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Potential Effects of the COVID-19 Pandemic through Changes in Outbound Tourism on Water Demand: The Case of Liège (Belgium)

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Abstract: The COVID-19 pandemic has led to many countries closing their borders, and numerous people spending their holidays at home instead of traveling abroad. This sudden reduction in travel activities, and other 'new normals', might have influenced people's water usage. Hence, using Liège as a case study, this study aims to address the potential effect of outbound tourism on water consumption and how the current situation might affect the total water demand. Statistical models were developed and validated using the total daily volume of 23 municipalities in the Liège conurbation, the monthly total number of outbound trips, and other meteorological data. Results suggest significantly lower water demand in the months with high numbers of outbound travel activities. Though the projected risk of increased water needs due to fewer people traveling is moderate, the threat becomes much higher during long periods of dry and hot weather.

Keywords: portable water demand; outbound tourism; climate; Liège; COVID-19

1. Introduction

The unprecedented COVID-19 pandemic has led many countries, including Belgium, to implement drastic measures such as border closures, travel restrictions, and quarantines. Since 4 May 2020, Belgium entered a gradual deconfinement process with the reopening of schools, shops, and restaurants. Non-essential flights resumed after June 15. However, the number of passengers passing through Brussels airport in July 2020 was still 80% less than that of July 2019 [1]. Being the first month of the summer holidays, July has historically been the busiest month for both inbound and outbound tourism in Belgium, often with around two million outbound trips being made [2,3]. This sudden drop in traveling patterns, in combination with other 'new normals' resulting from the pandemic, such as people working from home, is expected to influence the consumption of potable water [4,5]. Hence, understanding these effects is necessary for water services to better prepare for potential upsurges or downfalls in demand.

Since several European countries started lockdown-like measures in March 2020, unlike the drastic drop observed in energy consumption [6], the reported changes in water demand differed from one city to another. Balacco et al. reported a drop in both peak and base water demand in two Italian cities, Bari and Molfetta. At the same time, for smaller towns such as Cellamare and Lizzano, an increase in total daily volume was observed during weekends [4]. Additionally, a delay of 2–2.5 hours for morning peaks, and occasionally a merging of the morning and lunch-time peaks, were reported in several Italian and German cities [4,5]. Though the direct effect of complete lockdown on water consumption might be temporal, its long-term indirect effects through changes in working habits, travel patterns, and economic disruption could be expected even after the coronavirus crisis [7].

The influence of incoming tourism on water demand has been the main focus in literature [8–10], while the effect of people leaving during holidays has hardly been addressed. Studies carried out in major tourism destinations such as Majorca (Spain) or Montana (Switzerland) have shown a significant increase in total water demand during the tourist seasons [10,11]. However, for places with numbers of outgoing vacationers much higher than the number of those incoming, such as Belgium, the effect of inbound tourists on water demand remains marginal [12]. In contrast, the effect of outbound tourists on water use might be expected; for example, Wong et al. have observed a sharp drop in water consumption in Hong Kong during the New Year holiday, which can be linked to the local custom of traveling abroad during this occasion [13]. Whether people leave their homes during holidays or not depends on socio-demographic as well as cultural factors [14]. Research in other cultural contexts might yield different results from those found by Wong et al.

Besides the mentioned anthropogenic drivers, the surrounding literature has identified many other potential determinants which influence water demand, such as the price of water, population characteristics, building properties, technology implementation, climate, and location [15]. Whilst examining socioeconomic factors and land-use changes is significant when forecasting long-term demand, meteorological variables such as daily (maximum) temperature and rainfall have often been used for explaining short-term fluctuations [13,16]. Maidment et al. showed that there is often an immediate drop in water use after rainfall [17]. They have also hypothesized a non-linear relationship between temperature and water use, which was then confirmed by Gato et al. using data from East Doncaster (Australia) [17,18]. High consumption linked with high temperatures was often explained by the increase in outdoor summer use, such as irrigation gardens or filling swimming pools [19,20]. On the other hand, Gerin et al. has linked the increase in water use during cold months with lower tap water temperatures [21]. Rathnayaka et al. also reported higher shower water use during cold winter days, due to people showering for longer durations [22].

