Climate Change Impacts on Rainwater Tank's Potential Water Savings, Efficiency and Reliability Presenting Relationship Between 'Seasonality Index' and Water Savings Efficiency

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Abstract

The paper presents potential impacts of climate change on rainwater tanks outcomes such as water savings, reliability and water savings efficiency under two projected climate change scenarios; RCP4.5 and RCP8.5 utilising a case study using rainfall data from four stations within the city of Brisbane, Australia. Historical rainfall data were collected from the Australian Bureau of Meteorology website for the selected stations. Projected daily rainfall data were collected from Australian government data portal for the same stations within Brisbane. Using an earlier developed daily water balance model, eTank potential annual water savings were calculated for several weather and climate change scenarios with varied roof areas and rainwater demandValues of 'Seasonality Index (SI)', a commonly used factor representing rainfall variability within a year, were explored to validate earlier developed relationships between SI and water savings efficiency through rainwater tanks. It is found that in most cases water savings in future periods are expected to decrease and such decrease is not necessarily attributed to the expected decrease in rainfall amounts in future, rather also affected by future reductions in rainwater tank reliability. Linear relationships between potential future water savings and reliabilities for all the stations are found. Relationship between SI and water savings efficiency was established, and it is found that the relationship slightly varies with an earlier developed relationship using historical data. Compared to earlier established relationship, for lower SI values water savings efficiency is expected to become better, while for higher SI values the water savings efficiency is expected to become worse. Also, an increase of roof area from 100 m^2 to 200 m^2 will cause an average increase of water savings efficiency by 25% and an increase of rainwater usage from 200 L/day to 300 L/day will cause an average increase of water savings efficiency by 20%.

Keywords Seasonal variation · Rainfall variability · eTank · Rainwater tank · Brisbane

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1 Introduction

Seasonality effects has been studied a lot in different aspects of science and engineering (Liu et al. 2022; Rachid et al. 2021; Serrano et al. 2020). However, limited studies were conducted related to its measurement and impacts with rainfall and subsequent consequences. Seasonality index (SI), a measure of monthly rainfall variability within a year, is commonly used for water resources management involving rainfall. Such monthly rainfall pattern has got significant influence on decision-making related to water resources allocation and management, especially in irrigation projects where withdrawal/diversion from a common source is restricted. Many regions in the world often experience very high total annual rainfall, however with non-uniform monthly distributions, which contributes to either flood or less effective agricultural benefits compared to the situation where similar amount of rainfall is uniformly distributed throughout the year. SI was originally proposed by Sumner (1988) as shown in the following section.

Imteaz et al. (2021c) studied climatic and spatial variabilities of SI values and investigated potential variations of SI within distinct climates such as dry, average and wet years through using monthly rainfall data from six major Australian cities. However, the study concluded no clear trend of SI variations within the climatic variations.

It is well-established that one of the potential impacts of climate change on hydrological variables is changes in rainfall intensities and pattern and thus increases in extreme rainfall events are already emerging (Easterling et al. 2000; Mikhaylov et al. 2020). It is evident that not only the total annual rainfall amount will be affected by the climate change, but the interannual distribution of rainfalls will be also altered (Feng et al. 2013). Such changes in rainfall amount and pattern will significantly affect growths of different crops, which depend on seasonal rainfall amount and pattern. Especially, for Australian cities, where higher degree of rainfall variabilities are already predominant, effect of global warming and subsequent climate changes is likely to worsen the current hydrological swings (Chowdhury and Beecham 2010). Some climate studies predict that in many regions dry years are expected to become drier, while wet years are expected to become wetter and Kamruzzaman et al. (2013) reported an increasing trend of rainfalls towards the west, whereas a decreasing trend towards the northeast coast. Both the increase and decrease in usual rainfall amounts and their patterns cause additional complexity on the efficient water resources management for this dry continent (King et al. 2020); an increase in rainfall can be attributed to frequent flooding, while a decrease in rainfall can be attributed to the scarcity of fresh water for irrigation.

It was well-researched that Australian weather and rainfalls are influenced by several large-scale climate drivers such as El Niño–Southern Oscillation (ENSO), Southern Annual Mode (SAM), Madden–Julian Oscillation (MJO), Indian Ocean Dipole (IOD) and Atmospheric Blocking. It is recommended that such macro-scale indices be translated to suitable micro-scale parameters, as many regions are influenced by more than one index, which causes establishment of relationships between the indices and potential rainfalls, a complex task often needing an in-depth understanding of the dynamics and variation patterns of associated climate indices (Esha and Imteaz 2020; Hendon et al. 2007). SI is anticipated to be suitable micro-scale parameter, especially when rainfall pattern is the concern (Risbey et al. 2009). Compared to the large number of studies on the prevailing large-scale climate drivers and their relationships with different climate variables (Ghamariadyan and Imteaz 2021; Esha and Imteaz 2020, 2019; Hossain et al. 2020, 2018), studies related to SI and its relationship with potential atmospheric variable(s) are scarce. Pascale et al. (2015)

used a dimensionless seasonality index, which is very similar to the one used in the current study and established correlations between seasonality index and periods of drought under high carbon emission scenario for the next century.

