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Water Intensity Indicators in the Global Retail Sector

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Abstract
Retail water use accounts for up to 19% of public water globally supplied. However, the water intensity of retail stores and its drivers remains largely unexplored. This study is the first of its kind to provide water intensity indicators for retail buildings, namely Water Intensity per store Area (WIA), Water Intensity per Store (WIS), Water Intensity per Worker (WIW) and Water Intensity per Revenue (WIR), providing metrics for better water management in the retail sector. The water intensity of the world's highest revenue retailers was assessed through data published online in their sustainability reports. A statistical analysis on location, store size, number of workers and revenue was also performed to evaluate the influence of these variables in water intensity indicators. Results confirm that the number of workers, location, store size, and sales revenue statistically influence some of the four water intensity indicators analysed. These results contribute to assist retailers in setting best practice water consumption reference levels and to better understanding water variability, thus offering tools for improved sustainability and water efficiency across the retail sector.

Keywords Water consumption benchmarks · Water Intensity per store Area (WIA) · Water Intensity per Store (WIS) · Water Intensity per Worker (WIW) · Water Intensity per Revenue (WIR) · Retail stores

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1 Introduction

The demand for potable water is rising, primarily motivated by global population growth and increased water consumption intensity in many activities. In addition, poor land use management, water resources' pollution and climate change result in unsustainable pressure on water resources in many regions of the globe (Symeonidou and Vagiona 2018).

Commercial water use in buildings accounts for up to 20% of water withdrawal (U.S. Energy Information Administration 2012; U.S. Environmental Protection Agency 2009; World Bank Group 2010). Moreover, the global production and use of consumer goods are responsible for 80% of all water use (The Sustainability Consortium 2018), making retailers' water footprint an important environmental problem that requires a more sustainability-driven management solution. Thanks to its strategic position, the retail sector is uniquely placed to influence the overall direct water footprint of the retail sector, and its supply chain and consumers by helping them make informed decisions (Retail Forum for Sustainability 2014).

International regulation and voluntary standards are also urging retailers towards water stewardship, namely by the practical implementation of goal 6 of the UNSDGs, which proposes access to water and sanitation for all people (United Nations 2015), The Water Framework Directive (European Parliament 2000), or The European Communication on Water Scarcity and Droughts (European Parliament 2007), requiring the promotion of sustainability of water resources (Symeonidou and Vagiona 2018). Due to increased regional water stress, water accounting is becoming increasingly important for governments, institutions and corporations (Symeonidou and Vagiona 2018). In effect, water indicators are a crucial reporting figure in internationally recognised reporting methodologies, such as the Global Reporting Initiative or the Carbon Disclosure Project.

In terms of the literature review, studies on water consumption can be classified into three interlinked topics: i) water consumption pattern; ii) water consumption drivers; and iii) water end-use patterns. The water consumption pattern studies are the most simple and usually report total or specific water consumption patterns with different time resolutions. These studies allow the characterization of average water demand and the magnitude of its variability or time-related patterns (e.g., weekly and annual seasonalities). On this matter, Kılkış (2019) benchmarked of 120 cities based on the Sustainable Development of Energy, Water and Environment Systems City Index, Jayarathna et al. (2017) studied the application of geographic information systems in modelling residential water demand in 90 austrailian suburbs, Chen et al. (2015) proposed a benchmarking model for household water consumption based on data from three cities in Greece, Siddiquee and Ahamed (2020) estimated income elasticities of water consumption in 459 households in Dhaka city and Llop (2019) proposed a new method for decomposing temporal changes in water use intensity into various explanatory factors. Closely related are the water consumption drivers works, which expand the scope of water consumption patterns by also identifying the factors affecting water consumption, namely water price, demography, or end-users education (Gonzalez-Gomez and Garcia-Rubio 2018; Lu et al. 2019; Rios et al. 2018; van Noordwijk et al. 2014). The water end-use patterns studies complement water consumption pattern and water consumption drivers studies by disclosing the final destination of the water. In that respect, Melville-Shreeve et al. (2021) monitored the real-time water consumption in seven buildings on a university campus, whereas DeOreo et al. (1996) resorted to flow trace analysis to collect data about water use by individual fixtures and Di Cosmo et al. (2014) proposed two methods to disclose reasons behind sectoral water use in EU countries. In addition to these core water consumption research topics, some related subjects include water efficiency studies (Meireles et al. 2018), water-energy and water-food nexus studies (Kholod et al. 2021) or studies on rainwater harvesting (Almeida et al. 2021). Water efficiency studies are strongly related with the core water consumptions studies, in particular the water end-use studies: Gamarra et al. (2018) evaluated the aggregated energy and water consumption of two schools in a hot climatea and Vairavamoorthy (2009) reviewed the different tools and measures of urban water demand management applied in developed countries. In a more theoretical context, Symeonidou and Vagiona (2018), conducted a review on the the water footprint concept and in which ways it could contribute to the sustainable development of water use, Vanham (2016) investigated whether the water footprint concept addresseed the water–food–energy–ecosystem nexus, Haak and Pagilla (2020) developed a Water-Economy Index characterizing the social, economic, and environmental dynamics of water reuse, Cook et al. (2014) presented a study on the effects of water servicing options on water resources in Canberra, while van Roon (2007) addresseed the challenges in the transition to neighbourhood centred water-based services using 'Low Impact' design. Concerning the drivers for water use and water efficiency, Liu et al. (2019) investigated the potential impact of building information modelling on water efficiency, Deoreo et al. (2001) analysed water-conserving fixtures and appliances before-and-after building retrofitting and Wong and Mui (2008) developed an epistemic benchmarking model for residential buildings from existing domestic water consumption patterns based on 60 apartments in Hong Kong.

