for Water Management	
Tools for agricultural and forestry land development	**Agricultural and forest land management**	
	Friendly exchanges and transfers of rural buildings	
	Development of uncultivated lands	
	Regulation and protection of afforestation	
Zoning tools	**PPR**	**Reduce the vulnerability of spaces exposed to floods and other risks**
	PAPI	**Focus on preserving the mobility space of rivers and wetlands**
	EPRI / TRI / PGRI	**Establish a framework for the assessment and overall management of flood risks**
	PSR	**A particular coastal program proposing an integrated coastal risk management (marine and estuarine submersions, erosion ...)**
Insurance mechanism	**Cat Nat**	**Legal tool apart from all others**

TABLE 04. Legal tools that can be mobilized against flood risk. Cat Nat exactly enter in this category

DREAL	(Regional Directorate for the Environment, Planning and Housing): they have a coordination and animation role, particularly for cartography, preventive information and "raw" vigilance	-
DDT/M	(Departmental Direction of the territories and the sea): they have a recognized technical expertise, which they put at the disposal of the State at the same time of conducting its policies but also of the local authorities for the missions that they him trust.	Application of PPRNs and implementation of regulatory tools
EPCI	Public Institution of Intercommunal Cooperation. A bill of 29 November 2017 provides for the EPCIs and the municipalities concerned to manage the aquatic environment and prevent floods (GEMAPI). In general, they have either part of the powers of the communes or are at least consulted, particularly in the case of the definition of town planning rules.	Management of dikes and dams, flood prevention and flooding
Cities	They can provide project management for protection work, environmental maintenance and emergency management. The mayors, as responsible for the safety of the inhabitants of the municipality, are required to inform them of the risks by distributing the DICRIM (Communal Information Document on major risks) and the PPR.	Management of dikes and dams, prevention of floods and flooding. Intervenes in the development of PLU and SCoT
SMIDDEST	Public Territorial Basin Institution (EPTB) responsible for the prevention of flood risk prevention. Through a global reflection at the level of the estuary, the SMIDDEST ensures the coherence of projects related to floods by promoting territorial solidarity and the protection of people and property. Play a key role in flood risk management throughout the Gironde.	Supporting structure of the PAPI of the Gironde estuary and hydraulic simulation, among others
CMI	Mixed Commission flood. Issued by the guidance council for the prevention of major natural hazards (COPRNM) and the National Water Committee (CNE) (circular of 5 July 2011). It is a place of dialogue and exchange between the various actors concerned with flood prevention and links with water management, urban planning and spatial planning). It issues an advisory opinion, in particular on PAPI	-

TABLE 05. Actors involved in flood risk management. Not exhaustive

C. Towards a flood risk prevention strategy of Bordeaux Metropole ?[3]

Flood risks are the major impact of climate change in France. Many cities have developed on the sea and river littoral, the stakes are concentrated in urban areas and Bordeaux Métropole is a good example. In order to cope with extreme climatic hazards, the Grenelle II law invites the territories to undertake adaptation strategies, especially since climate change is considered inevitable (Servigne and Stevens, 2015). The subject of the internship invites to undertake an exploratory analysis to characterize, or not, the existence of a Bordeaux Métropole land strategy in the face of flood risk.

As we mentioned earlier, this internship is part of the URBEST project and must therefore allow the continuation and enrichment of this work. The question of the land strategy in the face of the flood risk runs up against a multiplicity of actors (see Table 05 above and map 10 below), at different scales and having specific prerogatives and objectives. Land policy is not limited to the land action but brings together a panel of legal, technical and fiscal tools that go beyond land planning and land acquisition. In addition, land policy may want to respond to seemingly contradictory objectives: among others, urban development and municipalities' attractiveness policies, preservation of biodiversity and management of natural and industrial risks. It therefore seems essential to complete the exploratory analysis with a qualitative approach, in particular through surveys of the various actors but falling outside the scope of this internship.

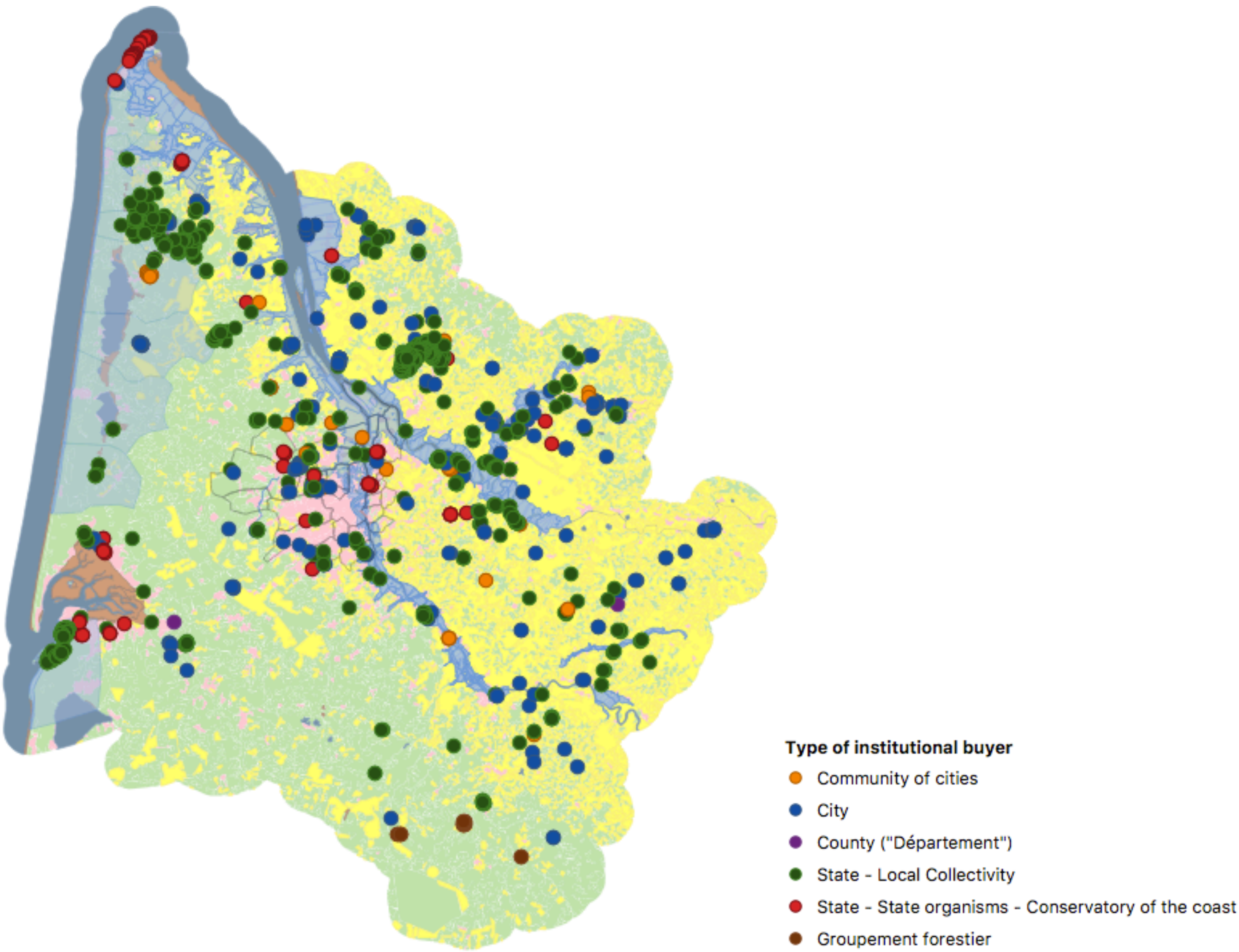
In order to carry out this quantitative analysis, we are using SAFER[4] data for the 2010-2016 period. The purpose of the SAFERs, tasked with general interest missions, is to reorganize farms as part

[3] *We made the request at the beginning of the internship to have access to the MAJIC data (land file), which give information on every parcel on our study area (stock) while SAFER and DVF give information on the flow with poor information on buyers and sellers.*

[4] *SAFER: Land development and rural settlement societies, Société d'aménagement foncier et d'établissement rural in french*

of a more productive agriculture, install young farmers but also protect the environment, landscapes, natural resources and support public authorities in their land strategies. In general, the SAFERs receive notifications of transactions by notaries and, in this context, they can exercise their right of pre-emption and acquire the parcels they deem necessary for the exercise of their missions which will then be retroceded or temporarily managed. The SAFER data makes it possible to know, among other things, the quality of the buyers and sellers, the parcel concerned, its localization and its destination. By crossing, by concatenation, the information on the parcels contained in the IGN cadastre database and by using several vintages (2010,2012,2013,2015) we were able to geolocate a little more than 60% of the parcels concerned by a transaction involving a public person.

However, on the map 10 below, we observe that cities seems to not buy a lot of parcel on the period 2010 – 2015 but it is not clear as the points "State – local collectivity" and " State – State organisms – Conservatory of the coast" might regroup a lot of different buyers: the information is to general.



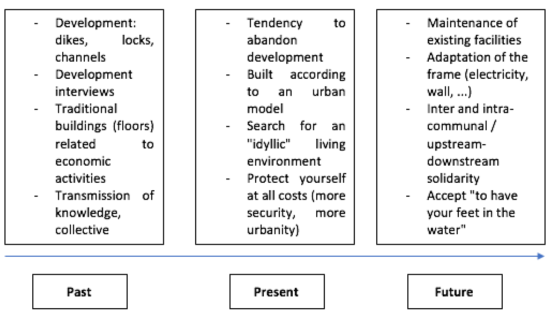
MAP 10. Map of parcels by type of buyer. SOURCE: SAFER

1. An ambiguous relationship between city and water that hinders adaptation to flood risk

Indispensable to urban life during settlement, central for the development of communication and commerce, the rivers in the city are expelled from the city landscape for security, health and economic reasons in the 18th century (Guillermé, 1984). The 19th and 20th centuries, through development infrastructures such as dikes and dams, accentuate this break between water and the city (Lechner, 2006). With the imperatives of sustainable development and a certain idea of nature in the city, the flood zones are now home to the symbolic development of cities (M.Gralepois, S.Guevara - 2015). The pressure on local taxation pushes local communities to exploit their wastelands, just as territorial competition encourages them to constantly defend their attractiveness in a context of local or even global competition (Demazière - 2014). Their defense strategy is deployed in particular by their ability to compile urban functions, notably to display urban projects integrating water. Flood-prone neighborhoods, often located in close proximity to downtown communications, offer an inevitable opportunity in this context: housing creation, leisure and tourism development, modern image (M.Gralepois, S.Guevara, -2015). Areas subject to flood risk can then be subject to competition in their development (see map 11 below on the destination of the plots).

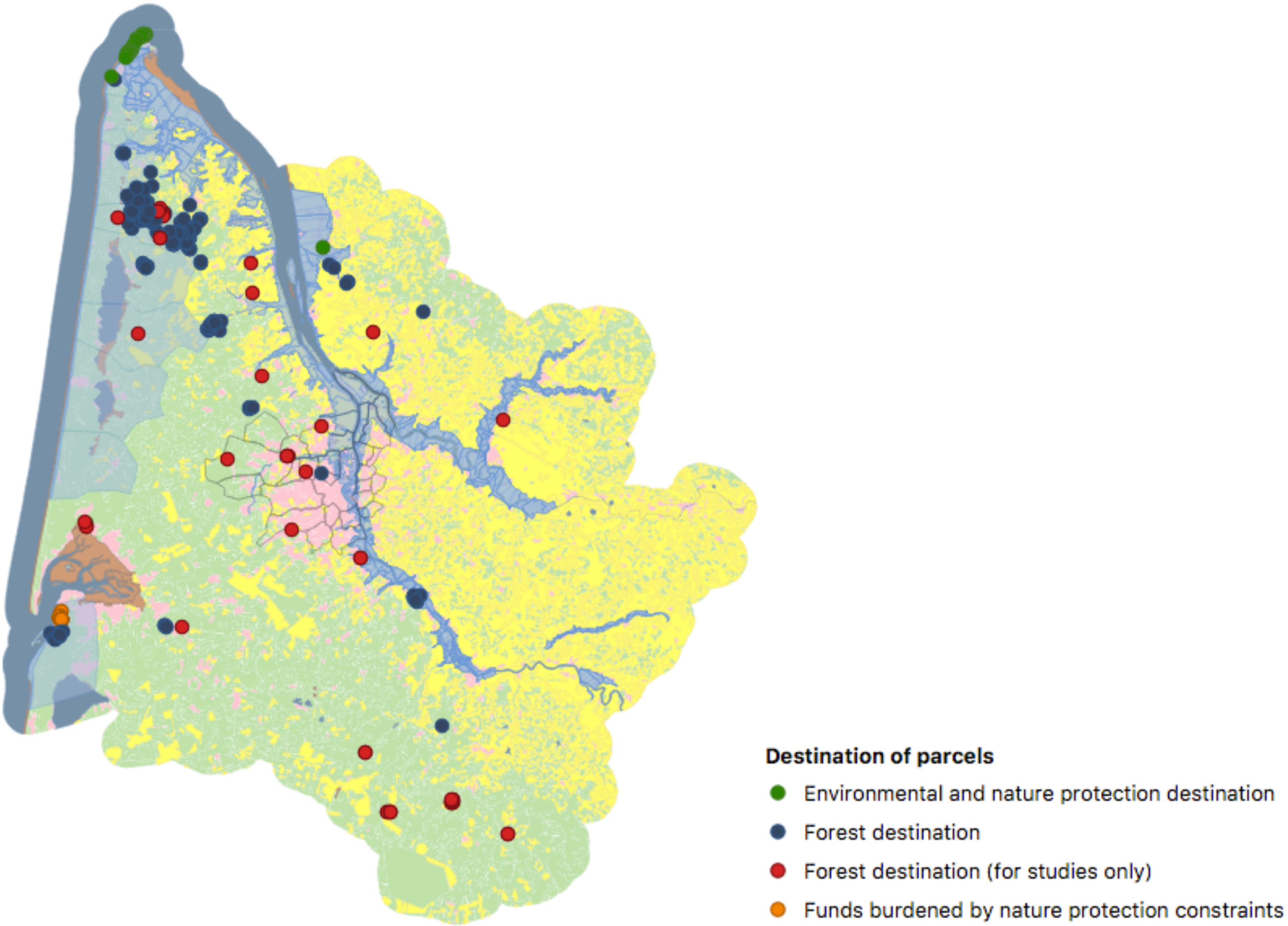
In fact, in order to promote a sustainable trajectory, urban planning by-laws such as Grenelle II highlight the compact city model, which limits urban sprawl and soil sealing, preserves green spaces and therefore does not accentuate the risk of flooding. At first glance, sustainable development promotes the consideration of natural hazards. However, in the implementation of urban projects, the scope of sustainable development to limit exposure to risks is very limited (Andres and Strappazzon - 2007), especially in urban pressure contexts. On the contrary, the promise of sustainable urban planning reinforces and justifies the tendency of cities to conduct operations in flood-prone areas, instead of sparing these spaces out of urban pressure. An example of this phenomenon is the Angers-Rives-Nouvelles floodplain development project, which combines habitats, natural areas and commercial areas, thus illustrating the expression "living with the rhythms of floods" (Which - 2012).

M.Dugast and A.Gassiat (2014) carried out a sociological survey of local actors (regions, departments, municipalities) and tried to know if climate change was taken into account into the implementation of their flood prevention strategy. From their speeches, they showed that their vulnerability trajectories are far removed from the problem of climate change, but that this issue can influence the reconfiguration of the risk prevention policy. A synthesis of these discourses was produced making it possible to highlight the vulnerability trajectories that the interviewed actors perceived as important.

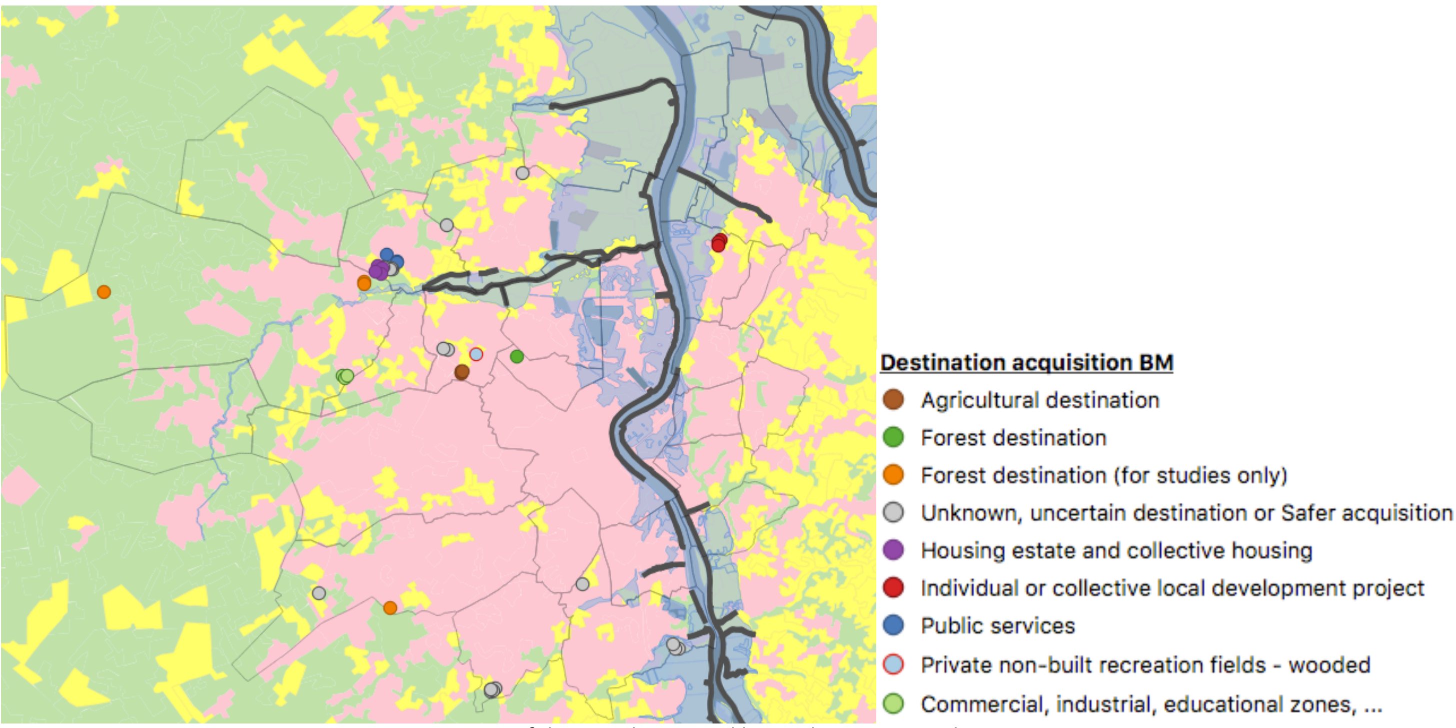


SOURCE : M.Dugast et A.Gassiat (2014)

We observe on the map 11 below a strong proportion of land bought by public actors that have a forest destination. On the other hand, we observe a few parcels that have an environmental and nature protection located in the PPRI and PPRL zoning. However, we cannot draw a conclusion from this map neither map 12.



MAP 11. Destination of the parcels with an environmental type. SOURCE: SAFER



MAP 12. Destination of the parcels acquired by Bordeaux Metropole. SOURCE: SAFER

2. An inadequate regulatory approach to flood risk prevention ?

In a context of disconnection between sustainable development policies and those of risk prevention (Gralepois, 2012), planning regulations have become the privileged lever of flood prevention policies since the 1980s. The objective of the regulatory approach is to map the hazard and the stakes (human, economic, energy, heritage) on a territory, then cross them to define risk zones, according to degrees of danger from weak to strong. The purpose of this scientific and cartographic construction is to lead to a regulatory component limiting land use. The logic of distance, between the danger and the urban occupation, is enshrined in the laws by the plans of exposure to the risks (law of July 13, 1982). The Barnier law of February 2nd, 1995, concerning the reinforcement of the protection of the environment, by proposing new plans of prevention of the risks (PPR), allows to go further in the control of the development: the PPR are worth easements of public utility and are integrated in local planning documents.

In the implementation of the PPR (risk prevention plan), the triple device "scientific hazard + technical mapping + regulatory constraint" creates tensions at each stage: territorial scale, data collection, probabilities or criteria retained. By focusing on the hazard in a regulatory vision, PPRs are described as a brake on adaptation to flooding. The rule imposed by the PPRs would undermine the "potential for technical innovations in this area" (CDC Workshop and Nexity 2011). However, other visions exist, in particular the concept of a resilient city resulting in a shift towards a search for adaptation, essentially concretized in certain urban forms in a flood zone. It may be, according to the practical guides of the Ministry of Ecology or CEREMA, to build the city around the water bodies or to have a topography with unevenness in order to store the flood waters. In cities, in the case of slow floods, it may be a question of converting wasteland into a flood zone by raising the habitable parts above the reference flood-side, or by using stilts, slabs or half-levels.

From the 1970s and still today, the banks of the Garonne and Gironde (outside major cities) attract residents in search of a "natural" living environment, which they imagine as "idyllic" but provided it is secure. At the same time, the facilities are less and less maintained. That is why in the future, the will is to maintain the existing facilities to contain the river or the estuary at maximum in bed, while proposing to the existing houses work of adaptation of the frame. The idea also makes its way as in the past to sometimes have feet in the water, while developing solidarity between municipalities and between the upstream and downstream (M.Dugast and A.Gassiat, 2014). These vulnerability trajectories proposed by the actors themselves are social and go beyond the framework of public policy, by translating the concerns of the neighboring populations essentially in terms of planning issues, quality of life and solidarity.

