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Rainwater 'Piggy Banks' and Green Roofs in School Buildings: Integrated Strategies for Sustainable Water Management

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Abstract

This study evaluates integrated water-saving strategies in two school centres (SC1 and SC2) located in Bragança, Portugal, combining rainwater harvesting systems (RWHS), green roofs (GR), and the replacement of conventional taps with high-efficiency models. Water consumption patterns were analysed, and nine scenarios were simulated to assess their feasibility and economic performance. Scenario 1, which focuses on replacing conventional taps, achieved the highest short-term cost-effectiveness, reducing potable water consumption by approximately 30% and providing a payback period of about one year. Scenario 3, integrating RWHS into conventional roofs with efficient taps, demonstrated the greatest overall benefits, reducing potable water demand by up to 60% and generating annual savings exceeding €7000 + VAT, with payback periods of eight years for SC1 and seven years for SC2. In contrast, scenarios involving extensive GR significantly reduced stormwater runoff but required higher investments and presented longer payback periods, ranging from 17 to 42 years. Overall, the results indicate that combining low-cost efficiency measures with RWHS maximises potable water savings and supports sustainable water management, while GR implementation should be considered selectively, particularly when broader ecological and thermal benefits are prioritised.

Keywords: water efficiency; rainwater harvesting; green roofs; school buildings; sustainability

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1. Introduction

Excessive resource consumption and rapid urban expansion are intensifying pressures on water, energy, food, and ecological systems [1–4], contributing to global environmental challenges such as climate change, air pollution, urban heat islands, and biodiversity loss [5,6]. Among these challenges, water stands out as one of the most vulnerable and strategic resources, making its sustainable management essential to safeguard ecosystem integrity and human well-being. Developing resilient and efficient approaches to water use has, therefore, become a key priority to mitigate these pressures and support sustainable development. To address these challenges, sustainable solutions such as rainwater harvesting systems (RWHS) and green roofs (GR) are being increasingly adopted to improve water efficiency and enhance urban sustainability [7,8].

RWHS provides a practical and scalable solution for both public and private buildings [9–13]. Depending on system design and usage, potable water savings range from 12%

to 100%, reaching 38–69% when rainwater is used for non-potable purposes such as toilet flushing, laundry, and irrigation [14–19]. In addition to reducing consumption, RWHS enhances water supply reliability, contributes to aquifer recharge, reduces stormwater runoff during heavy rainfall, and, when integrated with existing infrastructures, further improves water management efficiency and resilience [20–23]. Their adoption is increasingly supported by public policies due to their low environmental impact, easy implementation, and moderate operational costs [13,15,22,24].

GR are nature-based solutions consisting of vegetation layers placed over impermeable surfaces, designed to manage rainwater and improve building performance [25–28]. Based on substrate depth, they are classified as extensive (<15 cm), semi-intensive (15–25 cm), and intensive (>25 cm), with extensive systems being particularly suitable for retrofitting due to their lower weight, cost, and maintenance needs [29–31]. GR retains, delays, and evapotranspires rainfall, reducing runoff volume and peak discharge while improving water quality and enabling its reuse. They also contribute to urban sustainability by lowering surface temperatures, reducing greenhouse gas emissions, mitigating heat island effects, and enhancing air quality. Other benefits include increased biodiversity, noise reduction, energy savings, and positive impacts on well-being and comfort [23,25,32–42].

Nevertheless, the research cited above has mainly examined the hydrological and environmental performance of RWHS and GR under different climatic and urban conditions, providing valuable insights but generally treating them as isolated rather than complementary strategies. Their combined implementation—particularly in institutional buildings—remains underexplored [8,43,44], despite the potential to deliver significant environmental benefits [7,45–47]. In this context, the present study proposes a framework that integrates both RWHS and GR to evaluate their potential combined contribution to water savings and economic feasibility in educational buildings. Educational facilities generally tend to exhibit substantial water consumption due to daily activities and high occupancy levels [8,48–50]. Therefore, two schools in Bragança, Portugal—Centro Escolar de Santa Maria (SC1) and Centro Escolar da Sé (SC2)—were selected as reference sites for scenario analysis. This study relies on hypothetical implementation scenarios to assess the potential water savings and cost-effectiveness achievable in these buildings. The approach may be extrapolated to similar institutional buildings in other regions, providing insights to support future decision-making on sustainable water management.