Therefore, using Liège as a case study, this research aims to fill the gap in the literature and address the potential effects of outbound tourism on total water system demand, while controlling for meteorological and other probable factors. Potential water demands in summer 2020 were also discussed based on different weather scenarios, and the assumption that fewer people will travel for the summer holidays than in previous years.

2. Materials and Methods

2.1. Study Area

Daily water consumption data used in this study were provided by CILE (Compagnie Intercommunale Liégeoise des Eaux)—a public company that provides drinking water for nearly 564,000 inhabitants in the Liège province (Belgium) [23]. The service area of CILE includes the urban center of Liège and 22 neighboring municipalities (Figure 1). The majority of these belong to the conurbation of Liège, which is the third most populous urban area in Belgium.

Water consumption in Liège comprises mainly of residential use, as 93% of CILE customers are private households. Non-residential or professional uses in factories, commercial areas, and hospitals contribute to less than 20% of the total water use in the study area. Therefore, any displacement of activities in the non-residential sector is expected to have much less of an influence on the total water demand than the changes in residential activities.

Similarly to the rest of Belgium, Liège has an oceanic temperate climate, which is often characterized by mild summers, cool winters, and constant precipitation throughout the entire year. However, since 2017, along with a large part of Europe, the region often experiences a high frequency of heatwaves and droughts during the summer [24,25].

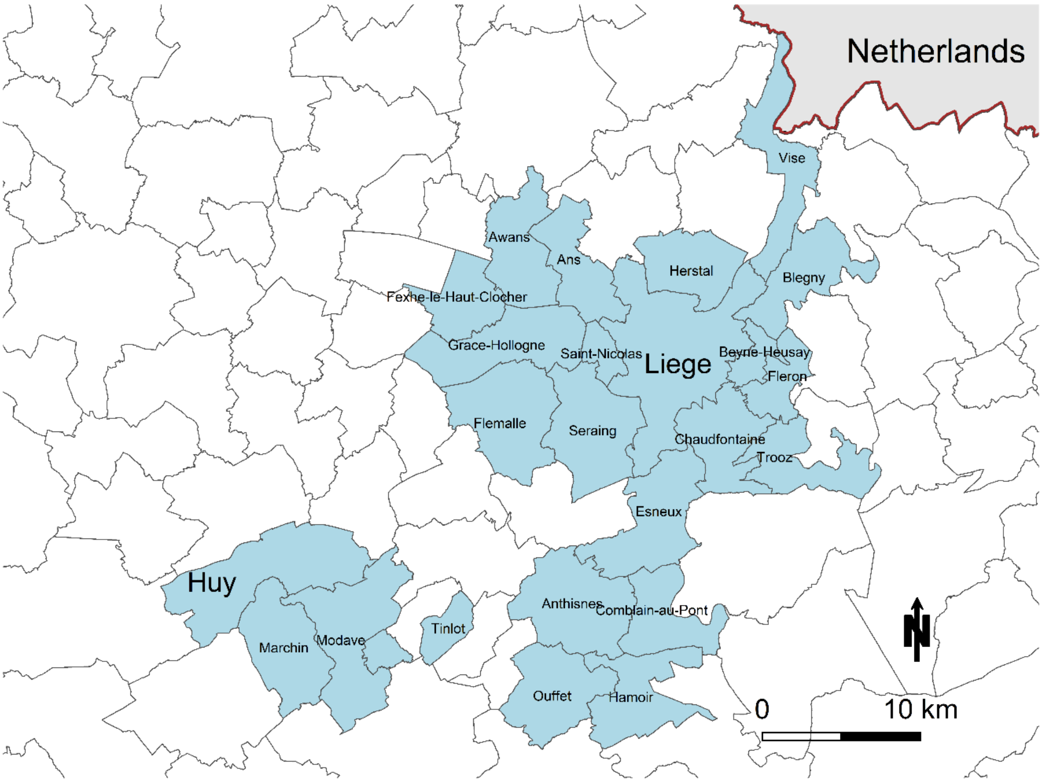

Figure 1. Map of CILE (Compagnie Intercommunale Liégeoise des Eaux) service area.