III. ANALYSIS OF THE RESIDENTIAL CHOICES OF INDIVIDUALS IN RELATION TO RISK FLOODING BY THE METHOD OF HEDONIC PRICES

We develop a hedonic price model in order to test the impact of vulnerability to flooding on land prices. We relate to the distinction of the impact of non-structural measures in the field of flood control. .We also take into account the "real" flooding hazard in Gironde by a simulation provided by the SMIDDEST. As far as the area of our econometric study is concerned, we are interested in the whole Gironde which we have endeavored to describe in the preceding part. It should also be noted that this area of study is particularly pertinent to the study of flood risk since it is highly subject to it, as we have tried to show in the previous section, and especially in the two most attractive areas; Bordeaux Metropole and Arcachon bay.

We first present the general approach adopted (A) and then the econometric estimation (B).

A. General approach

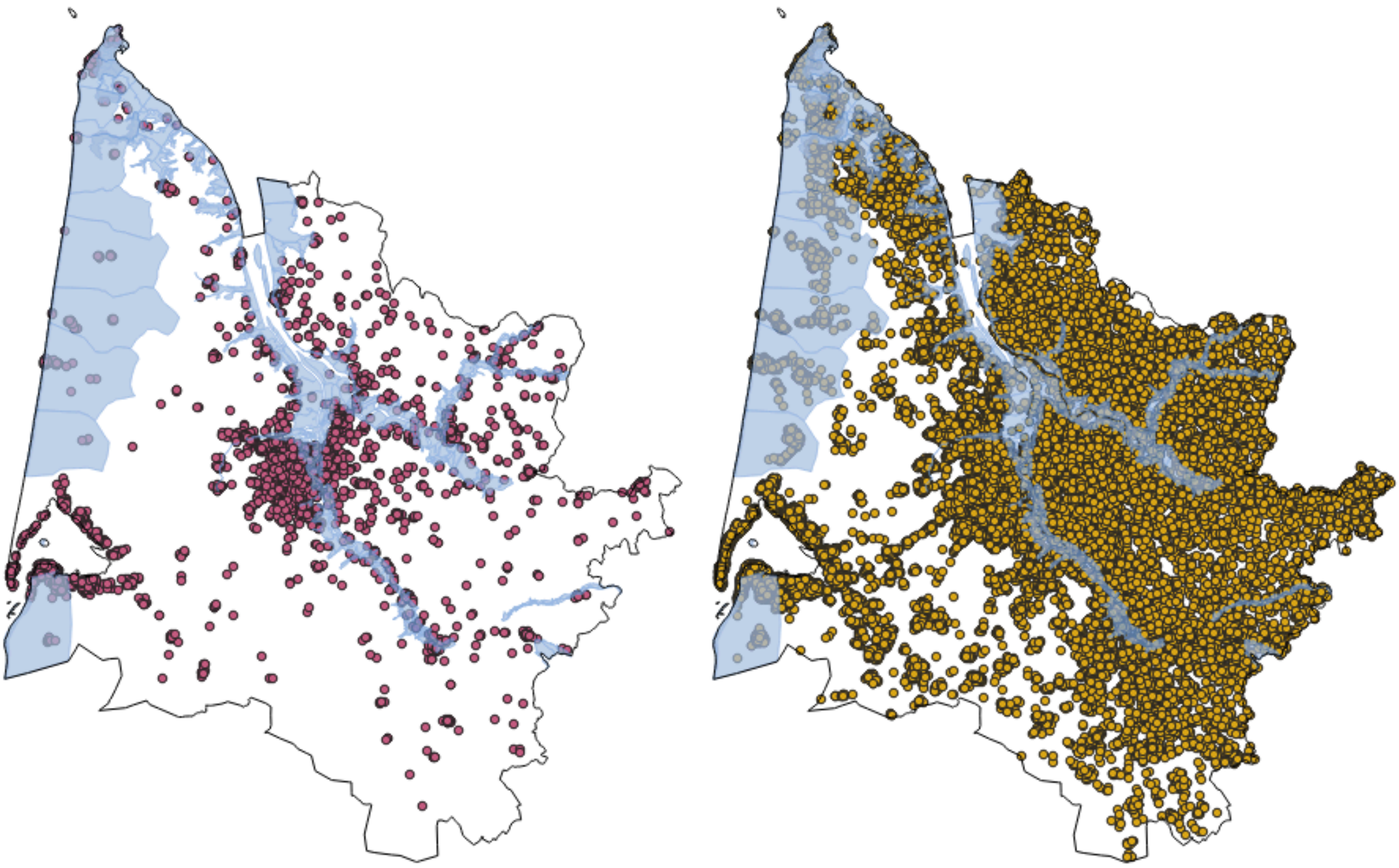
In this analysis, we use the DVF database at the Gironde county level. This database comes from the DGFiP[5] and lists the real estate sales published by the land registration service (formerly Mortgage Retention), completed by the description of real estate from the Cadastre. It includes changes in the building (apartments, houses and commercial premises) and non-buildings (bare land and sale in the state of future completion to individuals). We are working on all the transactions of the Gironde over the period 2010 - 2016 (see map 13 page 29). With regard to individual houses and apartments, we have information about their physical characteristics (number of rooms, building and land area, presence of an outbuilding), its location (parcel and address) and an indication of the quality of the buyer through the article of the General Tax Code to which the transaction corresponds. The first step was first to geolocate the mutations by crossing DVF with the "Parcellaires" database of the IGN and completed it by the "Address" database of the same organization, by concatenating a common identifier between databases. We managed to geolocate approximately 90% of the transactions. Then, it posed the problem of the mutations which concerned several parcels but for which we had only the global price of the mutation. For example, if a mutation contains three parcels, one of which is a house, we cannot distinguish the price of the parcel on which the house is from the other two. Therefore, in order to geolocate these mutations, we have choose the "main parcel" method: for mutations with a house or apartment, we geolocate the mutation to the parcel on which is built, or if we have two or more buildings, we choose the one with the largest living area. If it is a mutation without a building, we geolocate to the largest parcel in term of area. Note also that in the case of a mutation with several buildings, the intrinsic variables are the sum of the characteristics of the different buildings. We use the same method for the mutations without buildings but with several parcels: we sum up the characteristic when those are numeric. This method can be problematic in the sense that we can have observations that will have extremely high values for the number of rooms for example. We then detail how we correct these values.

The choice of variables for our econometric analysis depends both on the purpose of the study and also on the availability of data. Our objective is to estimate the respective share of different attributes (intrinsic or extrinsic) in the formation of real estate and land prices. In particular, we seek to estimate the impact of the flood risk on the price of the property, as Bordeaux Metropole, and the Gironde in general, is highly subject to this risk.

[5] *In french, DGFip : Direction Générale des Finances Publiques*

The intrinsic characteristics are directly derived from the DVF database and relate to the physical characteristics of the house or apartment and its price. It should be noted now that DVF is very poor regarding these characteristics and that it would have been necessary to have access to the MAJIC database which would have allowed us to greatly enrich those. Our analysis will then suffer from a significant bias due to the absence of MAJIC data. For example, we could have had access to the year of construction, the number of bedroom or bathroom.

Extrinsic variables are created from other data sources, mainly spatialized data capable of transcribing the residential environment but also data from INSEE at the tile, IRIS or city scale. Thus, each house is characterized by 21 variables, 8 with intrinsic characteristics and 13 with extrinsic characteristics. Finally, note that the heterogeneity of the properties concerned by DVF is important, and requires a segmentation of the analysis especially between houses and apartments that we will study separately. We would also have liked to include the building plots but because of geolocalisation problems and the different nature of soil, we were unable to obtain a sufficient number of observations for which we could be certain that it was 'building land' (only 684 observations). Indeed, some multi-parcel mutations contained one or more building lots but we do not have the individual price for each parcel. Also, we provided descriptive statistics (appendix 7 p. 61) and a correlogram between the variables (appendix 8 p.62).



MAP 13. Mutations concerning an apartments (left) or a houses (right). In light blue, the PPRI and PPRL approved. SOURCE: georisques.gouv.fr, DVF

1. Choice and construction of the intrinsic variables

These variables are directly derived from the DVF database and the selection is made on the double criterion of relevance and availability of the data. The availability of the variable are not uniform and leads us to exclude some of them, especially the variable "surface carrez". We also exclude the variables related to the nature of the soil and the reference to the general tax code which does not tell us about the characteristics of the housing. Finally, each housing is associated with location variables to locate the mutation to the municipality (with the associated INSEE code) and IRIS (with the associated IRIS code). In total, each observations is characterized by 8 variables, the details, for houses and apartments aggregated, of which are given in the following Table 06.

Variables	**Description**	**Availability (%)**	**Mean (or distribution for qualitative variables)**	**Median**	**Min**	**Max**
Price of the mutation (*prix)*	-	100%	257288.3	201000	1	264831008
Price by square meters (*prix_M2)*	-	100%	2697.811	2256.64	0	2787695
Year of the mutation *(Annee)*	-	100%	2009: 10260 2010: 12663 2011: 12067 2012: 10800 2013: 10528 2014: 9446 2015: 10921 2017: 1592	-	-	-
Outbuilding (*surface_terrain)*	Available only for houses. In square meter	100%	2380.363	537	0	5529025
Number of outbuildings of the mutation (*nombre_bati)*	-	100%	1.0548	1	1	9
Number of parcel of the mutation (*nombre_parcelle)*	-	100%	1.679317	1	1	208
Number of rooms (*nombre_pieces_principales)*	-	100%	4.09	4	1	81
Living area (*surface_reelle_bati)*	In square meter	100%	103.3689	93	1	997

Table 06: Descriptive table of the intrinsic variables. Presentation after fixed missing and outlier (p. 37)

2. Choice and construction of the extrinsic variables

Extrinsic variables aim to characterize the residential environment of housing representing the everyday environment seen and perceived by the individuals who reside there (Rougerie, 1975). In other words, it is an organized space in its structure and functions (Antoni, 2014). Based on the literature and the variables available, we characterize the environment by 13 variables whose construction are detail below:

Variables	Description	Availability (%)	Moyenne (ou répartition)	Median	Min	Max
Distance to the town hall (*distance_mairie)*	Distance to the town hall of the municipality of the mutation (in meter)	100%	24946.29	21434	41	87766
Distance to Bordeaux town hall (*distance_BX)*	Distance to Bordeaux town hall (in meters)	100%	24806.42	20283	28	89761
Bordeaux_Metropole *(Bordeaux_metropole)*	Binary variable that indicates whether the mutation was made within Bordeaux Metropole (= 1)	100%	0 = 53766 1 = 34957	-	-	-
Distance to the primary road network *(route_primaire)*	Distance to the nearest primary road (in meters)	100%	25947.79	22128	48	84329
Area of vegetation (*surface_nature)*	Part of the vegetation within a radius of 200 meters around the mutation (in square meters)	100%	32172.94	23509	0	247214
Urban density (*surface_bati_m2)*	Densité nette du bâti dans un rayon de 200 mètres autour de la mutation (en mètre carré)	100%	4225.722	2921	0	45713
Average height (*hauteur_moyenne)*	Average height in a radius of 200 meters around the mutation (in meters)	100%	5.240879	4.692308	0	28.71429
Social composition of the neighborhood (*cluster_social)*	The social composition of the neighborhood at the IRIS scale. Categorical variable	100%	G1 : 48920 G2 : 7124 G3 : 32679	-	-	-
Enclosure of the IRIS (*indice_enclav)*	Indirectly represents the rate of equipment at the IRIS scale	100%	11238.84	9566.222	580.305	44889.55
PPRI risk level (*PPRI)*	Indicates whether the mutation is made in an area subject to the PPRI. Binary variable	100%	0 = 84404 1 = 4319	-	-	-
PPRL risk level*(PPRL)*	Indicates if the mutation is made in an area subject to the PPRL. Binary variable	100%	0 = 83274 1 = 5449	-	-	-
Cat Nat threshold (*CatNat)*	Defined on the base of the distribution of the number of orders by municipality. Takes the value 1 if the municipality has known at least 9 number of orders for natural disaster	100%	0 = 29504 1 = 59219	-	-	-
Flooding simulation *(simulation)*	Binary variable. Indicate if a mutation is located in the area. Represent the “real” risk of flooding	100%	0 = 84732 1 = 3991	-	-	-

Table 07: Descriptive table of the extrinsic variables. Presentation after fixed missing and outlier (p. 37)

Concerning the construction of the 200-meter scale variables, the choice of the threshold is based on the work of Larue et al. (2013) and Sahraoui et al. (2014). The first reference examines the type of land use preferred by individuals and establishes the neighborhood of housing within a perimeter of 100 to 500 meters. The second uses two thresholds, one representing the immediate neighborhood within a radius of 50 meters (environment visible from the housing) and a second the nearby environment within a radius of 500 meters (the so-called travel space). We choose an intermediate threshold of 200 meters, fixed in order to be able to correctly analyze the intersections between the BD Topo of the IGN and the geolocated mutations.

i. Green amenity

This variable is constructed on the scale of the mutation. We calculate the vegetated area within a radius of 200 meters around the DVF mutation. We justified the choice of the radius at the beginning of point B but it is important to add that the individuals are sensitive to what they see from their window but that the distant landscape has only little value (Cavailhès et al. 2007). In addition, individuals value the presence of green amenities in large area but not the proximity to it, the accessibility to large green spaces depends on the endowment to the scale of the city or even the agglomeration (Larue , Appéré and Travers, 2013). We therefore suppose that the presence of vegetation can only affect the price of housing if it is in the immediate neighborhood of the housing.

Concerning the construction of the variable, we use the topography database of the IGN and in particular the "vegetation zone" and "water surface" layers. Thanks to QGIS, we create a buffer zone of 200 meters around each DVF mutation (we first make a fusion between the two layers of the BD topo and then an intersection between the buffer zones and the merged layer thus allowing to "cut" polygons within each buffer zone). Then, we perform a loop on the software R to calculate the surface of natural space (surface "cut" by the intersection, which is found by calculating the air of the polygon on R) based on the identifier of the mutation.

ii. Urban density

This variable is built at the scale of the mutation and represents the urban area within a radius of 200 meters around the mutation. It is very similar to the previous variable in its construction but instead we use the "undifferentiated building" layer. We then construct a buffer around each mutation and we intersect every buildings in the 200 meters buffer and sum up the living area. It gives us the total living area in square meter in a radius of 200 meters around the mutation.

The urban density as we built it approximate the potential social interaction of a location. From a theoretical point of view, Brueckner and Largey (2008) assume that interactions usually occur in the close neighborhood.

iii. Neighborhood social composition at the IRIS scale

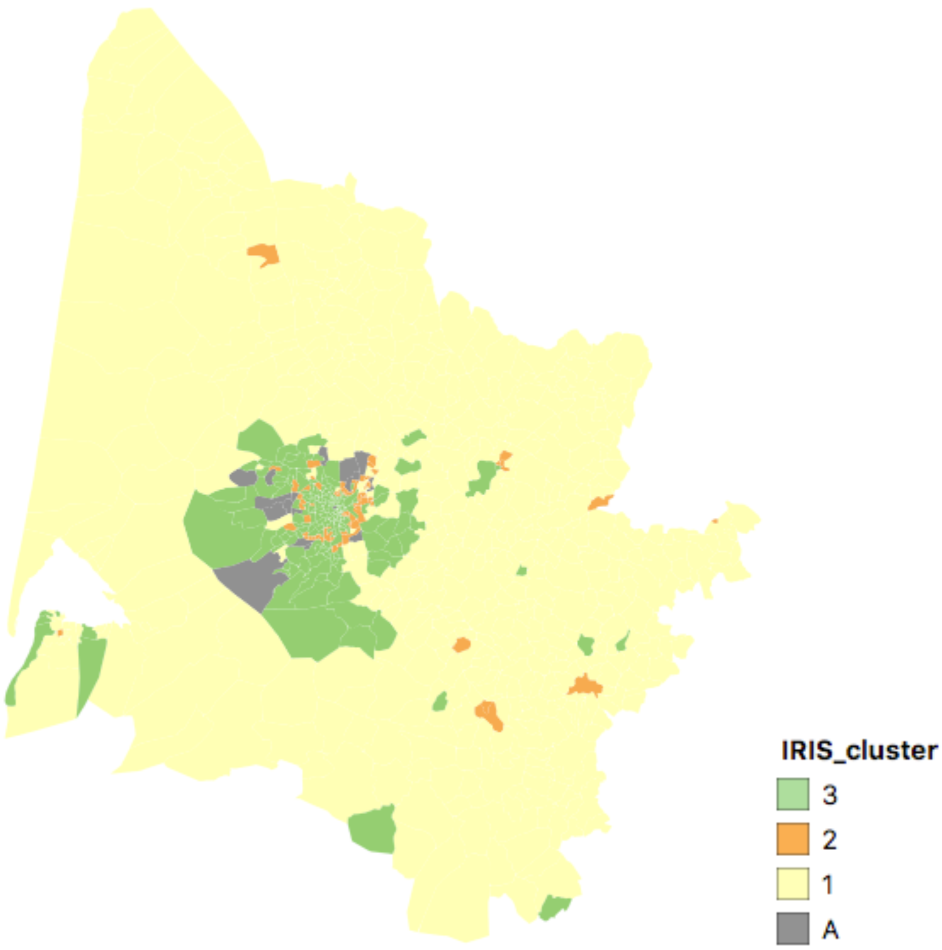
This variable is constructed at the IRIS scale using the census of the population from INSEE (2014). We implement an IRIS clustering on the Gironde aiming at summarizing the socio-economic conditions at the finest possible scale. However the scale of this social-economic clustering typology can be justified by the fact that the spatial externalities related to the social composition of spaces have a wider spatial scope and not only impact the immediate residential environment but spread to the neighborhood scale. (Baumont, 2009). We consider 17 variables divided into 5 main indicators that we present in the following table

INDICATOR	VARIABLES
Active population	Share of executives in the labor force Share of employees in the labor force Share of workers in the labor force
Unemployment	Share of the unemployed in the labor force Share of 15-24 year olds in the unemployed Share of unemployed 15-24 year olds
Population	Share of foreigners Share of single-parent families

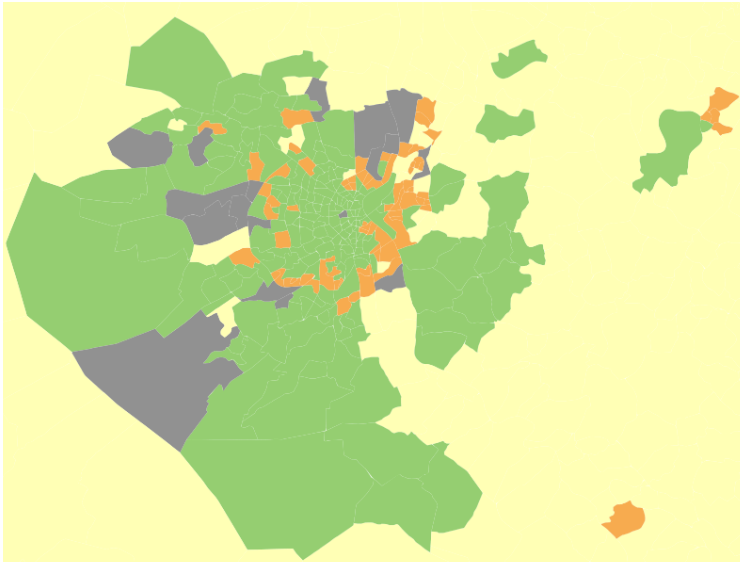
Education	CAP or BEP share Baccalaureat degree share Higher education share
Housing	Owner's share Share of tenant Share of vacant housing Share of social housing (HLM)

TABLE 08. Variables taken for the Socio-economic clustering by IRIS

This typology is carried out using the method of partitioning K-means. The goal is to obtain a convergent and stable partition that minimizes intra-class inertia and maximizes inter-class inertia. It has the advantage of changing the assignment of IRIS between the different steps but requires the setting of a number of clusters a priori. We obtain a partitioning in three similar classes with the method of K-means and CAH (for comparaison) allowing to classify our IRIS according to their socio-economic conditions.



MAP 14. Socio-economic typology of IRIS. In gray the IRIS of activity and not taken into account in the clustering



MAP 15. Socio-economic typology of IRIS – centered on Bordeaux Métropole.