However, most of the water consumption studies have either considered the city scale or residential buildings. Fewer studies exist on assessing water consumption indicators in the commercial sector; Lúcio et al. 2020 and Sousa et al. (2019) studied the performance of water efficiency measures in commercial buildings and Farreny et al. (2013) developed indicators on Water Intensity of Purchase and Potential Water Self- Sufficiency from rainwater harvesting systems regarding Spanish Retail Parks. This lack of studies is, at least, partially explained by the complexity of the water consumption in commercial buildings, in particular in retail, as water consumption varies according to the sector's diversity (Morales and Heaney 2014).

On this matter, a US Environmental Protection Agency (U.S. EPA) white paper entitled "Water efficiency in the commercial and institutional sector" (U.S. Environmental Protection Agency 2009) cited a lack of subsector-specific data and particularly of water benchmarks that allow establishing operational targets (Morales and Heaney 2014). This is due primarily to the lack of a standardised classification system and the large array of drivers for water use within the retail sector, and the lack of the classification of end-use devices (Morales and Heaney 2015). Nonetheless, these missing metrics are key to increase water efficiency and sustainable water management.

Regarding the lack of standardised classification systems, some studies estimated the water use intensity in retail by employee, namely for water infrastructure sizing purposes (Dziegielewski et al. 2000; Gleick et al. 2003). Morales and Heaney (2014, 2015) developed a benchmarking method for nonresidential water use efficiency and nonresidential water users and proposed to estimate yearly commercial water use by heated building surface (Morales et al. 2011). The U.S. EPA (2009) did not present water intensity metrics for the retail sector but rather a breakdown of total water consumption by end-use. Similarly, in a study by Gleick et al. (2003), a breakdown of the percentage of water consumption in the retail sector by end-use was provided, without further normalisation. LEED and BREEEAM, as green building certification schemes, do not propose strict water performance targets either, but rather emphasise the performance of a building as a whole to achieve higher sustainability building assessment classifications (Liu et al. 2019). In addition, Dziegielewski et al. (2000)

presented water intensity benchmarks for supermarkets based on a survey conducted in five stores. The conclusions of this work emphasised the need to expand research to other commercial and institutional buildings, a gap in knowledge that the present research will address for retail stores.

Hence, it is apparent that the Water Intensity (WI) of retail stores remains largely unexplored. Insoforth, this study is the first of its kind to provide several WI indicators for retail stores and identify statistically significant predictors of water consumption within this sector, providing more adequate baselines for benchmarking, and supporting decision-making processes for improved water efficiency. The innovation in this study lies in presenting four types of WI indicators for retail stores, namely: Water Intensity per Store Area (WIA), Water Intensity per Store (WIS), Water Intensity per Worker (WIW) and Water Intensity per Revenue (WIR). Additionally, two specific questions were tested: i) "*What variables are good predictors of water consumption variability in the retail sector*?" and ii) *"What water management and savings' solutions are retailers recurring to?* Reliable water consumption indicators combined with high-performance water-saving solutions empower retail buildings' stakeholders in the decision-making process for improved water efficiency and water management in the retail sector.