2.2. Data

Data regarding daily water consumption were recorded by the telemetry system, which accounts for 94% of the whole network, from 1 January 2013, to 18 May 2020 (Figure 2). This includes mainly residential use, with a small share of non-residential use (less than 20%), as mentioned above. Occasional lags in data transmission resulted in both up and down peaks as well as missing records. These happened most often in 2015 and 2019. The 31-day centered moving average (Figure 2–red line) more accurately represents the trend in water consumption over time.

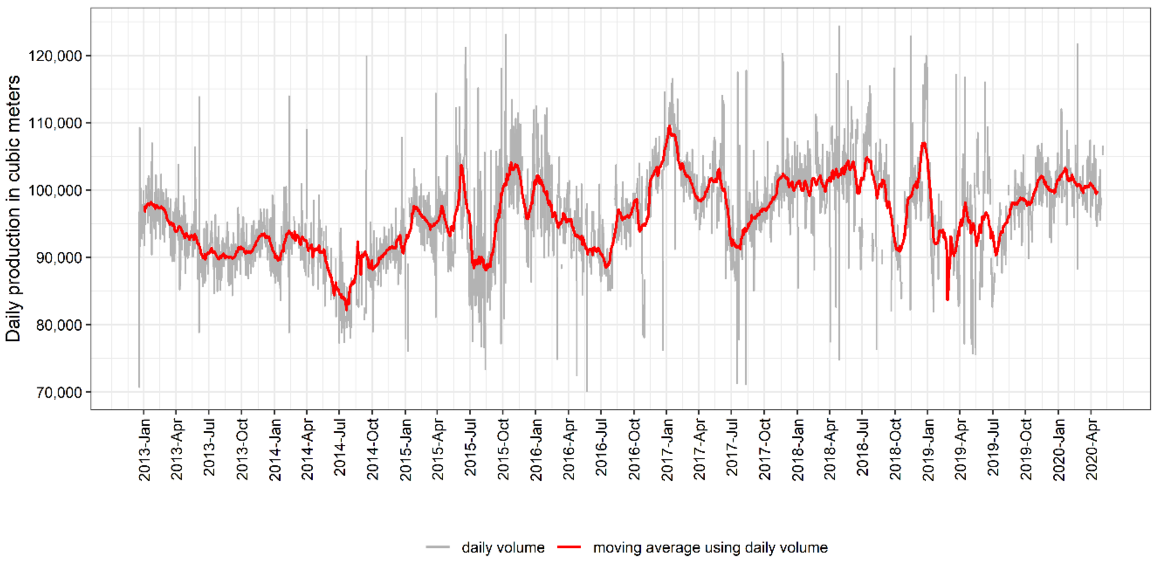

Figure 2. Daily water production of CILE in m^3 with a 31-day centered moving average line.

Since outbound tourism data are not available at detailed levels, the monthly total of trips outbound from Belgium lasting at least one day was used as a proxy variable. The data were obtained from the Eurostat website [2] for every month from January 2013 to December 2018. The travel pattern after 2018 was assumed to follow the average of previous years (Figure 3–black line) due to the lack of more recent data.