Groupe	cadre	ouvrier	employe	chomeur	chomeur_1524	chomeur_pop1524	etranger	mono	educ0	educ1	educ2	educ3	prop	locat	vacant	hlm
1	0,088	0,281	0,283	0,12	0,228	0,139	0,031	0,114	0,326	0,303	0,168	0,202	0,735	0,232	0,098	0,028
2	0,1	0,264	0,346	0,22	0,249	0,165	0,131	0,267	0,353	0,24	0,165	0,242	0,269	0,715	0,073	0,417
3	0,256	0,121	0,248	0,117	0,226	0,089	0,041	0,146	0,199	0,187	0,176	0,434	0,553	0,421	0,062	0,083
	IRIS d'activité, non pris en compte dans le clustering															

TABLE 09. Mean of the variables by group taken for the Socio-economic clustering by IRIS

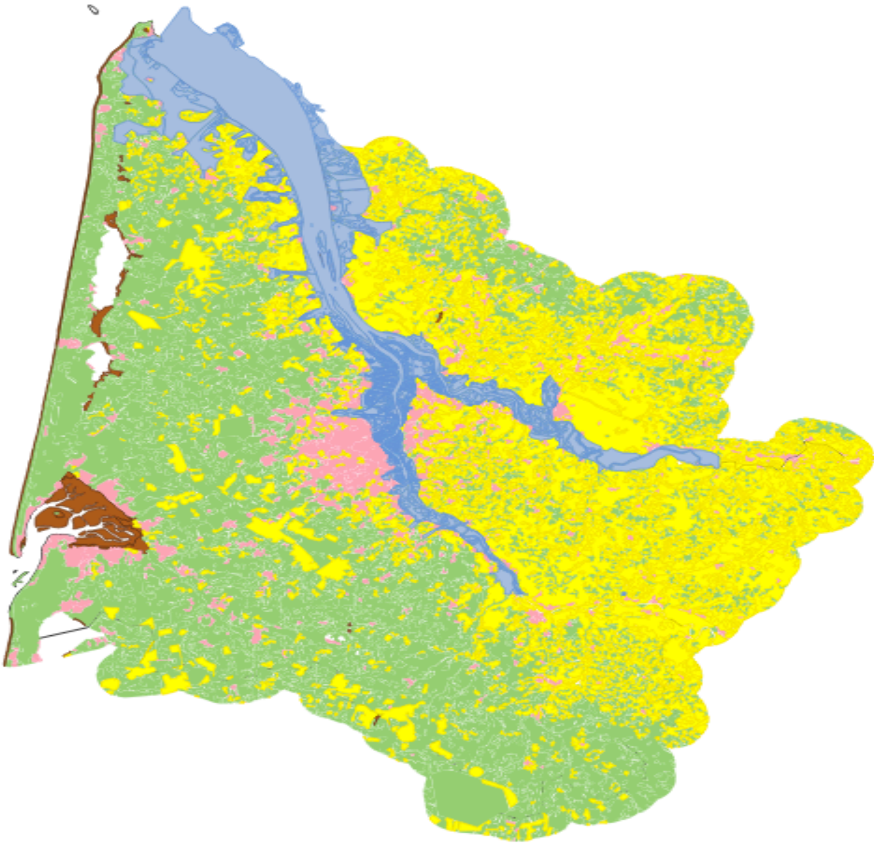
- Cluster 1 contains IRIS with mixed labor force and average level of education. It includes the strongest share of owner and little housing HLM. The IRIS of this cluster can be considered as "mixed" and correspond mainly to peri-urban areas;
- Cluster 2 contains IRIS in which low CSPs and foreign populations are overrepresented. The unemployment rate is high and the level of education is low. These IRIS contain a very high proportion of HLMs. The IRIS of this cluster can be considered as those with the most unfavorable socio-economic conditions;
- Cluster 3 contains the IRIS in which the upper and educated classes are predominantly present. The share of HLM is low and the individuals are mostly tenants. The IRIS of this cluster can be considered as those with favorable socio-economic conditions.

iv. Flood risk level

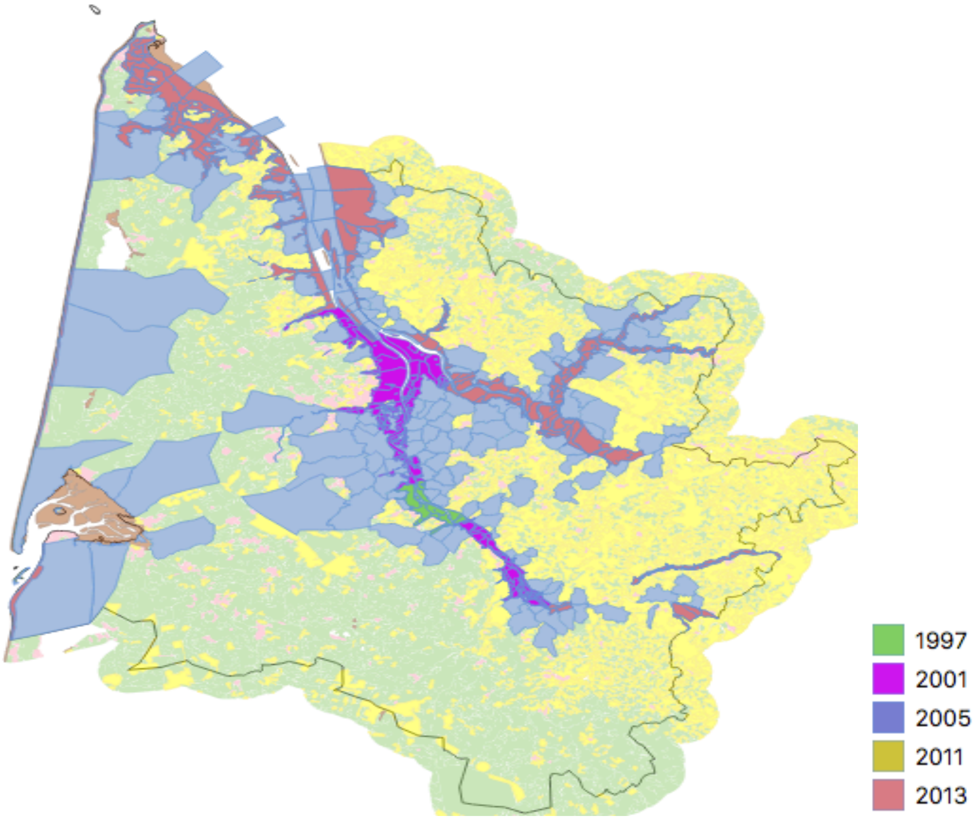
The variables related to flood risk are crucial in our empirical study on the price of buildings in the Gironde. We crossed the georeferenced data of the DVF mutations with the geographical layers of PPRI and PPRL (Flood / Littoral risk prevention plan). These are binary variables that indicate whether the mutation occurs in an area subject to flood risk under PPRI or PPRL. These variables are therefore limited in nature because they do not represent the real flooding risk in Gironde.

In addition, we use the GASPARD database and construct the CAtNat variable that represents the number of floods in the state. This dummy is defined on the basis of the distribution of the number of orders by municipality. It takes the value 1 if the municipality has not been updated (updated in 2018); it takes the value 0 if else. This threshold is based on the statistical distribution of the total number of orders. We consider the same threshold as Dachary-Bernard et al. (2014) with the 3rd quartile (in our case, at least 9 events). We represent in the map 17 below the cities for which Cat Nat equal 1. Finally, we use the shapefile provided by the SMIDDEST (that we represent below in the map

16) that represent a simulation of flooding hazard in Gironde and is based on event of 1999. We consider this variable as the real risk of flooding in Gironde but it do not concern the littoral coast.



MAP 16. Zoning of the simulation of flood hazard. SOURCE : SMIDDEST, Coline Land Cover



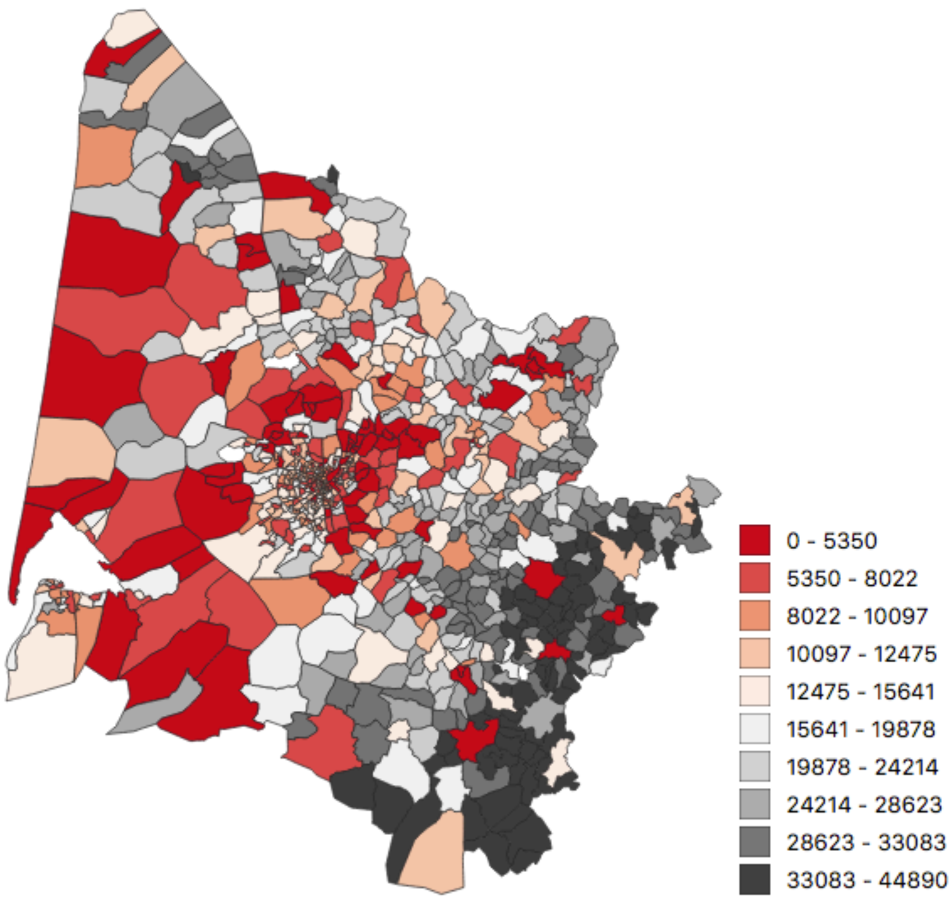
MAP 17. Cities for which the variable CAtNat = 1. In color, the years of implementation of the PPRI. SOURCE: georisques.gouv.fr

v. IRIS landlocking index

Using INSEE's permanent equipment base (BPE), we construct a variable representing the equipment level of an IRIS by counting the number of equipments present among the following 34 (thus varying from 0 to 34).

Hypermarket	Bookstore stationery newspapers	Emergency service	Playground
Supermarket	Gas station	Maternity	Multisport halls
Minimarket	Health facility stay course	Pharmacy	Theater
Grocery	Medium stay health facility	General practitioner	Cinema
Bakery	Établissement de santé long séjour	Dentist	Preparatory class
Kindergarten	Long-stay health facility	Technical College	Training and Research Unit
Primary school	Employment pole agency	Restaurant	Police station or gendarmerie
Middle School	Banking or insurance agency	Swimming pool	Airport
TGV train station	Train station (without TGV)		

Then, the enclavement of an IRIS is the average of the distances to the 34 reference equipments. The distance is 0 if the equipment is present in the IRIS and if it is not, the distance corresponds to that of the nearest IRIS (measured by the centroids) in which the missing equipment is located. This distance is weighted by the proportion of the population in the department who finds the equipment in their municipality. Thus, it is given more importance to distances related to the lack of equipment, or isolation, department IRIS are also common in all IRIS (eg Mérignac airport). Thus, the higher the value, the more the IRIS is said to be "landlocked". This variable was built on an original idea by Courson (1990).



MAP 18. IRIS landlocking IRIS. SOURCE: BPE INSEE

3. DVF data processing and choice of the functional form of the model

i. Fixed missing and outliers of DVF

Before we estimate the hedonic model, we analyze the distribution of our variables to correct missing values and outliers for each one. The DVF database comes from the DGFiP and despite the general quality of the latter, it is likely to contain errors when declaring and recording observations. However, erroneous values must be distinguished from extreme but correct values. It is therefore probable, a priori, to observe a wide distribution for the price or surface variables.

First, we delete observations that we could not geolocate to the plot or address, just under 10% of observations. We then delete the observations for which we have NA in the local label and in the surface of the field. Then we replace the NAs in the terrain surface with zero. Finally, we replace by NA the NAs in the actual area and room number variables when there is no building affected by the mutation. We tried to suppress as few observations as possible by replacing the missing values. This method is justified by the fact that a majority of observations contained at least one missing variable. Then we delete the observations for which the property value and the actual building area are missing. Then we delete the observations concerning an IRIS of activity (241 observations) and those of which we could not measure the index of isolation (95 observations). Finally, as we show on the previous map 17, the PPRIs were approved on different dates and we replace by 0 in the PPRI variable if the year of the transfer is lower than the year of the adoption of the PPRI.

Finally, we only keep the transfers that concern a house or an apartment and we exclude the observations that concern a bare ground or that concerns a commercial place, that is to say 90 763 observations. Then we keep only those relating to a sale, 89 280 observations. For the rest of the analysis, we distinguish apartments (9 022 observations) and houses (79 701 observations). We presented

ii. Standardization of the model's variable of interest

We study the distribution of the price variable per square meter. The latter includes total price and area information, allowing us to identify the first extreme observations. We observe in Table 17 (Appendix 3) that the price distribution / m² is very wide. We remove 1% of the observations on the right and left of the distribution for the apartments, ie 2% of the observations. For houses, we delete 1% left and 0.5% right, 1.5% of observations).

With regard to apartments, we notice in Figure 02 (Appendix 6 p. 59) that the distribution of the log property value approaches a normal distribution, but the quantile - quantile diagram shows that the distribution curve still imperfectly follow this law. Therefore, we choose to exclude 0.5% of the observations on the left and 0.5% on the right, 1%, allowing us, according to Figure 03 (Appendix 6 p. 59), to approach even more a normal law. For houses, we notice on figure 4 (Appendix 6 p. 60) that the distribution of the log of the property value approaches more imperfectly a normal law, which confirms the digraph quantile - quantile. So we choose to remove 2% of observations to the right and left, or 4%. According to figure 5 (Appendix 6 p.60), the distribution of the log of the real estate value is this time much more conformed with that of a normal law.

The database on which we will apply the MPH is therefore finally composed of 8 790 apartments and 74 798 houses.

iii. Functional form of the model

Concerning the functional form of the hedonic model, there is no consensus on the best form to apply to this type of model (Dubé et al. - 2011). The Box - Cox transformation makes it possible to generalize the different forms that the model equation can take but does not allow the use of dichotomous variables (Dubé et al. - 2011). However, an equation of linear, log-log or log-linear form allows for easier interpretation and the use of binary variables such as those related to flood risk. In addition, a logarithmic specification allows analysis in terms of elasticity, particularly suitable for studying the marginal willingness to pay individuals for each attribute of the good.

Given the nature of our variables, we opt for a mixed form model. Variables related to distance, area, and density will be expressed in terms of the log - log relationship. The binary variables, categorical and related to the number of room, parcel and room will be expressed in terms of log - linear relation. The logarithm of land value, the explained or endogenous variable, will be used to interpret the results in terms of elasticity.

$$\text{Log (valeur\_fonciere)} = A\beta_0 + X\beta_1 + \beta_2 Z + \varepsilon$$

With A the unit vector, X the matrix of the intrinsic characteristics and Z the) of the extrinsic characteristics, presented in the tables 6 and 7. β_0 corresponds to the constant, β_1 and β_2 are the vectors of the estimated coefficients of the variables and ε the matrix of the residuals of the estimate.

B. Econometric estimation

1. 1st OLS and correction of the distribution of the error term

We make a first estimate using the ordinary least squares method on the apartments and houses. In order to respect the hypothesis of normality, homoscedasticity and independence of the error terms, it is necessary to study the distribution of the error term in order to correct our model: whether to suppress observations or transform variables. However, we note on the figure 8 and 9 (appendix 9 p. 64) that some observations are very different from the central tendency, measured by the Cook's distance both for the apartments and the houses. In addition, the quantile - quantile graph shows that the error term is moving away from a normal distribution and particularly for extreme values. For homoscedasticity, the Bruch-Pagan test is significant, which means that the null hypothesis of no heteroscedasticity is rejected. However, this test is sensitive to the deviation of the normal law.

Consequently, we decide to slightly correct the error term for the apartments and houses by deleting the observations that have the leverage (hat value) greater than 0.05. Finally, we have 74 779 observations for houses and 8 778 observations for apartments.

Term	M1 house		M2 house		M1 appartment		M2 appartment	
(Intercept)	12.7138 (0.0701)	***	12.749 (0.0704)	***	11.0067 (0.2661)	***	12.2517 (0.2917)	***
surface_reelle_bati	0.5578 (0.0045)	***	0.553 (0.0046)	***	0.4841 (0.0128)	***	0.4855 (0.0127)	***
surface_terrain	0.0443 (9e-04)	***	0.0443 (9e-04)	***	0.1151 (0.0022)	***	0.1164 (0.0021)	***
nombre_pieces	0.018 (0.0012)	***	0.0201 (0.0012)	***	0.0282 (0.0053)	***	0.0284 (0.0053)	***
nombre_bati	-0.2479 (0.0059)	***	-0.2603 (0.0061)	***	-0.1663 (0.0224)	***	-0.1713 (0.0222)	***
dist_routes_prim	-0.0152 (0.0044)	***	-0.0149 (0.0044)	***	0.051 (0.023)		0.0322 (0.0222)	
dist_mairie	-0.6136 (0.0438)	***	-0.6204 (0.044)	***	-0.1579 (0.016)	***	-1.1109 (0.116)	***
dist_mairie_BX	-0.1322 (0.0057)	***	-0.1318 (0.0057)	***	0.0041 (0.0116)		-9e-04 (0.0113)	
surf_nature	0.0124 (0.0014)	***	0.0124 (0.0014)	***	-0.0067 (0.0025)	**	-0.0076 (0.0025)	**
surf_bati_m2	-0.0171 (0.0016)	***	-0.0175 (0.0016)	***	-0.0077 (0.0081)		-0.0085 (0.008)	
hauteur_moyenne	-0.0121 (0.0044)	**	-0.0116 (0.0044)	**	0.1452 (0.0176)	***	0.1475 (0.0174)	***
groupe_cluster_social2	0.0344 (0.0056)	***	0.0349 (0.0056)	***	0.1583 (0.0211)	***	0.1576 (0.0209)	***
groupe_cluster_social3	0.1394 (0.0042)	***	0.1397 (0.0042)	***	0.1752 (0.0213)	***	0.179 (0.021)	***
log_enclavement	-0.0263 (0.0018)	***	-0.0261 (0.0018)	***	-0.0451 (0.0102)	***	-0.0447 (0.0101)	***
Bordeaux_metropole	0.022 (0.0058)	***	0.0212 (0.0058)	***	0.1147 (0.0363)	***	0.1296 (0.0359)	***
Arcachon	0.2186 (0.009)	***	0.2179 (0.009)	***	0.4449 (0.0615)	***	0.4439 (0.0608)	***
CatNat	0.0097 (0.0033)	**	0.0099 (0.0033)	**	-0.0345 (0.0218)		-0.0412 (0.0216)	.
PPRI	-0.1459 (0.0145)	***	-0.1427 (0.0145)	***	-0.2496 (0.1343)	.	-0.2568 (0.1327)	.
PPRL	0.328 (0.0108)	***	0.3282 (0.0108)	***	0.6474 (0.0688)	***	0.6595 (0.0679)	***
simu	-0.0833 (0.0124)	***	-0.0831 (0.0124)	***	-0.3354 (0.1227)	**	-0.3387 (0.1212)	**
distance_garonne	-2,87e-06 (2,26e-07)	***	-2,89e-06 (2,26e-07)	***	-3,65e-07 (1,20e-06)		-7,29e-07 (1,22e-06)	
distance_cote	-6,59e-06 (1,41e-07)	***	-6,59e-06 (1,41e-07)	***	-8,41e-06 (9,37e-07)	***	-8,29e-06 (9,34e-07)	***
annee2010	0.0438 (0.0052)	***	0.0436 (0.0052)	***	0.072 (0.0156)	***	0.0691 (0.0154)	***
annee2011	0.09 (0.0052)	***	0.0899 (0.0052)	***	0.1859 (0.0172)	***	0.1866 (0.017)	***
annee2012	0.0899 (0.0053)	***	0.0894 (0.0053)	***	0.2357 (0.0183)	***	0.2382 (0.0181)	***
annee2013	0.0911 (0.0054)	***	0.0906 (0.0054)	***	0.2407 (0.0202)	***	0.2444 (0.02)	***
annee2014	0.0839 (0.0055)	***	0.084 (0.0055)	***	0.2332 (0.0206)	***	0.2319 (0.0203)	***
annee2015	0.0926 (0.0054)	***	0.0923 (0.0054)	***	0.2528 (0.0216)	***	0.2542 (0.0214)	***
annee2016	0.115 (0.0053)	***	0.1148 (0.0053)	***	0.3231 (0.0225)	***	0.321 (0.0223)	***
annee2017	0.1083 (0.0101)	***	0.1082 (0.0101)	***	0.2321 (0.0626)	***	0.23 (0.0618)	***
CatNat:PPRL	-0.121 (0.0119)	***	-0.1218 (0.0119)	***	-0.5122 (0.0743)	***	-0.5176 (0.0734)	***
CatNat:PPRI	0.0461 (0.0163)	**	0.0444 (0.0163)	**	0.2736 (0.1356)	*	0.2818 (0.134)	*
CatNat:simu	-0.014 (0.015)		-0.0141 (0.015)		0.2798 (0.1267)	*	0.2746 (0.1253)	*
Degree of freedom	74765		74746		8757		8745	
Residual standard error	0.3456		0.3454		0.4712		0.4654	
R^2 / Adjusted R^2	0.5466 / 0.5464		0.5471 / 0.5470		0.5023 / 0.5005		0.5116 / 0.5098	
F-Statistics / p-value	2817 / < 0.0000		2822 / < 0.0000		276,2 / <0.0000		286.3 / <0.000	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 / In parenthesis, standard error

TABLE 10. Ordinary least squares regression of model 1 and model 2 (after correction of the distribution of the error term)

2. Presence of spatial autocorrelation and choice of spatial weighting method

As mentioned above, housing has a spatial character because spatially similar properties share a common environment, have similar characteristics and there is frequently a phenomenon of spatial diffusion of property prices between neighboring properties. It is then necessary to construct a spatial weighting matrix to describe this phenomenon of interdependence.