2. Materials and Methods

The methodological framework of this study comprised three main steps: (i) characterisation of the study area and assessment of water demand in the selected schools, (ii) simulation of different water-saving scenarios, and (iii) evaluation of the technical and economic feasibility of each scenario.

2.1. Case Studies and Water-Saving Scenarios

Bragança is a medium-sized city located in northeastern Portugal (41°48′10″ N, 6°45′25″ W; 673 m a.s.l.; 34,582 inhabitants [51]). The region has a predominantly continental climate with Mediterranean influences, characterised by cold winters, dry summers, and annual precipitation ranging from 700 to 1000 mm, with most rainfall occurring during autumn and winter [52]. SC1 has 313 users (251 students, 53 teachers, and 9 staff), while SC2 has 419 users (354 students, 52 teachers, and 13 staff). Both institutions provide preschool and elementary education. The roofs of SC1 and SC2 measure 1537.79 m^2 and 1804.36 m^2, respectively, and are flat reinforced-concrete roofs with an approximate slope of 2%. Both buildings are connected to the municipal water network.

Bragança Municipality provided an estimate of the water-consumption pattern for both school centres (Table 1).

Table 1. Estimated monthly and annual water consumption of SC1 and SC2.

	SC1			SC2		
Devices	**(m^3/month)**	**(m^3/year)**	**%**	**(m^3/month)**	**(m^3/year)**	**%**
Washbasin taps	56.32	675.84	31.23	77.42	929.02	42.34
Flushing cisterns	55.03	660.36	30.51	63.04	756.44	34.47
Urinals	20.02	240.24	11.10	9.20	176.64	5.03
Kitchen taps	47.41	568.97	26.29	27.60	331.20	15.09
Other uses	1.57	18.79	0.87	5.60	67.20	3.06
Total	180.35	2164.20	100	182.86	2260.5	100

The washbasin taps, flushing cisterns, and kitchen taps together accounted for more than 80% of total potable-water use in both facilities. Based on the water-consumption patterns, nine water-saving scenarios (S1–S9) were established to assess the combined influence of three key measures: (i) installation of efficient taps, (ii) implementation of RWHS, and (iii) integration of GR with different coverage ratios (0%, 50%, 70%, and 100%). The conceptual basis of the scenarios was to evaluate both the isolated and interactive effects of these measures on potable-water savings and their economic performance, identifying scalable and cost-effective solutions adaptable to diverse technical and financial conditions faced by institutional decision-makers. Therefore, the following scenarios were analysed:

- S1—replacement of existing washbasin and kitchen taps with efficient models
- S2—installation of an RWHS with conventional roofs;
- S3—combination of S1 and S2;
- S4—RWHS integrated with a full green roof;
- S5—combination of S1 and S4;
- S6—RWHS with 50% green and 50% conventional roof;
- S7—RWHS with 70% green and 30% conventional roof;
- S8—combination of S1 and S6;
- S9—combination of S1 and S7.

2.2. Sizing of Rainwater Harvesting Systems

The sizing RWHS was designed using the simplified method based on [19], adopted in Portugal for sizing, designing, constructing, and maintaining such systems. The volume of rainwater to be utilised during a specific period can be determined by the following expression (1):

$$V_a = C \times P \times A \times \eta_f \tag{1}$$

where

- V_a: volume of rainwater in the reference period that can be used (L);
- C: runoff coefficient (dimensionless);
- P: average precipitation accumulated at the site (mm);
- A: roof area (m^2);
- η_f: hydraulic filtering efficiency (dimensionless).

