A Water Use Model for the tourism industry in the Asia-Pacific Region: The impact of water saving measures on water use

ABSTRACT

The Asia-Pacific region is a hot spot for population and tourism growth, both key drivers of water demand. Already, over 75% of countries in this region are experiencing water stress. The management of water is becoming increasingly pressing, including for the tourism industry. Yet, there has been little research into the predictors of water use in tourism in the Asia-Pacific region, and opportunities for water saving. Therefore this paper develops both total and per guest night water use models to determine the drivers of water use in accommodation in the Asia-Pacific region, delves into the differences between regions and assesses the effectiveness of different water saving measures. The results suggest geographical differences in water use that are influenced by climate zone and pool facilities. Importantly, the per guest night water use model indicates that there are economies of scale to water use and that low/dual flush toilets can significantly conserve water.

Keywords: Tourism, Water, Accommodation, Asia-Pacific

INTRODUCTION

Water is increasingly being recognised as a critical issue for environmental management, particularly as climate change is likely to impact significantly on water supplies and security in many countries around the world in the form of changes in precipitation patterns, hydrological disasters, and salt water intrusion of aquifers (ADB & A-PWF, 2013; IPCC, 2007; Tay & Paungmalit, 2010). The dominant user of water globally, as well as in Asia-Pacific, is agriculture; however, tourism is an increasingly important water user in some regions, because of its growing need for potable water. Indeed, the tourism industry is well known for its over-use of water, which has resulted in conflicts with local communities (Alonso, 2008; Cole, 2012). Despite this, there remains limited knowledge concerning water use in tourism and the impact tourism has on water withdrawal and distribution (Tortella & Tirado, 2011; Gössling, Peeters, Hall, Ceron, Dubois, Lehmann & Scott, 2012).

Research shows that tourism destinations are dependent on a sufficient amount of quality water supplies (Rico-Amoros, Olcina-Cantos & Sauri, 2009). Yet tourism businesses are often located in areas of environmental sensitivity, such as national parks, islands or coastal areas, which are often exposed or sensitive to water shortages, pollution and conflict (Moyle, Croy & Weiler, 2010). In addition, tourism can be highly seasonal and can place peak demand on water systems. For this reason, seasonal pricing for water and wastewater services at tourist destinations has been advocated (Cullen, Dakers & Meyer-Hubbert, 2004). In addition, tourists' water use can considerably exceed that of residents (Crase, O'Keefe & Horwitz, 2010), with some studies calculating that tourist water consumption in developing countries is between two and three times the local water demand (Garcia & Servera, 2003; UNEP, 2013).

More broadly, water scarcity has been recognised as a key strategic issue for tourism businesses and those involved in the environmental management of destinations (GSTC, 2012). As a result, there is a need to better understand how water conservation, efficiency and recycling can contribute to business sustainability in the tourism industry. Critically, the tourism industry “may be missing an opportunity to play a vital role in becoming a strong advocate for water conservation” (Alonso, 2008, p. 268). This could be due to many tourism operators being focused on their short-term profitability, with businesses only adopting responsible water use measures if there is a quick return on investment, or if there is no choice but to change current practices (Becken, 2013). Investigating the drivers of water use by tourism businesses, just as for residential users (Jorgensen, Graymore & O’Toole, 2009), is critical, as this can identify strategies for minimising water consumption.

THE ASIA-PACIFIC WATER PROBLEM

Asia-Pacific is a critically important region in the global water debate. Analyses of climatic trends reveal a complex picture. China, for example has experienced an overall decrease in precipitation in the last fifty years, although some areas in the West and the middle and lower reaches of the Yangtze River have seen an increase in rainfall. South East Asia and the Western parts of the South Pacific have recorded an increase in precipitation, whereas Fiji, the West of Australia and the East of New Zealand have received less precipitation. Common to most countries is an increase in extreme events where rainfall is experienced within shorter periods of time, often in the form of heavy precipitation and storms (Dore, 2005). The trend toward “extreme precipitation events over most of the mid-latitude land masses and wet tropical regions will very likely become more intense and more frequent by the end of this century” (Intergovernmental Panel on Climate Change, 2013, p. 21), In addition to changes in the hydrological regimes, there are significant variations in the development of the different countries in the region, their dependency on tourism and their access to potable water supplies. For example, in South Asia there is increasing concern that the glacial retreat in the Himalayas will impact the water supplies of millions of people (Tay & Paungmalit, 2010). In Australia and New Zealand, climate fluctuations result in floods and droughts, which often leave behind significant water shortages and impacts, such as contaminated water and damaged infrastructure (Berti, Bari, Charles & Hauck, 2004).

Importantly, the Asia-Pacific region is a hot spot for population and tourism growth, both key drivers of water demand (Becken, Rajan, Moore, Watt, & McLennan, 2013). Indeed, the Pacific Asia Travel Association (PATA, 2013) predicts international arrivals to Asia-Pacific to increase by 4.1 percent per annum between 2013 and 2017. A report by ADB and A-PWF (2013) indicates that over 75% of Asia-Pacific countries are experiencing serious water stress, with the region facing an imminent water crisis if immediate steps are not taken to improve water resource management. A recent Tourism and Water White Paper (Becken et al., 2013) argues that water is an increasingly critical concern for tourism planning and development, and is of particular importance for the Asia-Pacific region.