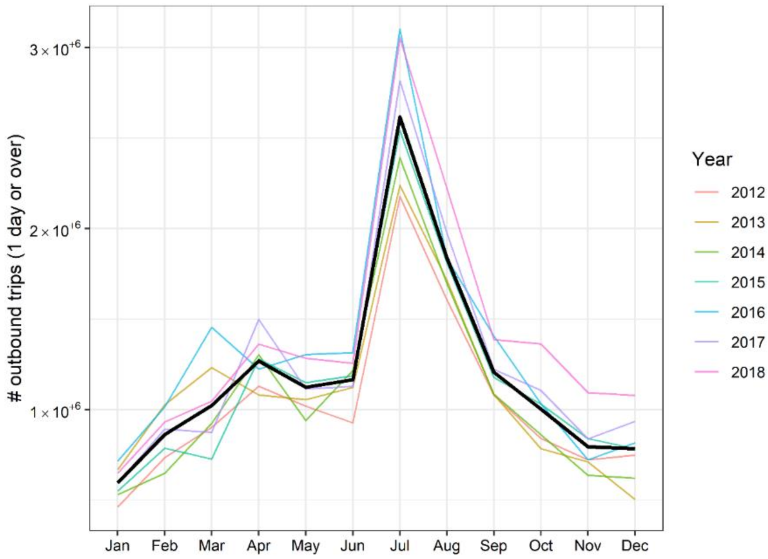

Figure 3. The number of outbound trips lasting at least 1 day made by residents of Belgium, by month. The black line represents the average trend of all years.

Additionally, dummy variables were created to assess other potential effects of public and school holidays on water demand. The following school holiday periods were considered: Christmas, Carnival, Easter, Ascension, and Autumn breaks. Considered public holidays included New Year's Day, Easter Monday, Labor Day, Ascension Day, Whit Monday, Belgian National Day, Assumption of Mary, Day of French Community, All Saints' Day, Armistice Day, and Christmas Day.

Daily meteorological data from 1 January 2000 to 18 May 2020 for the city center of Liège (50°38′ N and 5°34′ E) were obtained from the website of the Power project (https://power.larc.nasa.gov/data-access-viewer/). This includes the min, max, and mean air temperatures at 2 m, as well as precipitation. Examples of meteorological data, including daily mean temperatures and precipitations, are plotted in Figure 4. Additionally, several derived variables such as the number of days since the last rainfall, the number of previous consecutive days with max temperature above 25 °C, and the number of previous consecutive days with min temperature below −4 °C were also calculated, to study the effects of extreme weather on total water demand. To avoid possible multicollinearity, the differences between the measured weather of a specific day and the long-term average of that particular day (e.g., 1 January) were calculated and used instead.

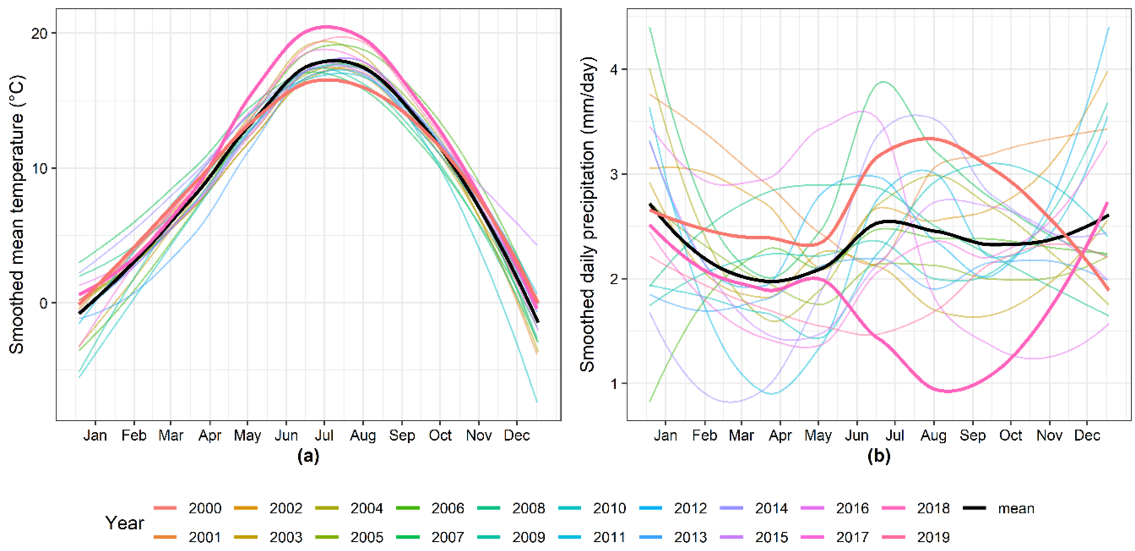

Figure 4. LOESS-smoothed daily mean temperature (**a**) and daily precipitation (**b**) in Liège from 2000 to 2019. The black line is the average of the whole period. Two thick lines represent years with an unusually cool and wet summer (2000), and an abnormally hot and dry summer (2018).