A runoff coefficient (C) of 0.8 was adopted for the concrete roofs of SC1 and SC2, while a lower value of 0.5 was applied for the extensive green roofs. According to ETA 0701 [19], these coefficients are based on international standards and adapted to national climatic conditions, reflecting the higher permeability and water retention capacity of green roofs. The value adopted for the hydraulic filtering efficiency (η_f = 0.9) corresponds to systems operating under regular maintenance and cleaning conditions, as recommended by the manufacturer. Average monthly rainfall data were obtained from [52], based on records from 2014 to 2024.

2.3. Economic Feasibility of the Proposed Scenarios

The initial investment estimates and the technical and economic feasibility analysis for each scenario were based on 2025 market prices. Economic viability was evaluated through the estimation of initial implementation costs, expected savings on water bills, and the payback period. The payback period was calculated as the ratio between the initial investment and the annual savings in water bills.

For S1, the replacement of "Class C" washbasins and kitchen taps with "Class A" devices (corresponding to the highest efficiency rating in the Portuguese labelling system [53]) was simulated. In this case, only the acquisition cost of the devices was considered, since installation and maintenance are carried out by municipal staff.

For scenarios involving the installation of RWHS, the investment comprised the acquisition and installation of the RWHS unit, remodelling of the rainwater drainage network, adaptation of the water supply network, and installation of a pump set with its accessories, as described in [54]. The estimated service life of the RWHS is at least 20 years, according to manufacturers' specifications. Although maintenance requirements are relatively low, regular inspections and periodic filter cleaning are essential to ensure proper performance and to extend the system's operational lifetime [19]. Energy consumption associated with the pumping system was not included in the financial projections. Although RWHS generally requires a pressurisation system, the associated energy demand is comparable to or lower than the conventional public supply [11]. According to manufacturers, the pumps used in the system have an estimated lifetime of at least 10 years, requiring minimal maintenance, mainly limited to periodic cleaning of condensate plugs and built-in check valves, which can typically be performed annually or as needed.

The green roof typology selected for the GR scenarios was an extensive system with a saturated weight of approximately 1 kN m^{-2}, suitable for existing buildings and requiring minimal structural reinforcement. The system included a substrate layer 8–15 cm thick and a vegetation cover mainly composed of *Sedum* spp. and other herbaceous species adapted to Mediterranean climates. This typology was also chosen for its low maintenance requirements compared with other roof types [25,55] and its long service life (30–40 years [25]), which matches that of the building's waterproofing system. Its higher durability compared with conventional roofs (~20 years) reduces replacement frequency and long-term operational costs [46]. For the GR scenarios, the investment analysis included the supply and installation of all functional layers: vegetation, substrate, filtration, drainage, protective membranes, and anti-root barriers. Based on market data and manufacturers' information, the total installation cost was estimated at approximately €100 m^{-2} + VAT, including materials and labour.

The initial investment projections included all expenses related to the replacement of taps, RWHS installation, and GR implementation. Expected reductions in annual water bills were estimated using the current municipal water tariffs of Bragança [56]. Projected costs were adjusted for inflation using an average Consumer Price Index (CPI) increase of 2.4% for 2025 [57], and the standard Portuguese VAT rate of 23% was applied [58].

3. Results and Discussion

3.1. Proposed Scenarios and Their Impact on Potable Water Saving

The RWHS storage tank capacities were set at 60 m^3 for SC1 and 70 m^3 for SC2 to achieve a cost-effective balance between system performance and overall investment, given that the storage tank represents the largest cost component of the RWHS [59–62]. In Scenario 2 (conventional roofs only), the RWHS could supply up to 619.7 m^3 in SC1 (93.84% of annual flushing demand) and 716.0 m^3 in SC2 (94.65%). Under S4 (100% GR), the harvested volumes decreased considerably, reaching 514.1 m^3 in SC1 and 603.3 m^3 in SC2 (Table 2).

Table 2. Simulated rainwater harvesting performance with storage tank capacities of 60 m^3 for SC1 and 70 m^3 for SC2.