Despite an urgent need to better understand tourism water use in the Asia-Pacific, this region has tended to be over looked in tourism water use studies. The existing literature on water use in a tourism context has focused on European and North American experiences and metrics. There is also research relating to tourism water use in dry areas of Australia (Crase et al., 2010; Pigram, 2001) and in the Mediterranean (Rico-Amoros et al., 2009; Tortella & Tirado, 2011). This research is the first to systematically investigate the Asia-Pacific context.

DEVELOPMENT OF WATER USE MODELS FOR TOURIST ACCOMMODATION

The accommodation sector records considerable water use and, with the cost of potable water increasing (White & Fane, 2002), there is a need for hotels to conserve water and reduce their water consumption. Research suggests that hotels should aim to conserve resources and reduce water consumption, while still providing tourists with a quality experience (Qiuyun, Guoji, Mulian, Yujun & Jingxuan, 2011). Consequently, there is a growing body of literature aimed at investigating the factors that impact water use in the accommodation sector (Chan, Wong & Lo, 2009; Bohdanowicz & Martinac, 2007).

While there have been some studies that have investigated the broader aspects of tourism water use (i.e. 'embodied' water in food, fuel and tourism activities; Hadjikakou, Chenoweth & Miller, 2013; Velazquez, 2006), the majority of studies have focused on direct water use by hotels (Charara, Cashman, Bonnell, & Gehr, 2011; Tortella & Tirado, 2011). Directly, tourists use water for drinking, using the toilet or shower and undertaking recreational activities, while indirectly they use water through the provision and maintenance of services and facilities, such as gardens, cleaning, laundry, pools, air-conditioning and food preparation (Kelly & Williams, 2007; Cullen et al., 2004).

A major determinant of potable water consumption in hotels is the climate in which the enterprise is located. Hotels in hot climates tend to consume more potable water than equivalent hotels located in cooler climates. Factors that possibly lead to this higher potable water consumption include increased rates of swimming pools, personal bathing and irrigation (Becken et al., 2013). Chan et al. (2009) also indicated that water use is influenced by seasonality, cuisine, facilities and water saving measures. Likewise, Kelly and Williams (2007) suggest that water use in tourism is determined by geographical or environmental conditions, seasonality and the use of water-intensive equipment, technologies and activities.

The literature indicates that water use depends on the hotel type (i.e. luxury versus lower-class hotels; Deng & Burnett, 2002) and size (Gössling, 2001). Bohdanowicz and Martinac (2007) developed a water use model that considered the number of guest nights, hotel floor area, climate zone, hotel standard or class, year of construction, food covers served and the in-house laundry load. Similarly, Tortella and Tirado (2011) investigated hotel water use by considering the number of hotel rooms, occupancy, number of months open, type of board offered, the size of the hotel chain, whether water saving initiatives had been implemented, the differentiation strategy and facilities such as day spas, pools and golf courses. Charara et al. (2011) also estimated a water use model using the number of hotel rooms, hotel floor area, occupancy, number of employees and the hotel standard/class.

A number of factors that have not yet been considered may contribute to hotel water use. Importantly, investigation into the influence of geographical differences between regions, countries and urban or regional localities is limited. Previous research has focused on individual case studies, rather than comparing water use across regions and countries. Therefore, this research includes variables relating to broad region, country and urban/regional location. In addition, water is often used as a marketing tool to portray luxury and thus more luxurious accommodation may be a higher user of water (Lehman, 2009). While research has considered the influence of hotel class (Bohdanowicz & Martinac, 2007), there remains a need to investigate the effect of price on water use. Further, Bohdanowicz and Martinac (2007) suggested that a critical area that has been neglected is conference facilities. In light of a growing business tourism market (Davidson and Rogers, 2012), this research includes related facilities in the water use model, such as business centres, meeting rooms and function rooms. Behavioural measures by tourists (see Jorgensen et al., 2009), while important, have not been included due to lack of data, but could be the focus of future research. While water saving initiatives in hotels have been examined, previous modelling work has simply indicated whether the initiatives have been implemented (Tortella & Tirado, 2011). Chan et al. (2009) also used a semi-open ended question to elicit the water saving measures used in Hong Kong hotels, determining that flow regulators and sub-metering were the most prevalent. However, the *extent to which* initiatives have been implemented has not yet been determined. The current research will therefore provide a more nuanced picture of the influence of water saving measures.

Lastly, the literature tends to measure water use in accommodation via water use per guest night. However, this fails to provide insight into reductions in total water use. Therefore this paper aims to develop total and per guest night water use models to determine the drivers of water use in accommodation in selected countries in the Asia-Pacific region, delves into the differences between regions and assesses the effectiveness of different water saving measures.

METHOD

3.1 Data sources, management and initial analysis

Environmental management and certification is increasingly popular for hotels, with a number of schemes now in existence (Cashman & Moore, 2012). EC3 Global manages one of the few global environmental certification schemes currently available. EC3 Global is an international tourism and environmental management and advisory group founded by the Cooperative Research Centre for Sustainable Tourism (STCRC) in Australia. The STCRC developed the EarthCheck benchmarking system based on Agenda 21 principles (UNCED, 1992) to gauge business' environmental and social performance indicators against baselines and best practice. The EarthCheck Standard was one of the first programs to require operators to supply verified data on potable and recycled water consumption. EC3 Global provided the researchers with access to water use data for 210 businesses located in Australia (n=88), New Zealand (n=27), Hong Kong (n=15), Singapore (n=9), Indonesia (n=32) and Thailand (n=39).