2.3. Methods

Before analyzing the data, abnormal peaks caused by occasional lags in data transmission were removed using cut-off values of 70,000 and 125,000 m^3. The data were divided into training (from 1 January 2013 to 31 December 2017) and validation (from 1 January 2018 to 18 May 2020) sets. The statistical models used in this study were adapted from Wong et al. [13] and can be expressed as:

$$y_d = \alpha_1 + \boldsymbol{\beta_1} \times \boldsymbol{X_{trend}} + e_1, \tag{1}$$

$$e_1 = \alpha_2 + \boldsymbol{\beta_2} \times \boldsymbol{X_{holiday}} + e_2, \tag{2}$$

$$e_2 = \alpha_3 + \boldsymbol{\beta_3} \times \boldsymbol{X_{weather}} + e_3, \tag{3}$$

$$e_3 = \alpha_4 + \boldsymbol{\beta_4} \times \boldsymbol{X_{calendar}} + e_4, \tag{4}$$

$$e_4 \sim N(0, \sigma), \tag{5}$$

where y_d is the daily water demand; α_1, α_2, α_3, α_4, $\boldsymbol{\beta_1}$, $\boldsymbol{\beta_2}$, $\boldsymbol{\beta_3}$, $\boldsymbol{\beta_4}$ are (vectors of) model parameters; $\boldsymbol{X_{trend}}$, $\boldsymbol{X_{holiday}}$, $\boldsymbol{X_{weather}}$, $\boldsymbol{X_{calendar}}$ are matrices of predictors; and e_1, e_2, e_3, e_4 are residuals. This method of deconstructing the total daily water demand was used instead of the regular multiple regression due to the high multicollinearity among the predictors.

Four groups of predictors, namely ***trend, holiday, weather***, and ***calendar***, were considered in this study. Explaining water demand evolution was not possible in this study due to a lack of data, such as the number of customers over time. Hence, the yearly average of the daily volume was first included to correct the general trend in water demand. Considered holiday and weather predictors have been discussed in Section 2.2. Dummy monthly variables, with January as the reference level, were included to capture the potentially-remaining differences in water demand between months. The day-of-the-week effects were also controlled using a set of dummy variables, with Monday as the reference level. The selection of predictors for the final model was based on the root mean square error (RMSE) of both training and validation sets.

Predictions of water demand were then made for summer 2020 (July, August, and September). Parameters used in this step were obtained by refitting the final model using the whole dataset. Weather data from summer 2000 were used as a scenario where the summer weather was particularly cool and wet, while summer 2018 data were used as an example of a hot and dry summer (Figure 2). As for travel patterns in summer 2020, four scenarios were considered: (1) business as usual; the number of outbound trips reduced by (2) 15%; (3) 30%; and (4) 45%.

3. Results and Discussion

In our studied period, apart from in 2018, water demand in Liège was often higher during the winter months December–January and lower in summer months June–October (Figures 1 and 5). The phenomenon of lower water consumption in the summer months is often not found in the literature. In fact, many studies considered water use in winter months as the base consumption with only indoor use, while summer demand comprises of both base and seasonal uses [18]. Changes in people's activities, such as traveling, could be the reason for the drop in water demand during the summer months. On the other hand, the effect of replacement activities in the non-residential sector is assumed to be negligible, since non-residential use accounts for less than one-fifth of the total water use.