Rainwater Harvesting				
	SC1		**SC2**	
Tank capacity (m^3)	60		70	
Conventional roofs (S2)	619.7 m^3	93.84%	716.0 m^3	94.65%
100% Green roofs (S4)	514.1 m^3	77.86%	603.3 m^3	79.75%
50% conventional roofs and 50% green roofs (S6)	587.0 m^3	88.89%	677.6 m^3	89.58%
70% green roofs and 30% conventional roofs (S7)	573.9 m^3	86.91%	662.3 m^3	87.55%

This reduction was explained by the greater rainfall retention within the GR substrate, with part of the captured water being lost through evapotranspiration [7,44].

These results are consistent with previous research on GR retention dynamics [47,63,64]. Under Scenario 4, rainfall retention reached 308.5 m^3 in SC1 and 362.0 m^3 in SC2, corresponding to about 37.5% of potential rainfall capture. For mixed configurations, retention decreased in proportion to GR area: S6 (50% GR) retained 154.2 m^3 (SC1) and 181.0 m^3 (SC2), while S7 (70% GR) achieved 215.9 m^3 (SC1) and 253.4 m^3 (SC2). These observations highlight the non-linear effect of increasing GR coverage. Although larger vegetated areas enhance stormwater retention and reduce runoff, they simultaneously decrease the volume available for reuse, thereby limiting overall RWHS performance.

The performance of the RWHS is also reflected in the supplemental public water required to meet residual demand. Under S2, additional volumes were minimal—40.64 m^3 (SC1) and 40.44 m^3 (SC2)—and restricted to the driest months (August and September). In contrast, Scenario 4 (100% GR) required the highest supplemental supply—146.20 m^3 in SC1 and 153.19 m^3 in SC2—extending over a longer period (June to September), with SC1 also requiring extra water in May. Intermediate outcomes were observed for mixed configurations: S6 (50% GR) required 73.36 m^3 (SC1) and 78.83 m^3 (SC2), while S7 (70% GR) required 86.45 m^3 and 94.19 m^3, respectively (Appendix A; Tables A1–A8). The impact of the proposed scenarios on potable water savings is summarised in Tables 3 and 4.

Table 3. The impact of the proposed scenarios on potable water savings SC1.

Average Annual Potable Water Consumption Volume for Each Scenario (m^3)										
	Initial	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Flushing cisterns	660.34	660.34	40.64	40.64	146.20	146.20	73.36	86.45	73.36	86.45
Washbasin taps	675.84	337.92	675.84	337.92	675.84	337.92	675.84	675.84	337.92	337.92
Kitchen taps	568.97	253.44	521.80	253.44	521.80	253.44	521.80	521.80	253.44	253.44
Urinals	240.24	240.24	240.24	240.24	240.24	240.24	240.24	240.24	240.24	240.24
Other uses	18.79	18.79	18.79	18.79	18.79	18.79	18.79	18.79	18.79	18.79
Total	660.34	660.34	40.64	40.64	146.2	146.2	73.36	86.45	73.36	86.45
Savings (%)		30.19	30.81	58.83	25.94	53.95	29.30	28.70	57.32	56.71

Table 4. The impact of the proposed scenarios on potable water savings for SC2.

	Average Annual Potable Water Consumption Volume with Measures (m^3)									
	Initial	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Flushing cisterns	756.44	756.44	40.44	40.44	153.19	153.19	78.83	94.19	78.83	94.19
Washbasin taps	929.02	437.93	929.02	437.93	929.02	437.93	929.02	929.02	437.93	437.93
Kitchen taps	331.20	165.60	331.20	165.60	331.20	165.60	331.20	331.20	165.60	165.60
Urinals	176.64	176.64	176.64	176.64	176.64	176.64	176.64	176.64	176.64	176.64
Other uses	67.20	67.20	67.20	67.20	67.20	67.20	67.20	67.20	67.20	67.20
Total	2260.5	1603.81	1544.5	887.81	1657.24	1000.56	1582.89	1598.24	926.2	941.56
Savings		29.05%	31.67%	60.73%	26.69%	55.74%	29.98%	29.30%	59.03%	58.35%