The sample used in this research is not representative of all hotels in the Asia-Pacific region, but it represents a group of generally larger hotels that have taken some leadership in the area of environmental management. The results presented here should therefore be interpreted as a better-than average level of water consumption of hotels in the region. Since one key objective of this research is to systematically compare hotels and their water practices across several Asia-Pacific countries, the bias towards sector leaders is of less concern, since all countries are exclusively represented through EarthCheck members.

The key variables included in this study were determined by the literature and data availability (Table 1). The variables of interest were total water use in kilolitres (KL) and water per guest night in litres (L/GN), corresponding to the calendar years of 2007 to 2011. Properties with no data in these years were deleted from the database. As some properties did not consistently report in all of these years, grand totals and averages for these two key variables were calculated for each property resulting in two variables called *avtotal* and *avpgn*. Therefore the dependent variables were 'total water use' and 'water per guest night' averaged over five years. In the case of Hong Kong hotels, the reported water use only refers to potable water use and excludes any saltwater used as part of Hong Kong's dual seawater (toilet) flushing system.

<INSERT TABLE 1 ABOUT HERE>

EC3 Global provided the climate zone for each hotel. As some countries range over significantly large latitudes and can experience different climates from one area to another, EC3 Global has developed a methodology to separate nations with latitudes that span over 10° into sub-regions. This resulted in 11 climate zones being identified within the data (see Table 2) and modelled as 11 dummy variables. The variables of water saving indicators are also of great interest. These are self-reported by the business and relate to measures such as how often the organisation checks for leaks. Depending on the answers to the six indicators the businesses is graded on a scale from 1 to 100, with 100 representing the highest score. An average water saving rating was then calculated. By converting the ordinal scales to a score out of 100 using logarithms in relation to the value '6', EC3 Global can report a total water savings rating out of 100 by combining the results of the different water saving measures and dividing by the number of items, which is more easily comprehended by users. As this method works very similarly to the ordinal scale (only it uses a score out of 100 rather than 7), this methodology provided by EC3 Global is adopted in this paper for consistency.

<INSERT TABLE 2 ABOUT HERE>

Data checking eliminated dummy operations, retail shops and accommodation establishments that were not classified by EC3 Global as business and vacation hotels. The data was analysed using descriptive statistics and tests for significance (including chi-square tests, t-tests and ANOVA) in STATA v12.0, a statistical software package. A combined skewness and kurtosis test for normality was performed, identifying that the water use dependent variables were not normally distributed. Therefore a ladder of powers search was undertaken, which indicated that the water use dependent variables should be transformed to log.

Multiple-Imputation Regression

Analysis revealed that the price and water saving variables had missing values, which was a concern as these were to be included in the regression model and generally list-wise deletion is employed, i.e. respondents with missing values are discarded. This would impact on the already relatively small sample and would reduce the reliability and validity of the models. Techniques for dealing with missing data are pairwise deletion, maximum likelihood estimation and multiple imputation (MI), with the latter being considered the most rigorous (Allison, 2002). MI is a simulation-based technique designed for dealing with missing data that produces consistent, asymptotically efficient and normal estimates through a three-step procedure (Schafer, 1997). Many of the drawbacks of MI, such as sophisticated but cumbersome implementation, are overcome by using software such as STATA. Being a simulation based technique, MI produces slightly different estimates every time it is employed, however STATA allows the user to specify the number of seeds to be used, which reduces the random component of the imputation process enabling results to be reproduced. Consequently, a MI regression model with robust standard errors was developed using the following set up procedure:

- The MI data style was set as "wide".
- The imputed variables (*watersaving*, *price, waterpoints1*, *waterpoints2, waterpoints3*, *waterpoints4, waterpoints5, waterpoints6* and *waterpoints7*) were registered.
- The regular variables (other model variables) were registered.

A variable called *_mi_miss* was generated to flag the cases with missing values in the water saving and price variables. A description of the MI model indicated that there were 192 complete cases and 18 incomplete cases. Once set up, the seed was set so that the results could be reproduced and then the imputation was performed using a multivariate normal regression model. This model imputes the missing values based on the regular variables using an iterative Markov Chain Monte Carlo (MCMC) method.

Initially five imputations were specified, which is the minimum imputations suggested in the literature (Rubin, 1987). This was increased to 15 imputations to improve the validity of the estimates. With 15 imputations the Expectation-Maximization (EM) algorithm converged at the 10th iteration indicating that the default 100 iterations for the burn-in period is sufficient for the convergence of MCMC. To further check the convergence of MCMC, a file containing the estimates of the Worst Linear Function (WLF) was generated during the imputation process. The WLF iterations were specified as time-series data and a time-series plot of the WLF was generated. The plot revealed that there was no long-term trend in the WLF data and it was assumed that the imputation model reached a stationary distribution. A plot of the autocorrelations was also undertaken and they clearly fell away indicating a stationary distribution was reached.

Using MI estimation, which pools the imputation results to run the regression, a linear regression model was specified with the sandwich (robust) estimator of variance (White, 1982). A small-samples adjustment was employed to calculate the complete degrees of freedom. Under MI estimation, some of the standard post-estimation procedures, such as goodness-of fit tests and likelihood-ratio tests, valid under complete-data regression, do not hold. However, post-estimation prediction continues to hold validity (Carlin, Galati & Royston, 2008); therefore we employed this tool for analysis.

In total six models were developed: three for each dependent variable (*avtotal* and *avpgn*) representing the Asia-Pacific, Australia/New Zealand and the Asian countries. All models were initially run with the full complement of independent variables, and then these were iteratively dropped based on the highest (least significant) *p*-values until only significant variables remained. As the dependent variable was log transformed, to interpret the results it was necessary to take the exponential of the coefficients to obtain an appropriate interpretation (UCLA Statistical Consulting Group, 2013). This is the geometric mean rather than arithmetic mean.