The spatial weighting matrix, which measures the neighborhood, can be defined according to three criteria: contiguity, threshold distance and closest neighbor. We are already eliminating the criterion of contiguity since it refers to aggregated spatial data.

- The choice of a threshold distance allows a heterogeneity/diversity of the number of neighbors. In addition, the existence of isolated observations should lead us to consider a wide perimeter so that all the goods have at least one neighbor. The neighborhood perimeter of our entire sample is therefore dependent on these isolated observations and a wide perimeter is not very compatible with the spatial scope of the autoregressive processes mentioned above.
- The choice of a set of nearest neighbors has the advantage that all observations have a neighborhood and all have the same number of neighbors. However, in the case of isolated observations, this leads us to consider nearby distant observations. However, apart from these observations, the nearest neighbor criterion seems to respect the spatial scope of the processes mentioned above.

Given the nature of our data, we will use the *nearest neighbor criterion* despite its limitation for the most remote observations. If an observation is considered to be one of the nearest neighbors of another observation, the corresponding element of the W matrix will take the value 1 and 0 if not. In terms of spatial statistics, the global indices (which make it possible to characterize as a whole a given sample) and the local indices (specific to certain observations or localizations) make it possible to transcribe the phenomena of interdependencies between observations.

The most widely used global indicator, revealing a spatial pattern under the hypothesis of homogeneity of observations, is the Moran index. This index is interpreted as the ratio of the covariance between neighboring observations and the total variance of the sample (Jayet 2001, Le Gallo 2002) and its value is between -1 and 1 which respectively represent a perfect dispersion (structure in chessboard) and a perfect correlation (concentration of similar values). When the Moran index is 0, there is no pattern of competition or spatial association. Formally, this statistics is written:

$$\mathrm{I} = \left. \frac{\sum_{\mathrm{i}} \sum_{\mathrm{j}} \mathrm{w}_{\mathrm{ij}} (\mathrm{x}_{\mathrm{i}} - \tilde{\mathrm{x}})(\mathrm{x}_{\mathrm{j}} - \tilde{\mathrm{x}})}{\mathrm{S}_0} \middle/ \frac{\sum_{\mathrm{i}} (\mathrm{x}_{\mathrm{i}} - \tilde{\mathrm{x}})}{\mathrm{N}} \right.$$

Anselin (1995) develops the Local Moran Index (LISA) to measure spatial autocorrelation at the local level. This index makes it possible to capture patterns of local spatial associations, ie concentrations of similar or dissimilar values over space. The observations are then classified into four clusters: HH (the observation has a high value and is surrounded by similar values); LL (the observation has a low value and is surrounded by low values); LH (the observation has a low value and is surrounded by high values) and HL (the observation has a high value and is surrounded by low values).

$$I_i = \frac{(n-1)(x_i - \tilde{x}) \sum_{j=1}^{n} w_{ij} (x_j - \tilde{x})}{\sum_{j=1}^{n} (x_j - \tilde{x})^2}$$

Although their uses are widespread, the indices of spatial correlations still present methodological limitations. First, the result of these indices depends on the previously defined spatial interaction matrix W. Finally, the mode of aggregation of spatial units or their statistical or administrative breakdown impacts the measure of the dependence between observations.

In order to fix the adequate number of neighbors in order to define which type of spatial effects would seem to play on real estate prices, we base ourselves on the maximization of the criterion of the Moran index of which we present the result for a weighted matrix of the nearest neighbors in Table 11 below:

Distance criteria (k nearest neighbor)	**Moran I statistic, two-sided - DVF_Appartement** *Signifiance)*	**Moran I statistic, two-sided - DVF_maison** *(Signifiance)*
K = 1	**0.1353064235133 (***0.000)*	**0.49970764998938 (***0.000)*
K = 2	**0.1372185572219** *(0.000)*	**0.49601295490492** *(0.000)*
K = 3	**0.1358548441388** *(0.000)*	**0.49299437389158** *(0.000)*
K = 4	**0.13687328857653** *(0.000)*	**0.49036236060357** *(0.000)*
K = 5	**0.13646581406263** *(0.000)*	**0.488092997183485** *(0.000)*
K = 6	**0.13651423145446** *(0.000)*	**0.486577391084927** *(0.000)*
K = 7	**0.13612082142584** *(0.000)*	**0.485346336868652** *(0.000)*
K = 8	**0.13658573763469** *(0.000)*	**0.484182567169188** *(0.000)*
K = 9	**0.13679273631346** *(0.000)*	**0.483256587731592** *(0.000)*
K = 10	**0.13614159799995** (*0.00)*	**0.482266804036149** (*0.00)*

TABLE 11. Two-sided Moran I statistic based on different weighted matrix by k nearest neighbor

Therefore, a spatial weighting matrix is chosen based on the k nearest neighbor with respect to houses and the next two neighbors for apartments. We observe, given our weight matrices, a positive spatial autocorrelation for the two segments but stronger for the houses. Furthermore, we measure the Local Moran Index (LISA) to measure the spatial autocorrelation and to capture local spatial association patterns, the following of which are shown in Table 12 and the maps in Appendix 10 p.65 show the result for the apartments and the houses.

	High – High	Low – Low	High – Low	Low – High	Non significatif	Total
Appartment	270	203	110	115	8076 (92,04%)	8774
House	4058	5196	352	325	64730 (86,69%)	74 661

TABLE 12. Result of LISA for apartment and house

Whether for apartments or for houses, there is a high rate of non-significance which reflects the fact that these localized spatial patterns are far from representing a general pattern at the scale of the study area and that consequently spatial autocorrelation seems to have a global origin. We notice for the apartments that there is no clear spatial pattern, except for a possible localization of HH north of Bordeaux Metropole (high-end and eco-friendly HUAT programs) and LL in the south, which could correspond to the location of the major universities and therefore a local real estate market marked by this specific condition. On the other hand, for houses, the phenomenon of metropolisation is quite clear with a concentration of HH around Bordeaux Metropole and the Arcachon bay. For the rest, along rivers, concentrations of LL values may suggest the effects of specific metropolitan and coastal territories but may also be possible negative effects of proximity to rivers.

3. Overview and regression of the different spatial model

We present here a quick overview of the main spatial econometrics model and their estimation. Note that we do not present the result of the regression for houses because of lack of computation power. We present in the next part the methodology that we are going to follow to choose the best spatial model given our data.

° **Spatial Lag Autoregressive Model (SAR) :** In this model, the spatial dependence is realized on the endogenous variable, in our case, the price of housing. This phenomenon occurs when the price of a property is set on the appraisal of the value of neighboring properties, so there is a real estate price diffusion effect between neighboring observations.

$$y = \alpha A + \rho W y + X\beta + \varepsilon$$
$$\varepsilon \sim iid\ (0, \sigma^2)$$

With y the vector (n × 1) of housing prices, X the matrix (n × l) of l characteristics and ε the vector (n × 1) of residuals. α is the constant and β is the vector of the estimated coefficients. W is the previously established weight matrix (n × n) that characterizes the relationship between each pair of observations. Wy is the lagged endogenous variable, which is the average price of dwellings close to an observation when W is standardized. The parameter ρ measures the degree of spatial dependence between the observations on the explained variable, it is the "endogenous interaction effect" (Elhorst 2010). In our case, it is the influence of neighboring housing prices on the price of a given dwelling. Failure to take into account this spatially shifted endogenous variable induces biased and non-convergent estimators (Le Gallo 2000).

° **Spatial Error Model (SEM) :** In this model, the spatial dependency is specified in the error term. The SEM model can account for a poor econometric specification. The spatial autocorrelation detection in the error term is interpreted as the omission of explanatory variables, measurement errors or the use of an unsuitable functional form (Le Gallo 2002). In the case of the real estate market, the spatial dependence of residues may be related to the existence of unobservable characteristics of a neighborhood or to the preferences of individuals.

$$y = \alpha + X\beta + \varepsilon$$
$$\varepsilon = \lambda W\varepsilon + \mu$$
$$\mu \sim \lambda iid\ (0, \sigma^2 I)$$

With y the vector (n × 1) of housing prices, X the matrix (n × l) of l housing characteristics and ε, the residual vector of the estimate. α is the constant, β the vector of the estimated coefficients and W the weight matrix. The intensity of the spatial dependence of the residues is transcribed by λ. Assuming that the residuals are independent of the explanatory variables, the failure to take into account the spatial autocorrelation of the errors generates unbiased but inefficient estimators (Le Gallo 2002).

° **Spatially Lagged X Model (SLX) :** In this model, the autoregressive process appears in the explanatory variables (Lesage and Pace 2009). This is the case when housing share similar intrinsic or extrinsic characteristics and / or they generate externalities (negative or positive) between them, it is "the effect of exogenous interaction between the independent variables" (Elhorst 2010). For example, in the case of extrinsic variables, we will have:

$$y = \alpha A + X\beta + WZ\gamma + \varepsilon$$
$$\varepsilon \sim iid\ (0, \sigma^2 I)$$

With y the vector (n × 1) of housing prices, X the matrix (n × l) of l intrinsic characteristics and Z the vector (n × m) of m extrinsic characteristics, source of spatial dependence. ε is the vector of the residuals of the estimate. α is the constant, β and γ are the vectors of the estimated coefficients. W is the weight matrix and WZ is the lagged endogenous variable, which is the average extrinsic characteristics of the neighboring dwellings of an observation when W is standardized. In the absence of another form of spatial dependence, the model estimated by the OLS provides unbiased and efficient estimators.

° **Spatial Durbin Model (SDM) :** The Durbin Spatial model is a combination of the SAR and SLX model. It makes it possible to take into account both the spatial dependence linked to the explained variable and that relating to the exogenous variables. It allows us to consider the effects of real estate price diffusion on neighboring properties as well as the impact of similar environmental characteristics and the effects of neighborhood externalities.

$$y = \alpha A + \rho W y + X\beta + \theta W Z + \varepsilon$$
$$\varepsilon \sim iid\ (0, \sigma^2 I)$$

With y the vector (n × 1) of housing prices, X the vector of l intrinsic characteristics and the vector Z that of m extrinsic characteristics, correlated spatially. Wy is the spatially shifted endogenous variable and WZ the vector of spatially shifted exogenous variables. The parameter ρ tells us about the intensity of spatial dependence associated with the endogenous variable, α is the constant, β and θ are the vectors of the estimated coefficients and ε is that of the residuals. Note that this model is a generalization of more specific SAR and SLX models. We find the SAR model when θ = 0 (the exogenous variables are not spatially shifted) and the SLX model when ρ = 0 (no effect of spatial diffusion of real estate prices).

° **Spatial Durbin Error Model (SDEM) :** This model considers that spatial autocorrelation is present both in the explanatory variables and in the residuals, it is a combination of the SLX model and the SEM model.

$$y = \alpha + X\beta + WZ\gamma + \varepsilon$$
$$\varepsilon = \lambda W \varepsilon + \mu$$
$$\mu \sim \lambda iid\ (0, \sigma^2 I)$$

With y the vector (n × 1) of housing prices, X the matrix (n × l) of l housing characteristics and ε, the residual vector of the estimate. α is the constant, β the vector of the estimated coefficients and W the weight matrix. The intensity of the spatial dependence of the residuals is expressed by λ. Assuming that the residuals are independent of the explanatory variables, the failure to take into account the spatial autocorrelation of the errors generates unbiased but inefficient estimators (Le Gallo 2002). The SEM model can account for a poor econometric specification. The spatial autocorrelation detection in the error term is interpreted as the omission of explanatory variables, measurement errors or the use of an unsuitable functional form (Le Gallo 2002).

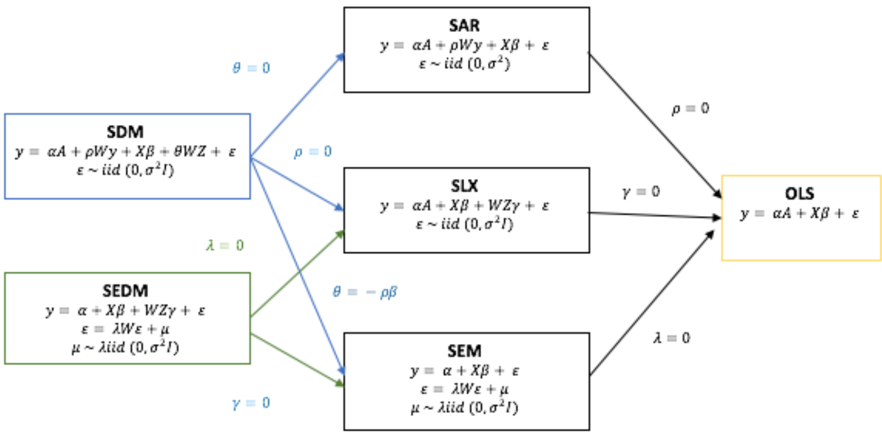


FIGURE 01. Summary of the different spatial models used and their links. SDM and SDEM are not nested. SAR, SLX and SEM are also not nested

	SDM	SDEM	SLX	SAR	SEM		MCO	
(Intercept)	9.4071 (0.2949) ***	10.575 (0.3078) ***	10.5666 (0.2791) ***	10.5071 (0.2811) ***	11.1951 (0.2873)	***	12.2517 (0.2917)	***
surface_reelle_bati	0.4757 (0.0126) ***	0.4785 (0.0126) ***	0.4783 (0.0127) ***	0.4825 (0.0126) ***	0.4802 (0.0126)	***	0.4855 (0.0127)	***
surface_terrain	0.121 (0.0021) ***	0.1199 (0.0021) ***	0.1196 (0.0022) ***	0.1164 (0.0021) ***	0.1195 (0.0021)	***	0.1164 (0.0021)	***
nombre_pieces_principales	0.0315 (0.0052) ***	0.0305 (0.0052) ***	0.0305 (0.0053) ***	0.0287 (0.0052)***	0.0306 (0.0052)	***	0.0284 (0.0053)	***
nombre_bati	−0.1688 (0.022) ***	−0.1708 (0.022) ***	−0.1711 (0.0223) ***	−0.1704 (0.0221) ***	−0.1682 (0.0221)	***	−0.1713 (0.0222)	***
dist_routes_prim	−0.0709 (0.3891)	−0.0929 (0.3839)	−0.0613 (0.3944)	0.0431 (0.0227)	0.0459 (0.0252)	*	0.0322 (0.0222)	

dist_mairie	0.4692 (0.3225)	0.447 (0.3219)	0.5088 (0.3268)	−0.1504 (0.0159) ***	−0.1607 (0.0176)	***	−1.1109 (0.116)	***
dist_mairie_BX	0.0915 (0.2979)	0.0896 (0.2957)	0.0822 (0.3019)	0.001 (0.0114)	−0.0009 (0.0125)		-9e-04 (0.0113)	
surf_nature	−0.0174 (0.0083) .	−0.0171 (0.008) .	−0.017 (0.0084) *	−0.0075 (0.0025) .	−0.0081 (0.0027)	***	−0.0076 (0.0025)	**
surf_bati_m2	−0.0265 (0.0133) .	−0.0264 (0.013) .	−0.0262 (0.0135) .	−0.007 (0.008)	−0.0097 (0.0085)		−0.0085 (0.008)	
hauteur_moyenne	0.0855 (0.0241) ***	0.0915 (0.0232) ***	0.0917 (0.0244) ***	0.1479 (0.0173) ***	0.144 (0.0184)	***	0.1475 (0.0174)	***
groupe_cluster_social2	0.0766 (0.0617)	0.0827 (0.0603) *	0.0848 (0.0626)	0.1565 (0.0208) ***	0.1606 (0.0229)	***	0.1576 (0.0209)	***
groupe_cluster_social3	−0.0096 (0.0631)	0.0031 (0.0615)	0.006 (0.064)	0.1695 (0.0209) ***	0.1702 (0.023)	***	0.179 (0.021)	***
log_enclavement	−0.0874 (0.0284) *	−0.0852 (0.0277) *	−0.0846 (0.0287) **	−0.0441 (0.0101) ***	−0.0471 (0.0111)	***	−0.0447 (0.0101)	***
Bordeaux_metropole	0.1626 (0.2223)	0.1547 (0.2143)	0.1975 (0.224)	0.115 (0.0358) .	0.1163 (0.0397)	***	0.1296 (0.0359)	***
Arcachon	0.3604 (0.061) ***	0.405 (0.0682) ***	0.4018 (0.0616) ***	0.3905 (0.0611) ***	0.4221 (0.0678)	***	0.4439 (0.0608)	***
CatNat	−0.1083 (0.0694)	−0.1006 (0.0676)	−0.1159 (0.0671) .	−0.0393 (0.0215)	−0.0428 (0.0237)	*	−0.0412 (0.0216)	.
PPRI	−0.2582 (0.1545)	−0.255 (0.1515)	−0.2956 (0.1504) *	−0.2266 (0.132)	−0.2324 (0.1381)	*	−0.2568 (0.1327)	.
PPRL	0.2777 (0.2709)	0.2911 (0.2598)	0.5538 (0.2848) .	0.6417 (0.0679) ***	0.6393 (0.0751)	***	0.6595 (0.0679)	***
simu	−0.2779 (0.143)	−0.2732 (0.1406)	−0.3381 (0.1514) *	−0.351 (0.1206) .	−0.3527 (0.126)	***	−0.3387 (0.1212)	**
distance_garonne	0.000009 (0.00002)	0.000009 (0.00003)	0.0000027 (0.000029)	− 0.00000005 (0.000001)	−0.00000008 (0.000001)		-7,29e-07 (1,22e-06)	
distance_cote	−0.000009 (0.000027)	−0.0000068 (0.000027)	−0.0000075 (0.000028)	−0.0000087 (0.0000009) ***	−0.000009 (0.000001)	***	-8,29e-06 (9,34e-07)	***
annee2010	0.073 (0.0151) ***	0.0712 (0.0152) ***	0.0716 (0.0153) ***	0.0695 (0.0153) ***	0.0726 (0.0152)	***	0.0691 (0.0154)	***
annee2011	0.1929 (0.0167) ***	0.1907 (0.0169) ***	0.1917 (0.017) ***	0.1867 (0.017) ***	0.1911 (0.0168)	***	0.1866 (0.017)	***
annee2012	0.2463 (0.0178) ***	0.2432 (0.0179) ***	0.2429 (0.018) ***	0.2394 (0.018) ***	0.2457 (0.0179)	***	0.2382 (0.0181)	***
annee2013	0.2504 (0.0196) ***	0.2492 (0.0197) ***	0.2505 (0.0199) ***	0.2434 (0.0198) ***	0.2461 (0.0197)	***	0.2444 (0.02)	***
annee2014	0.2421 (0.02) ***	0.2412 (0.0201) ***	0.2417 (0.0203) ***	0.2296 (0.0202) ***	0.2332 (0.0201)	***	0.2319 (0.0203)	***
annee2015	0.2688 (0.0211) ***	0.2658 (0.0212) ***	0.2658 (0.0213) ***	0.2573 (0.0213) ***	0.2647 (0.0211)	***	0.2542 (0.0214)	***
annee2016	0.333 (0.0219) ***	0.3324 (0.0221) ***	0.3325 (0.0222) ***	0.322 (0.0222) ***	0.3242 (0.0219)	***	0.321 (0.0223)	***
annee2017	0.2322 (0.0607) ***	0.2259 (0.0611) ***	0.2324 (0.0615) ***	0.2327 (0.0615) ***	0.2392 (0.0609)	***	0.23 (0.0618)	***
CatNat:PPRL	−0.2167 (0.2501)	−0.2261 (0.2356)	−0.556 (0.4055)	−0.5111 (0.0733) ***	−0.5075 (0.0811)	***	−0.5176 (0.0734)	***
CatNat:PPRI	0.1762 (0.1623)	0.1784 (0.1589)	0.2382 (0.1573)	0.2441 (0.1334)	0.2472 (0.1398)	*	0.2818 (0.134)	*
CatNat:simu	0.1884 (0.1472)	0.1856 (0.1446)	0.2594 (0.157) .	0.286 (0.1246) .	0.2818 (0.131)	**	0.2746 (0.1253)	*
lag.surface_reelle_bati	0.0012 (0.0164)	0.0537 (0.016) ***	0.0532 (0.0158) ***	–	–		–	
lag.surface_terrain	−0.0332 (0.0029) ***	−0.0206 (0.0027) ***	−0.0209 (0.0027) ***	–	–		–	
lag.nombre_pieces_principales	−0.0214 (0.0066) *	−0.0186 (0.0067) **	−0.0193 (0.0066) **	–	–		–	
lag.nombre_bati	−0.0292 (0.0283)	−0.0502 (0.0289)	−0.0465 (0.0286)	–	–		–	
lag.dist_routes_prim	0.1304 (0.3897)	0.1594 (0.3846)	0.128 (0.395)	–	–		–	
lag.dist_mairie	−0.6112 (0.3239)	−0.6065 (0.3234)	−0.6687 (0.3282) *	–	–		–	
lag.dist_mairie_BX	−0.0757 (0.2979)	−0.0728 (0.2957)	−0.063 (0.3019)	–	–		–	
lag.surf_nature	0.0123 (0.0084)	0.0113 (0.0082)	0.0111 (0.0085)	–	–		–	