For SC1, annual savings ranged from 30.19% in S1 (efficient taps only) to 58.83% in S3, where RWHS on conventional roofs was combined with efficient taps. SC2 followed a similar trend, with savings ranging from 29.05% (S1) to 60.73% (S3). These results are consistent with previous studies reporting annual water savings between 12% and 79% across diverse RWHS applications [65–67], 21% to 100% in residential systems (average 76%) [68], approximately 21.6% for domestic uses [69], and up to 74.4% when combining RWHS with efficient taps for toilet flushing [14]. In contrast, scenarios with higher GR coverage showed lower savings due to reduced harvested volumes: in S4 (100% GR), savings dropped to 25.94% (SC1) and 26.69% (SC2), while Scenario 7 (70% GR) achieved 28.70% (SC1) and 29.30% (SC2). Although integrating RWHS with GR can enhance stormwater management by delaying runoff and reducing overflows, the additional retention limited the water volume available for use [7,44]. However, given the limited number of studies addressing the combined performance of these systems, further comparative research is needed to better evaluate their potential and optimise design strategies.

Overall, the results obtained demonstrate that maximising potable water savings requires a careful balance between RWHS storage capacity and GR retention. Among all configurations, S3, which combined RWHS on conventional roofs with efficient taps, achieved the highest savings, with 58.83% in SC1 and 60.73% in SC2, while maintaining minimal dependence on the public water supply.

3.2. Economic Feasibility of the Proposed Scenarios

Table 5 (SC1) and Table 6 (SC2) summarise the results for the nine scenarios, including installation costs, cost breakdown, annual savings, and corresponding payback periods.

Table 5. Initial investment, savings, and payback period for SC1.

	Initial Investment	**Taps**	**RWHS**	**Roofs**	**Water Bill with Measures**	**Annual Bill Reduction**	**Return on Investment**
	(€ + VAT)	**(€ + VAT)**	**(€ + VAT)**	**(€ + VAT)**	**(€/year + VAT)**	**(€/year + VAT)**	**(years)**
S1	2556.00	2556.00	-	-	8699.31	3678.91	1
S2	54,785.57	-	54,785.57	-	8623.83	3754.39	14
S3	57,341.57	2556.00	54,785.57	-	5210.45	7167.77	8
S4	208,564.57	-	54,785.57	153,779.00	9218.11	3160.11	42
S5	211,120.57	2556.00	54,785.57	153,779.00	5804.73	6573.49	25
S6	131,675.57	-	54,785.57	76,890.00	8808.03	3570.19	28
S7	162,430.57	-	54,785.57	107,645.00	8881.71	3496.51	33
S8	134,231.57	2556.00	54,785.57	76,890.00	5394.65	6983.57	17
S9	164,986.57	2556.00	54,785.57	107,645.00	5468.33	6909.89	20

Table 6. Initial investment, savings, and payback period for SC2.

	Initial Investment	Taps	RWHS	Roofs	Water Bill with Measures	Annual Bill Reduction	Return on Investment
	(€ + VAT)	**(€ + VAT)**	**(€ + VAT)**	**(€ + VAT)**	**(€/year + VAT)**	**(€/year + VAT)**	**(years)**
S1	2556.0	2556.00	-	-	9223.39	3697.15	1
S2	49,679.70	-	49,679.70	-	8889.44	4031.09	12
S3	52,235.70	2556.00	49,679.70	-	5192.30	7728.24	7
S4	203,458.70	-	49,679.70	155,779.00	9524.20	3396.34	39
S5	206,014.70	2556.00	49,679.70	155,779.00	5827.05	7093.49	23
S6	139,897.70	-	49,679.70	90,218.00	9105.57	3814.96	28
S7	175,984.70	-	49,679.70	126,305.00	9192.03	3728.51	35
S8	142,453.70	2556.00	49,679.70	90,218.00	5408.43	7512.11	17
S9	178,540.70	2556.00	49,679.70	126.305,00	9223.39	3697.15	20