RESULTS

Table 3 presents an overview of the sample by region. The results show that operators in the Asian countries ($\bar{x}$=118,500 KL) use significantly (Pr(|T|>|t|)<0.001) more water per annum than those in Australia/New Zealand ($\bar{x}$=31,440 KL). This was also true on a per guest night basis (Pr(|T| > |t|)<0.001, 677 L compared with 313 L). In addition, the Asian operators had significantly more guest nights (Pr(|T|>|t|)<0.001, $\bar{x}$=185,200 nights compared with $\bar{x}$=101,250 nights) and hotel rooms (Pr(|T|>|t|)<0.001, $\bar{x}$=339 rooms compared with $\bar{x}$=229 rooms) than those in Australia/New Zealand – indicating the size of the hotel may influence water use. Comparing between countries, there were no significant difference in total water use between the Asian operators (Prob>F=0.903), nor did the Australian operators' total water use differ from that of the New Zealand operators (Pr(|T|>|t|)=0.110). Given this, it was considered appropriate to develop an overall Asia-Pacific model, as well as two regional models, one for Australia/New Zealand and the other for the Asian countries.

<INSERT TABLE 3 ABOUT HERE>

The Asian countries had significantly lower prices compared to those in Australia/New Zealand (Pr(|T|>|t|)=0.047, $\bar{x}$=AU$167 compared with $\bar{x}$=AU$189 per night). However, despite having lower prices, operators in Asia were significantly more likely to have a fitness facility (Prob>chi2<0.001), a day spa (Prob>chi2<0.001), more pools (Prob>chi2<0.001), a business centre (Prob>chi2=0.001) and more dining venues (Prob>chi2<0.001) than those in Australia/New Zealand. In addition, operators in Australia/New Zealand had a significantly higher "water saving" rating than those in Asia (Pr(|T|>|t|)=0.003, $\bar{x}$=78 compared with $\bar{x}$=72). Considering individual water saving measures, there was no difference between the two regions for *waterpoints1* (Pr(|T|>|t|)=0.492), *waterpoints2* (Pr(|T|>|t|)=0.125), *waterpoint3* (Pr(|T|>|t|)=0.436), *waterpoints5* (Pr(|T|>|t|)=0.535) and *waterpoints7* (Pr(|T|>|t|)=0.327). However, there were significant differences for *waterpoints4* (Pr(|T|>|t|)<0.001) and *waterpoints6* (Pr(|T|>|t|)<0.001). This suggests that Australia/New Zealand is more likely to have low/dual flush toilets installed ($\bar{x}$=82.9 compared with $\bar{x}$=67.3), while the Asian countries were more likely to use water from a recycled, grey or rain water source ($\bar{x}$=43.1 compared with $\bar{x}$=12.6).

Drivers of Total Water Use

The Asia-Pacific model revealed that guest nights, the percentage of low/dual flush toilets installed, whether the operator was in Australia/New Zealand or Asia, the price per night (*price*), the number of hotel rooms (*hotelrooms*), the presence of pool facilities (*pool*) and whether the operator was located in *NZ1* or *HK1* climate zones significantly influenced total water use (Table 3). Notably, Australia/New Zealand hotels had 53% lower total water use than those in Asia, hotels in New Zealand's Southern climate zone and Hong Kong had significantly lower total water use (31% and 62% respectively) than other climate zones, and hotels with a pool had 34% higher total water use than those without a pool.

Post-estimation prediction revealed that if guest nights were to increase by 10% then average total water use would increase from $\bar{x}$=42,284 to $\bar{x}$=44,815 KL (or by 2,531 KL). Likewise, a 10% increase in hotel rooms resulted in the average total water use increasing to $\bar{x}$=44,316 KL (or by 2,032 KL). Thus, if the size of the hotel increased, then logically total water use would also increase. The price per night of the establishment was used as an indicator of luxury. Scenario prediction revealed that if the price per night increased by 10% then average annual total water use would increase to 43,211 KL (or by 927 KL). Notably, a 10% increase in guest nights had a greater impact on total water use than a similar increase in price, suggesting that increasing luxury may be a more effective strategy to boost revenues without having a negative impact on water supplies. The *waterpoints4* variable, which relates to the percentage of toilets with low/dual flush, was significant in the Asia-Pacific model, but not in the Asia or Australia/New Zealand models. Scenario prediction indicated that if properties in the Asia-Pacific were to increase the percentage of low/dual flush toilets by 10%, annual total water use would decrease to 41,864 KL (or by 420 KL).

In the Australia/New Zealand model, guest nights, hotel rooms and whether the establishment had pool facilities, significantly predicted total water use. Businesses with a pool had a 43% higher total water use than those that did not have a pool. Scenario prediction revealed that if businesses in Australia/New Zealand were to increase their guest nights by 10%, total water use would increase from 36,501 KL to 40,191 KL (or by 3,690 KL) per establishment. Similarly, if businesses in Australia/New Zealand were to increase number of hotel rooms by 10%, total water use would increase to 38,454 KL (or by 1,953 KL). No other variables were found to be significant in the Australia/New Zealand total water use model.