With ever-increasing water demand while having limited supply, water authorities in many cities are encouraging installation of rainwater tanks for non-potable water demands. Emerging impacts of climate change prompted several studies (Imteaz et al. 2021a; Imteaz and Moniruzzaman 2020; Zhang et al. 2019) investigating the impacts of climate change on potential water savings through rainwater tanks. However, as mentioned earlier there is scarcity of studies involving implications of SI on potential water savings through different harvesting techniques including rainwater tank. The pioneer study on this was conducted by Jenkins (2007), who applying historical rainfall data from twelve Australian cities into a daily water balance model, established a relationship between SI with rainwater tank's water savings efficiency and demonstrated that rainwater savings efficiency decreases with increase in SI values. Later, Imteaz et al. (2021b) utilizing rainfall data from six Australian cities and corresponding water savings potentials through rainwater tanks calculated using a daily water balance model, derived a continental-scale relationship between SI and water savings efficiency. However, such continental-scale relationship may not remain same for regional scale. As such, further investigations are required investigating applicability of the continental-scale relationship to different regions. Imteaz and Shadeed (2022) investigated the future applicability of the earlier developed relationship under changed climate scenarios using projected rainfall data for four regions in Sydney and reported that overall, a decrease in water savings efficiency is likely to occur. Again, such estimated potential reductions in efficiency warrant validation. As such this study investigates relationship of SI with the water savings efficiency of rainwater tanks under climate change scenario using projected rainfall data from Brisbane. Also, another important parameter of rainwater tank is the reliability of intended supply. However, the effect of reliability in relation to SI and future climate change was not evaluated in the earlier studies. This study evaluates effect of climate change on the reliabilities of rainwater tank supply using the same projected rainfall data. Reliability is defined as percentage of days in a year when rainwater tank is able to supply the intended demand for a particular condition. Also, the earlier studies did not consider separate emission scenarios under the projected climate. This study segregated two emission scenarios and presented the outcomes under two different scenarios (RCP 4.5 and RCP 8.5). With the impacts of climate change, current study outcomes are expected to provide significant insights and guidelines towards future sustainable water resources management.

2 Methodology and Data

The SI equation is given as follows:

$$SI = \frac{1}{R} \sum_{j=1}^{12} \left| X_j - \frac{R}{12} \right| \tag{1}$$

where, SI is the Seasonality Index, R is the mean annual rainfall and Xj is the mean monthly rainfall for month 'j'.

It is to be noted that the primary study on this was performed for Sydney, the largest city of Australia. Due to availability of enough complete data, the third-largest Australian city,

	Rainfall Station	Station Number	Elevation (m)	Location of station
Table 1 Details of the rainfall stations and location	Toombul	40237	22	Northern
	Sunnybank	40244	50	Southern
	Oxley	40463	20	Western
	Manly	40231	25	Eastern

Brisbane, which is the capital of Queensland was selected for this study. The climate of the city is classified as "humid subtropical" having hot, wet summers and moderately dry, moderately warm winters. The annual mean minimum temperature is 16.6 °C and mean maximum temperature is 26.6 °C. Four rainfall stations covering different spatial directions having minimal missing data were selected from the city of Brisbane. Table 1 shows the details of the selected rainfall stations, where directions are mentioned with respect to city centre. Figure 1 shows the locations of the stations within Brisbane metropolitan area. Australian government has produced future projected climate data for different regions of Australia as detailed in the website: https://climatechangeinaustralia.gov.au/en/. The widely used technique, Statistical Downscaling Modeling (SDSM) was applied for the projection of data. The SDSM uses multi-linear regression technique and stochastic weather generator to downscale climate variables from the original coupled atmosphere–ocean general circulation models developed under Coupled Model Intercomparison Project, CMIP (https://esgf-node.llnl.gov/projects/cmip5/). Out of forty CMIP5 models, Australian government has selected eight for further assessments. Among the eight selected models, the Australian Community Climate and Earth-System Simulator (ACCESS 1.0) weather model was found to produce simulations with high skill score with regard to historical climate. This study used ACCESS 1.0 projected daily rainfall data for the future periods. The projected data
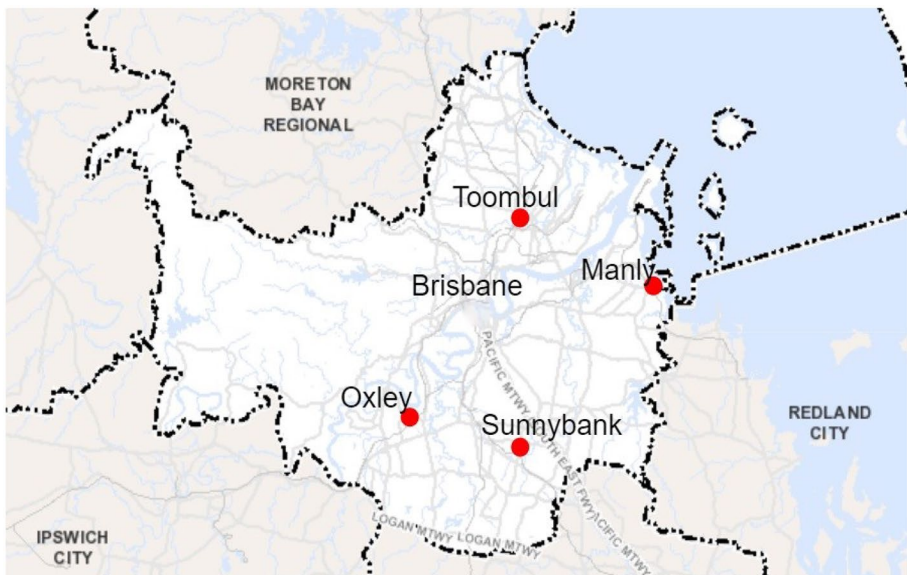
Fig. 1 Map of Brisbane metropolitan showing selected rainfall stations

were extracted for two projection scenarios (CO_2 concentration pathways); RCP4.5 (optimistic scenario – moderate emission) and RCP8.5 (pessimistic scenario – high emission).