S1 (replacement of conventional taps with efficient models) stood out as the most cost-effective and straightforward option. This measure required the lowest investment (€2556.00 + VAT in SC1 and €2646.00 + VAT in SC2) and achieved significant annual savings (€3678.91 and €3697.15, respectively), resulting in a payback period of one year for both school centres. Given its simplicity, this measure could likely be implemented by municipal staff. Among the scenarios combining efficient taps with rainwater harvesting systems (RWHS), S3 provided the best balance between technical feasibility, potable water savings, and economic viability. In SC1, it achieved annual savings of 1273.14 m^3 (€7167.77 + VAT/year) with a payback period of eight years, while in SC2 it saved 1372.69 m^3 (€7799.00 + VAT/year) with a payback period of seven years. Other scenarios integrating RWHS, such as S2, S5, and S8, also delivered relevant water savings but required higher investments, leading to longer payback periods ranging from 14 to 42 years.

Scenarios involving green roofs (S4, S6, S7, and S9) required substantially higher initial investments—up to €208,564.57 + VAT in SC1 and €222,672.57 + VAT in SC2—and therefore resulted in extended payback periods of 17 to 42 years. However, green-roof implementation entails greater technical complexity and may involve additional costs that were not accounted for in this study. Prior to installation, it would be necessary to evaluate the structural capacity of the existing buildings, diagnose potential pathologies, determine reinforcement requirements, and ensure compliance with current construction standards and safety regulations [70–74]. Furthermore, maintenance costs for green roofs were not included in the financial analysis. Furthermore, maintenance costs for green roofs were not included in the financial analysis because these activities are expected to be part of the regular maintenance routines performed by municipal staff and should not represent additional operational expenses if any of these scenarios are implemented in the future. In fact, the municipal building of Bragança already includes a green roof maintained by municipal staff in accordance [75]. However, this assumption should be regarded as a limitation when extrapolated to different management contexts.

The available literature highlights the limited number of robust economic analyses for green roof applications and the variability of their associated costs [2,44,49,59], underscoring the need for further context-specific assessments [25,44,76]. Consequently, a phased implementation strategy is recommended: in the short term, prioritising S1 given its high cost-effectiveness and immediate return on investment; in the medium term, integrating RWHS through S3, as it allows for optimised potable water savings with an acceptable payback period; and in the long term, considering the implementation of green roofs (S4, S6, S7, S9), provided that structural feasibility, lifecycle performance, and maintenance requirements are thoroughly addressed. These observations demonstrate that combining low-cost efficiency measures with decentralised water harvesting strategies maximises both environmental and economic benefits, whereas high-cost green infrastructure options should be implemented selectively and strategically.

4. Conclusions

This study provides an integrative framework for evaluating different water-saving strategies. Simultaneously comparing RWHS, GR, and efficient devices, it offers an original contribution by clarifying the trade-offs between stormwater retention and rainwater use, which are usually analysed separately. The proposed approach enables a comprehensive assessment that supports the selection of technically feasible and economically balanced solutions for decentralised water management. Overall, potable-water savings ranged from 38% to 69%, confirming the high efficiency of combined strategies for water demand reduction. Among the solutions analysed, low-cost measures—such as replacing conventional taps with high-efficiency models—proved to be the most effective for reducing potable-water demand. When combined with RWHS, these measures further enhanced water savings, offering an attractive balance between economic feasibility and resource efficiency. In contrast, GR showed more limited economic viability due to higher investment requirements. These results underline the need for context-specific assessments, as the effectiveness of each strategy depends on building characteristics, climatic conditions, and local priorities. Despite its relevance, this study is not exempt from limitations. The analysis was based on simulated scenarios and therefore does not account for potential variations in user behaviour, water-use patterns, or maintenance efficiency. Maintenance costs were also excluded from the financial analysis, as they are currently integrated into municipal routines, which may differ under other management contexts. Likewise, some additional costs related to technical assessments or structural reinforcements were not considered and should be included in future evaluations. Future research should address the implementation and long-term monitoring of combined systems under real operating conditions to validate the assumptions used and refine the simulations. Further studies are also needed to assess the structural performance of GR when integrated with RWHS and to explore the use of digital tools and artificial intelligence for real-time optimisation of water use and system performance. Extending this type of analysis to different building typologies and diverse climatic contexts would provide valuable insights to support more informed decisions in sustainable water management.