In Asia, total water use was found to be significantly driven by guest nights, whether the property was located in a regional or urban areas, the price per night, hotel rooms, whether there were function rooms, the number of dining and bar facilities and whether the property was located in Hong Kong. Key findings of the Asia total water use model were that Hong Kong properties were found to have 46% lower total water use than other Asian based operators. In addition, urban properties had 22% lower total water use than regional properties and properties with function rooms had 46% higher total water use.

The median number of dining facilities per hotel in the Asian countries was six, which differs from the median of only three in Australia/New Zealand. Scenario prediction found that increasing the number of dining/bar facilities by one per establishment resulted in average total hotel water use in the Asian countries increasing from 68,967 KL to 73,454 KL (or by 4,487 KL). Similarly, increasing guest nights by 10% resulted in total water use in Asia increasing to 71,864 KL (or by 2,897 KL) and increasing hotel rooms by 10% resulted in total hotel water use increasing to 71,787 KL (or by 2,820 KL). To a lesser extent, an increase in price of 10% resulted in total water use in Asia increasing to 70,897 KL (or by 1,930 KL).

<INSERT TABLE 3 ABOUT HERE>

Drivers of Per Guest Night Water Use

MI estimation of per guest night water use in the Asia-Pacific revealed that guest nights, the region, the percentage of all toilets installed being low/dual flush, price per night, hotel rooms, pool facilities, dining and bar facilities and whether the property was located in Hong Kong or Indonesian Climate Zone 2 were significant predictors (Table 4). Businesses in Australia/New Zealand had a 45% lower per guest night water use than those in Asia. If an establishment had pool facilities, then they had on average 33% higher water use. In addition, if the hotel was located in Hong Kong, then water use was 43% lower, while those in the Indonesian Climate Zone 2 had 26% higher water use than other climate zones.

If guest nights were to increase by 10%, water use would decrease from 399 L to 387 L per guest night (or by 12 L). Note that this is the opposite relationship to that of guest nights and total water use, suggesting that there are economies of scale in water use, with more guests reducing per guest night water use. This is possibly due to fixed water use associated with irrigation and facilities, such as pools. Conversely, a 10% increase in the number of hotel rooms would increase per guest night water use to 411 L (or by 12 L), while a 10% increase in price would increase per guest night water use to 408 L (or by 9 L). Likewise, increasing the number of dining or bar facilities by one in each establishment would increase average per guest night water use to 422 L (or by 23 L). Notably, should low/dual flush toilet installation increase by 10% (to a maximum of 100 points) across all businesses, water use would decrease to 396 L per guest night (or by 3 L).

The drivers of per guest night water use in Australia/New Zealand were found to be guest nights, the percentage of all toilets installed being low/dual flush, the price per night, the number of hotel rooms, whether the hotel had pool facilities, and whether they were located in *AU3* climate zone. Pools remained a key driver of water use per guest night, with businesses that had a pool using 24% more water per guest night. It was found that businesses located in the Australian Climate Zone 3 (North Australia) had 37% higher per guest night water use, possibly due to all hotels in this climate zone having pools, compared with just

65% of properties in other Australian/New Zealand climate zones. The warmer climate may also result in other behavioural changes that might inflate water use, such as increased bathing, drinking and irrigation.

Scenario prediction suggests that increasing guest nights by 10% would result in per guest night water use declining from 282 L to 271 L (or by 11 L). Conversely, increasing hotel rooms by 10% would result in water use increasing to 293 L (or by 12 L) and increasing the price per night by 10% would increase water use to 289 L (or by 7 L). The results also suggested that if businesses in Australia/New Zealand improved their water saving practices by 10% (to a maximum of 100 points), per guest night water use would decrease to 281 L (saving 1 L per guest night).

The Asian model of per guest night water use found that the number of guest nights, the percentage of low/dual flush toilets installed, the percentage of water consumption from recycled, grey or rain water sources, price per night, the number of hotel rooms, whether there were fitness facilities, pool facilities and dining/bar facilities and being located in Hong Kong, to be significant predictors. While found to be significant predictors, Asian based hotels without fitness or pool facilities were rare (sample of three and two respectively), thus they are not interpreted further.

Properties located in Hong Kong had 40% lower per guest night water use than those located in the other Asian countries. Scenario prediction revealed that if properties were to increase their guest nights by 10%, per guest night water use would decrease from 494 L to 480 L (or by 14 L). However, if the properties were to increase hotel rooms by 10% per guest night, water use would increase to 511 L (or by 17 L). Similarly, if properties were to increase price per night by 10% then per guest night water use would increase to 505 L (or 11 L) and if the number of dining facilities increased by one, per guest night water use would increase to 521 L (or by 27 L).

In terms of water saving measures, a 10% increase in the percentage of low/dual flush toilets installed would reduce per guest night water use to 490 L (or by 4 L), while a 10% increase in the percentage of total water consumed from recycled, grey or rain water sources would increase per guest night water use to 498 L (or by 3 L). This may indicate a rebound effect where the use of recycled, grey or rain water results in more water used per guest night. Or perhaps more likely, the high water users in the Asian countries are located in areas that only have recycled, grey or rain water sources. Supporting this premise is the finding that Asian properties with water use per guest night exceeding 500 L were more likely to be located in regional areas (Prob>chi2 = 0.001) and to be located in Indonesia and Thailand, rather than Hong Kong and Singapore (Prob>chi2<0.001). According to ADB and A-PWF (2013), on a scale from 1 “Hazardous” to 5 “Model”, Indonesia and Thailand have a National Water Security Index of 2 (Engaged), with Hong Kong and Singapore scoring 3 (Capable) and Australia and New Zealand scoring 4 (Effective). Thus the hotels with high use of recycled, grey or rain water may not be aiming to conserve water; they may simply have little choice but to use this form of water.