2 Materials and Methods

A quantitative analysis was made on water consumption indicators of retail stores, normalised by store area, store unit, number of workers and revenue. The initial sample was selected out of Deloitte's Global Powers of Retailing Rank, encompassing the 250 largest retailers in terms of revenue (Deloitte 2017). Online retailers were excluded since they do not have physical store locations.

This research project methodological approach was structured according to six consecutive steps (Fig. 1a):

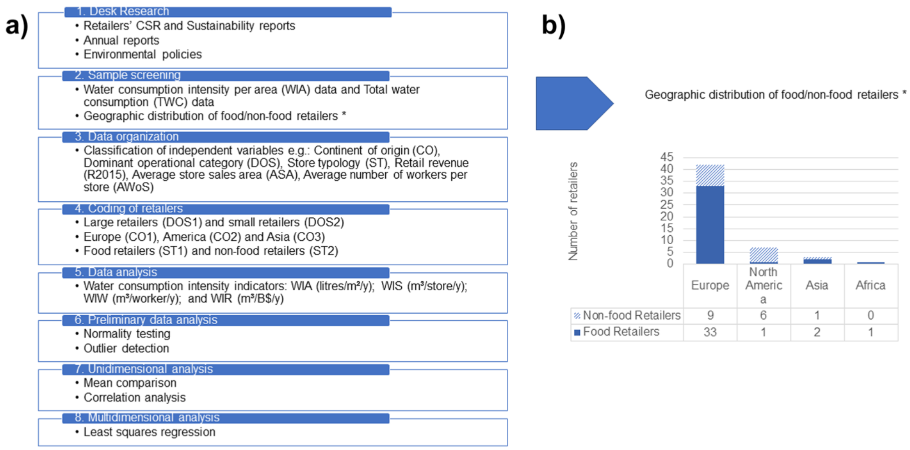

Fig. 1 **a** Statistical analysis methodology and **b** Geographic distribution of the analysed food/non-food retailers

1. *Desk research* – Sustainability reports, annual reports and CSR reports were searched for each retailer, as well as their environmental policies. Reports dating from 2016–2020 were considered data sources, as not all companies publish reports yearly.
2. *Sample screening* – Most analysed retailers (57%) either did not have sustainability reports or did not present water consumption data in them. 22% retailers presented WI data per m^2 of sales area, whereas 16% presented data on total water consumption in m^3 or gallons. Some retailers presented water consumption data per volume of sales (i.e., per thousand of $ sold) (1%), per unit of product sold (2%) or per visitor or worker (1%). Additionally, some retailers provided water consumption data according to the typology of business operation or the country of operation. For this study, analysed retailers reported either yearly "Water consumption intensity per area" (WIA) or "Total water consumption" (TWC). Hence, the sample was reduced to 52 retailers (37 food retailers and 15 non-food retailers) [dataset 1]. Nonetheless, the analysed retailers present aggregated data for 91.413 stores, which is an indicator of the representativeness of the sample and increases the robustness of the data presented. 79% retailers were from Europe, 13% were from North America, 6% were from Asia and 2% were from Africa (Fig. 1b).
3. *Data organisation* – each retailer was classified in a table according to the following independent variables: "Revenue ranking" (RR), "Company name (CN)", "Continent of origin" (CO)," Dominant operational category" (DOS)," Store typology" (ST), "Retail revenue in 2015" (R2015)," Number of countries of operation" (NC), "Number of stores" (NS)," Average store sales area" (ASA)," Total store sales area" (TSA)," Average number of workers per store" (AWoS), "Total number of workers" (TWo), and "Revenue per store area" (RSA) [dataset 1]. Some of these variables were retrieved from sustainability reports, while others were calculated when possible (e.g. ASA = TSA / NS). Not all variables were available for all the retailers publishing WIA or TWC. The data retrieved from online sustainability reports were uploaded to a data repository [dataset 2] to ensure permanent data availability.
4. *Retailer's categorisation* – retailers with store sales area above 1000 m^2 were firstly coded as large retailers (DOS1), whereas retailers with store sales area below 1000 m^2 were coded as small retailers (DOS2), following the criteria of Galvez-Martos et al. (2013). Secondly, retailers were coded according to continent of origin, namely Europe (CO1), North and South America (CO2) and Asia (CO3). Africa was excluded as only four retailers had African provenance. Lastly, retailers were coded according to their main trade area as food retailers (ST1) or non-food retailers (ST2). Food retailers included cash & carry stores, convenience stores, supermarkets and hypermarkets. Non-food retailers included home improvement/Do-It-Yourself stores, pharmacies and drug stores, decoration and furniture stores, department stores, office supplies stores, household appliances/electronics stores, auto-shops, and other speciality stores.
5. *Data analysis* – a statistical analysis of the dataset was performed on four different water consumption intensity indicators: i) WIA, expressed in litres/m^2/year; ii) WIS, expressed in m^3/store/year; iii) WIW, expressed in m^3/worker/year; and iv) WIR, expressed in m^3/B$/year. The choice of these indicators has advantages and disadvantages, and like any indicator, may introduce bias to results. For instance, luxury goods have a higher unit value per product, implying that a smaller store may generate considerable revenue. On the other hand, luxury goods require personalised treatment of the clients, demanding more workers for the same store size. This research did not intended to find the best indicator, but rather to provide a base-