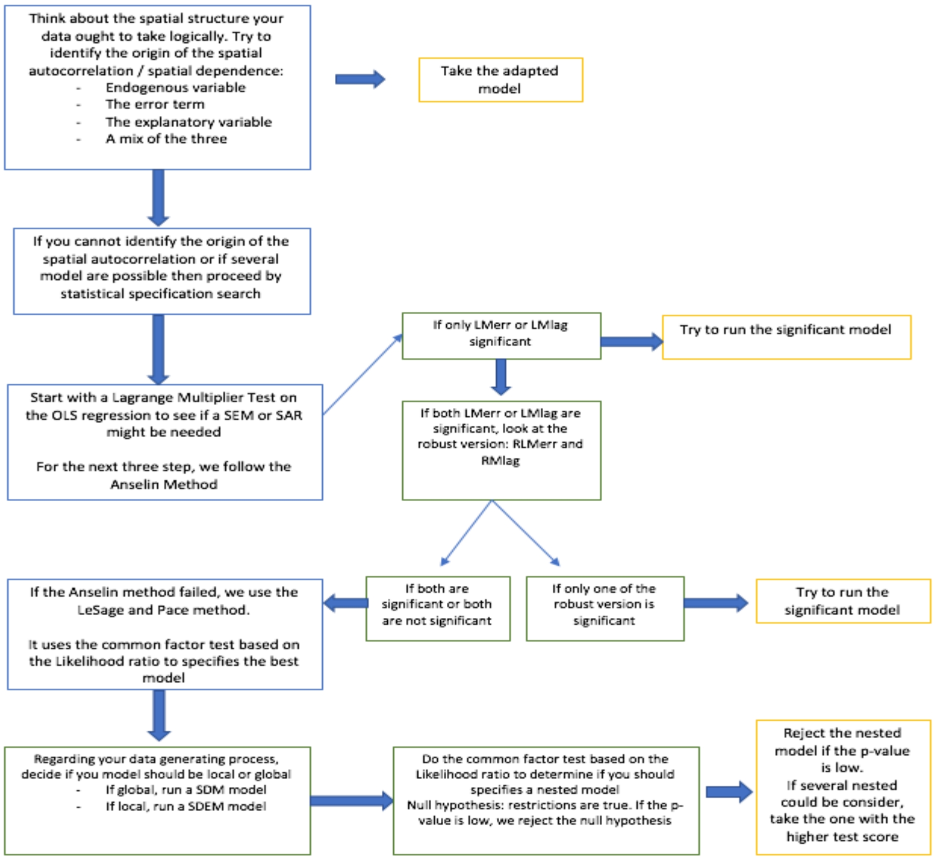
lag.surf_bati_m2	0.0258 (0.0151)	0.0256 (0.0152)	0.0249 (0.0153)	–	–		–	
lag.hauteur_moyenne	0.0433 (0.0263)	0.0523 (0.0257) .	0.0534 (0.0266) *	–	–		–	
lag.groupe_cluster_social2	0.0442 (0.0625)	0.053 (0.0614)	0.0524 (0.0633)	–	–		–	
lag.groupe_cluster_social3	0.1605 (0.0643) .	0.1652 (0.063) *	0.1668 (0.0651) *	–	–		–	
lag.log_enclavement	0.0571 (0.0292)	0.051 (0.0287)	0.0499 (0.0295) .	–	–		–	
lag.Bordeaux_metropole	−0.0575 (0.223)	−0.0366 (0.2153)	−0.0813 (0.2246)	–	–		–	
lag.CatNat	0.0863 (0.0701)	0.0748 (0.0686)	0.0879 (0.067)	–	–		–	
lag.PPRI	−0.0089 (0.1588)	−0.0512 (0.1593)	0.0189 (0.1523)	–	–		–	
lag.PPRL	0.2659 (0.2701)	0.3187 (0.2595)	0.0616 (0.2794)	–	–		–	
lag.simu	0.0093 (0.1461)	−0.0345 (0.1462)	0.0929 (0.1602)	–	–		–	
lag.distance_garonne	0 (0)	0 (0)	0 (0)	–	–		–	
lag.distance_cote	0 (0)	0 (0)	0 (0)	–	–		–	
lag.annee2010	−0.0396 (0.0191) .	−0.0339 (0.0196)	−0.0311 (0.0193)	–	–		–	
lag.annee2011	−0.0591 (0.0212) *	−0.0403 (0.0217)	−0.0373 (0.0214) .	–	–		–	
lag.annee2012	−0.084 (0.023) *	−0.0589 (0.0234) .	−0.0586 (0.0231) *	–	–		–	
lag.annee2013	−0.0364 (0.0249)	−0.0152 (0.0254)	−0.0084 (0.0251)	–	–		–	
lag.annee2014	−0.0342 (0.0255)	−0.009 (0.026)	−0.0093 (0.0257)	–	–		–	
lag.annee2015	−0.0802 (0.0268) *	−0.0559 (0.0273)	−0.0536 (0.027) *	–	–		–	
lag.annee2016	−0.0504 (0.0276)	−0.0129 (0.0281)	−0.0158 (0.0278)	–	–		–	
lag.annee2017	−0.1428 (0.0802)	−0.1166 (0.0819)	−0.1216 (0.0812)	–	–		–	
lag.CatNat:PPRL	−0.2211 (0.2501)	−0.2643 (0.236)	0.067 (0.4026)	–	–		–	
lag.CatNat:PPRI	0.147 (0.1668)	0.1895 (0.1668)	0.0997 (0.1597)	–	–		–	
lag.CatNat:simu	0.0473 (0.1517)	0.0857 (0.152)	−0.0596 (0.1669)	–	–		–	
Rho	0.1084013	–	–	0.04610582	–		–	
Lambda	–	0.1081079	–	–	0.1095365		–	
LR test (p)	118.0603 (<0.000)	116.907 (<0.000)	–	31.4745 (<0.000)	117.324 (<0.000)		–	
z-value (p)	10.97302 (<0.000)	10.9189 (<0.000)	–	5.6745 (<0.000)	11.069 (<0.000)		–	
Wald statistic (p)	120.4072 (<0.000)	119.222 (<0.000)	–	32.201 (<0.000)	122.515 (<0.000)		–	
ML residual variance	0.2079985	0.2080324	–	0.2143518	0.211 (<0.000)		–	
AIC	11304.51	11305.66	11477.906	11465.37	11379.52		–	
Number of observations	8 774	8 774	8 774	8 774	8 774		8 774	
LM test (p)	4.215861 (0.0400)	–	–	108.249 (<0.000)	–		–	
I moran on residuals (p-value)	−0.002 (0.89)	−0.0015 (0.8951)	0.122 (<0.000)	0.069077 (<0.000)	−0.0019 (0.87)		–	
R^2 / Adjusted R^2	–	–	0.519 / 0.5164	–	–		0.521 / 0.5108	
F-statistic	–	–	149.727 (<0.000)	–	–		287.2 (<0.000)	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 / In parenthesis, standard error

TABLE 13. Regression for five spatial econometric models. Only for apartments. SLX is computed by hand because of an error in the spdep package. In this case, AIC is extracted using extractAIC ( ) on a lm object.

4. Methodology and choice of the best specification of the spatial model

From a practical point of view, different exploratory methods of specification research can be implemented to determine the most suitable spatial model. The "specific to general" and "general to specific" methods are generally distinguished in the literature (Anselin and Florax 1995, Anselin et al., 1996, Le Gallo 2002, Vega and Elhorst 2015). The first approach, specific to generic, starts from a specific. form of model, of type MCO or SLX, then to apply the tests of the multiplier of Lagrange and their robust versions. These tests make it possible to choose between a SAR or SEM specification. The second approach, general to specific, starts from a general method, of type SDM or SDEM, integrating the different forms of spatial dependence. The common factor test based on the likelihood ratio is then applied. Based on the likelihood ratio, the common factor test is used to determine whether a more specific form, such as SAR or SEM, is more suitable than the general approach.Regarding the choice of the best specification, we choose to follow the path proposed by L.Burkey in his manual. This methodology takes the best of the two approaches and can be summarized as a fellow:



The choice of the SAR or SEM model is made on the Lagrange multiplier test. Then, if no conclusive results can be drawn, we do a second test based on the common factor test with the maximum likelihood method, based on three hypothesis tests to choose the best specification about the available data (Osland, 2010). First, we test $H_0: \rho\beta + \theta = 0$ against $H_1: \rho\beta + \theta \neq 0$ and if H_0 is not rejected then the best specification is a SEM, otherwise it is a SDM. In a second step, we test $H_0: \theta = 0$ against $H_1: \theta \neq 0$ and if H_0 is not rejected then the best specification is a SAR, otherwise it is a SDM. Finally, we test $H_0: \rho = 0$ against $H_1: \rho \neq 0$ and if H_0 is not rejected then the best specification is a SLX, otherwise it is a SDM.

Lagrange multiplier diagnostics for spatial dependences		
Model	Score test	p-value
LMerr	116.35594	< 0.00000
LMlag	31.203406	< 0.00000
RLMerr	113.07805	< 0.00000
RLMlag	27.92552	< 0.00000

TABLE 14. Lagrange multiplier diagnostic for spatial dependences

	SDM	SEM	SAR	SLX
Common factor test score	- 5586,25	- 5654,76	- 5697,68	-5646.81
P value du LR test	-	<0.000	<0.000	<0.000

TABLE 15. Result of the common factor test. Each p-value associatied with eahc of the three tests where p <0.00000

Concerning the choice of the model, we can retain the three following points of our analysis of the different spatial models. The statistical criteria would lead to the retention of an SDM model. In fact, the SDM model has the lowest AIC (AIC represents a measure of model fit, a lower AIC indicates a better fit) closely followed by the SDEM and SEM model. In addition, the common factor assumption is rejected for the SEM, SAR and SLX models. However, the choice of a SEM or SDEM model could be considered since the AIC is very close to the SDM model. The interpretation of these models is easier than a SDM model since we focus only on the direct effects. Plus, it was not possible for us to run the impacts () command of the spdep package and, therefore, we cannot interpret the total effects (only indirect and direct effects). Finally, the I Moran statistic on the residuals of the regression show that we corrected the spatial autocorrelation with the spatial error model (p-value non-significant) but not with the spatial autoregressive model. Consequently, we choose a Spatial Error Model. This means that the spatial autocorrelation is mainly contained in the error term which means that this spatial dependence is explained by the omission of variables.

5. General interpretation of the model

We performed a first linear regression by the OLS method on our sample of 8,774 flats and then developed a spatial error model (SEM). We present the results of SEM model on flats, which are robust compared to OLS; then we will discuss the results obtained by the OLS method for houses. Our two models of linear regression explain for apartments and houses (74 746 observations), respectively, 51.2% and 54.7% of the variability of our models. We calculate a pseudo R square for our SEM model:

(1-(SSE / (var (log_prix) * (number of observations -1))) = 0.5218464541

Therefore we can estimate, with caution, that our SEM specification can explain 52.2% of the variability.

Regarding the intrinsic characteristics of housing, we find, by reasoning ceteris paribus, that the surface, the number of rooms and the surface of the ground have a positive and significant effect on the price of the property: increasing the surface of the appartment of 10 % leads to a 4.8% increase in price while an increase in the same rate of garden area leads to a 1.1% increase in price. Similarly, all else being equal, the marginal consent to pay for one more room is 0.28%. In contrast, the marginal consent to pay for additional building is -1.7%, indicating a preference for "concentrated" habitats. These results are similar between our two models, MCO and SEM, and highly significant, similar results are to be noted with regard to houses. These results are consistent, in terms of sign and significance, with other studies (Baumont - 2009, for example, finds an elasticity - surface price of 0.93) although it is however to remember that our model is imprecise on the intrinsic variables.

With regard to the residential housing environment, the natural areas (expressed in m²) within a radius of 200 meters around the property has a negative effect on the prices of apartments and is highly significant: all else being equal, an increase of 10% in natural surfaces causes a price drop of 0.081% for our SEM model. On the other hand, the effect is significant and opposite for the houses: 0.0124%. You can see the premium on the view of "green", valued for houses, but not for apartments. This variable does not ultimately translate into accessibility to recreational and urban recreational spaces (which may be more than 200 meters from the houses). The area built in square meters, which represents the density perceived by the inhabitants within a radius of 200 meters around the housing, is significant and plays negatively, but weakly, on the prices of the apartments for our two models as well as for the houses. On the other hand, and surprisingly, the average height is significant and positively affects the price of the apartments: a 10% increase causes, everything else being equal, a 1.44% price increase for our SEM model but negatively influences the price of the apartments. The results is inversed for houses (-0,116%). According to Wu et al. (2014), individuals express a preference for open spaces and poorly urbanized, which is the case in our study with the surrounding building density negatively impacting prices but does not explain the surprising result of average height, except at this is a measure of density that also plays a role in revealing social interactions. The social environment plays an important role in the appreciation of housings. As in Baumont (2009), neighborhood externalities that depend on the socio-economic composition of IRIS are capitalized in prices. For housing located in our cluster 2 (the most disadvantaged), the availability to pay for an apartment increases by 1.6% and by 1.7% in the most favored (cluster 3), compared to cluster 1 (IRIS " mixed, mainly rural) in our SEM. The valuation of cluster 3 is lower than in other studies (Girard - 2016 for example, with nearly 20% valuation for the Dijon agglomeration) but can be explained in particular by the fact that our study covers all the department of Gironde. The result for Cluster 2 is more surprising, but can in particular mark the attractiveness of Bordeaux Metropole where these IRIS are mainly concentrated. The result is similar for homes with our MCO model but the impact is stronger for cluster 3 than cluster 2 (0.349% for cluster 2 and 1.397% for cluster 1). Finally, the rate of equipment of the IRIS of the mutation and its proximity to the most equipped IRIS plays a positive role on prices. Built as an IRIS landlocking rate, and everything else being equal, the 10% increase in the index decreases the price of apartments by 0.475% for our SEM model. The same effect is to be noted for houses.

Regarding accessibility, the fact that a transfer was made within Bordeaux Metropole or the Arachon bay leads to an increase in price, all else being equal, of respectively 1.1363% and 4.221% for apartments in our SEM model. The impact is similar for houses. This result reflects the very strong attractivity of the two most dynamic territory of the Gironde in particular by the fact that they concentrate the areas of activity. This positive result can notably highlight the fact that these two zones represent both the main centers of activity (main and secondary pole of employment) but also concentrate some of the historical and modern amenities (Brueckner and others - 1999).

For the other extrinsic variables, the distance to the primary roads for the apartments is not significant in our MCO model and becomes weakly significant and negative in our SEM model: all else being equal, a 10% increase in the distance to the primary roads causes a 0.3% increase in price. The result may seem surprising, since we would have expected a negative relationship reflecting accessibility to the transportation network. It is finally most probably the negative externalities, especially the noise, associated with the proximity of this network which are here negatively valued in the prices. As expected, the distance to the town hall of the municipality of the mutation and the center of Bordeaux is significant and has a negative impact on the price of apartments: a 10% increase in the distance to the town hall of the town leads to a drop of 1,6% of the price of the apartment for our model SEM but the effect of increasing the distance to the center of Bordeaux does have a very small impact on price. This decreasing price gradient reflects the search for local amenities. The results of the MCO model for apartments are consistent with this result. For houses, the results are similar but the distance to the center of Bordeaux causes a more important drop in price (-1.6% for a 10%

increase in distance, everything else being equal.) This difference between apartments and houses can be explained by the fact that the changes concerning apartments is mainly located in Bordeaux Metropole

With regard to flood risk, we have included in the model the variable "simu" which measures the "real" risk on the Gironde. We also integrated the two zoning variables (PPRI and PPRL) as well as the variable CatNat which indicates the frequency of the floods recognized as a natural disaster by the state. By exploiting all these variables we look at the effects of risk on prices through i) a physical measurement, ii) an institutional dimension and iii) an economic and insurance dimension. The results must be read through this reading grid. The PPRI and PPRL zoning variables are both weakly significant and have opposite signs: everything else being equal, the location of an apartment in the PPRI zone result in a drop of 2.324% in price but a 6.393% increase of the price for the PPRL, compared to a mutation outside these two areas. On the other hand, the "simu" variable, representing the "real" risk of flooding in Gironde, is strongly signifiant and has a negative impact on prices: compared to a mutation outside this zone, the price of an apartment is 3.57% lower (-0.831% for OLS). For the Cat Nat variable, highly significant, the effect is negative, everything else being equal, and leads to a price decrease of 0.428% when the mutation concerns an apartment that has been made in a municipality that has known at least 9 recognition for natural disaster flood. The results are similar for homes with the exception of Cat Nat, which plays a positive role in house prices in our MCO model. With respect to the intersection of the risk variables (PPRI, PPRL and simu) with the Cat Nat variable, the significance is variable (strong for “Cat Nat: PPRL” and weak for “Cat Nat: PPRI” and “Cat Nat: simulation”) but has a sign totally opposed to the risk variables taken alone. Indeed, the mutation of an apartment built in a municipality whose Cat Cat = 1 and in a PPRL area sees its price, all things being equal, decrease by 5.075%, while it increases by 2.472% if the mutation is located in a PPRI zone, and 2.818% in an area affected by flood risk according to the simulation variable. The results are similar for houses with the OLS method with the exception of "Cat Nat: simulation" which is non-significant. The negative effect of the PPRI is consistent with previous studies and especially on the Gironde estuary alone (Dachary-Bernard et al., 2014). However, while the risks must be reflected in the price of housing, local real estate markets are nevertheless subject to a very large number of determinants (quality of housing, location, tension between supply and demand, etc.) and flood risk exposure is most often the undesirable side of an often attractive environment (view of a lake, a river, the proximity of the coast and its beaches, etc.), which tends to confuse the price signal (Mauroux - 2015). We therefore note in our results the existence of risk aversion on the part of residents. On the other hand, for the risk on the littoral (translated by PPRL) the results are surprising since the impact of the variable is positive on the price of the real estate. It reflects in fact the attractiveness of the Arcachon bay which is obvious, and refers to the obsolete nature of the PPRL device, unlike the PPRI (the flood risk management policy is primarily a water policy, not a sea policy).

Regarding the intersecstion of the risk variables with the Cat Nat variable, it can partially reveal the institutional efficiency to respond to floods, the reactivity of municipalities to trigger the insurance mechanism associated with the CatNat system (Dachary-Bernard et al., 2014). It is found that the positive effect of CatNat crossed to PPRI is positive, in the opposite direction of the only variable PPRI. This reflects the bonus given to triggering compensation, and highlights the revealing perverse effect of a contradiction between the two state policies: preventive (via zoning) and compensatory (via insurance). The 2002 decree (Cazaux et al., - 2018) proposes to compel the CatNat to the existence of a preventive measure on the city to prevent municipalities from paying higher insurance deductibles. In this sense, it can be considered that Cat Nat's insurance system has a destructive effect on the prevention policies that normally return to the municipalities and therefore a disempowering effect. The negative effect of CatNat crossed to PPRL underlines however the character "revealer" of the disaster in terms of risk on the coast where the PPRL are considered obsolete and ineffective (Perherin - 2017). Moreover, over the period of interest, coastal disasters have been significant: Xynthia in 2010 and storms on the coast Gironde during the winter of 2013-2014.

IV. CONCLUSION

The main interest of our study was to look at the effect on real estate prices the respective impact of flood risk prevention: PPRI and PPRL as well as damage compensation as effective measure to deal with flooding risk. We implement a hedonic price approach for apartments and houses, taken separately, on the Gironde which constitute an interesting study of area. In fact, the most attractive areas: Bordeaux Metropole and Arcachon bay, that are subject to flooding risk but of different nature. For Arcachon bay, the flooding risk comes from the sea, for Bordeaux Metropole it comes from the Garonne and if we consider the estuary it comes from both the sea and the Garonne (and Dordogne).

Regarding the main focus of our analysis, we can conclude that land real estate market integrate the vulnerability to flooding. In fact, both flood protection: PPRI and PPRL and institutional response to experienced flood, measured by the number of orders of flooding as natural disaster, have been taken into account by markets but do not have a similar influence. PPRI and the variable “simu”, which measure the “real risk”, negatively impact the price for apartments while PPRL positively impact it. However, when we consider at the same time the zoning effect and the compensation measure, the results are totally opposed. The effects are almost the same for houses but we were not able to provide an econometric model that correct the spatial autocorrelation (because of the size of the data), which we did for the apartments through a spatial error model. This indicate that zoning and natural disasters orders give land buyers an indication of the magnitude of flooding and in that sense individuals take a decision based on their risk profil and arbitrate between amenities and flood hazard.

This study may also be an illustration of the destructive effect on the prevention policies that normally return to the municipalities and therefore a disempowering effect. Also, it might highlight the fact that PPRL is obsolete and ineffective and so individual measure the disaster in term of risk on the coast through the number of orders of flooding as natural disaster on not thgrough the flood risk prevention tool: PPRL

However, we did not success to prove any flood strategy based on the acquisition of land as it was not possible to clearly identified the seller and buyer and the destination of land. However, we discussed the inadequate regulatory approach to flood risk prevention that our model illustrate.