SI values for the selected stations were computed using Eq. (1). To assess effects of different weather conditions, three different weather conditions such as 'dry', 'average' and 'wet' were considered. Dry, average and wet years were defined as the years having annual rainfall close to the historical 10th percentile, median and the 90th percentile values respectively (Imteaz et al. 2016). To avoid the influence of any particular year having unusual pattern, data from three years were selected to represent any particular weather condition. Calculations of SI, reliability and potential water savings were performed for each of the selected years and an average of the three values (from three selected years for a particular weather) are reported.

Potential water savings and reliabilities under historical and future climate change scenarios were calculated using an earlier developed daily water balance model, eTank (Imteaz et al. 2017). eTank has been widely used for many cities around the world (Imteaz and Shadeed 2022; Moniruzzaman and Imteaz 2017 and Imteaz et al. 2012). Details of theoretical backgrounds, mathematical processes and accuracy assessments of the eTank tool were described by Imteaz et al. (2017). The calculations covered three aspects; i) Comparison of expected future water savings and reliability values with the historical water savings and reliability values under different scenarios, ii) Comparison of current relationship between SI and water savings efficiency with the earlier developed relationship and effect of climate change, and iii) Evaluation on the effect of roof size and rainwater demand. For the first two aspects, to be able to compare with the earlier findings, the input data were kept same as the earlier study; i.e. roof area = 100 m², rainwater demand = 200 L/day, tank volume = 5000 L and rainfall loss = 15%. To assess the effect of roof size and rainwater demand, other scenarios were evaluated for the roof size of 200 m² and demand of 300 L/day.

3 Results and Discussions

3.1 Impacts on Water Savings and Reliability

Table 2 shows the selected historical and future years, along with their corresponding annual rainfall amounts for all the selected stations. Table 2 also shows the calculated water savings and reliability values for all the selected stations under three categories; past, future RCP4.5 and future RCP8.5. For each category and each weather condition three years were selected, and the Table shows all the three calculated results. From the table it is clear that compared to historical values, expected water savings are likely to decrease in future years, except for few cases. For 'Manly', future water savings are expected to decrease in all cases, except in average and wet years under the RCP4.5 scenario. For 'Sunnybank', future water savings for all the cases/scenarios are expected to decrease. For 'Toombul', future water savings are also expected to decrease, except in average year under RCP4.5 and in wet years under both the RCP4.5 and RCP8.5 scenarios. For 'Oxley', future water savings are expected to decrease in all the cases, except in dry year under RCP8.5. It is to be noted that not all the decrease/increase in water savings can be attributed to the corresponding decrease/increase in annual rainfall amounts. In some cases, calculated water savings are likely to increase, although projected annual rainfalls are likely to decrease (i.e. for Manly in average year under RCP4.5, for Toombul in average year under RCP4.5 and in wet year under RCP8.5) and vice versa (for Many in dry year under RCP4.5). These discrepancies

Table 2 Calculated SI values, expected water savings and corresponding annual rainfall amounts for the selected years

Location	Weather	Past				RCP 4.5				RCP 8.5			
		Year	Rainfall (mm)	SI	Water Saving (kL)	Year	Rainfall (mm)	SI	Water Saving (kL)	Year	Rainfall (mm)	SI	Water Saving (kL)
Manly	Dry	1914	704	0.63	46.0	2026	729	0.77	42.2	2023	708	0.86	40.9
		1960	705	0.59	49.0	2065	784	0.80	45.1	2064	620	0.90	39.8
		1979	709	0.61	48.9	2073	787	0.84	39.6	2065	546	0.84	35.9
	Avg	1951	1109	1.04	40.9	2030	1133	0.93	43.2	2026	955	1.01	42.1
		1980	1109	0.98	47.5	2040	1063	0.85	47.9	2037	929	0.88	41.8
		2004	1120	0.87	42.7	2077	1067	0.85	50.4	2049	980	0.92	37.6
	Wet	1947	1588	0.74	50.5	2049	1415	0.80	51.6	2055	1572	0.80	41.4
		1950	1496	0.63	52.5	2057	1558	0.82	49.6	2093	1631	0.90	41.1
		1956	1619	0.79	47.0	2089	1616	0.80	52.7	2094	1481	0.81	51.7
Sunnybank	Dry	1960	713	0.56	48.0	2082	607	0.65	38.7	2069	587	0.63	48.7
		1901	718	0.57	49.2	2091	581	0.67	41.7	2039	574	0.63	44.1
		1907	718	0.64	53.1	2052	572	0.65	43.5	2027	630	0.68	48.2
	Avg	1984	1074	0.59	61.8	2033	931	0.87	41.4	2040	877	0.78	49.5
		1935	1083	0.54	59.2	2042	931	0.90	39.1	2078	878	0.73	47.9
		1985	1085	0.49	65.0	2087	914	0.90	39.7	2091	880	0.72	48.9
	Wet	1934	1498	0.59	66.2	2047	1284	0.81	52.9	2028	1239	0.66	57.2
		1963	1555	0.62	52.9	2057	1286	0.89	42.5	2029	1235	0.59	51.6
		1988	1532	0.69	62.7	2059	1302	0.82	51.3	2096	1234	0.68	48.6