<INSERT TABLE 4 ABOUT HERE>

DISCUSSION

The availability of freshwater is of increasing concern in the Asia-Pacific region, yet not all countries face the same challenges. It is therefore important to understand regional and national differences in water use patterns and opportunities for increasing water efficiency. This research provided an analysis of water use drivers for the tourism sector in six Asia-Pacific countries using a MI regression model to determine predictors of total and per guest night water use in 210 accommodation properties in the region.

The results revealed significant geographical differences impacting total and per guest night water use. The water use models for the Asian countries had a greater complexity than the Australian/New Zealand water use models, suggesting a greater variability in the type of hotels in the Asian countries (see also Deng & Burnett, 2002) and potentially more unexploited opportunities for improving water efficiency. Moreover, the climate zone in which the property was located and whether or not the property had pool facilities was found to influence total and per guest night water use. Four stand-out climate zones were New Zealand Climate Zone 1 and Hong Kong Climate Zone 1 with lower water use, and the Indonesian Climate Zone 2 and Australian Climate Zone 3 with higher water use. It should be noted however, that the climate zone variable could be a proxy for other parameters; for example in the case of Hong Kong, where specific policies, such as the saltwater flushing system (Deng & Burnett, 2002), lead to different water use profiles. The impact of country-specific legislation, policies and practices requires further research, especially when trying to reduce tourism water use across all operators, rather than those that voluntarily participate in environmental certification.

Total water consumption is the sum of water use for a wide range of functional areas in a hotel, such as air conditioning, room water use, and laundry. The hotels in this study do not sub-meter their water use systematically and, as a result, information on water use is much less detailed than it could be. This means that while water use by various sections of a hotel, such as landscaping and laundry, are accounted for in the total and per guest night water use, it is not possible to identify which sections of the hotel are particularly water intensive. However, this paper attempted to link key services with overall water use to address this gap somewhat. Unfortunately, due to data limitations, some sections could not be identified or accounted for, such as the hotel laundry and should be considered in future research. Of those drivers that could be identified, this research found that pools are a significant key predictor of total and per guest night water use (see Table 5). While 98% of businesses in the Asian countries had pools, in Australia/New Zealand only 67% had pools. Notably, in New Zealand, just 48% of properties had a pool. In contrast, when considering Hilton International and Scandic Hotels in Europe, Bohdanowicz and Martinac (2007) did not find spa/pool facilities to be significant based on t-tests. Instead, they determined that the area of landscaped grounds, guest nights sold, total hotel floor area and food covers sold, were significant. Indeed, they concluded that the size of the floor and garden area of the hotel is more important than guest nights and attributed this to the extensive irrigation required in hot climates.

This research also found total water use was not influenced by the business type (maybe because business and vacation hotels become increasingly alike and difficult to conceptually separate), but was highly influenced by the size of the hotel, supporting Stipanuk and Roffman (1996) and Gössling (2001). In Barbados, Charara et al. (2011) also determined that the key predictors of water use were the number of guest nights and the number of employees, which are both measures of the size of the establishment. Per guest night water use, on the other hand, revealed more interesting results including economies of scale and that there are improvements to be made due to water saving practices.

Average per guest night water use by hotels in the Asian countries was about 677 L per guest night, with Australia/New Zealand's water use being more than half this at 313 L. Halcrow (1994) indicated that hotels should aim to average 200 L per guest night, however, Gössling (2001) noted that this would be difficult for hotels to achieve as they tend to average much higher per guest night water use rates. While Australian and New Zealand properties could reduce per guest night water use to under 300 L per guest night, it would be quite challenging for the Asian countries to do so. Yet, the results indicated that properties in the Asian countries that had a higher percentage of low/dual flush toilets implemented had a lower per guest night water use than other properties. Thus, implementing more low/dual flush toilets could reduce per guest night water use in the Asian countries, but perhaps not to the extent required.

Implementing low/dual flush toilets was the only water saving measure considered in this study that was found to significantly reduce total or per guest night water use in the Asia-Pacific. Undoubtedly, more needs to be done for water saving measures to drive a decrease in total and per guest night water use. In their research, Chan et al. (2009) found that the decrease in water use in hotels in Hong Kong could be primarily attributed to the adoption of water saving measures, such as flow regulators and sub-meter devices. Likewise, Tortella and Tirado (2011) indicated that water saving initiatives could improve the hotels image and reduce hotel water consumption by 14%. Water savings can also occur by incorporating innovative building design and landscaping into new developments and renovations (Kelly & Williams, 2007).

While it has been argued that "Tourists are often unaware of local water scarcity and cannot be expected to compromise the quality of their hard-earned holiday by making pro-environmental choices" (Hadjikakou et al., 2013, p. 554), there are areas in which tourists can and should make pro-environmental choices (Ramkissoon, Smith & Weiler, 2013). As Charara et al. (2011) argue, water consumption in accommodation is influenced by the behaviour of both tourists and staff. Yet, it is often difficult for tourists and staff to make pro-environmental choices as their decision is dependent on whether the option has been provided by the hotel or destination (Kelly & Williams, 2007). Businesses catering for tourists need to supply water saving choices to provide tourists the option to make environmentally sustainable decisions with respect to water conservation. One choice that tourists can make that has the potential to reduce total water use is the installation of dual flush toilets by businesses. It is then the decision of the tourists to select the low flow flush option, which this research suggests may be occurring. However, a key problem is that hotel managers' awareness of available water saving measures and technology appears limited (Chan et al., 2009).

