

## ABSTRACT

Understanding factors influencing water consumption is vital for water utilities and policy makers to accurately predict the future demand. Using Wallonia as a case study, mixed effect models were developed and validated to study the temporal and spatial variation in residential water consumption. Results confirmed the importance of household size, income, alternative sources of water, and dwelling characteristics (such as living area and garden) in explaining residential water demand. Additionally, an annual constant drop of 1.5% was observed for household water consumption from 2009 to 2018 in Wallonia. After controlling for these key factors, the location of household still possesses a marginal, though significant, effect on water consumption.

## INTRODUCTION

Reliable water demand forecast is essential for water companies in sizing their system to avoid both superfluous implementation cost and water shortage. Majority of current research in demand forecasting used aggregated data at provider or block levels [1,2]. While these studies provided a good knowledge on water consumption determinants [3], they have not been able to adequately address the spatial heterogeneity among households.

On the other hand, a large number of drivers of domestic water demand has been identified in literature. Even though these factors are often correlated and influencing each other, most of previous studies have only focused on a limited number of explanatory factors due to the lack of data, especially at household-level [3].

By combining data from different sources, this study aimed to simultaneously assess the effects of household characteristics, dwelling properties, alternative water sources, as well as temporal and spatial effects on household water consumption in Wallonia.

## DATA

Data used in this study includes:

- Historical annual water consumption of families in Wallonia from 2009 to 2018

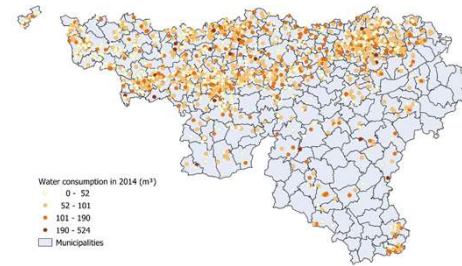


Fig 1. Water consumption of studied households in 2014

- Survey data on Water and Energy Consumption collected by AQUAWAL and CEHD in 2015 for 2000 households in Wallonia. The data includes socio-demographic factors (e.g. household size, income), dwelling characteristics (e.g. living area, presence of garden, dwelling types), alternative water sources, and water appliances (e.g. washing machine, water-saving toilet)
- Annual weather data of Wallonia such as average temperature in summer/winter months, number of day with significant rainfalls, number and intensity of heat-wave or cold-snap.
- Level of built-up in Wallonia was used as an indication for urbanization.

## METHODS

Mixed effect model [4] with random intercept at municipalities levels were employed to explore the spatial variability.

$$Y_{ijk} = \mathbf{x}_{ijk}^T \boldsymbol{\beta} + u_i + \varepsilon_{ijk}$$

Explanatory factors included in fixed effects were selected based on literature review. Root mean squared error was used for model evaluation. The statistical software R with packages “lme4” were used for modelling and QGIS was used for mapping.

## RESULTS

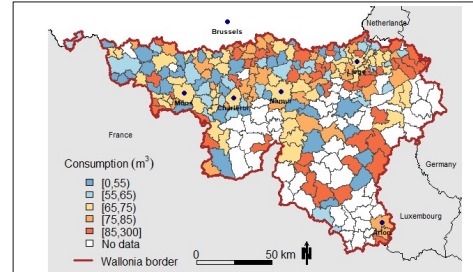


Fig. 2 Average household water consumption at different municipalities in Wallonia.

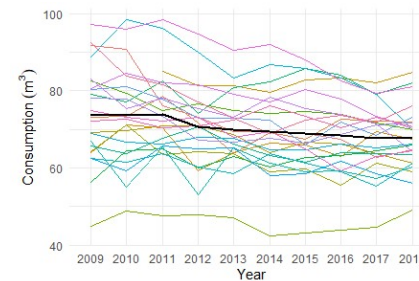


Fig. 3. Average household water consumption in recent years at different municipalities (colored-lines) and the global average for the whole Wallonia (black line).

Table 1. Fixed effects estimates of the final model

	Estimate	Std. Error	P-value
Number of adults	20.71	0.40	<0.001***
Number of children	7.78	0.43	<0.001***
Income - precarious	-5.81	1.15	<0.001***
Income - modest	-2.65	0.76	<0.001***
Income - high	1.82	1.00	0.0695
Rainwater - not using	27.38	0.86	<0.001***
Rainwater - indoor only	10.80	2.90	<0.001***
Rwtuse - outdoor only	22.65	0.94	<0.001***
Built year - 1946-1970	1.50	0.84	0.0738
Built year - 1971-1990	0.83	0.88	0.3446
Built year - 1991-2000	2.06	1.29	0.1101
Built year - 2001 and after	-5.82	1.18	<0.001***
Number of bedrooms - 2	-0.20	1.11	0.8588
Number of bedrooms - 3 or more	5.88	1.12	<0.001***
Number of bathrooms - more than 1	5.16	0.96	<0.001***
Living areas	3.61	0.39	<0.001***
Garden	8.75	0.86	<0.001***
Pool	25.62	2.23	<0.001***
Bathtub	6.50	0.74	<0.001***
Year	-1.13	0.12	<0.001***
Urban density - low	-5.39	2.04	0.0082**
Urban density - medium	-4.48	1.78	0.0118**
Urban density - high	-5.71	1.89	0.0025**

## DISCUSSION

Even though both spatial and temporal patterns can be observed in household water consumption in Wallonia, the main drivers of water demand were household composition, rainwater use, and dwelling characteristics. The effects of time and urban density are both significant, though marginal. The general belief that households in the same neighborhood often consume similar amount of water can be explained by the shared characteristics such as income, living standard, or presences of garden and pool.

The effects of water prices, and weather factors (temperature and rainfall) are not significant in the current study. It is expected since the variations in water price and/or weather in our study areas are limited. The whole area shares a temperate climate and a unified tariff structure.

## REFERENCES

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## ACKNOWLEDGEMENT