Table 2 (continued)

Location	Weather	Past				RCP 4.5				RCP 8.5			
		Year	Rainfall (mm)	SI	Water Saving (kL)	Year	Rainfall (mm)	SI	Water Saving (kL)	Year	Rainfall (mm)	SI	Water Saving (kL)
Toombul	Dry	1975	725	0.58	61.5	1929	717	0.77	47.8	1947	696	0.77	35.9
		1960	724	0.59	60.8	1953	728	0.80	39.0	1973	693	0.88	33.7
		2002	723	0.53	58.2	1987	695	0.60	49.1	1981	667	0.81	32.1
	Avg	2058	1121	0.56	91.0	2022	1033	0.73	82.0	2056	855	0.71	50.3
		2065	1150	0.74	83.1	2040	1078	0.80	76.8	2057	950	0.87	48.6
		2073	1110	0.82	78.0	2075	1026	0.85	71.1	2089	953	0.80	51.3
	Wet	2035	1579	0.68	134.2	2024	1564	0.62	120.8	2029	1341	0.71	83.0
		2058	1559	0.81	117.5	2031	1479	0.78	104.7	2093	1405	0.85	79.0
		2064	1553	0.82	121.8	2038	1532	0.73	109.1	2096	1379	0.66	100.7
Oxley	Dry	1977	560	0.63	39.8	2036	674	0.87	35.7	2027	663	0.66	31.2
		1994	715	0.86	35.8	2045	482	0.61	37.1	2050	470	0.53	37.6
		1986	737	0.60	52.3	2025	401	0.63	34.1	2062	712	0.71	45.6
	Avg	1982	1023	0.70	48.1	2030	927	0.95	38.9	2026	1054	0.77	62.2
		1984	1032	0.52	62.9	2037	952	0.73	47.6	2061	1003	0.64	49.1
		1995	1060	1.01	42.4	2041	876	0.97	35.0	2087	815	0.92	36.7
	Wet	1983	1384	0.60	65.0	2031	1267	0.59	53.2	2070	1199	0.59	55.2
		1981	1471	0.83	51.5	2068	1277	1.10	39.6	2057	1187	0.96	38.0
		1996	1488	0.83	55.1	2080	1278	0.98	37.1	2098	1248	0.96	37.4

may occur due to inclusion of any unusual year (having unusual distribution) in the calculation. Also, these discrepancies can be attributed to the corresponding rainwater tank reliability, which is affected by unusual distribution. Figure 2a–d show the average of the three values of calculated reliabilities under all the categories and weather conditions for; a) Manly, b) Sunnybank, c) Toombul and d) Oxley. From the figures, some of the earlier-mentioned discrepancies can be justified. Few examples are; i) Manly average year RCP4.5 showing higher water savings even though annual rainfall amount is expected to decrease; this can be attributed to higher reliability for the same scenario, ii) Manly wet year RCP8.5 showing lower water savings even though annual rainfall amount remains almost same; this can be attributed to lower reliability for the same scenario, and iii) Toombul average year RCP4.5, Toombul wet year RCP4.5 & RCP8.5 all showing higher water savings even though annual rainfall amounts are expected to decrease; these all can be attributed to higher reliabilities for the same corresponding scenarios.

Figure 3a–d show the relationships between the calculated reliabilities and expected annual water savings considering data from all the categories and weather conditions for; a) Manly, b) Sunnybank, c) Toombul and d) Oxley. It is found that for all the stations, variations of annual water savings linearly vary with the variations of reliabilities. It is to be noted that the calculated reliabilities can be represented with the corresponding SI values, and earlier studies (Jenkins 2007; Imteaz et al. 2021b) have established linear relationships between SI and the rainwater tanks' water saving efficiency. Following sections describe the potential climate change impacts on such established relationships.

3.2 Impacts on Water Saving Efficiency

To evaluate the impacts of future SI values and its relationship with the water savings efficiency under climate change scenario, eTank model was used for calculating potential annual water savings for all the selected years. For the selected years, daily projected rainfall values were downloaded from the mentioned data source and fed as input data in the model. Other model parameters are mentioned in the 'Methodology' section. Rainwater saving efficiency was defined as the ratio of expected annual water savings and annual rainfall amount (Imteaz et al. 2021a).