line for benchmarking water indicators in the global retail sector and disclosing consumption patterns based on statistical analysis.

The number of retailers for which each indicator was possible to estimate and the corresponding confidence interval for a confidence level of 95% is presented in Online Resource 1. The retailers for which the total water consumption data was possible to obtain (in total 52 retailers) represent between 20 to 30% of the total sales revenue of Delloite's rank regarding the world's 250 largest retailers. The range is considered herein since the number of online retailers on the list has been increasing since 2015.

The methodology used to perform the statistical analysis of the dataset is depicted in Fig. 1a. The analysis was carried out with software SPSS 26 and, given the sample size limitations, bootstrap was applied whenever available for the algorithm used. The analysis without outliers was also limited to the indicator with the largest sample (WIA) to avoid further limiting statistical validity.

The preliminary analysis included the typical descriptive statistics, testing for normality of the data and outlier identification. The Shapiro–Wilk test was used instead of the Kolmogorov–Smirnov since it is typically recommended for smaller sample sizes (Mishra et al. 2009). Distribution outlier identification was carried out for WIA using the Tukey criterion.

The unidimensional analysis included a comparison of means for categorical predictors, and correlation analysis, for continuous predictors. Both parametric and non-parametric approaches were adopted depending on the normality of the data. Mean comparison was made using the parametric t-test or the non-parametric Mann–Whitney test (for categorical predictors with only two classes) and the parametric ANOVA or the non-parametric Kruskal–Wallis test (for categorical predictors with three or more classes). The parametric Pearson correlation and the non-parametric Kendall's *tau* and Spearman's *rho* correlations were used for assessing the relationship between the indicators and the continuous predictors.

Finally, least-squares linear regression was used for the multidimensional analysis. The selection of the predictors to include in the regression models was made using the stepwise algorithm. Multicollinearity was evaluated using the Volume of Inflation Factor (VIF) and heteroskedasticity with the Breusch-Pagan, F and White tests. The normal and robust standard errors were used to estimate the regressions coefficients.

6. *Water-savings solutions* – Retailers' sustainability/CSR reports were searched for water management and saving solutions to assess retailers' action on water use. Data were organised in Online Resource 2, according to the methodology of Sullivan and Gouldson (2013) and Bălan (2010). Key categories and patterns were assessed via maximum variation sampling (Suri 2011). In addition, these categories were approved by the authors to be sensibly inclusive of the data analysed. Hence, for each water management and savings' solution, data were classified according to the broadest category that it could enfold: "Buildings", "Landscaping", "Water managing"," Behaviour" or "Cleaning". To validate the research category classification, these key categories were also successfully used as search words in the sustainability/CSR reports from which data was collected.

3 Results

3.1 Water Intensity Indicators in Global Retail

Descriptive statistics and frequencies are reported for the continuous and categorical variables (Online Resources 3 and 4). These provide an overview of the dataset used but are of little use for knowledge inference or practical applications.

The mean value of the water consumption indicators should be used conscientiously considering the difference to the more robust measure of central tendency reported in Online Resource 3 (median). The WIA is highly skewed, indicating the probability of existing extremely high values and a non-normal distribution of the data. The existence of extreme high values has a significant impact on the mean, as further confirmed by the calculation of other robust measures of central tendency, M-estimators, and using bootstrapping. Online Resource 5 reports these results for WIA, and similar patterns are observed for the other indicators. This skew affects the normality of the data, as confirmed by the Shapiro–Wilk test. Normality testing was done to all indicators and by the classes of the categorical variables. Except for the class of the countries with the smallest sample size, the data were non-normally distributed. For variable ST2 the WIW indicator was also found to be normally distributed. Consequently, preference to reporting non-parametric mean comparison and correlations was given.

