Impacts of demography on drinking water supply networks in Gironde (France)

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Abstract
To consider the long-term management of the water resources used to produce drinking water in Gironde (south-west of France), the SMEGREG (public watershed establishment in charge of deep aquifers in Gironde, France) and INRAE (French public research institute) are leading a collaboration which, in order to forecast changes in the level of water losses, focuses on the impact of demography and urbanization on the assets of drinking water supply networks (DWSN). Analyses are carried out at the scales of the Gironde county and the Bordeaux metropolitan area (BM), based on demographic and geographic databases, French observatory of water services database and the GIS of the BM's DWSN.
The first results obtained show that an increase in the population served by a DWSN translates into a much smaller increase in the length of pipes and a comparable increase in the number of service connections. They also show that the higher the urban density of an area, the lower the impact of population growth on the increasing of pipes length.

Keywords
Demographic and geographical data processing, Drinking water supply networks growth forecasting, Geographic information system, Water infrastructure asset management, Water losses, Water resources

Introduction

The Gironde county (GC), located in the south-west of France and whose main city is Bordeaux, is mainly supplied with drinking water produced from deep groundwater, some of which are overexploited. To consider the long-term management of these water resources, in addition to the drinking water consumption of users, it is necessary to take an interest in the needs of the system, most of which consists of water losses from the drinking water supply network (DWSN). Thus, estimating the evolution of these water losses requires taking an interest in the evolution of pipes networks, from a qualitative standpoint but also from a quantitative point of view.

To move forward on this question, the SMEGREG (public watershed establishment in charge of deep aquifers in Gironde, France) and INRAE (French public research institute) are leading a research collaboration to develop a prospective approach of water losses from the DWSNs in Gironde (Renaud & Husson, 2021). While the first part of this study examines the links between urban density and the performance of services in terms of water losses, the second, which is the subject of this contribution, examines the influence of demography and town planning on the evolution of DWSNs assets.

Methods

The study is being carried out at two spatial scales, the territory of the GC (which includes the city of Bordeaux) and the territory of the Bordeaux metropolitan area (BM).

Approach at the GC scale

This first approach is based on the one hand on data from SISPEA, the French observatory of public drinking water services (SISPEA, 2021), and on the other hand on municipal demographic data from INSEE, the French institute of statistics (INSEE, 2021). The asset information available within SISPEA is, for each DWSN, the total length of pipes excluding service connections (*L*) and the number of subscribers (*N*) (generally close to the number of service connections). In addition to the population, the INSEE data includes, for each municipality, information on housing (type, occupation). After concatenation of demographic data at the DWSN level, the usable data cover the period 2010-2017. For each relevant variable *X*, an annual average change ratio *RA-X* is calculated. These ratios are then compared with each other.

Approach at the BM scale

This second approach mobilizes the GIS of BM's DWSN, the demographic data of the INSEE at the level of the IRIS which is an infra-municipal statistical subdivision (INSEE, 2021), as well as European land use mapping (Corine Land Cover, 2018) and IGN (French geographical institute) building mapping (IGN, 2021). After geoprocessing, the available data make it possible to study, at the IRIS scale and by land cover classes, the changes in the variables from 2006 to 2017.

Results

GC scale

In 2017, the GC had 1,584,000 inhabitants, or 703,000 subscribers served with drinking water by 19,000 km of pipes managed by around 100 DWSNs. For each service, the annual average changes in demographic indicators, network length (*L*) and number of subscribers (*N*) between 2010 and 2017 were calculated. For most services, the evolution of *N* is very close to that of the population (*POP*). On the other hand, it appears that, for most services, the length of the network grows much slower than the population. Figure 1 represents the annual average ratio of changes in length of pipes (*RA-L*) as a function of that of the population (*RA-POP*). It shows that most services with a growing population have a growth in the length of pipes lower than that of the population (groups G4 and G5 in green).

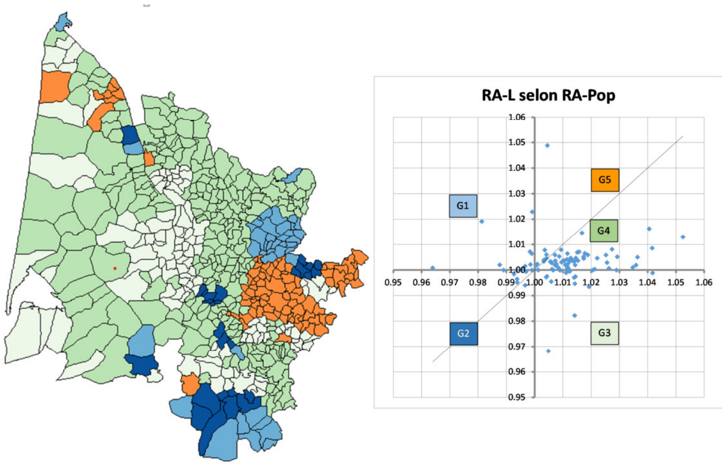

Figure 1 Comparative evolution of population and length of pipes for GC's DWSNs from 2010 to 2017

BM scale

The types of land use in the Corine Land Cover inventory have been grouped into five classes: CLC 1 Continuous urban; CLC 2 Discontinuous urban; CLC 3 Artificial; CLC 4 Agricultural and CLC 5 Natural. Each IRIS of BM has been assigned the class which covers the largest part of its territory (Figure 2).