Figure 4 shows the scattered plot of calculated SI values with the corresponding water savings efficiency values. An expected general trend is that with the increase of SI values, water savings efficiency decreases; trendline drawn (solid line) on the plot conforms with the expected general trend. Figure 4 also shows two more dashed lines derived from earlier studies showing the earlier established relationships between SI values and water savings efficiencies. Among the two dashed lines, the upper line is based on historical rainfall data from several Australian cities described in Imteaz et al. (2021b) and the lower line is through impact of future climate change scenario based on projected rainfall data for Sydney described by Imteaz and Hossain (2023). The average trendline under climate change scenario presented in the later study (with Sydney data) followed exactly similar trend having same slope of the earlier developed trendline based on historical data from six cities. Imteaz and Hossain (2023) reported that overall water savings efficiency under climate change scenario will be lower than the water savings efficiency based on historical values even with the same SI value. Current study reveals that such overall general reduction in water savings cannot be generalised, as in the figure it is shown that the future relationship
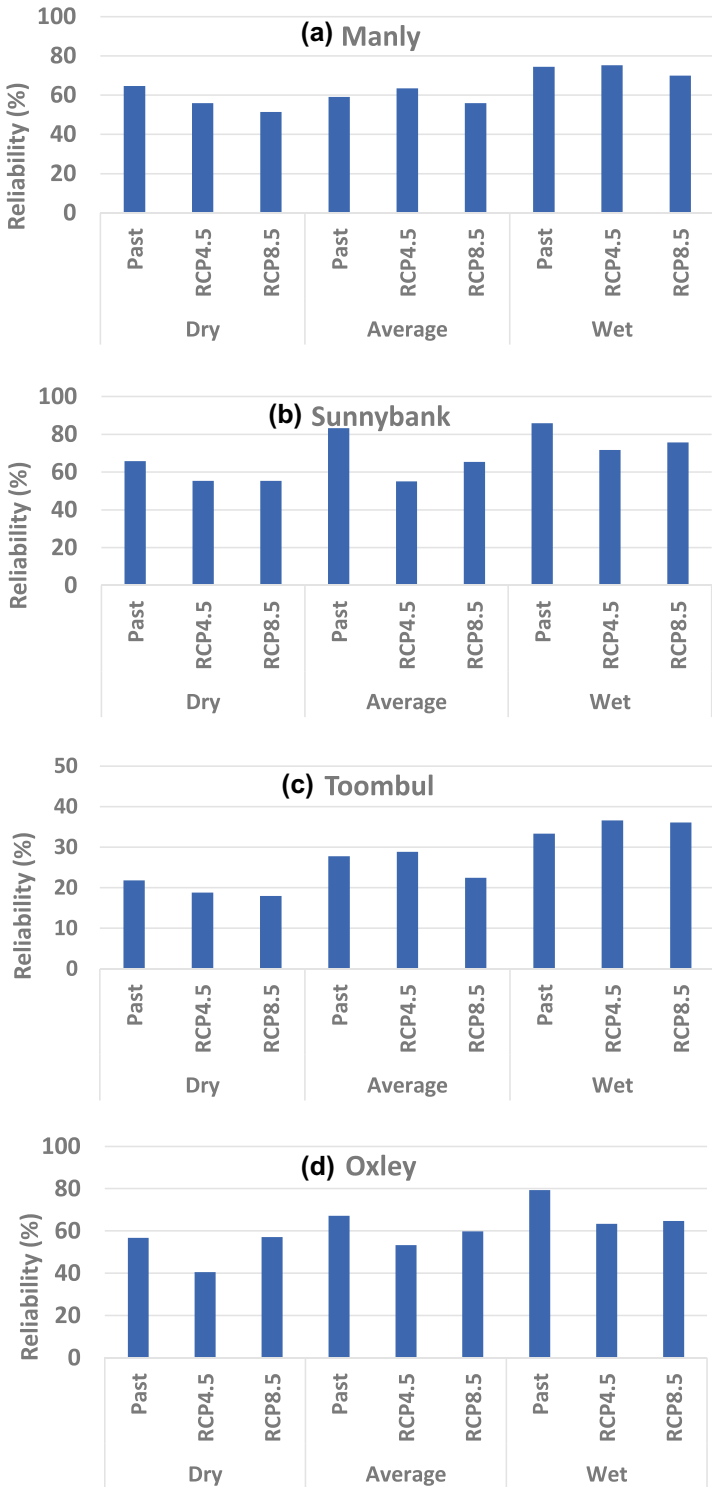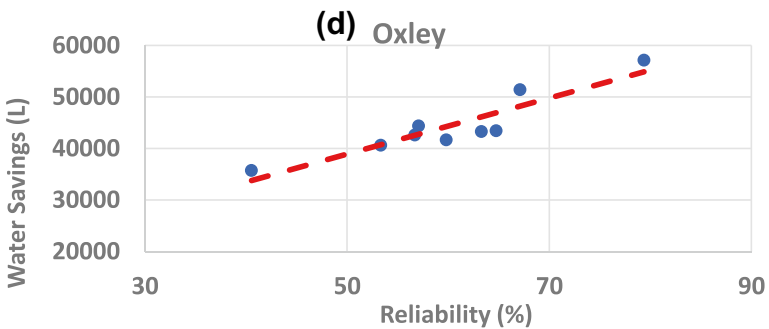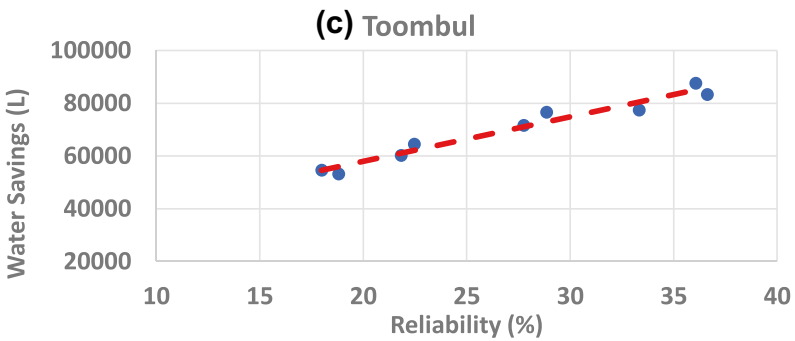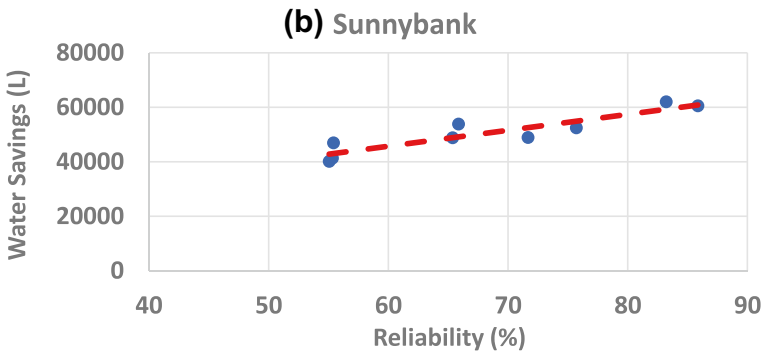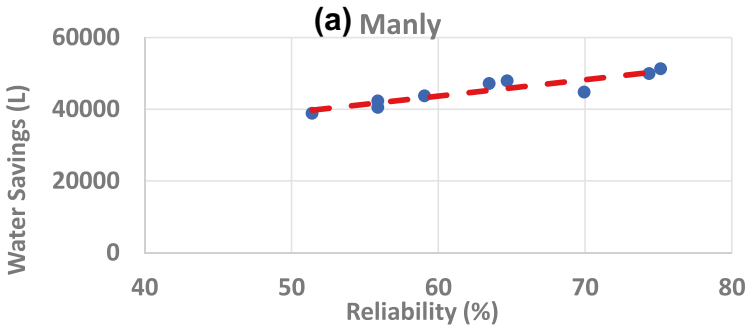
with water savings efficiency and SI is likely to be steeper as per the Brisbane projected
data. With the Brisbane data, under the climate change scenario, for lower SI values (<0.8)
water savings efficiency is likely to increase, whereas for higher SI values (>0.8) water
savings efficiency is likely to decrease.

