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Rainwater harvesting for watering greenery at Polish university as a climate change adaptation strategy

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Abstract. Considering progressive climate change and decreasing water resources, rainwater harvesting is gaining popularity as an alternative water source. This research presents the concept of sustainable rainwater management at the Wrocław University of Science and Technology (Poland). In the proposed solution, rainwater collected in a tank will be used for watering green areas. The Yield After Spillage model was used for analyzing the rainwater harvesting system operation, based on water demand (10 m^3/day) and rainfall data for the 2000–2021 period. Simulations were performed for 14 tank sizes (from 10 to 140 m^3). For each variant, annual needs coverage, water savings and investment costs were calculated. The results indicated that the most attractive in terms of both return period and mains water savings were tanks with intermediate capacities, with the best variant having a capacity of 60 m^3 (corresponding to 6 days' demand), allowing for mains water savings of 77.2% on average.

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1. Introduction

Climate change is becoming increasingly noticeable, posing a challenge to many countries (Kociuba & Wajs, 2021). The results of climate change may be loss of biodiversity of regions, increased temperatures, crop losses, extreme weather phenomena and human health deterioration (EP, 2023). As of 2019, the average global temperature had risen by ~1.1°C compared to the pre-industrial period, represented by the multi-year period 1850–1900, reaching the value of 0.98°C (EC, 2023). A warming of 2°C leads to severe negative consequences (Dobrowolski, 2021; EC, 2023). Currently, more than 3.3 billion people live in regions that can experience water shortages (Dobrowolski, 2021; IPCC, 2007). Extreme events such as floods or droughts are affecting the economies and population growth of regions (Castellari & Kurnik, 2017). Understanding climate change is crucial if its impacts are to be prevented.

According to the World Meteorological Organisation (WMO), Europe is the fastest-warming region (WMO, 2023). Also, high spatial and temporal variability of precipitation (Nogueira, 2020) poses environmental risks in both excess (causing flooding) and deficiency (leading to droughts) (Sun et al., 2021).

Water is one of the most important elements affecting the environment and human activities. It covers more than 70% of the Earth, but only 0.6% is freshwater (GUS, 2020). Accelerating population growth, climate change and water-intensive lifestyles reduce water resources (Setegn et al., 2011; EEA, 2012; EEA, 2021).

Freshwater in Europe can be divided into two main sources: groundwater and surface water. Between the years 2000 and 2019, a slow increase (from 19 to 23%) in total groundwater abstraction was observed, whereas surface water still constitutes the main water source for living purposes. The main factor in this situation is climate change, leading to variations in surface water availability (EEA, 2022).

Water stress occurs when water resources per capita are less than 1,700 m^3 (GUS, 2020; Manungufala, 2022). Currently, four countries in Europe are suffering from water stress, including Poland, with its 1,600 m^3 resources (GUS, 2020). Freshwater in Poland is extracted primarily from groundwater (71%) and surface water (29%) (GCNP, 2018). Poland is a country with small water resources and has the problems of highly variable precipitation and a variable water balance (GCNP, 2018; Piasecki et al., 2023).

One manifestation of climate warming is the frequency of thermal anomalies (Falarz, 2021; Hejduk et al., 2021; Pratap & Markonis, 2022). In Poland, changes in temperature and air humidity are also observed. In recent years, the country has experienced meteorological droughts that have led to water shortages (*Klimat Polski*, 2021). The 20 years (1999–2018) analyzed in the report (Kubiak-Wójcicka & Machula, 2020) indicate a significant climate warming in Poland. The reaction of the catchment area to the rainfall deficit depends on its physiographic characteristics (permeability, type of terrain, climatic conditions, human activities) (Kubiak-Wójcicka & Machula, 2020). The reduced flow in the rivers leads to an increase in the concentration of harmful pollutants (Kubiak-Wójcicka & Bąk, 2018), and extreme weather events can affect water contamination (by organic material, pesticides, or other undesired substances) (Zarrineh et al., 2020; Brosse et al., 2022).

Climate change can be described based on long-term precipitation and temperature trends (Abbass et al., 2022), and it is a multi-sector problem (Hurlbert & Osazuwa-Peters, 2020). In view of climate change, new solutions should be implemented to enable a flexible approach to water resources management (PGWWP, 2020; Fan et al., 2023). The trend of these changes depends on the site location (IPCC, 2021). People derive benefits from nature, and the totality of these benefits is referred to as "ecosystem services". Water functions in ecosystem services can be: supplying (e.g., providing water for drinking and industrial purposes), regulatory (e.g., rainwater retention, hydrological flows regulation, wastewater collection and neutralization, land surface and air purification), habitats (for animals), and cultural (e.g., recreational and educational spaces with a positive impact on health) (Rosiek, 2016).

Nowadays, Poland stands at a large-scale risk related to accelerated climate change (Burchard-Dziubińska & Grzelak, 2022). In recent years, there have been limitations of water supply (IMGW, 2021). The problems were related to pressure drops in the water supply system caused by increased watering of household greenery (de Graaf et al., 2019; PGWWP, 2020).

Water inputs in urban locations include rainfall, surface runoff and groundwater recharge. Evapotranspiration, surface runoff and groundwater discharge are taken as water output. Water retained in the soil, vegetation and other natural features of the urban landscape are responsible for water storage. Urban drainage systems are intended to manage surface runoff and decrease the probability of flooding in urban areas. Traditional drainage systems usually consist of networks of pipes, channels and culverts that transport surface runoff to nearby water bodies (Reyes, 2023). On the other hand, in summer periods, during heavy rainfall, there was an accumulation of rainwater on impermeable surfaces and overloading of the drainage systems due to their insufficient capacity. The practice of sealing surfaces in cities increases flood risk (Rosiek, 2016). Green infrastructure like permeable pavements, green roofs or rain gardens mimic natural hydrological processes and help to manage surface runoff at the source (Reyes, 2023). Metropolitan areas of both hemispheres (Southern and Northern) experience extreme droughts and unsustainable levels of water consumption. Recently, about 80 cities around the world have experienced water shortages caused by droughts. It is expected that the water crisis is going to escalate, which necessitates the search for new sustainable water management solutions (Savelli et al., 2023).