Studies from Mallorca indicate that mass tourism results in lower water consumption per capita compared with luxury-focused tourism (Hof & Schmitt, 2011; Rico-Amoros et al., 2009). Tortella and Tirado (2011) suggested that while a shift toward higher quality should probably result in lower total hotel water consumption, this effect is overcome by the presence of pools and golf courses and the fact that luxury hotels stay open for longer with lower occupancy. Similarly, in Hong Kong, Deng and Burnett (2002) determined that the more luxurious hotels consumed more water. This research also found that on a per guest night basis, an increase in price increased water use, while an increase in guest nights decreased water use. However, in terms of total annual water use, the findings suggest that a 10% increase in guest nights has a greater impact on total water use than a 10% increase in the price per night. So increasing luxury, rather than quantities of guests, could be a more beneficial strategy when aiming for minimising increases in water demand.

Tortella and Tirado (2011) found that meal preparation increases water consumption in all-inclusive hotels. Likewise, this research found that the number of dining and bar facilities in a hotel impacted the average per guest night water use. Other research has also concluded that dining facilities increase water consumption by guests and hotels (Bohdanowicz & Martinac, 2007; Deng & Burnett, 2002). However, even if a hotel does not have dining facilities, the guests will dine in another location outside of the hotel, which will still consume water in the region. So, reducing dining facilities in a hotel may save water for the hotel, but it reduces its revenue and forces guests to leave the accommodation to purchase their meals, and possibly results in the same amount of water being used in the region regardless of where it is consumed. This study, like previous studies, is too narrowly focused on accommodation providers to truly determine if the impact at the regional level is a net benefit by having fewer dining facilities in hotel establishments. Future research should aim to develop a water use model at a destination level, which would include different types of tourism businesses.

CONCLUSION

Quality water is becoming an increasingly scarce resource, particularly in the fast developing Asia-Pacific region, and due to the exacerbating effects of climate change. Thus, water management is at the centre of environmental management more broadly. Tourism is a key growth industry in the region that has been recognised as having high water use well above resident use levels. Regardless, limited research has explored the drivers of tourism water use in the Asia-Pacific region. To address this gap, this research identified the predictors of total and per guest night water use in Asia-Pacific hotels. Importantly, significant regional differences were found supporting the need for regional studies, highlighting the requirement for a global model with regional segmentation and emphasising that regional management of water resources and consumption in tourism is necessary.

This research considered seven water saving measures that have been implemented by leading environmentally conscious hotels in the Asia-Pacific. Of the seven, only low/dual flush toilets were found to significantly reduce water use in hotels in the Asia-Pacific. Charara et al. (2011) suggests other water saving measures that include increasing business and consumer awareness, outsourcing water-consuming activities, and increasing the financial attractiveness of water conservation measures through tax concessions and increased water prices. Kelly and Williams (2007) argue that educating managers, staff and tourists about water use and the impacts of tourism is more promising than regulation due to enforcement and compliance issues. While tourists' water use has important implications for planning and development, there has been a dearth of studies relating to their water use behaviour (Crase, et al., 2010). Consequently, future research should be focused in this area.

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Table 1. Variables used in this research

Variable	Variable name	Description
Total water use	*avtotal*	Total KL averaged over 5 years
Water use per guest night	*avpgn*	L/GN averaged over 5 years
Hotel rooms	*hotelrooms*	Number of hotel rooms
Guest nights	*nights*	Number of guest nights per annum
Hotel type	*type*	The hotels were classified as either business or vacation
Region	*region*	Broad geographic region classified as either Asia or Australia/New Zealand
Water savings rating	*watersaving*	The mean of the water saving indicators
Water saving indicator 1[a]	*waterpoints1*	How often does the organisation check for leaks?
Water saving indicator 2 [b]	*waterpoints2*	What percentage of all shower fittings installed are low flow?
Water saving indicator 3 [b]	*waterpoints3*	What percentage of all tap fittings installed are low flow?
Water saving indicator 4 [b]	*waterpoints4*	What percentage of all toilets installed are low/dual flush?
Water saving indicator 5 [b]	*waterpoints5*	What percentage of the landscaping requires minimal irrigation?
Water saving indicator 6 [b]	*waterpoints6*	What percentage of total water consumption is from recycled/grey/rain water?
Water saving indicator 7 [b]	*waterpoints7*	What percentage of water sprinklers are used/operated after dark?
Urban/regional	*location*	Urban or regional location of the property
Climate zone	*AU1, AU2, AU3, NZ1, NZ2, HK1, SG1, ID1, ID2, TH1, TH2*	Please refer to Table 2
Price	*price*	Best available online price (in Australian dollars) from property website for two adults for one night in April 2013
Business rooms	*busrooms*	Includes business centre, business lounge and other designated spaces for business activities
Meeting rooms	*meetrooms*	Includes board rooms or meeting rooms with less than 100 people capacity
Function rooms	*funcrooms*	Includes conference, ball and function rooms with 100 or more capacity
Fitness facilities	*fitness*	Includes onsite fitness centre, gym, spa, sauna
Day spa facilities	*dayspa*	Includes a separate onsite facility with massage and/or beauty services
Pool facilities	*pool*	A dummy variable of whether pool facilities were available
Dining/bar facilities	*dining*	Includes separate restaurant and bar facilities

a. Collected on a scale of 1 “Never” to 7 “Every week”, which was converted into a water savings score where “Never”=0, “Relevant/Not Available”=50, “Once a year”=54, “Every 6 months”=58.8, “Every 3 months”=65.1, “Every month”=73.9, “Every 2 weeks”=88.9, “Every week”=100

b. Collected on a scale of 1 “0%” to 7 “100%”, which was converted into a water savings score where “0%”=0, “Relevant/Not Available”=50, “1-19%”=54, “20-39%”=58.8, “40-59%”=65.1, “60-79%”=73.9, “80-99%”=88.9, “100%”=100