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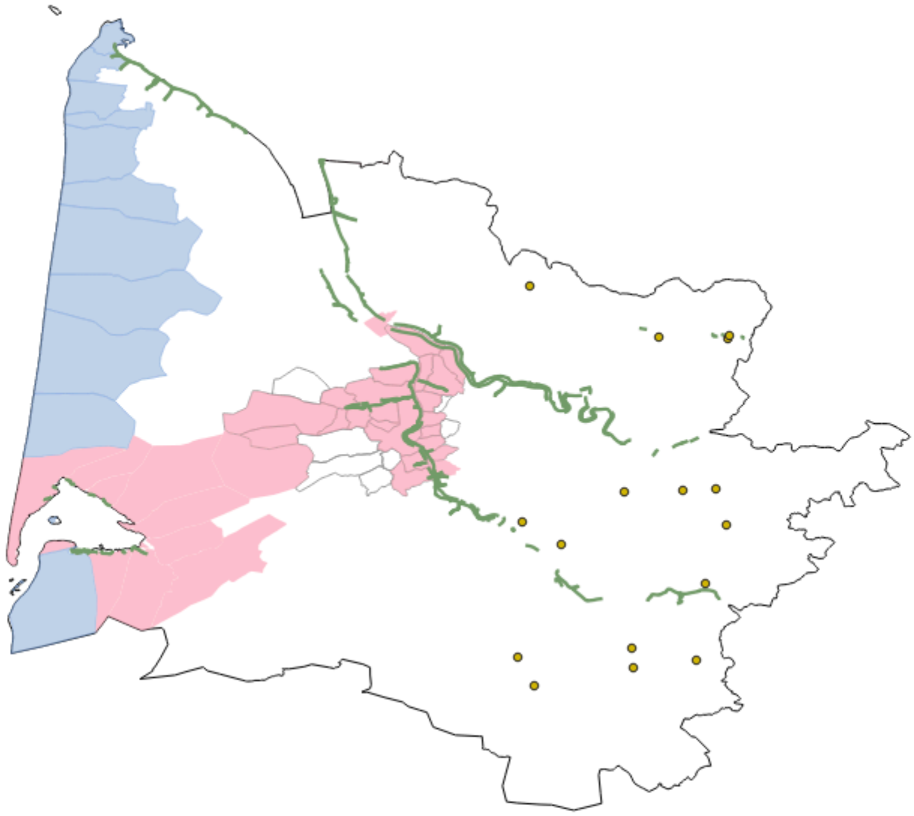
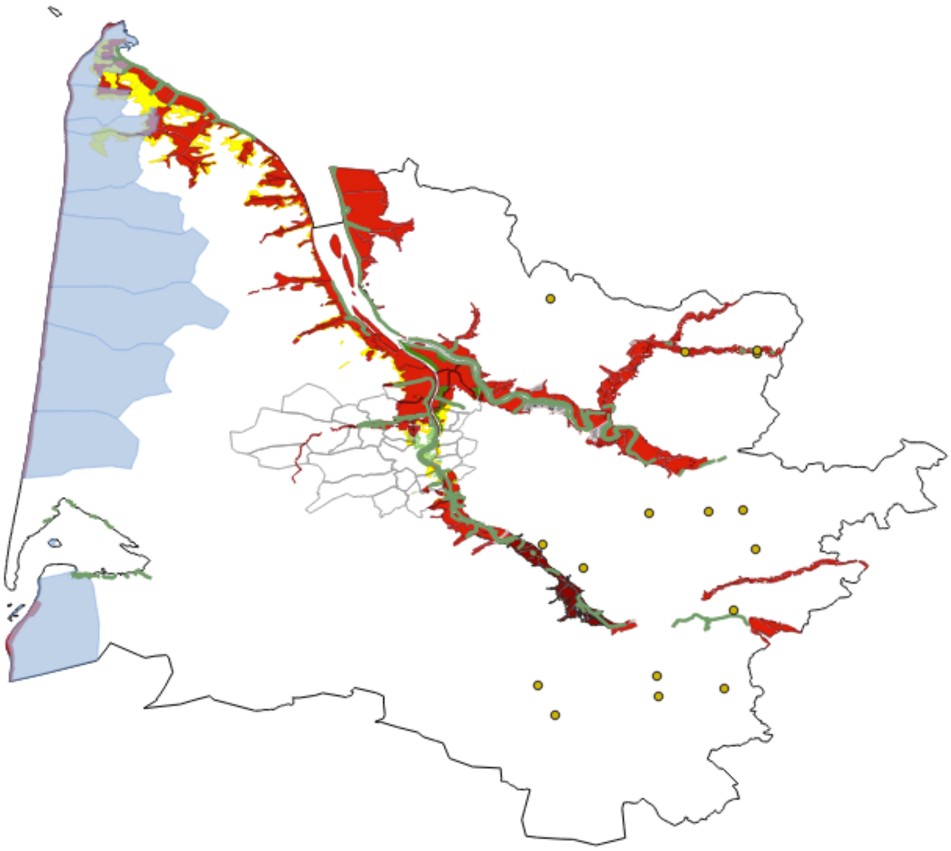
APPENDIX 1: MAP OF THE GIRONDE

MAP 19. Map of the study area. SOURCE: Wikipedia

APPENDIX 2: FLOOD ZONING IN GIRONDE

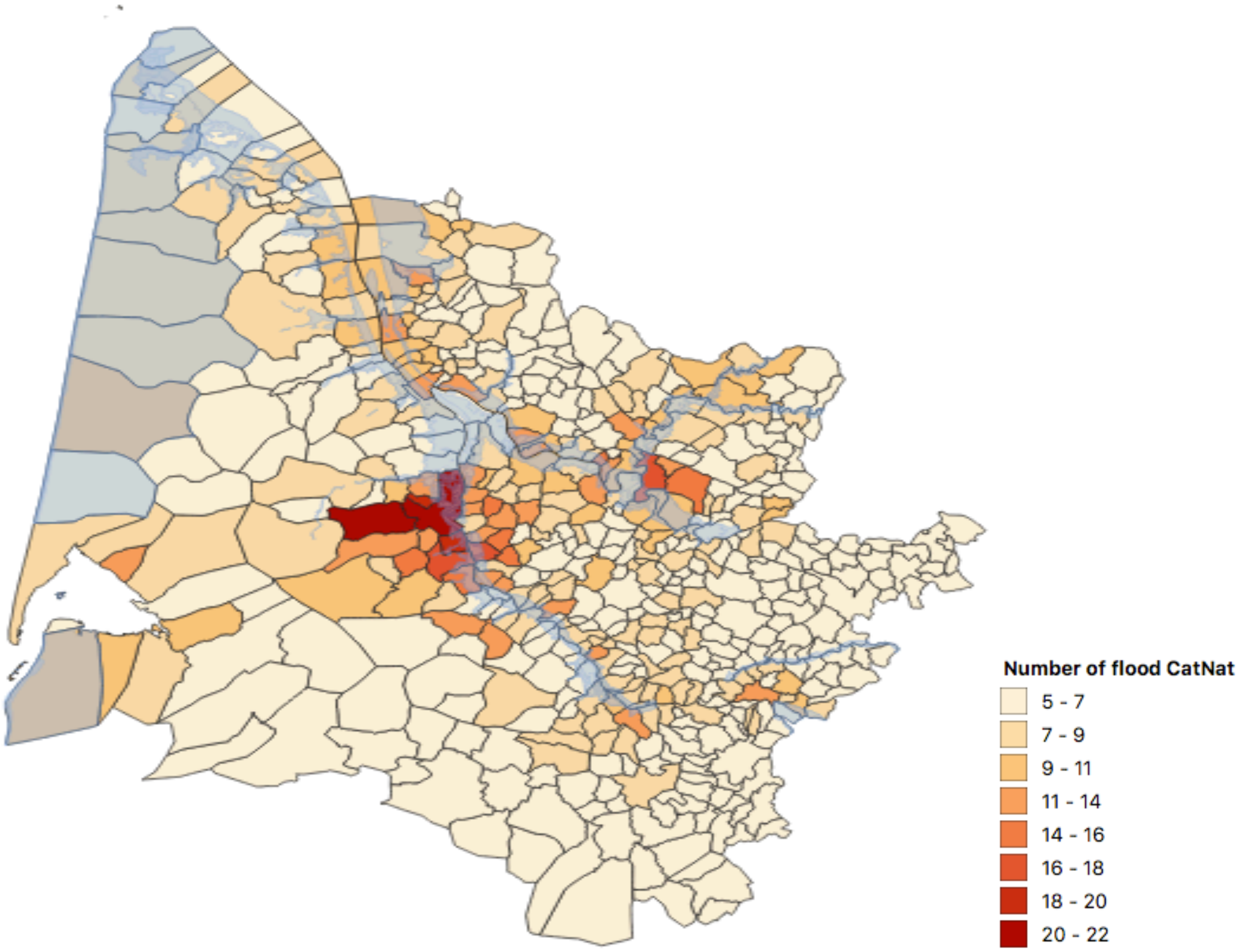


MAP 20. Coastal risk prevention plan. In blue the approved PPRL, in pink the PPRL not yet approved. In green the dikes of the Gironde. The dots represent the dams. SOURCE: georisques.gouv.fr



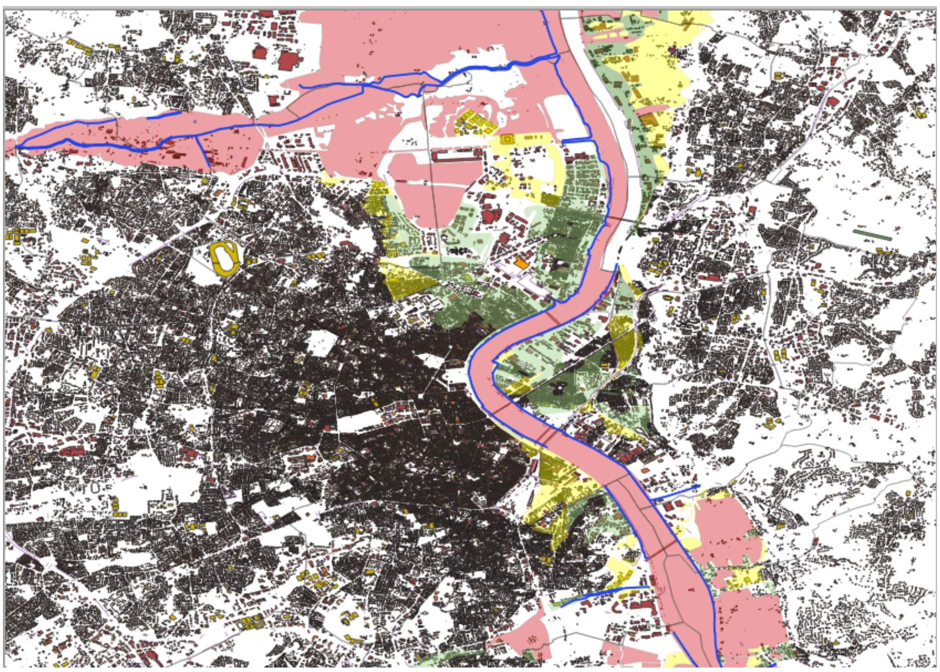
MAP 21. Flood Risk Prevention Plan. SOURCE: georisques.gouv.fr

APPENDIX 3: NUMBER OF CAT NAT RECOGNITION



MAP 22. Representation of the number of Cat Nat recognition. SOURCE: georisques.gouv.fr –

APPENDIX 4: FLOOD RISK PREVENTION PLAN AT BORDEAUX



Map 23. Representation of flood risk prevention plan at Bordeaux. SOURCE: georisques.gouv.fr and BD Topo IG

APPENDIX 5: SAFER LAND DESTINATION AND TYPE OF BUYER

Destination	Notification	Retrocession	Notification_BM	Notification_ inond
Forest destination	194	165	1	13
Certain agricultural destination	20	312	1	-
Environmental and Nature Protection Destination	-	36	-	16
Forest destination (for study only)	47	-	4	2
Individual local development	-	2	-	-
Emprise d'infrastructure : route, autoroute, TGV, aéroport, ...	10	8	-	3
Infrastructure footprint: road, motorway, TGV, airport, ...	51	45	-	-
Leisure and Tourism	1	2	-	-
Individual or collective local development project	27	17	4	8
Wildlife protection, flora, ecosystems	-	3	-	-
Landscape protection	-	1	-	-
Public services	340	29	3	28
Crafts, commercial, industrial, educational area, ...	20	1	-	-
Unknown, uncertain destination or SAFER acquisition	816	-	17	138
Housing estate and collective housing	38	-	4	-
Built-up property for primary or secondary residence	23	-	-	2
Water resource protection	1	-	-	-
Individual building plot excluding subdivision	11	-	-	2
Private non-built recreation fields - wooded	18	-	1	4
Private undeveloped recreational land - land and meadow	13	-	-	4
TOTAL	1630	621	35	220

TABLE 16. SAFER land destinations by notification and retrocession for the whole base then by notification for Bordeaux Metropole (Notification_BM) and by notification for all parcels in flood zone (Notificiation_inond). SOURCE: SAFER

APPENDIX 6: STANDARDIZATION OF THE EXPLICIT VARIABLE

Quantile	0.0025	0.005	0.01	0.1	0.5	0.9	0.99	0.995	0.9975
Price per square meter for houses	21.7631	120.1584	250	920	2199.99	3804.35	8571.43	12016.9644	18330.4656
Price per square meter for apartments	0.019875	4.68	274.7135	1311.655	2750	7680.175	23799.2785	30690.0512	43756.0573

TABLE 17. Quantile of the price per square meter for houses and apartments

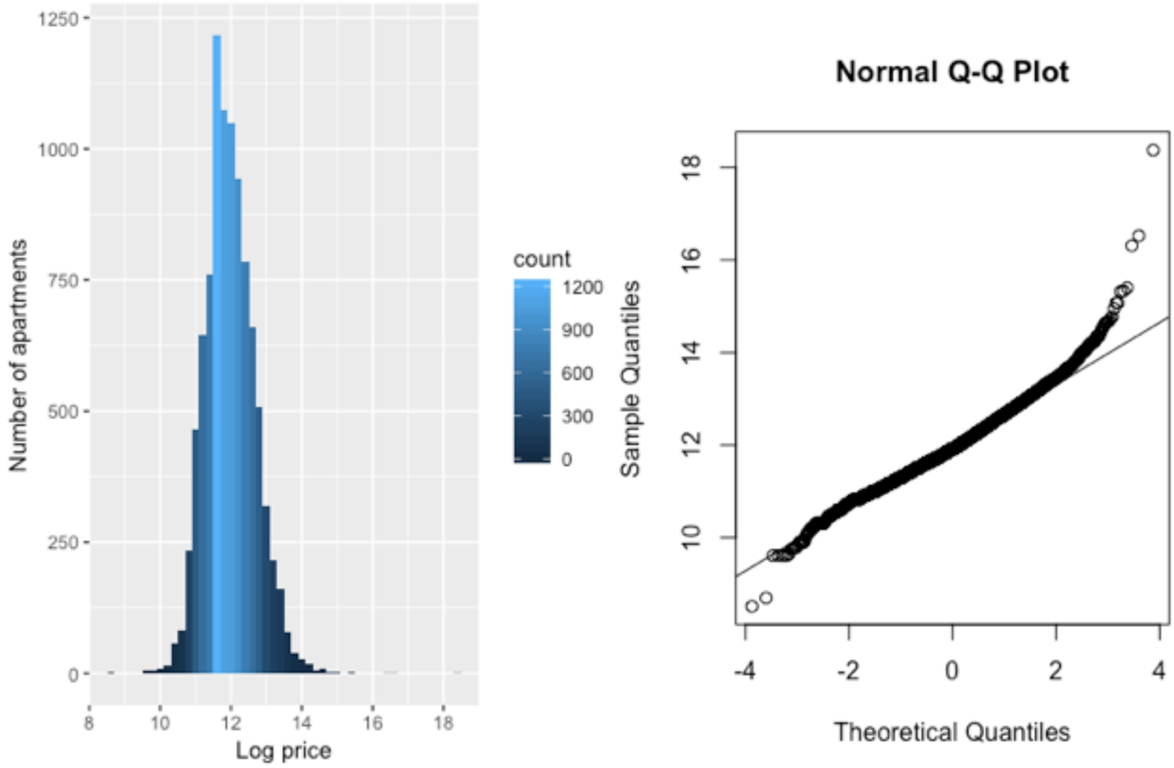


FIGURE 02. Distribution of the log of the property value for apartments. Histogram on the left and normal quantile - quantile plot on the right

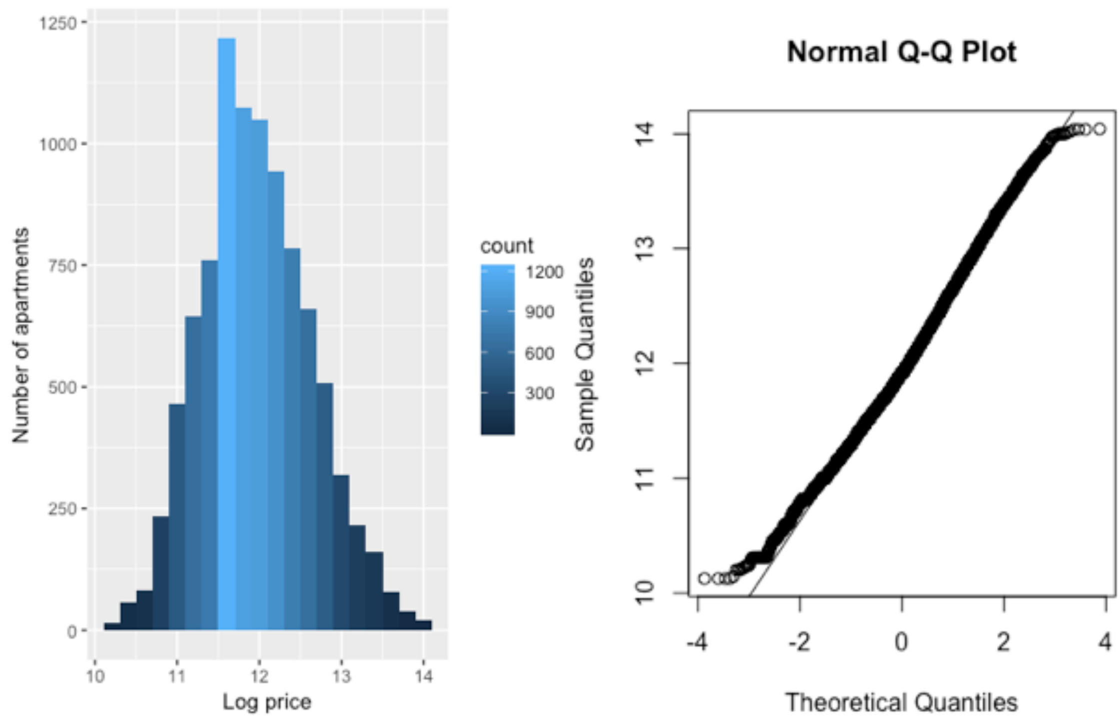


FIGURE 03. Corrected distribution of the log of the property value for appartments. Histogram on the left and normal quantile - quantile plot on the right

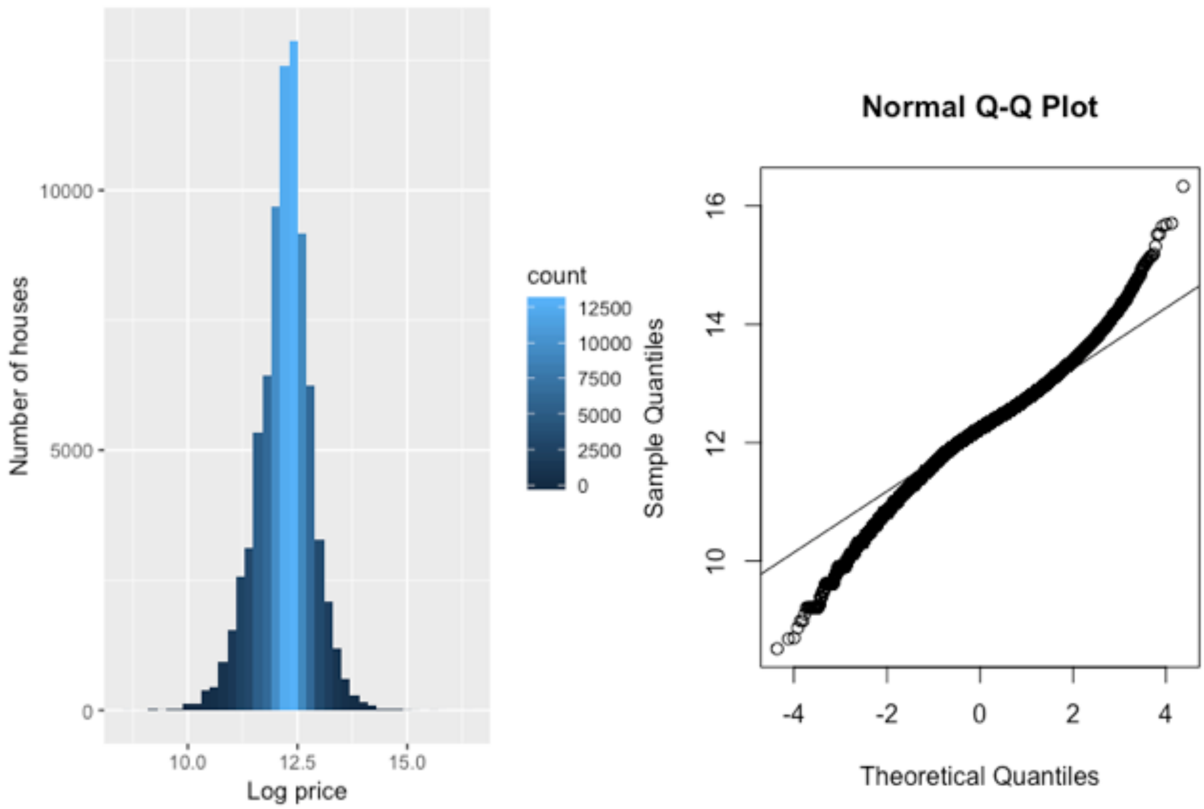


FIGURE 04. Distribution of the log of the property value for housess. Histogram on the left and normal quantile - quantile plot on the right