The choice of optimal adaptation to climate change requires an individual approach. The rate, intensity and scope of climate change need to be considered (Kalbarczyk & Kalbarczyk, 2020). Rainwater harvesting (RWH) is one possible way of adapting to climate change. The RWH system is aimed at reducing the stream of rainwater flowing further into the stormwater drainage system. Rainwater is most often collected from roofs, which, combined with a gutter system, enables it to be led to a surface or underground storage tank, mostly made of high-quality plastics or concrete (Ahmed, 1999). Rainwater can be used as a source of water for greenery irrigation, flushing toilets, washing vehicles/machines, or washing clothes (Villarreal & Dixon, 2005). This work presents a concept for a rainwater harvesting system on the Wrocław University of Science and Technology (WUST) campus, where a significant amount of water is used to water greenery during the warm months (from May to September). The proposed location of a rainwater tank is intended to constitute an alternative water source. The solution will provide freshwater and financial savings. The article aims to analyze the changes in meteorological conditions related to climate change and to examine the effectiveness of the proposed solution in terms of operational stability in the face of climate change, employing variant simulations. The investment costs were also analyzed along with possible savings.

2. Research materials and methods

2.1. Research area and proposed RWH system

The research area is situated in the center of Wrocław. The city ranks among the country's highest in term of recorded annual average air temperatures, length of growing season (251 days on average) and number of hot days (>25 °C) per year (50 such days). In recent decades, the number of very hot days (temperature above >35 °C) has been increasing (DATA, 2024; Blachowski and Hajnrych, 2021).

Figure 1 shows a map of the main campus of the university along with the designated roofs of individual buildings belonging to it (in blue) and green areas (in green).

Green areas of the campus are irrigated from May to September using mains water. Table 1 shows water consumption readings from the garden water meters for the years 2017–2021. During five years, the total water consumption for watering the greenery of the university was 14,574.7 m^3.

The largest share in water consumption was attributed to the Professors' Alley – an events and recreation space on the campus, with 7,300 m^2 of grassy area. An average annual water consumption amounts to 1,418.2 m^3 – about 49% of the total irrigation water demand. Slightly less water – 1,325.0 m^3 annually (36%) – is used to water the greenery at the D-1 and D-2 buildings, while the remaining 15% goes to smaller green areas (Fig. 2).

Due to the significant water consumption for irrigation on the campus, a solution was proposed to minimize the mains water usage by implementing a rainwater storage tank as an alternative water source.

It was decided to locate the underground reservoir on the Professors' Alley, as it is characterized by the highest water consumption. The terrain conditions (lack of underground infrastructure) do not exclude the implementation of the proposed solution. It was assumed that rainwater would be collected from buildings C-13 and C-7 (Fig. 3). Large roof surfaces (7,024 m^2 in total) create favorable conditions for accumulating significant rainfall volumes. Rainwater will be discharged into the tank through the existing system of gutters and downspouts.

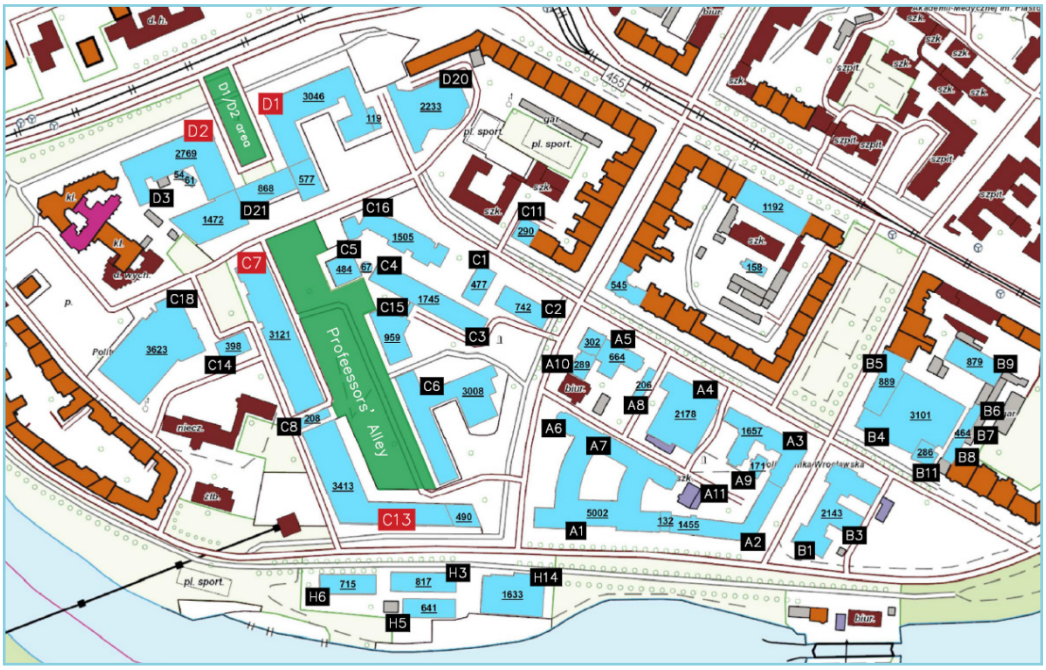

Fig. 1. Map of the WUST campus (building names mentioned in the text are highlighted in red)
Source: own elaboration

Table 1. Water consumption (m^3/year) for irrigation in 2017–2021 on the WUST campus

location	2017	2018	2019	2020	2021	total	mean
Professors' Alley	1,322.0	1,249.0	2,584.0	686.0	1,250.0	7,091.0	1,418.2
Buildings D-1 and D-2	no data	1,256.0	2,733.0	615.0	696.0	5,300.0*	1,325.0*
Other green spaces	274.0	556.0	446.0	444.0	463.7	2,183.7	436.7
Total	1,596.0	3,061.0	5,763.0	1,745.0	2,409.7	14,574.7	3,179.9
*calculated from a 4-year period due to incomplete data							