Table 2. EC3 Global climate zones

Climate Zone	Latitude	Variable Name
Australia Climate Zone 1	31 to 44 South parallel	*AU1*
Australia Climate Zone 2	21 to 30 South parallel	*AU2*
Australia Climate Zone 3	11 to 20 South parallel	*AU3*
New Zealand Climate Zone 1	40 to 46 South parallel	*NZ1*
New Zealand Climate Zone 2	34 to 39 South parallel	*NZ2*
Hong Kong Climate Zone 1	22 North parallel	*HK1*
Singapore Climate Zone 1	1 North parallel	*SG1*
Indonesia Climate Zone 1	5 North to 2 South parallel	*ID1*
Indonesia Climate Zone 2	3 to 9 South parallel	*ID2*
Thailand Climate Zone 1	13 to 20 North parallel	*TH1*
Thailand Climate Zone 2	6 to 12 North parallel	*TH2*

Table 3. Overview of the sample by region

	Australia / New Zealand	Hong Kong / Singapore / Indonesia / Thailand
Sample	115	95
Nights (mean)	101,250	185,200
Hotel rooms (mean)	229	339
Price per night (mean)	$167	$189
Total water use per year (KL) (mean)	31,440	118,500
Per guest night water use (L) (mean)	313	677
% located in urban areas	87%	66%
Facilities		
% with pool	68%	98%
% with fitness facilities	83%	97%
% with day spa facilities	29%	75%
% with business facilities	67%	86%
% with meeting rooms	97%	92%
Number of meeting rooms (median)	4	4
% with function rooms	78%	84%
Number of function rooms (median)	1	1
Number of dining facilities (median)	2	5

Table 4. Predictors of Total Water Use [log(*avtotal*)]

Multiple-imputation Linear Regression with Robust Standard Errors

Asia Pacific

Independent Variables	Coefficient	Standard Error
nights	0.000**	0.000
region	-0.756**	0.077
waterpoints4	-0.003**	0.001
price	0.001**	0.000
hotelrooms	0.002**	0.000
pool	0.292**	0.081
NZ1	-0.377*	0.164
HK1	-0.973**	0.119
Constant term	9.910**	0.135

Obs = 210
Imputations = 15
Complete Degrees of Freedom = 201
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

Australia/New Zealand

Independent Variables	Coefficient	Standard Error
nights	0.000**	0.000
hotelrooms	0.002**	0.000
pool	0.358**	0.088
Constant term	8.729**	0.126

Obs = 115
Imputations = 15
Complete Degrees of Freedom = 111
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

Hong Kong/Singapore/Indonesia/Thailand

Independent Variables	Coefficient	Standard Error
nights	0.000**	0.000
location	-0.251*	0.118
price	0.002**	0.001
hotelrooms	0.001**	0.000
funcrooms	0.378*	0.169
dining	0.063*	0.025
HK1	-0.622**	0.128
Constant term	9.696**	0.203

Obs = 95
Imputations = 15
Complete Degrees of Freedom = 87
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

*Significant at 5%
**Significant at 1%
Note: Coefficients expressed in the log transformation, therefore to interpret them it is necessary to take the exponential.

Table 5. Predictors of Per Guest Night Water Use [log(*avpgn*)]

Multiple-imputation Linear Regression with Robust Standard Errors

Asia Pacific

Independent Variables	Coefficient	Standard Error
nights	-0.000**	0.000
region	-0.595**	0.087
waterpoints4	-0.002**	0.001
price	0.001**	0.000
hotelrooms	0.001**	0.000
pool	0.282**	0.076
dining	0.056**	0.020
HK1	-0.569**	0.112
ID2	0.232*	0.104
Constant term	5.805**	0.154

Obs = 210
Imputations = 15
Complete Degrees of Freedom = 200
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

Australia/New Zealand

Independent Variables	Coefficient	Standard Error
nights	-0.000*	0.000
waterpoints4	-0.003*	0.001
price	0.001*	0.000
hotelrooms	0.002**	0.000
pool	0.214**	0.078
AU3	0.312**	0.116
Constant term	6.022**	0.252

Obs = 115
Imputations = 15
Complete Degrees of Freedom = 108
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

Hong Kong/Singapore/Indonesia/Thailand

Independent Variables	Coefficient	Standard Error
nights	0.000**	0.000
waterpoints4	-0.003*	0.001
waterpoints6	0.003*	0.001
price	0.001**	0.000
hotelrooms	0.001**	0.000
fitness	-0.845**	0.254
pool	1.187**	0.429
dining	0.050*	0.024
HK1	-0.501**	0.119
Constant term	5.647**	0.440

Obs = 95
Imputations = 15
Complete Degrees of Freedom = 85
Prob > F = 0.0000
DF Adjustment: Small Sample
Within VCE type: Robust

*Significant at 5%
**Significant at 1%
Note: Coefficients expressed in the log transformation, therefore to interpret them it is necessary to take the exponential.