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Appendix A

Table A1. Simulation of reservoir sizing using conventional coverage (S2) at the SC1.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1537.79	115.25	55.03	60.22	60	60.00	0.00
November	94.63		104.77	55.03	49.74		60.00	0.00
December	86.38		95.64	55.03	40.61		60.00	0.00
January	88.62		98.12	55.03	43.09		60.00	0.00
February	74.94		82.97	55.03	27.94		60.00	0.00
March	66.83		73.99	55.03	18.96		60.00	0.00
April	69.88		77.37	55.03	22.35		60.00	0.00
May	47.05		52.09	55.03	−2.94		57.06	0.00
June	38.82		42.98	55.03	−12.05		45.01	0.00
July	10.24		11.33	55.03	−43.69		1.32	0.00
August	13.89		15.38	55.03	−39.65		0.00	38.33
September	47.61		52.71	55.03	−2.31		0.00	2.31
Total	742.96		822.62	660.34				40.64

Table A2. Simulation of reservoir sizing using conventional coverage (S4) at the SC1.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1537.79	72.03	55.03	17.00	60	17.00	0.00
November	94.63		65.48	55.03	10.45		27.46	0.00
December	86.38		59.78	55.03	4.75		32.21	0.00
January	88.62		61.32	55.03	6.30		38.50	0.00
February	74.94		51.86	55.03	−3.17		35.33	0.00
March	66.83		46.24	55.03	−8.78		26.55	0.00
April	69.88		48.36	55.03	−6.67		19.88	0.00
May	47.05		32.56	55.03	−22.47		0.00	2.59
June	38.82		26.86	55.03	−28.17		0.00	28.17
July	104.09		11.33	55.03	−43.69		0.00	47.94
August	94.63		15.38	55.03	−39.65		0.00	45.42
September	86.38		52.71	55.03	−2.31		0.00	22.08
Total	742.96		514.13	660.34				146.20

Table A3. Simulation of reservoir sizing using conventional coverage (S6) at the SC1.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	768.90	93.64	55.03	38.61	60	38.61	0.00
November	94.63		85.13	55.03	30.10		60.00	0.00
December	86.38		77.71	55.03	22.68		60.00	0.00
January	88.62		79.72	55.03	24.69		60.00	0.00
February	74.94		67.41	55.03	12.39		60.00	0.00
March	66.83		60.12	55.03	5.09		60.00	0.00
April	69.88		62.87	55.03	7.84		60.00	0.00
May	47.05		42.32	55.03	−12.71		47.29	0.00
June	38.82		34.92	55.03	−20.11		27.19	0.00
July	104.09		9.21	55.03	−45.82		0.00	18.63
August	94.63		12.50	55.03	−42.53		0.00	42.53
September	86.38		42.83	55.03	−12.20		0.00	12.20
Total	742.96		668.37	660.34				73.36

Table A4. Simulation of reservoir sizing using conventional coverage (S7) at the SC1.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1076.45 [(a)] 461.34 [(b)]	85.00	55.03	29.97	60	29.97	0.00
November	94.63		77.27	55.03	22.24		52.21	0.00
December	86.38		70.54	55.03	15.51		60.00	0.00
January	88.62		72.36	55.03	17.33		60.00	0.00
February	74.94		61.19	55.03	6.16		60.00	0.00
March	66.83		54.57	55.03	−0.46		59.54	0.00
April	69.88		57.06	55.03	2.04		60.00	0.00
May	47.05		38.42	55.03	−16.61		43.39	0.00
June	38.82		31.70	55.03	−23.33		20.06	0.00
July	104.09		8.36	55.03	−46.67		0.00	26.61
August	94.63		11.34	55.03	−43.69		0.00	43.69
September	86.38		38.88	55.03	−16.15		0.00	16.15
Total	742.96		606.68	660.34				86.45

[(a)] Area of 70% of the total existing coverage; [(b)] Area of 30% of the total existing coverage.