Source: own elaboration

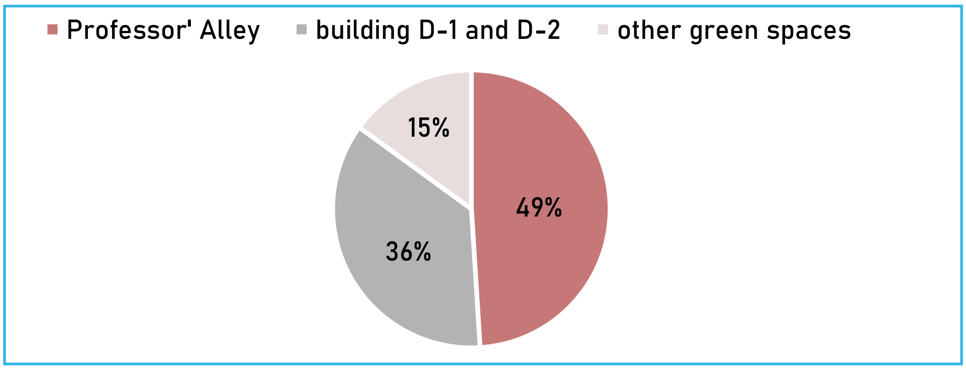

Fig. 2. Mains water intake distribution for irrigation on the WUST campus in 2017–2021
Source: own elaboration

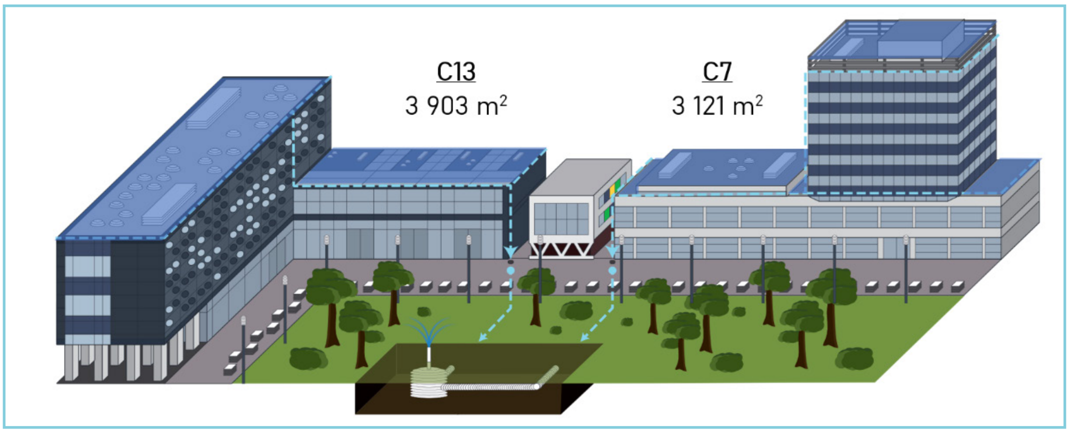

Fig. 3. Visualization of the proposed rainwater harvesting solution
Source: own elaboration

2.2. RWH system simulation model

To analyze the functioning of the RWH system in the study area, a simulation model must be used describing the conditions of the inflow of rainwater to the tank, its accumulation, intake, and the outflow of excess rainwater to the sewage system. The diagram of the RWH system operation is shown in Figure 4.

Fewkes (2000) presents two behavioral models that use basic algorithms for the rainwater tank operation: yield after spillage (YAS), based on a daily time frame, and yield before spillage (YBS), which simulates the operation in a monthly time frame. The decisive factor in choosing a specific behavioral model was its accuracy analysis. It is assumed that the larger the surface of the storage tank, the larger the analyzed time interval should be. Bearing in mind the conclusions of the research presented by Imteaz et al. (2023) and also the research area, it was decided to use the 24-hour YAS behavioral model, as it was expected to be more accurate.

The principle of operation of the YAS algorithm is described by the following two relationships:

$$Y_t = min\begin{cases} D_t, \\ V_{t-1}, \end{cases}$$

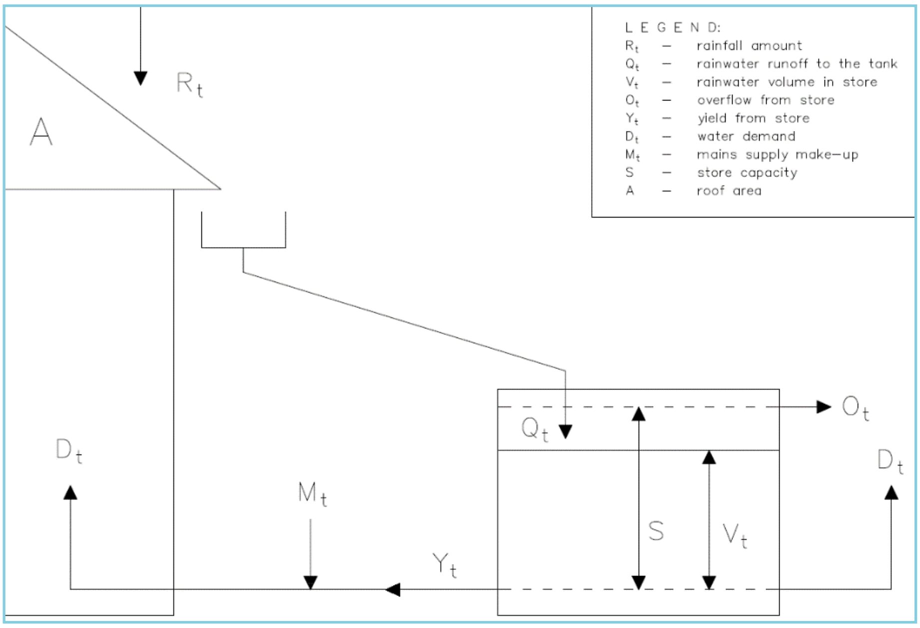

Fig. 4. Rainwater harvesting system scheme (Fewkes, 2000)
Source: own elaboration

and

$$V_t = min\begin{cases} V_{t-1} + Q_t - Y_t, \\ S - Y_t, \end{cases}$$

where:

Y_t – yield from store (hereinafter also referred to as efficiency) in the time interval, m^3

V_t – water volume in store in the time interval, m^3

D_t – water demand in the time interval, m^3

Q_t – rainwater runoff to the reservoir in the time interval, m^3

S – store capacity of the tank, m^3

The operation principle of the YAS model assigns efficiency as the volume of rainwater in the tank from the previous time interval or the water demand in the current time interval, whichever is less. Then, the rainwater runoff into the tank in the current time interval is added to the volume of rainwater in the tank from the previous time interval, along with any excess that has spilled over the overflow, from which the efficiency in the current time interval is then subtracted. At the same time, the active volume of the tank is defined as its maximum capacity reduced by the consumption in a given time interval. When the volume of rainwater in the tank is insufficient to cover the entire water demand, the missing amount is taken directly from the mains water supply network.

To simulate the operation of the RWH system, water demand, rainfall data and tank capacity assumptions are required. Taking into account the average annual demand for watering the selected area of 1,418.2 m^3 and the period when WUST green areas are watered (May to September – 153 days), the average daily water demand was 9.3 m^3/d. Due to prognoses indicating prolonged dry spells and the consequent increased water intake for greenery irrigation purposes, the value was rounded to 10 m^3/d for the purpose of further calculations.

The YAS model was loaded with precipitation data from the years 2000–2021 (22 years) obtained from the meteorological station in Wrocław. According to the research presented by Zhang et al. (2020), a representative rainfall time series length of 17 years for lawn irrigation is verified to be sufficient to generate equivalent effects to those obtained using a 30-year time series recommended by the WMO (1989) as the minimum period of rainfall observation for hydrological calculations). For further calculations, the rainfall data from May to September was used as corresponding to the irrigation period of the research area.

The simulation of the RWH system operation was run for 14 different capacities of the rainwater storage tank – from 10 to 140 m^3, enabling the coverage of the water demand for a period from 1 day to two weeks (14 days). The maximum storage duration was estimated to be 14 days, based on the recommended rainwater storage period of 2–3 weeks for individual RWH systems (Canales et al., 2020; Struk-Sokołowska et al., 2020). As a result, 14 simulation variants were obtained.

3. Research results

3.1. Changes in meteorological conditions driven by climate change

According to an analysis performed for 1951–2018 at 52 weather stations, it can be stated that, in Poland, rainfall is somewhat intermittent with alternately wet and dry decades. In the springtime, precipitation amounts increased much higher than precipitation frequency. In winter, precipitation intensity increased in northern Poland, with the opposite tendency in southern Poland (Gabryszewski, 1983; GUS, 2020). The greatest monthly variability of precipitation occurred in July and June. The period from January to March was the most stable (Kubiak-Wójcicka & Bąk, 2018).

Figure 5 presents mean annual precipitation and its anomalies in Poland in the years 1979–2021. A slight increase in the annual precipitation sum was confirmed. An anomaly of annual precipitation is the most important for sustainable water management. This parameter indicates how much more or less precipitation occurred in a given year in comparison to the 30-year climatic average for 1980–2010. In the last two decades, a growing number of years with increasing deviations from the mentioned climatic average can be noticed. The nature of the precipitation in Poland has undergone rapid changes over the last few years and has become more uneven (Szwed, 2019).

In recent decades, the number of very hot days (>35 °C) has been increasing (DATA, 2024; Blachowski & Hajnrych, 2021). On the other hand, 206 cloudy days are noticed yearly (Tokarczyk-Dorociak et al., 2017). Over the years 1979–2021, there was an intensified increase in the average annual air temperature, as shown in Fig. 6. The anomaly of yearly average air temperature has

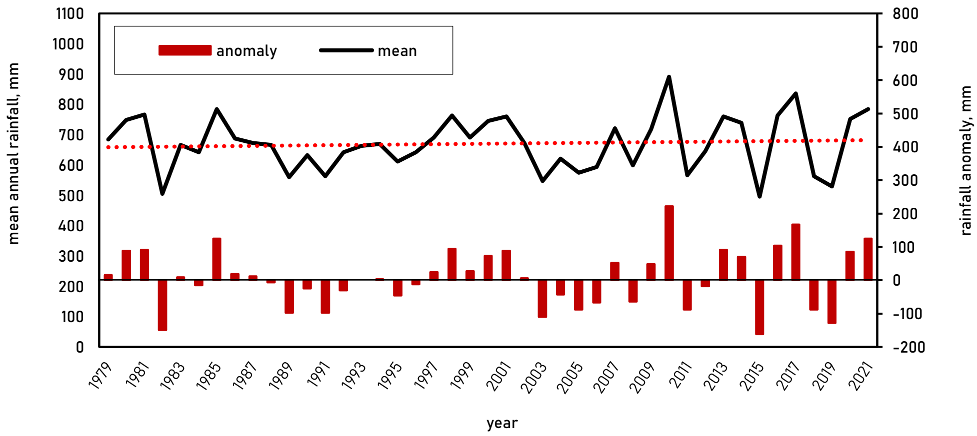

Fig. 5. Mean annual precipitation and its anomalies in Poland, 1979–2021 (based on IMGW [2023] data)