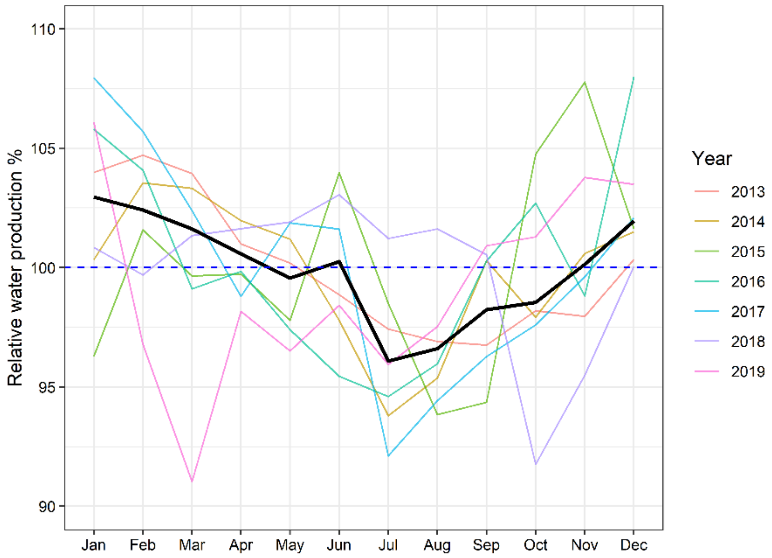

Figure 5. Relative water demand in CILE service areas by month. The blue dashed line corresponds to the average daily demand of that year. The black line is the average relative water production of all years.

When comparing the monthly pattern of water demand (Figure 5) with that of the outbound trips (Figure 3), an opposite trend can be observed. Months with higher water demand are often also the months with lower travel activities, and vice versa. Additionally, a sharp drop in water consumption of around 4% in July, which is also the first month of the summer holidays, suggests a potential link between the number of people taking holidays and water consumption. The results of the final model (Table 1) also support this hypothesis. A 3162 m^3 reduction in total demand was estimated for every increase of one million in the number of outbound trips (p-value < 0.001).

On the other hand, the estimated weather effects on water demand in this study agree with what has been reported in the literature. Both original variables (such as daily temperatures and precipitation) and derived variables were considered. The non-linear relationship between air temperatures and water demand discussed in Maidment et al. [17] is again supported by the significant effect of the square term of the mean temperature. Among the variables representing rainfall, the number of days since the last rainfall improved the predictive power of the model the most, and hence was included in the final version. Water demand significantly increased during long periods of hot and dry weather (measured by the number of previous consecutive days with max temperatures above 25 °C, and the number of days since the last rainfall). Since summer months such as July and August are characterized by both warmer weather and higher travel activity, the effects of summer weather on water use might be counterbalanced by the impact of people vacationing, leading to a generally-lower water demand in the summer months. This might also explain the absence of a drop in water use in summer 2018 (Figure 5), since it was considered the hottest summer in Belgium in almost 200 years, and had the lowest number of days with recorded rainfall [26].

Table 1. Parameter estimates of the final model with their standard errors and p-value.

Parameters	Units	Estimates	Standard Errors	*p*-Values
Intercept 1		−1573.92	4133.30	0.7034
Year average		1.02	0.04	<0.001
Intercept 2		3897.08	323.54	<0.001
Total outbound trips	million	−3162.43	237.79	<0.001
School holiday—Ascension Day		−751.58	2001.53	0.7073
School holiday—Autumn holidays		−3978.63	935.00	<0.001
School holiday—Carnival holidays		1138.28	1010.68	0.2602
School holiday—Christmas holidays		−1359.35	718.02	0.0585
School holiday—Easter holidays		144.88	646.81	0.8228
Intercept 3		−615.57	156.73	<0.001
Δ Mean temperature	°C	101.23	64.35	0.1158
Δ Mean temperature square	$°C^2$	35.92	8.84	<0.001
Δ Max temperature previous day (d − 1)	°C	222.20	57.79	<0.001
Δ Number of previous days without rainfall	days	604.10	189.82	0.0015
Δ Number of previous consecutive days with max temperature above 25 °C	days	639.62	76.56	<0.001
Δ Number of previous consecutive days with min temperature below −4 °C	days	214.12	131.31	0.1031
Intercept 4		2886.51	481.06	<0.001
February		−93.27	567.05	0.8694
March		−346.09	569.24	0.5433
April		−832.86	552.85	0.1321
May		−1681.85	563.18	0.0029
June		−1232.88	588.83	0.0364
July		−1096.13	572.55	0.0557
August		−3160.79	585.66	<0.001
September		−2875.64	583.85	<0.001
October		−2767.46	571.69	<0.001
November		−1324.15	570.11	0.0203
December		−558.55	572.62	0.3294
Tuesday		−1392.81	448.61	0.0019
Wednesday		−2047.86	449.67	<0.001
Thursday		−2176.00	442.19	<0.001
Friday		−1311.03	450.23	0.0036
Saturday		−3271.17	445.68	<0.001
Sunday		−1207.70	435.08	0.0056