Statistically significant differences in mean were found only for the WIA value depending on the continent where the stores were located and for the WIS as a function of the dominant operational size of the stores. A statistically significant difference could also be reported for indicator WIR depending on the continent where the stores are located, if a less stringent significance threshold is adopted (10% instead of the usual 5%). In a unidimensional analysis, the type of stores did not induce any statistically significant difference in any of the water intensity indicators considered.

Regarding the statistically significant difference found for WIA depending on the stores' continent location, the difference is between Europe (the lowest value) and Asia (the highest value). WIA values in America are intermediate between Europe and Asia and not statistically different from them.

The correlations analysis results showed that only some of the variables related to the WI indicators revealed statistically significant results. For instance, WIS had a statistically significant correlation with the number of stores (Kendall's tau = -0.339, Spearman's rho = -0.481), the average store area (Kendall's tau = 0.496, Spearman's rho = 0.657) and the total store area (Kendall's tau = 0.234, Spearman's rho = 0.334). In addition, WIW and WIR are correlated with the total store area (WIW–Kendall's tau = 0.273, Spearman's rho = 0.394; WIR–Kendall's tau = 0.249, Spearman's rho = 0.325). The full correlation results are presented in Online Resource 6. In the majority of the cases, outliers were identified in all indicators globally and for the classes of the categorical variables under analysis.

The unidimensional analysis highlights the existence of some statistically significant differences, but it does not account for potential interactions between multiple predictors and the dependent variable. The multidimensional analysis enables evaluating the statistically significant effect of an independent variable while controlling for the effect of the others. The multidimensional analysis was done resorting to multiple linear regression, implying that i) the relation between the predictors and the dependent variable is linear, and ii) there is no interaction between the predictors. Although regression modelling is still one of the most commonly used tools, the sample sizes for each indicator was limited, which did not allow the use of more advanced tools (e.g., artificial neural networks) that require splitting the dataset into training, testing and validation subsets.

In the dataset, the sample size limitation is an issue of the indicators and the potential predictors. For instance, when using all variables as potential predictors for the WIA indicator, a model with 5 variables (CO, DOS, ST, NS, and R2015) with an adjusted R^2 of 0,631 was obtained. However, this came with the cost of reducing the sample size from 55 cases to only 28 cases. Consequently, it was chosen to use only the variables that did not reduce the sample size of each indicator as potential predictors. By doing so, the only variables common to all models were CO, DOS and ST. Variables such as R2015, NS, TSA and TWo were only used for some of the indicators.

Online Resource 7 presents the only two statistically significant models obtained. Both models are of limited accuracy but are consistent with the results of the unidimensional analysis, i.e., that the continent where the stores are located is statistically significant in terms of WI. On the other hand, it is also noteworthy that store type was not statistically significant for any indicator in the unidimensional analysis, but became significant when controlling for the continent in the WIW indicator. The bootstrap results confirm the significance of the coefficients of the model for WIA but not for WIW. This result is an indication of the importance that the outliers have in the model.

The results of the multidimensional analysis were limited, but considering the existence of significant outliers in any of the indicators, such was expected. Therefore, the multidimensional analysis was repeated, removing the outliers. This solution was limited to the indicator with the largest sample size (WIA) to avoid developing regression models with small samples.

A statistically significant regression model was obtained with CO and ST variables by removing the outliers from the WIA indicator. The normal and modified Breusch-Pagan, the White and F test confirmed that the variance of the regression errors depended on the values of the independent variables (heteroscedasticity). Two approaches were used to prevent this: i) transforming the dependent variable; and ii) performing a weighted least squares regression (WOLS). The transformation was done by estimating the regression on the logarithm of WIA, and the weights were estimated from the errors of the residuals.

The three regression models without outliers for WIA are detailed in Table 1. Overall, the best performing is the WOLS regression. It presents an accuracy similar to the normal ordinary least squares (OLS) regression, but is not affected by heteroscedasticity (confirmed by the normal and modified Breusch-Pagan, the White and F tests).

The prediction capability of any of the models is reduced. The adjusted R^2 is under 0.5 in most cases. Still, the important conclusion that can be retrieved is that continent and store type have a statistically significant influence on WIA. Recalling the results of the unidimensional analysis, only continent resulted in a statistically significant difference for this indicator. Even excluding the outliers and repeating the Mann–Whitney test on the dominant typology of stores, no statistically significant difference was found for WIA. This provides additional information for understanding the water performance in the retail sector and highlights the interface between the various independent variables.