Imteaz and Hossain (2023) has shown that relationships significantly vary among the stations
within a city (i.e. Sydney). To explore such spatial variabilities, For more clarity, Fig. 5 shows
separate best-fit trendlines for all the four locations, which reveals significant spatial variations.
Current findings conform with the earlier findings of Imteaz and Hossain (2023), who concluded
that in addition to impacting rainfall magnitude and intensity, climate change will also impact
intra-annual rainfall pattern, which will eventually impact waters savings efficiency through rain-
water tanks. Moreover, such impacts will not be spatially uniform over a large city, i.e. magni-
tudes of deviations are likely to be different for different areas within a large city.

To assess the effect of the representative concentration pathway (RCP) scenarios on
such relationship, Fig. 6 shows the relationships of future water savings efficiencies with
the corresponding SI values for the two RCPs considered in this study, along with the
established relationship based on historical data. It is shown that the average relationship
curve for RCP4.5 is steeper than the average relationship curve for RCP8.5, i.e. deviations
from the past established relationship are likely to be more for the case of RCP4.5 in com-
pared to the case of RCP8.5, while both having similar trend.

3.3 Effects of Roof Area and Water Demand

As potential water savings efficiency values and its relationship with the SI is likely to be
affected by the roof area and rainwater demand, further calculations were performed to cal-
culate future water savings efficiencies with different roof area and rainwater demand for all
the stations under both the RCP4.5 and RCP8.5 scenarios. It is to be noted that Imteaz and
Hossain (2023) presented similar relationships with varying roof area and rainwater demand,
however considering only one station from a large city, Sydney. Whereas, this study estab-
lished the similar relationships incorporating all the data from all the four stations in Brisbane.
For the sake of comparison, the input variables are kept same; to assess the effect of roof area,
two roof areas considered were 100 m² and 200 m2, while the demand was assumed as 200 L/
day and to assess the effect of demand, two demands considered were 200 L/day and 300 L/
day, while the roof area was assumed as 200 m². Figure 7 shows the effect of roof area on the
relationship water savings efficiency with SI. From the figure it is found that overall trends of
both the best-fit curves follow the similar pattern, while an average 25% increase in water sav-
ings efficiency with a roof area of 200 m² compared to a roof area of 100 m². It is to be noted
that Imteaz and Hossain (2023) through data of only one station in Sydney reported an average
increase of 20% in water savings efficiency with the same increment of roof area. Figure 8
shows the effect of rainwater demand on the relationship of water savings efficiency with SI.
It is found that overall trends of both the best-fit curves follow the similar pattern, while an
average 20% increase in water savings efficiency with a demand of 300 L/day compared to a
demand of 200 L/day. Imteaz and Hossain (2023) through data of only one station in Sydney
reported an average increase of 20% in water savings efficiency with the same increment of
roof area. In both the above-mentioned cases, the produced best-fit lines are converging with
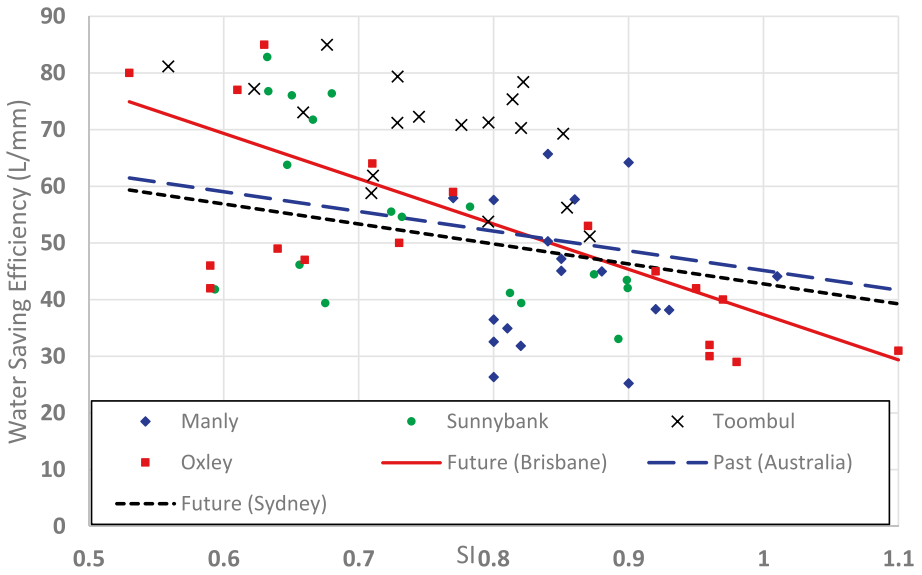the increase of SI value.