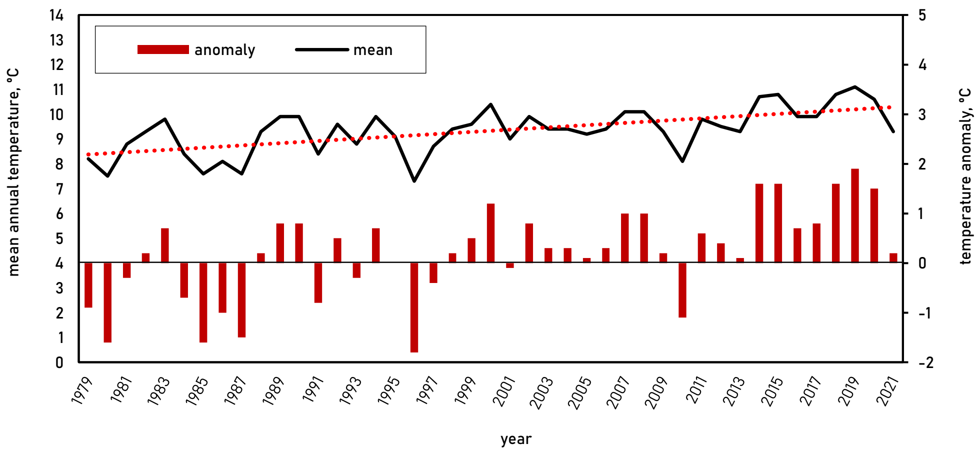

Fig. 6. Mean annual air temperature and its anomalies in Wrocław, 1979–2021 (based on IMGW [2023] data)

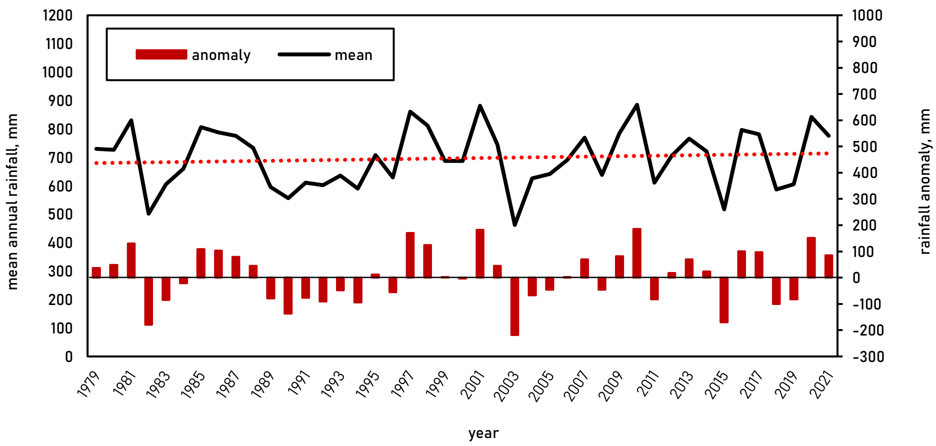

Fig. 7. Mean annual precipitation and its anomalies in Wrocław, 1979–2021 (based on IMGW [2023] data)

assumed positive values since 2011, indicating a continuous microclimate warming for Wrocław.

The mean annual precipitation and its anomalies in Wrocław in the years 1979–2021 are given in Fig. 7. Average annual precipitation is 697.0 mm. Precipitation distribution does not indicate tendencies that differ from those of the entire country. In the last two analyzed decades, the average annual precipitation sum in Wrocław was ~10% lower than for the whole country. A similar trend is observed for mid-year precipitation anomalies. The nature of precipitation has taken on a more uneven form, which translates into potential problems with predicting rainfall distribution and forecasting dry years in Wrocław in the future.

Figure 8 presents the annual precipitation amounts in Wroclaw in this period, while Fig. 9 shows the distribution of monthly precipitation sums. The mean of the annual sum of precipitation is 547.7 mm. The monthly rainfall data, however, illustrates the unevenness of precipitation distribution throughout the year. It can be seen that the period with the highest rainfall is the summer months, which are also the ones with the highest recorded temperatures and the longest dry periods (according to data presented in Section 2). The highest precipitation amounts over the years were found in the period from May to August, and the average amounted to 283.7 mm on average, which is nearly 52% of the average annual rainfall.

3.2. Analysis of RWH system performance

In the simulation of rainwater harvesting tank operation, two key parameters were considered: the percentage of water demand coverage for surrounding greenery irrigation and annual water savings (based on water meter data). The results are presented in Table 2. Depending on the tank volume (10 to 140 m^3), projected demand coverage and savings vary. The average demand coverage ranges from 47.2% to 92.8%, with water savings varying from 671.0 to 1,320.9 m^3 per year. Notably,

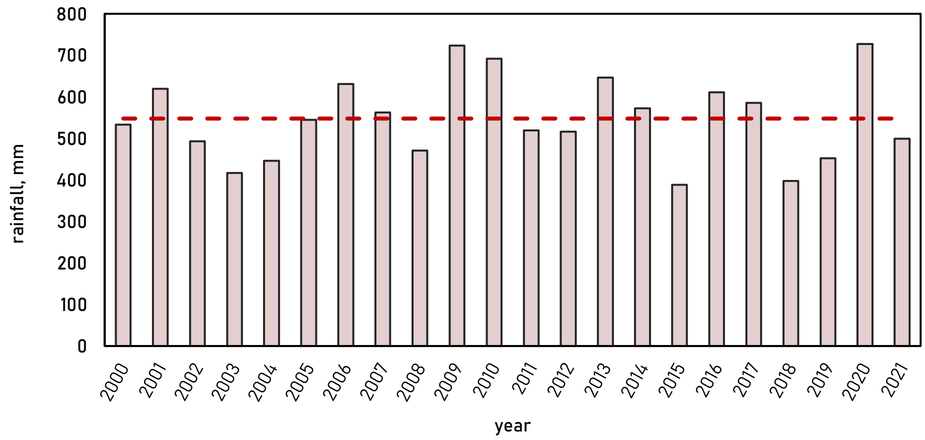

Fig. 8. Annual precipitation amounts in Wrocław, 2000–2021 (red dashed line – mean; based on IMGW [2023] data)