When breaking down WIA according to retail sub-type (Online Resource 8), some patterns seem to emerge, particularly in food retailers: the mean WIA distribution according to retail subtype in these retailers increases from discount stores to supermarkets, cash & carry stores and hypermarkets. According to store size, the increase in WIA suggests that bigger stores, with more sales, customers, and workers, may have an exponential increase in WI. Considering the sample size, these results have no statistical

Table 1 Regression models without outliers for Water Intensity per store Area (WIA)

Parameter	B	Robust Std. Error	Bootstrap[a]				
			Bias	Std. Error	Sig. (2-tailed)	95% Confidence Interval	
						Lower	Upper
OLS of WIA (adjusted $R^2 = 0.300$)							
Intercept	999.638	233.669	13.602b	219.481b	0.001[b]	609.583b	1487.705b
[CO=1]	–723.928	192.93	–4.952b	177.154b	0.001[b]	–1079.888b	–381.949b
[CO=2]	–104.438	359.282	–13.407b	344.085b	0.739[b]	–798.119b	550.715b
[CO=3]	0		0[b]	0[b]		0[b]	0[b]
[ST=1]	466.188	182.02	–10.579b	169.844b	0.020[b]	117.988b	797.128b
[ST=2]	0		0[b]	0[b]		0[b]	0[b]
OLS of Log(WIA) (adjusted $R^2 = 0.235$)							
Intercept	2.913	0.105	0.000b	0.101b	0.001[b]	2.735b	3.147b
[CO=1]	–0.382	0.073	0.000b	0.072b	0.001[b]	–0.525b	–0.247b
[CO=2]	–0.12	0.146	0.007b	0.140b	0.401[b]	–0.409b	0.147b
[CO=3]	0[a]		0[b]	0[b]		0[b]	0[b]
[ST=1]	0.244	0.111	0.000b	0.105b	0.032[b]	0.035b	0.448b
[ST=2]	0[a]		0[b]	0[b]		0[b]	0[b]
WOLS of WIA (adjusted $R^2 = 0.293$)							
Intercept	1021.34	0.015	21.382b	204.019b	0.001[b]	700.676b	1474.213b
[CO=1]	–659.473	0.013	–24.196b	187.372b	0.002[b]	–1090.304b	–344.247b
[CO=2]	–140.22	0.015	–2.972b	289.442b	0599[b]	–726.055b	456.156b
[CO=3]	0[b]		0[b]	0[b]		0[b]	0[b]
[ST=1]	381.168	0.021	–3.930b	133.445b	0.007[b]	121.386b	638.658b
[ST=2]	0[b]		0[b]	0[b]		0[b]	0[b]

[a] Unless otherwise noted. bootstrap results are based on 1000 bootstrap samples

[b] Based on 998 samples

validity, and a different pattern may exist in reality. Nevertheless, they raise the possibility that retail sub-sector may be a potential driver for WIA.

4 Discussion

4.1 Water Intensity Indicators in Retail

This research is innovative in presenting water consumption indicators for retail stores, namely WIA, WIS, WIW, and WIR. In brief:

- mean WIA values were 1123 l/m^2/y, with minimum values at 95 l/m^2/y and maximum values at 4320 l/m^2/y;
- mean WIS values were 4411 m^3/store/y, with minimum values at 38 m^3/store/y and maximum values at 90000 m^3/store/y;

- mean WIW values were 47 m^3/worke/y, with minimum values at 3 m^3/worker/y and maximum values at 407 m^3/worker/y;
- mean WIR values were 483 lt/B$/y, with minimum values at 8 lt/B$/y and maximum values at 12700 lt/B$/y.

Mean values of the water consumption indicators should be used with relative caution given the difference to the sample's median.

For non-food retailers, the number of workers was a reliable predictor of water consumption. Statistically significant differences in mean corroborated that WIA also varied according to the continent where the stores were located, and WIS varied according to the dominant operational size of the stores.

A statistically significant difference could also be reported for indicator WIR according to the continent, if a less stringent significance threshold of 10% is adopted.

In a unidimensional analysis, WIS had a statistically significant correlation with the number of stores, the average store area and the total stores. In addition, WIW and WIR were correlated with store area. These findings corroborate those of Dziegielewski et al. (2000), in which water consumption increased according to the number of employees and building size. These findings are also in line with those of U.S. EPA (2009), according to whom water consumption in retail may vary in relation to sales and the number of people that used restrooms.