The final model works reasonably well for both the training and validation periods (Figure 6), except for 2015 and 2019, when abnormal peaks and missing records occurred most often. The spike in both observed and fitted water demand at the beginning of August 2018 corresponds with a period of nearly a month with the max temperature above 25 °C, and little rainfall. The R-square of the final model is 0.41, which is relatively low, but understandable with the occurrence of missing and abnormal records.

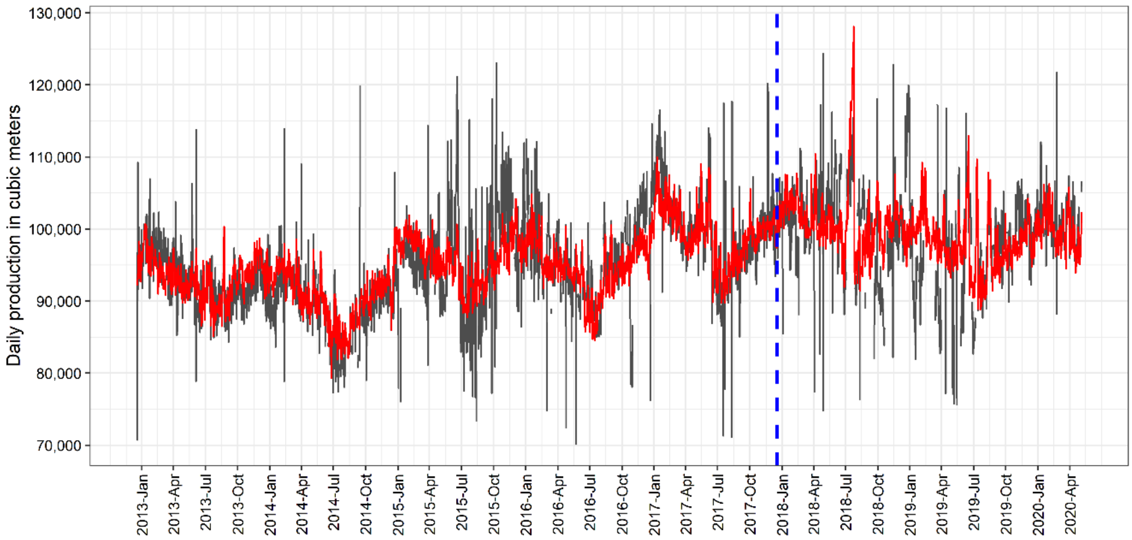

Figure 6. Observed (grey line) daily volume of CILE and fitted (red line) values using the final model for the training set (before the blue dashed line) and the validation set (after the blue dashed line).