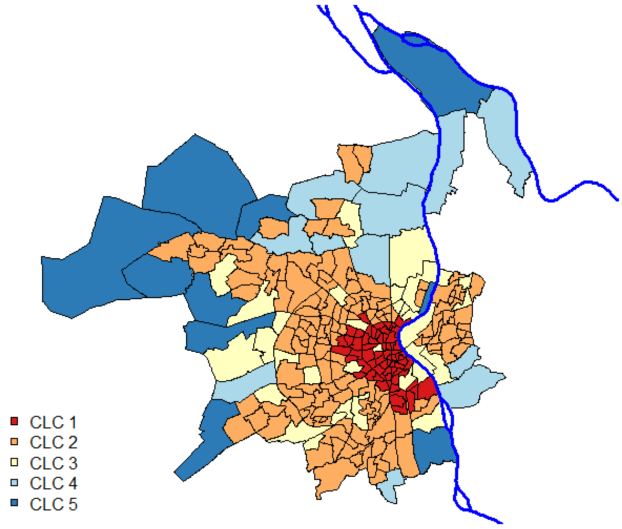

Figure 2 Mapping of BM IRIS by land use class

The surface area of BM is 504 km^2, more than half of which concerns predominantly agricultural or natural areas (Table 1). Logically, the population, which rose from 670,000 inhabitants in 2006 to 744,000 in 2017, resides mainly in the most urban areas.

Table 1 BM. Population and surface areas by land use class

	IRIS	Surface area		2006 population		Density
	u	km^2	%	u	%	u/km2
CLC 1 - Continuous urban	65	21.7	4%	179 870	27%	8 304
CLC 2 – Discontinuous urban	143	156.3	31%	384 688	57%	2 461
CLC 3 - Artificial	32	70.0	14%	56 866	8%	812
CLC 4 - Agricultural	12	100.5	20%	27 456	4%	273
CLC 5 - Natural	10	155.1	31%	20 911	3%	135
BM	**262**	**503.6**	**100%**	**669 791**	**100%**	**1 330**

Table 2 summarizes the first results obtained. For the studied period (2006 - 2017), BM's population (*POP*) increased by 11%. In number of inhabitants, this increase mainly concerns the "Discontinuous urban" and "Artificial" IRIS (classes CLC 2 and CLC 3), but in percentages, the less urbanized IRIS (CLC 3 to CLC 5) experience the strongest population growth.

If we look at the network lengths (*L*) we see that for all the classes their increase is in proportions very much lower than that of the population (which confirms the results obtained at the GC scale). Moreover, while more than half of the new pipes (nearly 30 km) were installed in "Agricultural" and "Natural" IRIS (classes CLC 4 and CLC 5), these only received a little more than 10% of the additional inhabitants. These observations are also reflected in the length of pipe required to serve a new inhabitant, which is increasing significantly from classes CLC 1 to CLC 5.

The variations in the number of service connections (*Nsc*) remain close to those of the population except for the "Artificial" IRIS (class CLC 3) for which the average increase in *Nsc* is much lower than that of the population (12% for 32%).

Table 2 BM. Comparative evolution of DWSNs and population between 2006 and 2017

	Variation between 2006 and 2017 (%)			Evolution between 2006 and 2017 (units)		Pipe length per inhabitant L/POP (m / capita)		
	POP (%)	*L* (%)	*Nsc* (%)	*POP* (u)	*L* (m)	2006	New	2017
CLC 1 - Continuous urban	4%	0%	3%	6 408	-797	2.31	-0.12	2.23
CLC 2 – Discontinuous urban	11%	1%	9%	40 658	20 066	4.31	0.49	3.95
CLC 3 - Artificial	32%	3%	12%	18 084	9 248	6.20	0.51	4.83
CLC 4 - Agricultural	19%	4%	20%	5 170	10 103	9.94	1.95	8.67
CLC 5 - Natural	20%	9%	22%	4 115	19 881	10.55	4.83	9.61
BM	**11%**	**2%**	**9%**	**74 435**	**58 501**	**4.36**	**0.79**	**4.00**

Conclusions

The study conducted by SMEGREG and INRAE at the scales of the Gironde county and the Bordeaux metropolitan area to assess the influences of demography and urbanization on the evolution of drinking water supply networks leads to the first following results:

- For the vast majority of DWSNs, an increase in the population translates into a much smaller increase in the length of pipes and a comparable increase in the number of service connections;

- The level of urbanization of the area concerned (assessed according to land use) has a strong impact on the influence of demography on the evolution of pipes length. This influence is zero for continues urban areas and increases when the level of urbanization decreases;

- Seen from another way, the additional pipes length per additional inhabitant is significantly lower than the average length per inhabitant of the service. For all land use classes average pipes length per inhabitant decreases as the population increases.

The study will now be extended to two other DWSNs within the GC (one on the outskirts of BM, the other on the coastline). Other geographic factors that can potentially impact the effects of demography on pipes length growth will be analysed (roads, structure of buildings, etc.). The impacts of demography on the characteristics of the network (materials, diameters, ages, etc.) will also be considered.

Ultimately, by combining these results with those obtained in the first part of the research collaboration (influence of urbanization on the performance of networks in terms of losses), orders of magnitude of water losses from drinking water supply networks associated with different demographic scenarios will be calculated.

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