(a) Manly

(b) Sunnybank

(c) Toombul

(d) Oxley

Fig. 4 Relationship between SI and water savings efficiency and comparison with earlier studies
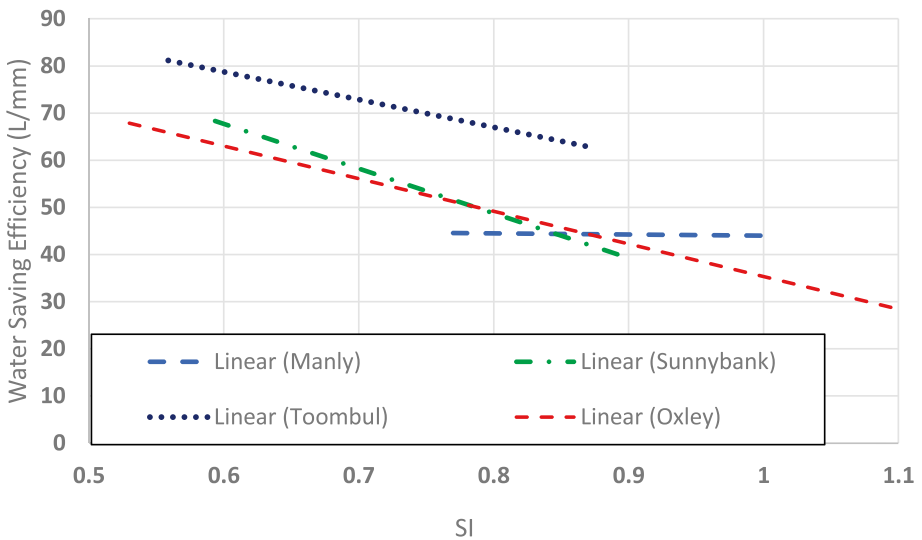

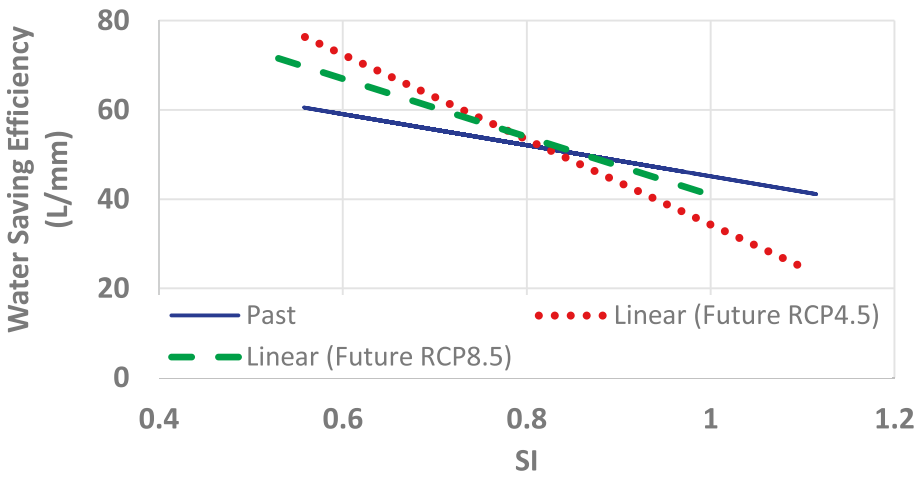**Fig. 5** Individual trendlines for SI value versus water savings efficiency for four locations

Fig. 6 Trendlines for SI value versus water savings efficiency showing two RCPs separately
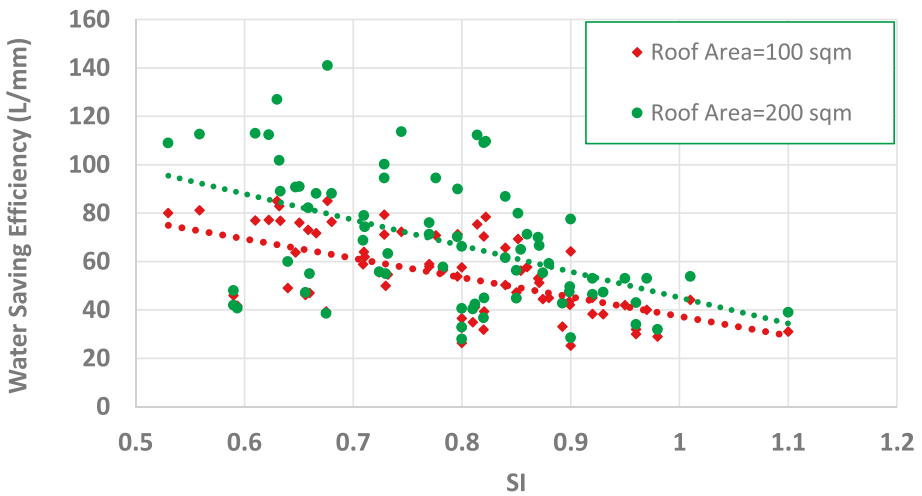