Predictions were made for summer 2020 using the obtained parameters from refitting the final model with the whole dataset (Figure 7), and different travel and weather scenarios. As mentioned in Section 2.3, a business-as-usual scenario and three other situations with a 15%, 30%, and 45% reduction in travel patterns were simulated. Since the estimated effect of outbound trips was negative (Table 1), the predicted demand was higher when fewer travel activities were assumed. In both weather scenarios, forecasted values for the most extreme travel scenario (55% as normal, Figure 7—pink lines) are 2% to 5% higher than the ones for the normal scenario (Figure 7—purple lines). Additionally, when cool and wet weather was assumed (using the weather data of 2000), lower projected water demand in July (in comparison with August and September) was still observed (Figure 7–solid lines). In contrast, a nearly 19% surge was predicted for the end of July and the beginning of August, extrapolating using the weather data of 2018, which was the chosen example for a hot and dry summer. Though significant, the effect of vacation on water demand in Liège is modest in comparison with the effect of extreme weather. This might be because the percentage of people in Belgium taking holidays is not high, especially in comparison with neighboring countries [14].

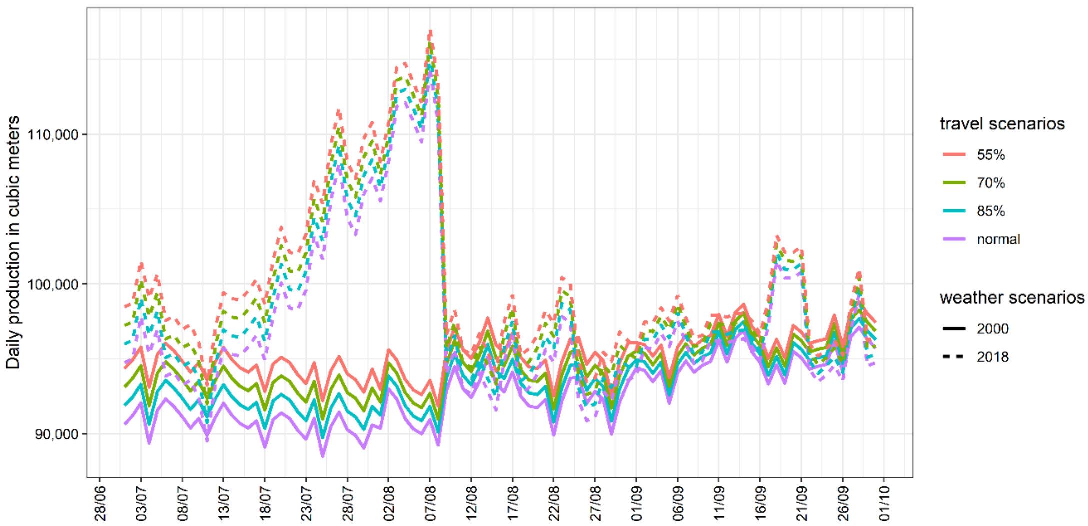

Figure 7. Predicted water demand for summer 2020 with different weather and travel scenarios.

Though our results suggest a significant association between the number of outbound trips with water demand, no causality should be concluded yet. However, in combination with existing (though limited) evidence from other studies such as the one carried out by Wong et al., caution regarding a potential increase in water demand due to current travel restrictions should be made, especially when it is combined with long periods of extreme weather. Additionally, as previously discussed, the custom of traveling during the holidays is subjective to study locations. For cities with a much higher outbound flow of tourists than inbound, such as Liège, higher demand might occur when fewer people travel. However, for other cities which usually attract tourists, the sudden reduction in the number of people arriving might lessen the demand for water. Hence, further studies in different contexts should be carried out to validate the relationship between outbound tourism and water demand.

4. Conclusions

This study attempted to address the gap in the literature regarding the potential effect of outbound tourism on water demand. Statistical models were developed using the daily water use in the Liège area, monthly outbound trips, and meteorological data. Our results suggest a decrease in water demand during the months with high outbound activities. This raises the concern of whether the current travel restrictions might lead to fewer people traveling for the summer holidays, resulting in a higher water usage. The prediction values for summer 2020 using different travel and weather scenarios show that the risk of increasing water demand when travel activities reduce is modest. However, the risk is much higher when this is combined with long periods of hot and dry weather. Since the custom of traveling during the holidays changes from one place to another, other case studies are needed to quantify the potential effect of outbound tourism on water demand, especially when the pre-COVID-19 travel pattern is not expected to return any time soon.

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