However, store type became statistically significant in a multidimensional analysis when controlling for the continent in the WIW indicator. Additionally, other OLS methods showed that continent and number of stores had a statistically significant influence in WIA, as suggested for food retailers in Online Resource 8. These findings corroborate those of Gleick et al. (2003), according to whom water use varied considerably among the different types of retail stores.

Findings for food retailers regarding supermarkets are in line with those of Dziegielewski et al. (2000), placing the WI of the supermarkets at 907 l/m^2/y. Food retailers also seem to have a higher WIA mean when compared to non-food retailers, which may be explained by the fruit/vegetables/floral, fresh fish or seafood departments (Dziegielewski et al. 2000) due to sinks and dishwashing nozzles in meat and deli departments, and also by moisture in fruit/vegetables, fresh fish and seafood departments, as well as ice-makers (U.S. Environmental Protection Agency 2009). Also, floor sanitation in food preparation and receiving areas are more water-intensive than in non-food retail. In contrast, non-food retailers seem to use water mostly for restrooms and space cooling (Gleick et al. 2003).

Other general differences in retailers' water performance may be related to merchandising, store occupancy, water efficiency and to the choice of water fixtures, occupant's behaviour and maintenance. Marketing and client segmentation strategies may also influence water consumption in HVAC systems, restrooms and landscape irrigation. Newer stores with newer equipment may also give retailers a water-efficiency advantage. Local culture could also impact the variability of water intensity in retail since the majority of the lowest water consumption were located in European countries, followed by American and lastly by Asian countries.

4.2 Water Management and Saving Solutions

The most successful way to achieve large water savings in retail is through a combined indoor, outdoor, behavioural and water-efficiency management strategies. An integrated approach that combines climate, technology, occupancy, and maintenance is important to improve water efficiency and reduce water use.

Overall, the most reported water-saving solutions by retailers (Online Resource 9) were high-efficiency fixtures (48%), water management systems (48%) and rainwater harvesting (41%). The extent to which these solutions are implemented in retailers' stores was not disclosed in sustainability/CSR reports. Working with Non-governmental organizations (NGOs) in water programs also ranked high amongst retailers (41%), which reinforces water as an important issue.

In the "Buildings" category, high-efficiency fixtures (48%), wastewater recycling (22%) and wastewater treatment (15%) were the solutions most cited by retailers. The use of high-efficiency fixtures is in line with the suggestions of Dziegielewski et al. (2000) as an appropriate water conservation strategy. Retailers disclosed little investment in the water-efficiency of cooling water, which accounts for half of the total water end-use in food retailers (Dziegielewski et al. 2000). For instance, regarding water use in refrigeration systems, 7% retailers indicate that they recycle heat from refrigeration systems to heat water, and 4% indicate that they recover steam condensate from hot processes or capture water condensed on refrigeration and HVAC equipment.

In the "Landscaping" category, the use of indigenous plants (22%) and smart irrigation systems (15%) were the solutions most cited by retailers. These solutions are in line with outdoor water-saving opportunities cited as good practice by the U.S. EPA (2009), including the use of drought-tolerant, water-efficient plant species, reported by 4% of retailers.

The "Cleaning" category was not frequently cited by retailers, though optimising cleaning-in-place processes, reusing rinse water to clean truck tanks and dry ice blasting were mentioned by 4% of retailers.

In the "Water management category", water management (48%), rainwater harvesting (26%), water submetering (15%), and water leaks repair (11%) were the solutions most cited by retailers. These results suggest that it is essential to measure water consumption by end-use to decrease water consumption and plan water reduction goals and investments, as in a study carried out by Sousa et al. (2019). Water consumption reduction can be hampered by behaviour or maintenance factors, highlighting the importance of human behaviour in water reduction strategies. Nonetheless, in the "Behaviour" category", staff training on water savings was mentioned by 15% of retailers, whereas working with NGO's in water programs (41%) and selling water sensitive products to clients (22%) scored higher. Additionally, 4% retailers mentioned the need to develop a water manual for suppliers, to tackle supply chain's indirect water footprint.