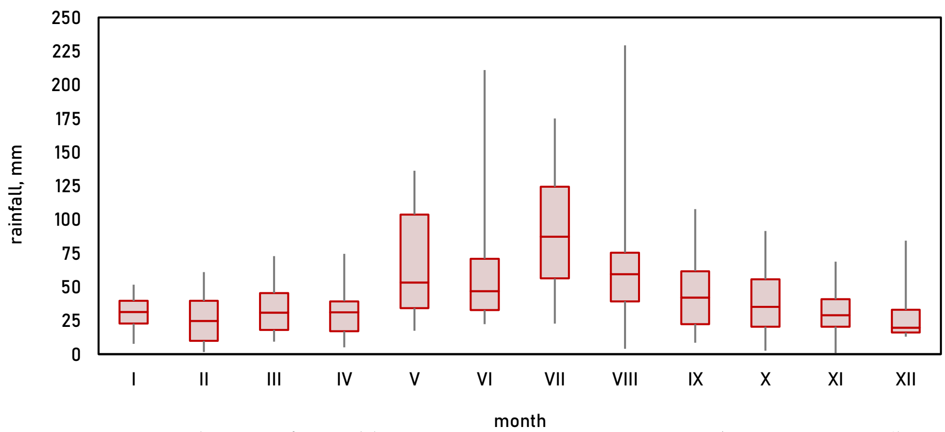

Fig. 9. Distribution of monthly precipitation amounts in Wrocław, 2000–2021 (based on IMGW [2023] data)

as tank volume increases, the gain in coverage and savings decreases. Only the largest tank achieves full demand coverage in the most optimistic scenario. Nonetheless, performance analysis alone does not fully demonstrate the solution's real-world potential. Therefore, an economic evaluation is necessary to supplement the analysis of tank operation and propose the most optimal and cost-effective solution.

The graph (Fig. 10) depicts a logarithmic relationship, with an initial rapid increase in benefits followed by a gradual leveling. Correlations align with Gossen's 1st law, the economic law of diminishing marginal utility (Dach, 2012). This law asserts that, as the consumption of a good rises, the marginal utility of each successive unit decreases. The graph reflects this, indicating that achieving the same increase in demand coverage (ΔP) as tank capacity increases requires a significantly larger storage volume (comparing areas ΔT_2 and ΔT_1).

To verify the results, a simplified economic analysis over a 30-year tank operation was conducted. In 2022, Wrocław's water distribution cost was PLN 5.62 per m^3 (MPWiK, 2024), projected to increase by 2% annually for the first ten years and 3% for the subsequent 20 years. With an exchange rate of PLN 1 to USD 0.24 (National Bank of Poland, 24.08.2023), the total cost of the investment was calculated based on average list prices, including the cost of the equipment and services required for installation, defined as 50% of the cost of the high-density polyethylene (PEHD) tank itself (Onninen, 2024). Table 3 summarizes investment costs and profits in USD, revealing payback periods ranging from 10 to 29 years for the considered investments (Fig. 11).

3.3. Economic analysis

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Tank prices generally rise proportionally with capacity, but a notable price increase occurs for capacities over 70 m^3, leading to an extended payback period. However, the maintenance costs should also be taken into account, such as inspection, cleaning and potential repair of gutters and drainpipes, as well as regular removal of sludge from the tank.

Table 2.. Annual needs coverage and water savings for 14 analyzed variations of tank size

	annual needs coverage, %			savings, m^3/year		
tank volume, m^3	min	max	mean	min	max	mean
10	33.8	63.9	47.2	481.4	909.9	671.0
20	42.3	72.0	56.6	601.8	1,0241	806.0
30	48.8	78.3	63.7	693.8	1,114.3	905.7
40	54.9	84.0	69.3	781.9	1,194.6	985.9
50	60.2	87.0	73.6	856.1	1,237.5	1,047.8
60	64.1	90.4	77.2	912.1	1,285.8	1,098.7
70	66.9	92.4	80.3	952.1	1,315.3	1,142.1
80	69.7	93.8	82.8	992.1	1,335.3	1,178.5
90	71.3	95.3	85.0	1,014.6	1,355.3	1,209.5
100	72.7	96.7	87.0	1,034.6	1,375.3	1,238.2
110	74.1	98.1	88.8	1,054.6	1,395.3	1,263.1
120	75.5	98.9	90.3	1,074.6	1,407.8	1,284.6
130	76.9	99.6	91.6	1,094.6	1,417.8	1,303.6
140	78.3	100.0	92.8	1,114.6	1,422.9	1,320.9

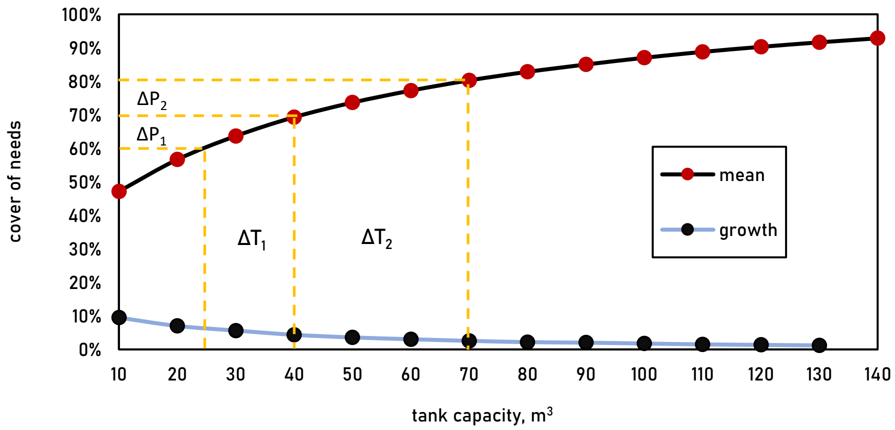

Fig. 10. Averaged water demand coverage for the 14 analyzed alternatives

Table 3. Input data for economic analysis of the project

tank volume, m^3	savings, m^3/year	tank list price, USD	total investment cost, USD
10	671.0	6,000	9,000
20	806.0	8,400	12,600
30	905.7	10,800	16,200
40	985.9	13,200	19,800
50	1,047.8	15,600	23,400
60	1,098.7	19,200	28,800
70	1,142.1	24,000	36,000
80	1,178.5	30,000	45,000
90	1,209.5	32,400	48,600
100	1,238.2	36,000	54,000
110	1,263.1	39,600	59,400
120	1,284.6	43,200	64,800
130	1,303.6	45,600	68,400
140	1,320.9	48,000	72,000