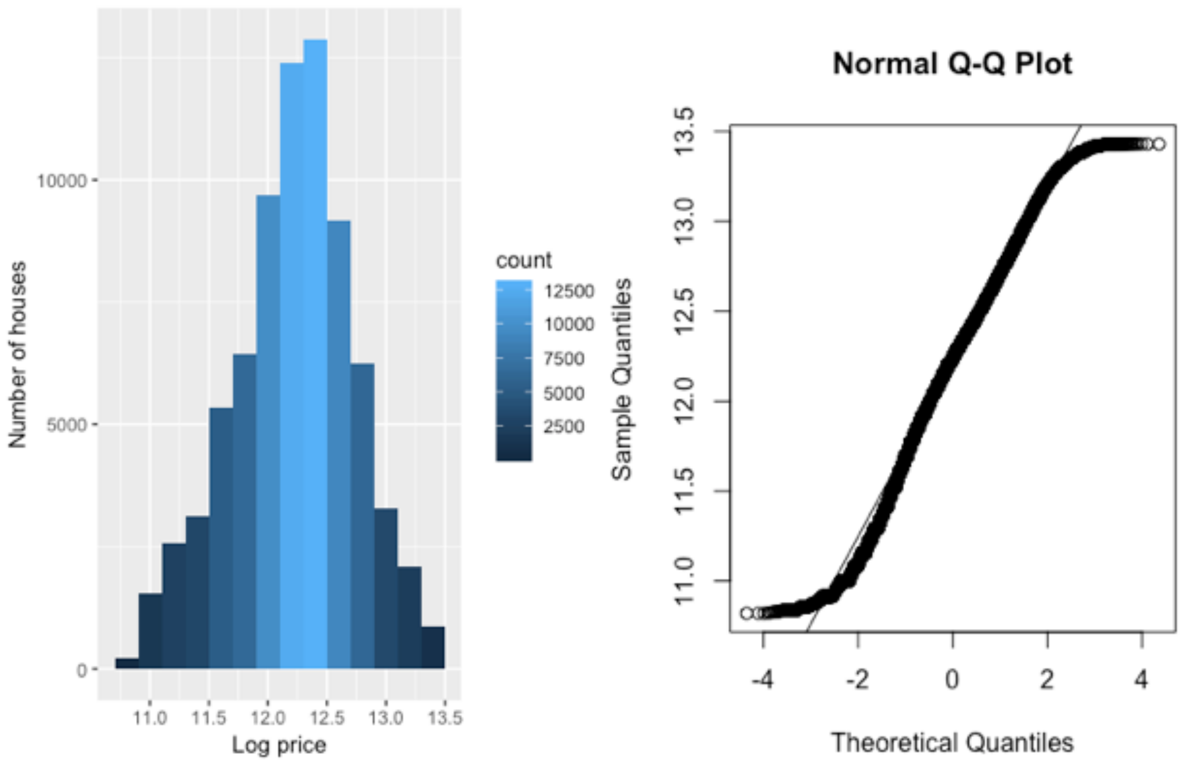
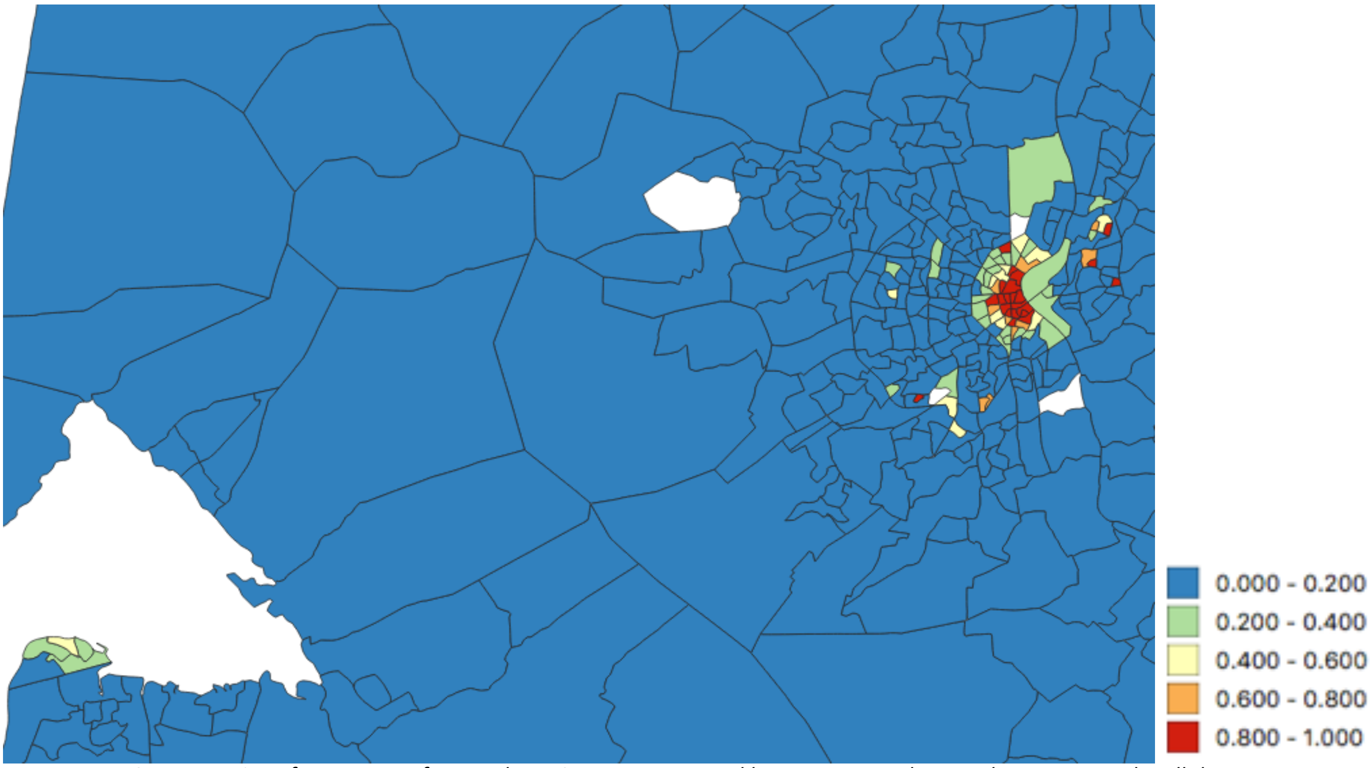
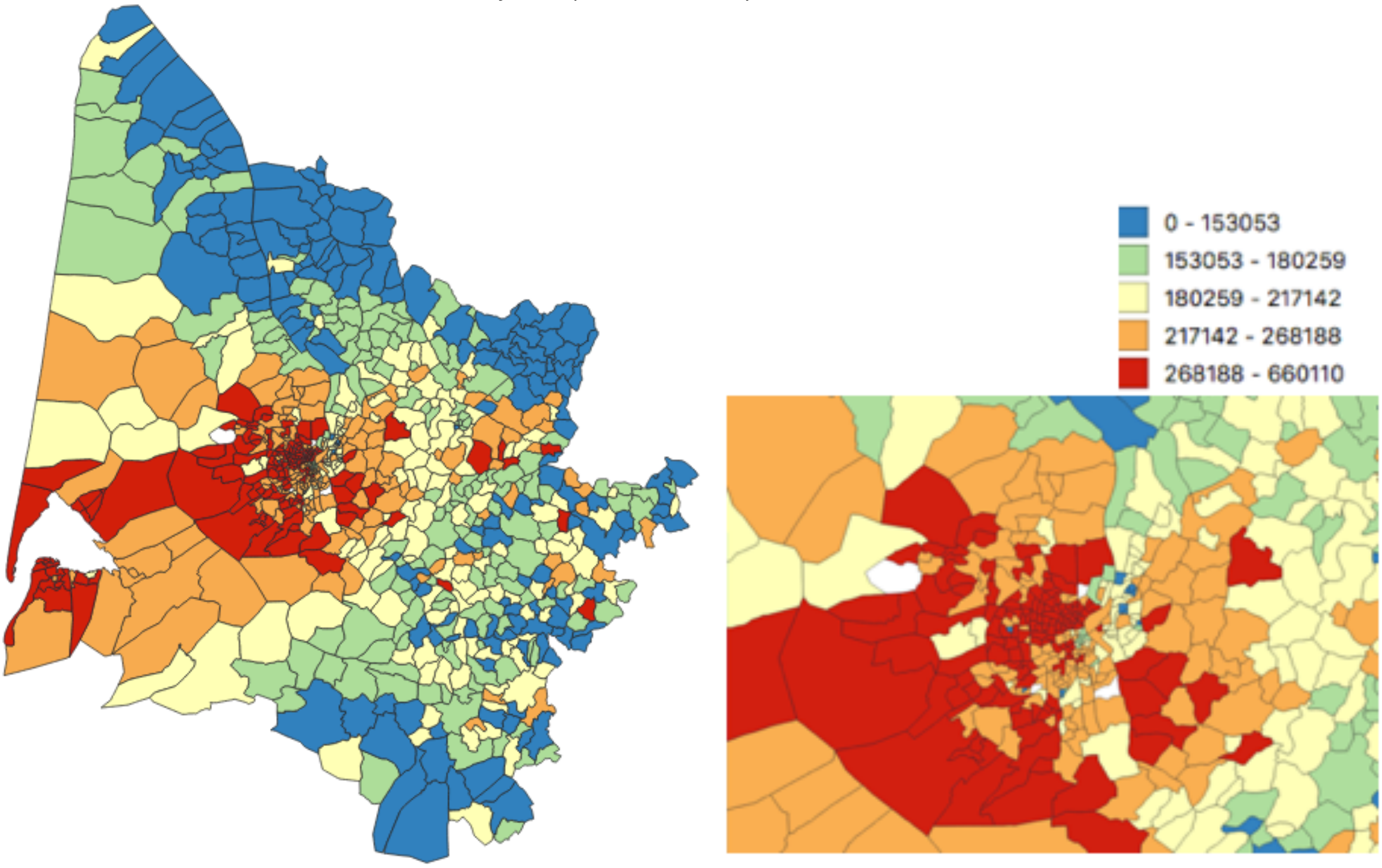


FIGURE 05. Corrected distribution of the log of the property value for houses. Histogram on the left and normal quantile - quantile plot on the right

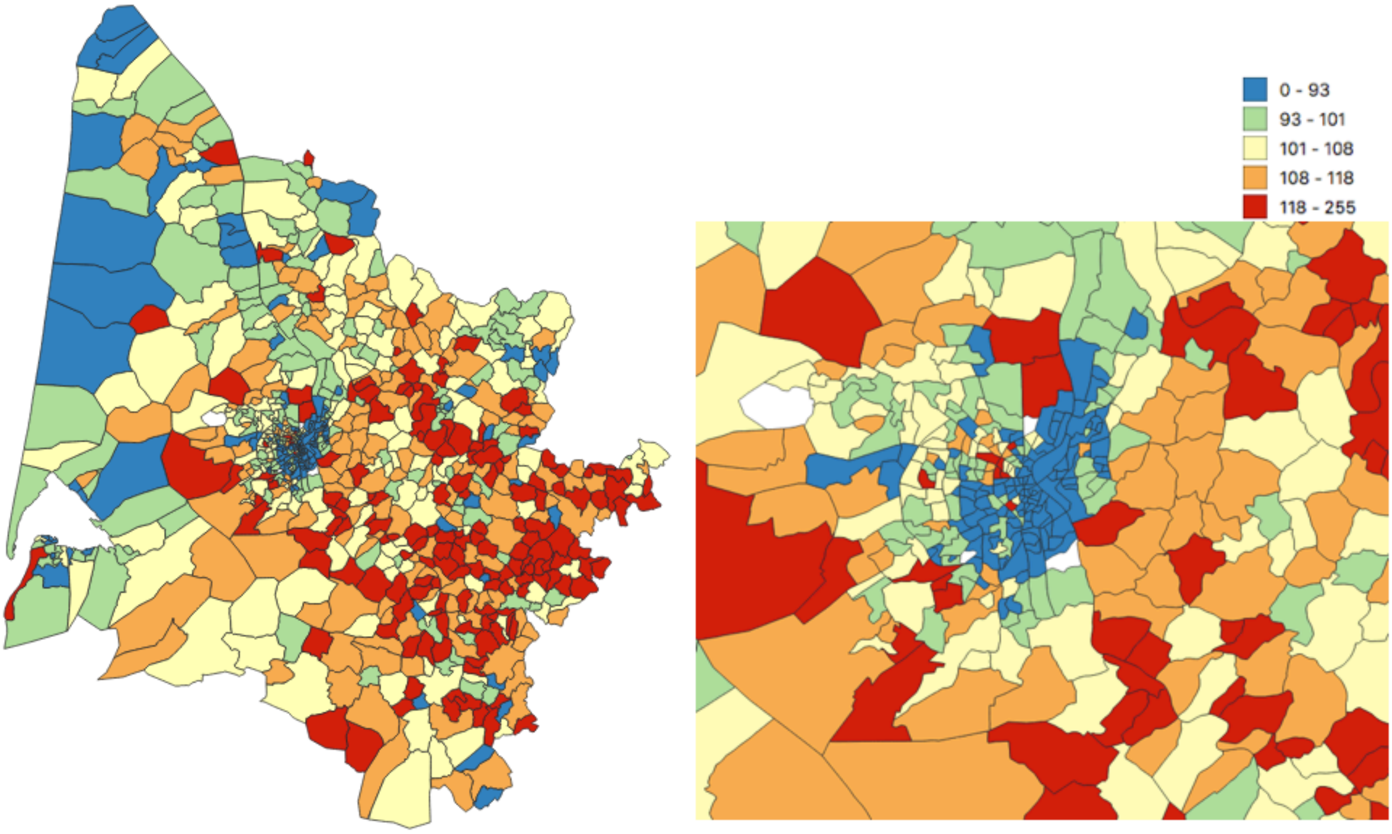
APPENDIX 7: EXPLORATORY ANALYSIS OF THE DVF DATA



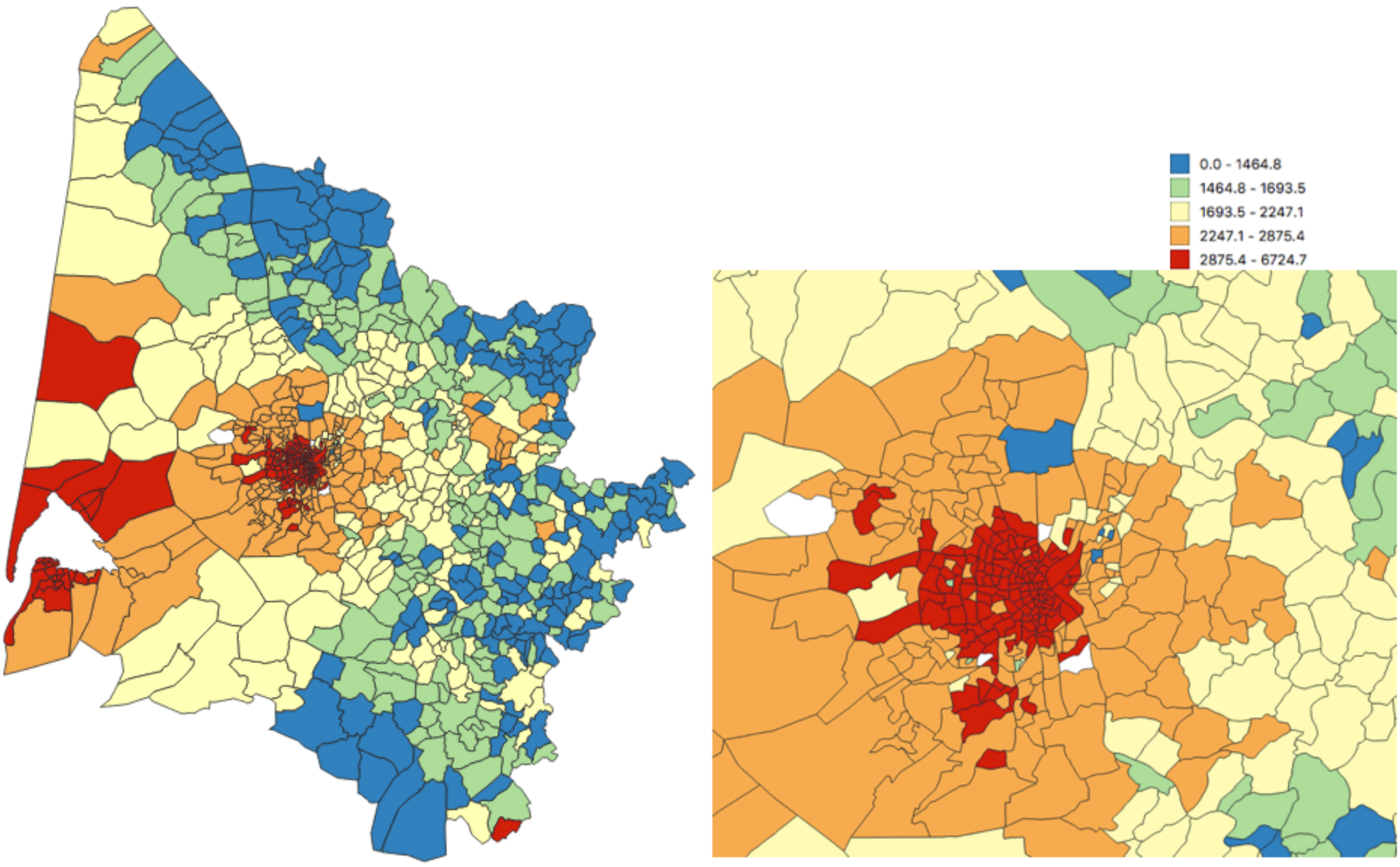
MAP 25. Proportion of apartments for DVF by IRIS - Apartments and houses, centered on Bordeaux Metropole. All the rest of the department is mostly houses



MAP 26. Distribution of the average property value for DVF by IRIS - Apartments and houses, centered on Bordeaux Metropole on the right and on the Gironde on the left



MAP 27. Distribution of the average surface for DVF by IRIS - Apartments and houses, centered on Bordeaux Metropole on the right and on the Gironde on the left



MAP 28. Distribution of the average price per square meter for DVF by IRIS - Apartments and houses, centered on Bordeaux Metropole on the right and on the Gironde on the left