The use of water-efficiency measures reported by most retailers suggests their interest in reducing water consumption (Cassino et al. 2013). Cost reduction and the minimisation of water risks seem to be corporate driving factors for water stewardship (Auchan 2015; Edeka 2016; IKEA 2015; J Sainsbury plc 2018; Kroger 2016; Symeonidou and Vagiona 2018; Wesfarmers 2018; Woolworths 2018). Nonetheless, studies estimate that the financial payback of water-efficiency strategies is context-dependent, despite the environmental benefits in terms of water savings (Sousa et al. 2019). Cost-effective solutions to minimise retailers' water footprint could include the pretreatment of wastewater of sinks, showers, and rainwater for toilets, flushers, and irrigation use. In regions with water scarcity, retailers could also install water tanks for backup domestic water supply. Additionally, stormwater control techniques could be used in retail buildings to mitigate stormwater systems overload.

International regulation and local building codes encourage the reduction of WI by water use restriction during drought or by water-efficient plumbing fixtures such as water taps, showerheads, urinals and toilets (Standards 2018; U.S. Environmental Protection Agency 2009). Nonetheless, the water savings potential estimated by Gleick et al. (2003) for the retail sector was up to 43%, whereas the WI variability found in the present study suggested an even higher potential. This represents an important opportunity to positively impact the direct water footprint of this sector, which is specially relevant in regions that face water stress.

4.3 Water as a Material Issue in Retail

Improved water use in retail enhances operational costs, environmental performance and business management. Indeed, becoming water positive or closing the water cycle is a publicly expressed goal for some retailers (Coop Group 2015; ICA Gruppen 2015; IKEA 2016; Kingfisher 2016; Kohl's_Corporation 2015; Lidl 2015; Norgesgruppen 2015; Walmart 2015), which first aim at reducing water consumption in their stores and later across the supply chain (ENDS Carbon – University of Edinburgh Business School 2009).

WI indicators allow retailers to compare their water metrics to those of competitors, and can also be useful to project teams when designing new or refurbished stores, targeting at optimum infrastructure sizing. This can be quite impactful for water consumption reduction, given the large number of stores owned by global retailers and the frequency of refurbishment processes within the sector, which typically occur every 5–15 years (Lowry 1997). As intermediates between supply chains and end-consumers, retailers may further instigate water stewardship by promoting water labelling, green product certification and supply chains' water accounting, with focus on water shortage and water pollution issues (Symeonidou and Vagiona 2018).

4.4 Limitations

Data retrieved online may be outdated since water consumption metrics in reports refer to the previous fiscal year, and retailers may also not disclose all water-related solutions implemented during that period.

The statistic analysis confirmed that continent and store type have a statistically significant influence on WIA. Nevertheless, different countries in the same continent can vary importantly in their water stress levels, implying that a specific analysis of these differences will be in order shortly.

The multidimensional analysis assumed a linear relationship between the predictors and the dependent variable since the goal was not to optimise the prediction capability but rather to detect significance statistically. Nonetheless, the relation between the variables may be non-linear, and interaction between predictors may exist. Evaluating such possibility would require transforming the variables or resort to artificial intelligence modelling tools (e.g. artificial neural networks, support vector machines), which was out of the scope of the present investigation and not possible due to the sample size available.

5 Conclusions

The main goal of this study was to establish WI indicators for retail stores and identify statistically significant predictors of water consumption within the sector, providing more adequate baselines for benchmarkings, and in turn support retailers in decision-making for improved water efficiency and management in the retail sector. Mean water consumption metrics for retail buildings were summarised as follows: i) WIA: 1123 $l/m^2/y$; ii) WIS: 4411 m^3/store/y; iii) WIW: 47 m^3/worke/y; and iv) WIR: 483 m^3/B$/y.

The unidimensional statistical analysis revealed that only two categorical variables (CO and DOS) resulted in statiscally significance between the categories in one of the indicators. Conversely, only two continuous variables (R2015 and TWo) did not have a statiscall significant correlation with at least one of the indicators developed. This indicates that the predictors selected have the potential to explain a portion of the water consumption variability observed.

The multidimensional analysis is limited by the sample size. However, it reveals that the water consumption pattern is explained by a combination of the variables. Furhtermore, it also shows that variables that are not statistically significant in the unidimensional analysis may be so when the effect of other predictors is controlled. In particular, the model developed for WIA includes ST as predictor, which was not statistically significant for any of the indicators in the unidimensional analysis.

With regards to the water savings' solutions used in the retail sector, high-efficiency fixtures (48%), water management systems (48%) and rainwater harvesting (41%) were preferable choices. The different degrees of implementation of water efficiency solutions is likely correlated to some of the water consumption variability observed.

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Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

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