Source: own elaboration

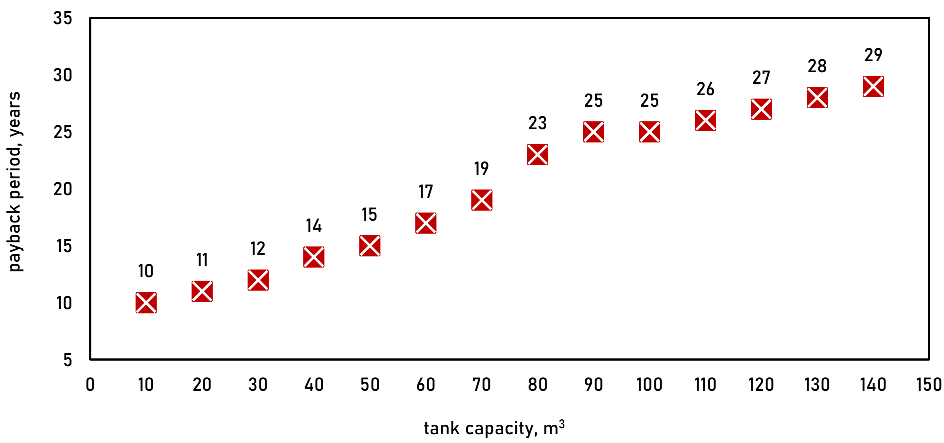

Fig. 11. Investment payback period

These costs were estimated at $100 per year for a 10 m^3 tank, with a 10% increase for each subsequent storage volume variant, assuming a projected rise in the cost of maintenance services. These costs were included in the profit analysis (Table 4). It should be noted that the calculations do not include electricity expenditures and maintenance of the existing pumping system, as these do not represent new expenses.

Profit analysis over a 30-year operation reveals that intermediate solutions, particularly the 60 m^3 tank, are the most profitable. The tanks with the shortest and longest payback periods exhibit the lowest potential overall profits.

Based on the economic analysis, considering the payback period and potential returns and assuming optimal operational conditions, a 60 m^3 tank was chosen. Further analysis of monthly and annual coverage of needs was conducted (Figs. 12 and 13). Figure 12 illustrates stable system operation, with quartile distributions close to the maximum values and occasional events near the minimum. Over the period 2000–2021, the annual simulated savings distribution (Fig. 13) averages 77.2% coverage, (or 1,098.7 m^3) for irrigation on Professors' Alley. The maximum benefit occurred in 2020 at 1,285.8 m^3 (90.4%), and the minimum in 2015 at 912.1 m^3 (64.1%), with 50% of cases exceeding 1,111.9 m^3.

4. Discussion

The precipitation and thermal conditions in Wrocław exhibit notable anomalies when compared to historical meteorological data. This deviation is primarily attributed to population growth, which has significantly increased the demand for urban infrastructure, including energy systems, industrial intensification and housing construction. These changes, coupled with improvements in quality of life, have resulted in a surge in greenhouse gas emissions – an influential factor in climate change. Consequently, climate change affects weather patterns and contributes to the occurrence of extreme weather events (Bazazzadeh et al., 2021), leading to disturbances in the stormwater drainage system and, in severe cases, urban flooding.

The Urban Climate Change Adaptation Plan for Wrocław by 2030 (MPA, 2019) underscores the city's prominent challenges, particularly rising temperatures and an escalating frequency of heavy rainfall. The existing infrastructure is proving insufficiently efficient in addressing these concerns. The primary objective, therefore, is to raise awareness about adapting to climate change and to implement coordinated actions aimed at enhancing resilience to current and future climate threats. The plan aligns with the sustainable development concept for the city. The proposed rainwater harvesting solution

Table 4. Results of economic analysis of the investment

tank capacity, m^3	mains water savings	mains water cost	investment cost	profit
	USD			
10	39,556	44,045	9,000	-16,489
20	47,515	36,086	12,600	-4,472
30	53,392	30,209	16,200	3,352
40	58,115	25,487	19,800	8,835
50	61,769	21,832	23,400	12,145
60	64,768	18,833	28,800	12,304
70	67,326	16,275	34,200	11,535
80	69,468	14,133	45,000	4,490
90	71,296	12,305	48,600	3,960
100	72,988	10,613	54,000	1,300
110	74,458	9,143	59,400	-1,866
120	75,723	7,878	64,800	-5,515
130	76,847	6,754	68,400	-7,722
140	77,865	5,736	72,000	-10,228

Source: own elaboration

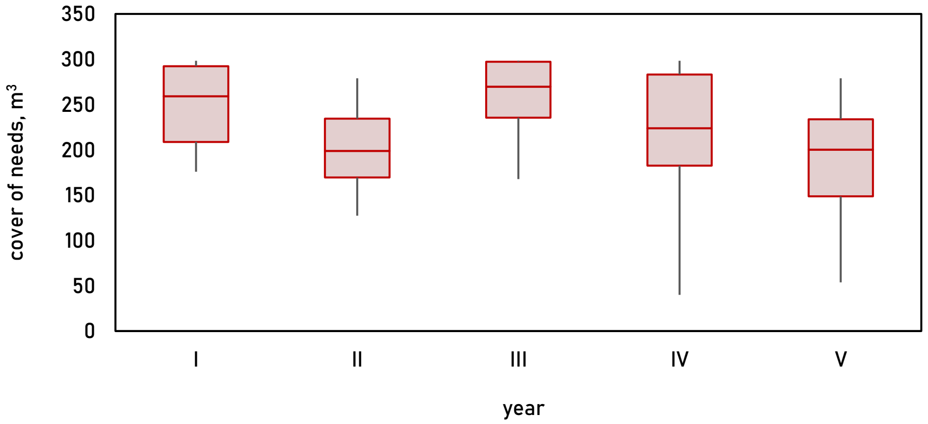

Fig. 12. Water demand coverage for 5-month irrigation period, 2000–2021 (60 m³ tank)