APPENDIX 8: PEARSON CORRELATION BETWEEN THE DIFFERENT VARIABLES

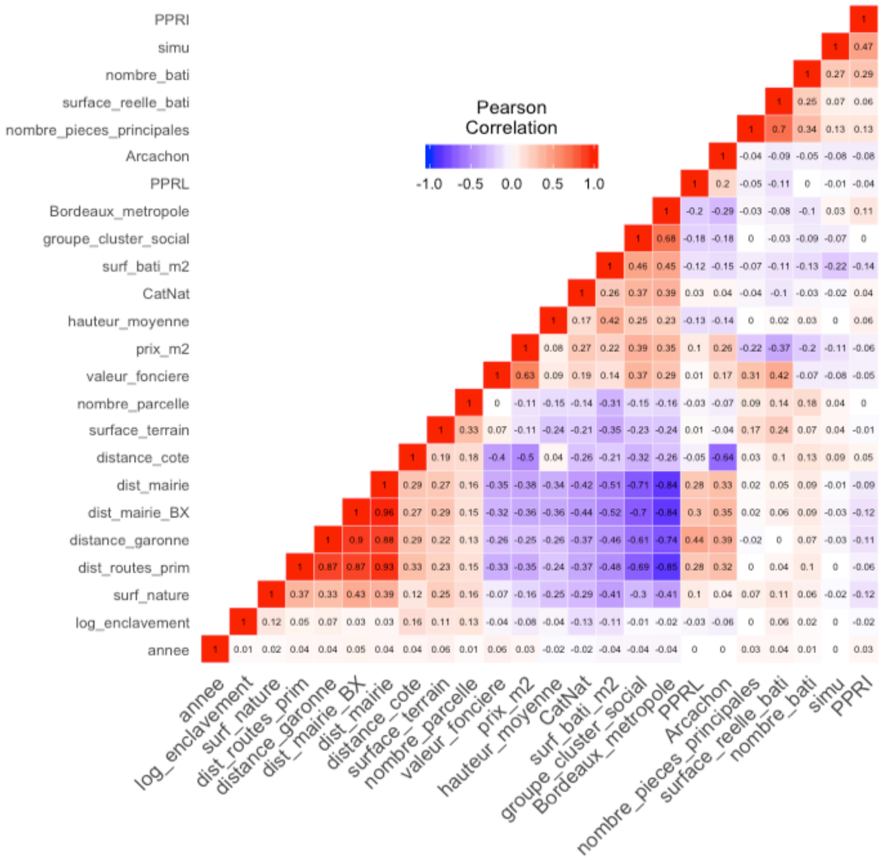


FIGURE 06. Pearson correlation for houses

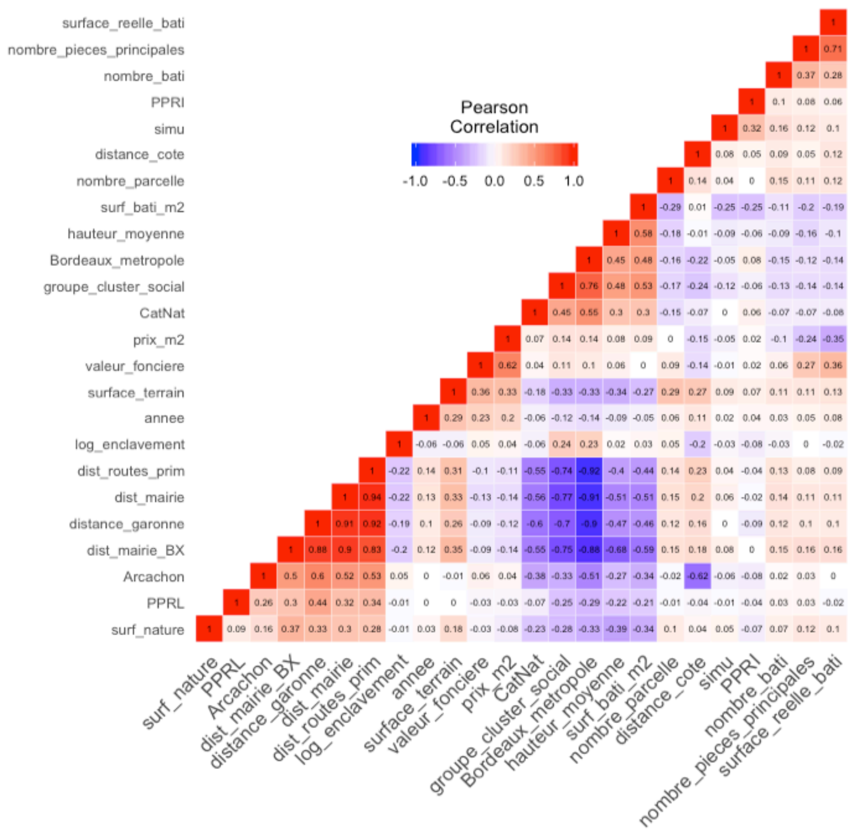


FIGURE 07. Pearson correlation for apartments

APPENDIX 9: ERROR TERM OF THE FIRST OLS REGRESSION

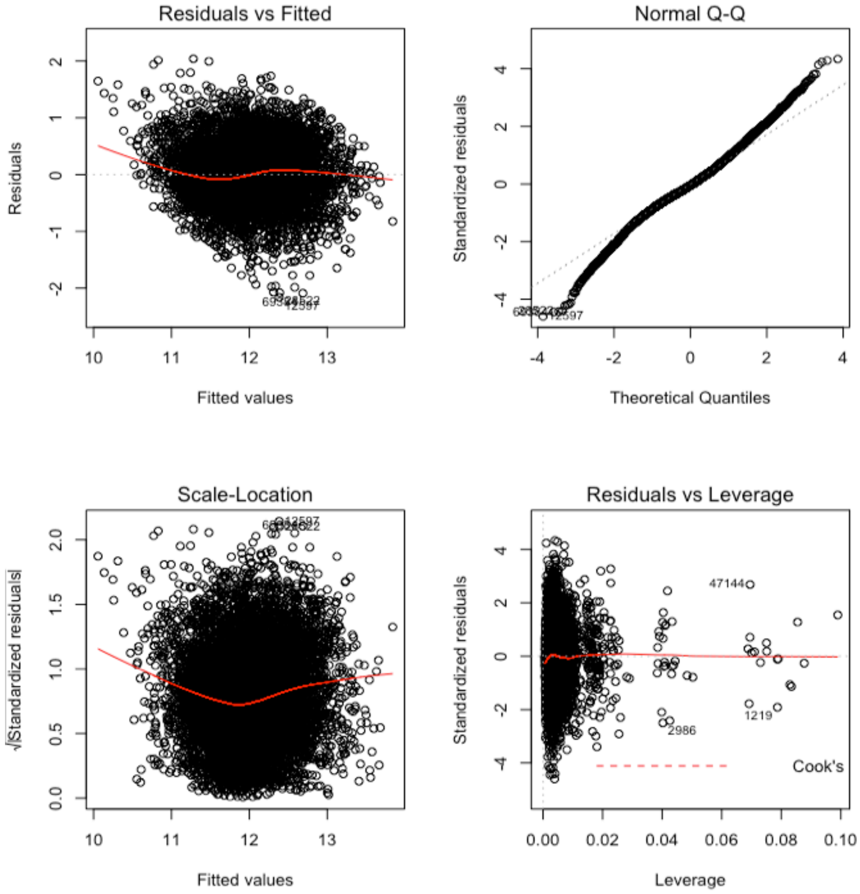


FIGURE 08. Error term for the first OLS – apartments

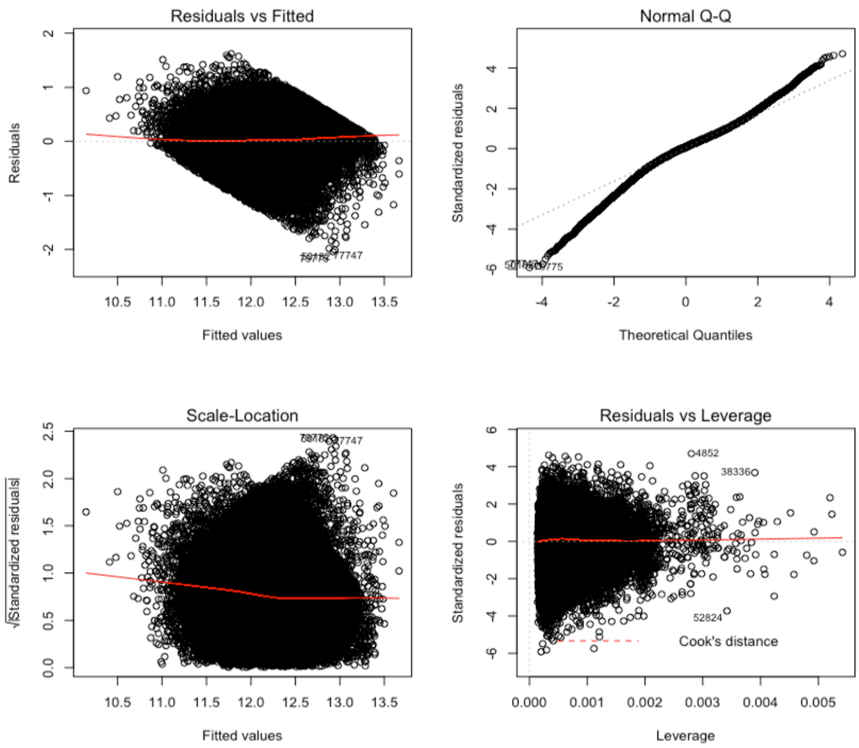
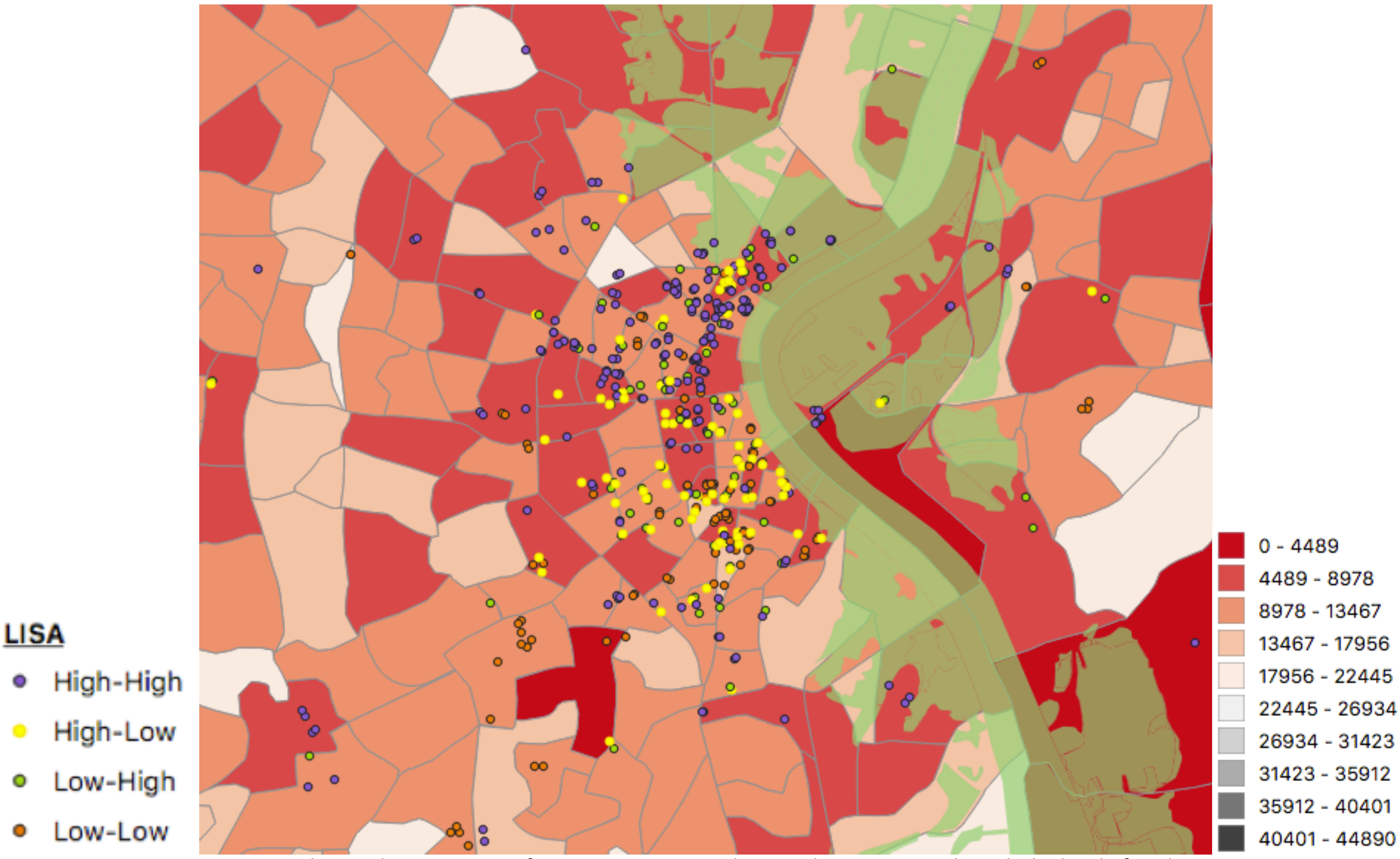
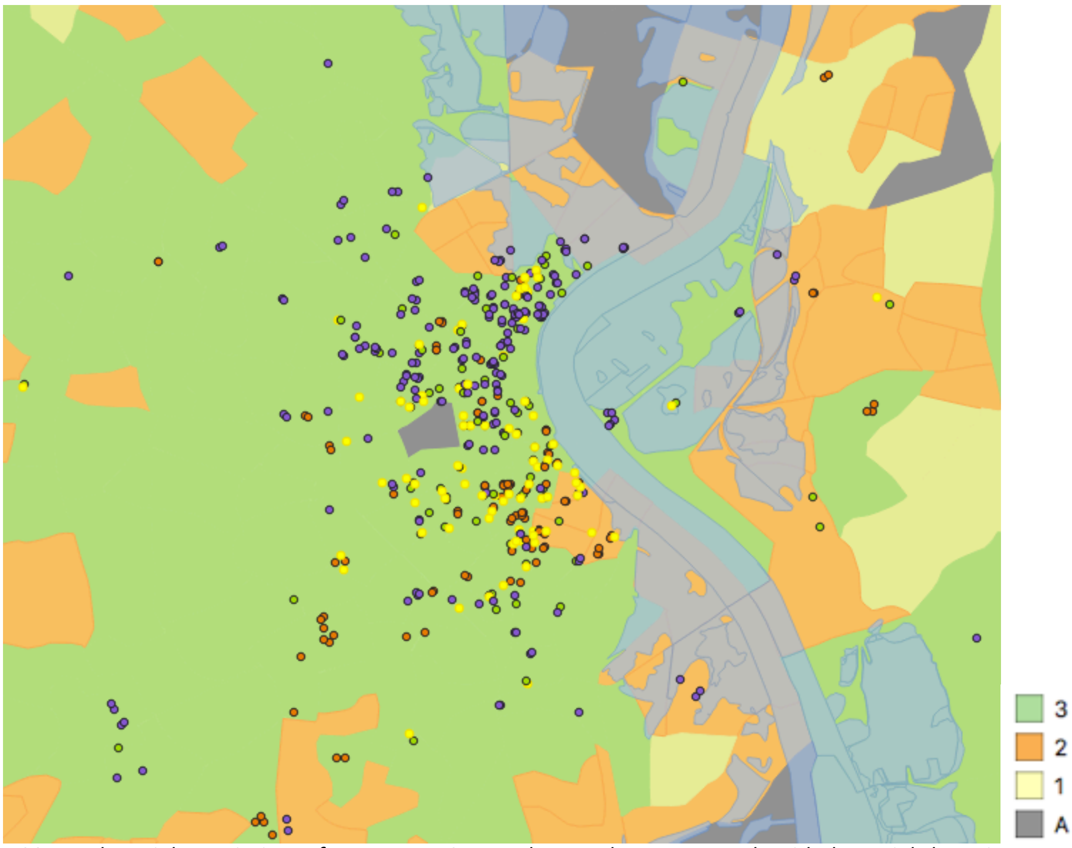


FIGURE 09. Error term for the first OLS – apartments

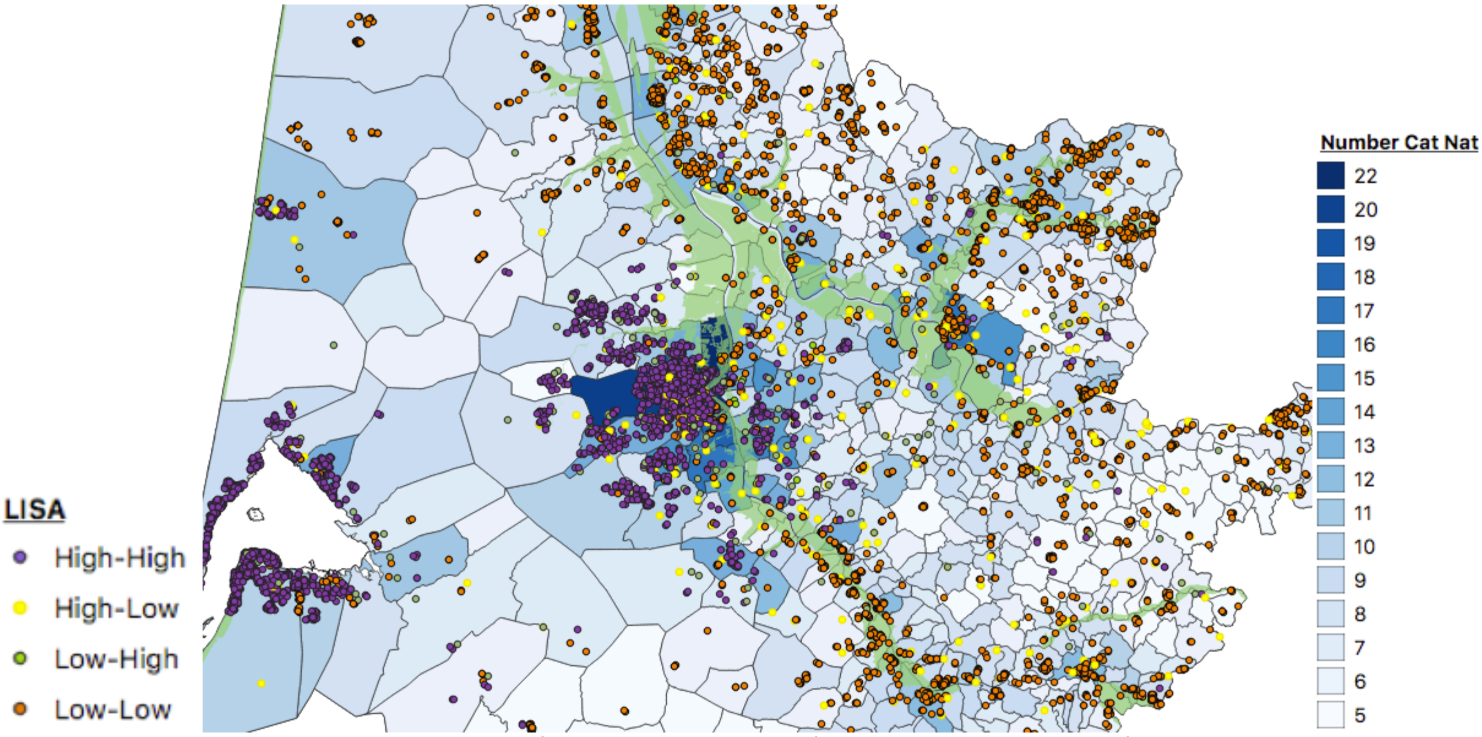
APPENDIX 10: CARTOGRAPHY OF LOCAL SPATIAL ASSOCIATION (LISA)



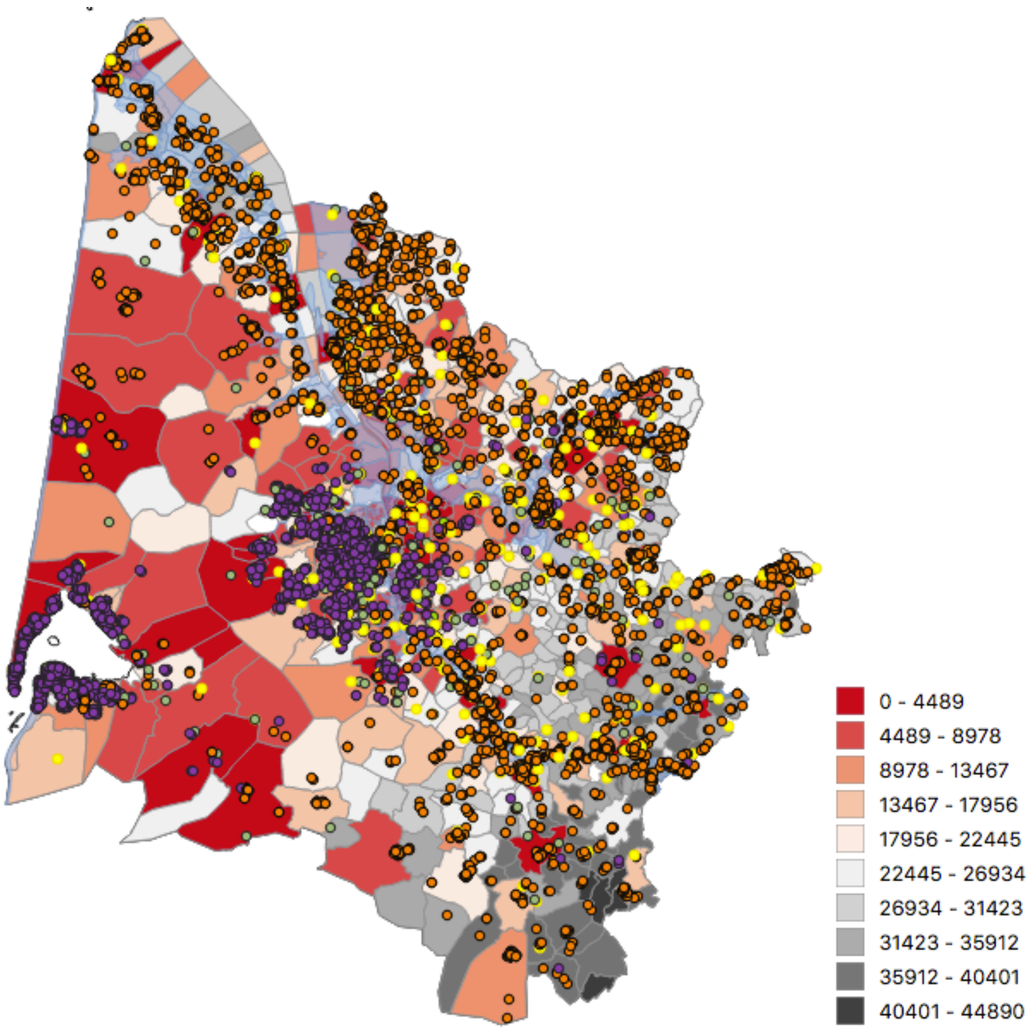
MAP 29. Local spatial associations of apartment. Centered on Bordeaux Metropole with the level of enclosure



MAP 30. Local spatial associations of apartment. Centered on Bordeaux Metropole with the social clustering



MAP 31. Local spatial associations of houses. Centered on part of the Gironde with the number of Cat Nat recognition



MAP 32. Local spatial associations of houses. Centered on the Gironde with the social clustering