Table A5. Simulation of reservoir sizing using conventional coverage (S2) at the SC2.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1804.36	135.23	63.04	72.19	70	70.00	0.00
November	94.63		122.93	63.04	59.90		70.00	0.00
December	86.38		112.22	63.04	49.19		70.00	0.00
January	88.62		115.13	63.04	52.09		70.00	0.00
February	74.94		97.35	63.04	34.32		70.00	0.00
March	66.83		86.82	63.04	23.78		70.00	0.00
April	69.88		90.79	63.04	27.75		70.00	0.00
May	47.05		61.12	63.04	−1.92		68.08	0.00
June	38.82		50.43	63.04	−12.61		55.47	0.00
July	104.09		13.30	63.04	−49.74		5.74	0.00
August	94.63		18.05	63.04	−44.99		0.00	39.26
September	86.38		61.85	63.04	−1.19		0.00	1.19
Total	742.96		965.21	756.44				40.44

Table A6. Simulation of reservoir sizing using conventional coverage (S4) at the SC2.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1804.36	84.52	63.04	21.48	70	21.48	0.00
November	94.63		76.83	63.04	13.80		35.28	0.00
December	86.38		70.14	63.04	7.10		42.38	0.00
January	88.62		71.95	63.04	8.92		51.30	0.00
February	74.94		60.85	63.04	−2.19		49.11	0.00
March	66.83		54.26	63.04	−8.78		40.33	0.00
April	69.88		56.74	63.04	−6.30		34.03	0.00
May	47.05		38.20	63.04	−24.84		9.20	0.00
June	38.82		31.52	63.04	−31.52		0.00	22.32
July	104.09		8.31	63.04	−54.73		0.00	54.73
August	94.63		11.28	63.04	−51.76		0.00	51.76
September	86.38		38.66	63.04	−24.38		0.00	24.38
Total	742.96		603.26	756.44				153.19

Table A7. Simulation of reservoir sizing using conventional coverage (S6) at the SC2.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	902.18	109.87	63.04	46.84	70	46.84	0.00
November	94.63		99.88	63.04	36.85		70.00	0.00
December	86.38		91.18	63.04	28.14		70.00	0.00
January	88.62		93.54	63.04	30.50		70.00	0.00
February	74.94		79.10	63.04	16.06		70.00	0.00
March	66.83		70.54	63.04	7.50		70.00	0.00
April	69.88		73.76	63.04	10.73		70.00	0.00
May	47.05		49.66	63.04	−13.38		56.62	0.00
June	38.82		40.97	63.04	−22.06		34.56	0.00
July	104.09		10.80	63.04	−52.23		0.00	17.67
August	94.63		14.66	63.04	−48.38		0.00	48.38
September	86.38		50.25	63.04	−12.78		0.00	12.78
Total	742.96		668.37	756.44				78.83

Table A8. Simulation of reservoir sizing using conventional coverage (S7) at the SC2.

Month	Monthly Precipitation (mm)	Roof Area (m^2)	Available Rainwater Volume (m^3)	Monthly Consumption (m^3)	Available Consumption (m^3)	Cistern Volume (m^3)	Water at the End of the Month (m^3)	Public Network Supply (m^3)
October	104.09	1263.05 (a) 541.31 (b)	99.73	63.04	36.69	60	36.69	0.00
November	94.63		90.66	63.04	27.63		64.32	0.00
December	86.38		82.76	63.04	19.73		70.00	0.00
January	88.62		84.91	63.04	21.87		70.00	0.00
February	74.94		71.80	63.04	8.76		70.00	0.00
March	66.83		64.03	63.04	0.99		70.00	0.00
April	69.88		66.95	63.04	3.92		70.00	0.00
May	47.05		45.07	63.04	−17.96		52.04	0.00
June	38.82		37.19	63.04	−25.84		26.19	0.00
July	104.09		9.81	63.04	−53.23		0.00	27.04
August	94.63		13.31	63.04	−49.73		0.00	49.73
September	86.38		45.62	63.04	−17.42		0.00	17.42
Total	742.96		711.84	756.44				94.19

(a) Area of 70% of the total existing coverage; (b) Area of 30% of the total existing coverage.

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