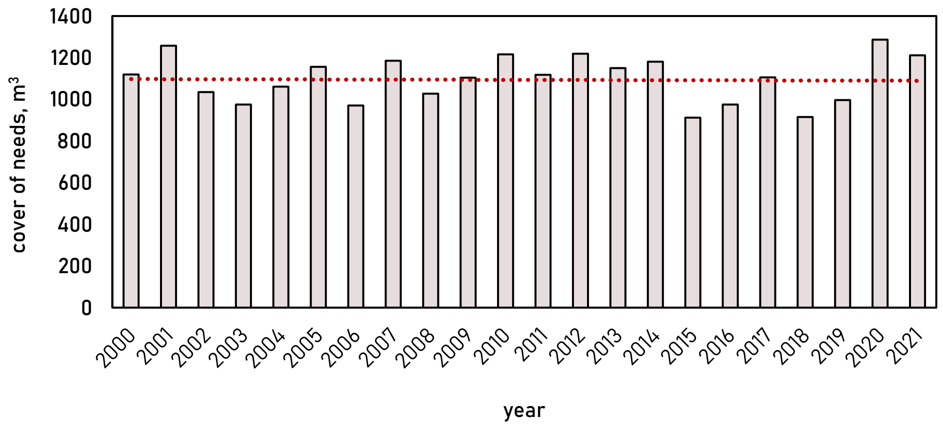

Fig. 13. Annual coverage of water demand, 2000–2021 (60 m³ tank)

on the WUST campus not only promises potential economic gains but also contributes to improving sewage network functionality and safeguarding water resources. These actions are in line with EU legislation, such as *Regulation 2020/741* (EU, 2020) which supports RWH-related activities as solutions supporting adaptation to climate change and the circular economy (Dias et al., 2024). The benefits of saving mains water are particularly important given the expected increase in prices for full-price water recovery under the European Union (EU) Water Framework Directive (Farreny et al., 2011).

It is worth mentioning that the number of studies on residential RWH systems has increased significantly in recent years, and there is still only a limited number of studies on large public buildings or spaces, such as universities (Almeida et al., 2023). Studies similar to that presented in the article were conducted for Melbourne (Australia) university campus (Imteaz et al., 2011), for Federal University of Pará (UFPA) in Belém (Brazil) (Cardoso et al., 2020) and for universities (as a part of the studies) in Addis Ababa (Ethiopia) (Adugna et al., 2018). Other studies related to non-potable water consumption in universities (not necessary for irrigation purposes) can be found, for example, in works by Bonnet et al. (2002), Wichowski et al. (2019) and Marinoski and Ghisi (2008).

The simulation of 14 computational variants validates the real benefits of the proposed rainwater harvesting solution. An analysis of investment costs highlights the attractiveness of tanks with intermediate capacities, particularly in terms of investment return period and profits linked to mains water savings. The economic analysis concludes that a 60 m³ tank is the optimal solution, proving to be the largest profitable one in the series, with a 19-year payback period. This storage volume ensures the accumulation of water exceeding the six-day demand for irrigation, creating stable operating conditions considering precipitation time variability.

The proposed investment has the potential to reduce mains water consumption by an average of 77.2%.

It is important to note that the economic analysis primarily considered investment costs, while the complete costs include maintenance and regular inspections. Frequent checks of strainers and tank filters are essential, and sludge deposited in the tank bottom requires regular removal. The cleaning frequency depends on rainwater quality, necessitating regular monitoring.

The most significant challenge in weather-related modeling lies in the variability of analyzed parameters over time. An analysis of Wrocław's meteorological history reveals that it is challenging to predict a definite direction of climatic changes for the next 30 years. Therefore, choosing a tank that guarantees the storage of a volume of rainwater corresponding to the weekly demand both fulfills storage time requirements and demonstrates economic investment potential. Undoubtedly, Wrocław holds one of the largest potentials in the country for harvesting intensified rainfall. The promotion of such initiatives unequivocally supports the process of adaptation to climate change, combating its destructive impact on the microclimate.

5. Conclusions

The article addresses the pressing challenges of water management in the face of climate change, proposing the adoption of rainwater harvesting (RWH) as an adaptive solution. Applied to the Wrocław University of Science and Technology (WUST) campus in Poland, the system collects rainwater from two buildings, directing it to an underground reservoir for irrigating the Professors' Alley green area.

The installation of a retention tank emerges as a strategic response to mitigate challenges related to climate change impacts and facilitate rational rainwater management locally.

Utilizing the Yield After Spillage (YAS) model, 14 simulations correspond to different tank capacities from 10 to 140 m^3. The results underscore the pivotal role of tank size in influencing water savings, with larger volumes enabling almost double the conservation compared to smaller tanks. However, the paper acknowledges increased investment costs, emphasizing the need for balanced decision-making.

The economic analysis identifies intermediate tank sizes as most advantageous, with the 60 m^3 tank yielding a profit of 71,396 PLN. Larger tanks enhance water savings but diminish total profits due to heightened investment costs. The decision to select a 60 m^3 tank, capable of storing rainwater for a six-day demand, takes into account challenges in weather-related modeling. The potential mains water consumption reduction averages 77.2%, with a 19-year payback period. Tanks exceeding 60 m^3 are deemed financially unviable within the 30-year operational period, highlighting the significant potential of RWH systems in local water conservation and climate change adaptation.

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