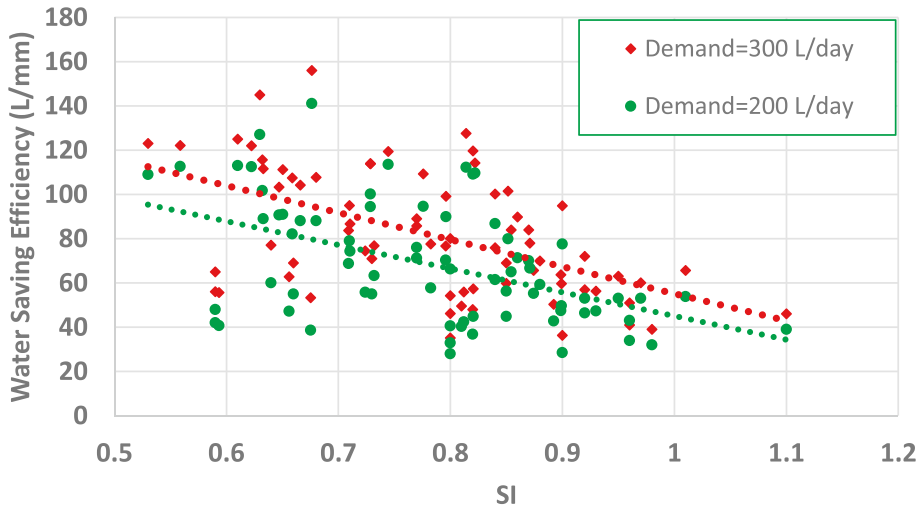**Fig. 7** Effect of roof area on SI-water savings efficiency relationship

Fig. 8 Effect of rainwater demand on SI-water savings efficiency relationship

4 Conclusions

It is anticipated that the climate change impacts will not be only limited to magnitudes of rainfall amounts, rather also on the frequency and distribution of rainfalls, and such variations will be different for different cities. As such variations will have significant influences on sustainable water resources management including green infrastructures, this study investigated potential climate change impacts on future water savings, reliability and water savings efficiency of rainwater tanks considering rainfall data from the third-largest Australian city, Brisbane. Also, as intra-annual rainfall variabilities can be well-represented by the seasonality index (SI), which was well-related with the rainwater tanks water savings efficiency, this study also explored the effect of climate change on the relationship of SI and water savings efficiency. Four rainfall stations covering the whole metropolitan Brisbane with fewer/no missing rainfall data were selected for this purpose. Future rainfall data were extracted from Australian government's Climate Change in Australia (CCIA) data portal. As it is offered from the data portal, the future rainfall data was analysed under two projection scenarios; RCP 4.5 and RCP 8.5. To explore any variation among the weather conditions, available data were segregated under three weather conditions; dry, average and wet. An earlier developed daily water balance model, eTank was used for the estimations of water savings and reliability through a rainwater tank. For comparison with the earlier similar studies, the following rainwater tank parameters were considered; roof area = 100 m², rainwater demand = 200 L/day, tank volume = 5000 L and rainfall loss = 15%. Later, for the assessment of the effects of roof area and rainwater demand, additional simulations were performed with a roof area of 200 m², as well as for a rainwater demand of of 300 L/day.

From the results it is revealed that for most of the studied cases in all the stations the expected future water savings through rainwater tanks are likely to decrease, except in very few cases. Also, it is found that increase/decrease of annual water savings not solely depends on annaul increase/decrease of rainfall amounts. Rather rainwater tank reliability values are having significant influence on annual water savings and for all the stations variations of annual water savings are linearly correlated with the variations of reliabilities in

each station. Findings on relationship between SI and water savings efficiency reveals that an earlier finding of average reduction in water savings efficiency cannot be generalised for all the cities, rather from the current study it is found that the future relationship with water savings efficiency and SI is likely to be steeper compared to the relationship based on historical data; for lower SI values (<0.8) future water savings efficiency is likely to increase, whereas for higher SI values (>0.8) future water savings efficiency is likely to decrease. Contrary to the general perception, it is found that the average SI-water savings efficiency relationship curve under the RCP4.5 scenario is likely to be steeper than the average relationship curve under the RCP8.5 scenario. It is found that an increase in connected roof area from 100 m^2 to 200 m^2 is likely to cause an average 25% increase in annual water savings efficiency. And, with an increase in rainwater usage from 200 L/day to 300 L/day is likely to cause an average 20% increase in annual water savings efficiency. Combining with the earlier study, this can now be generalised that an increase of roof area from 100 to 200 m^2 or rainwater usage from 200 to 300 L/day is likely to deliver an increase in rainwater saving efficiency by 20–27%.

It is to be noted that the current study was perfomred with ACCESS 1.0 climate model projected data. Obviously, there are uncertainties with model projected data, which is a separete vast study and was out of scope for this study. However, future study should investigate the same effects with other climate model data and difference of current findings with the findings of other model projected data.

Declarations

Ethical Approval Not required as no animal/human was involved in the study.

Consent to Participate Authors agreeing to participate any survey or feedback tasks.

Consent to Publish Authors providing consent publication of the manuscript to the journal publisher.

Competing Interests There is no competing interest in regard to the study.

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