‘Technical solutions and benefits of introducing rain gardens – Gdańsk case study’ (Kasprzyk et al., 2022) –

An Article Critique By Uttam Kumar Tamboli

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Environmental Management

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Introduction

Paper Overview

The paper 'Technical solutions and benefits of introducing rain gardens – Gdańsk case study' (Kasprzyk et al., 2022) is a case study of Gdansk, Poland which investigated the effectiveness of rain gardens in terms of rainwater treatment and provision of ecosystem services.

In recent times Nature Based Solutions (NBS) such as rain gardens have been found to be helpful in the treatment and infiltration of stormwater (Venvik & Boogaard, 2020 cited in Kasprzyk et al., 2022).

Due to the increasingly unpredictable patterns, varying intensities and durations of rainfall, the current sewerage system struggles to manage floods and prevent the contamination of water bodies. Additionally, (European Environment Agency, (2015); IPCC, F. C., (2014); Ipcc, C. C. (2014) cited in Kasprzyk et al., 2022) also pointed out that extreme weather in many parts of the world is causing drought, heat island effects and loss of biodiversity. This explains the vitality of the paper. The paper also pointed out the necessity of this research for construction authorities and decision-makers.

Methods

For rainwater treatment, the authors with the help of rain gauge and pressure transducers calculated the actual infiltration rate and precipitation retaining capacity of the rain garden systems. For ecosystem services, biodiversity enhancement was analysed with the help of biodiversity indexes. Moreover, the study also used the concept of Urban Circularity Challenges (UCC) to examine the potential of rain gardens as a multi-functional NBS. Apart from this, the effect of rain gardens on heat island mitigation was also analysed with the help of remote sensing and thermal imagery. Lastly, current challenges in terms of urban residual waste, and their possible solutions were worked upon.

Main Results and Interpretation

From the local assessment data and research objects, the locations of five selected rain gardens for this study were determined. Additionally, the study included a Hypsometric map detailing Gdansk's elevation.

Fig 1: Locations of selected Rain gardens in Gdańsk, Poland cited by (Kasprzyk et al., 2022)

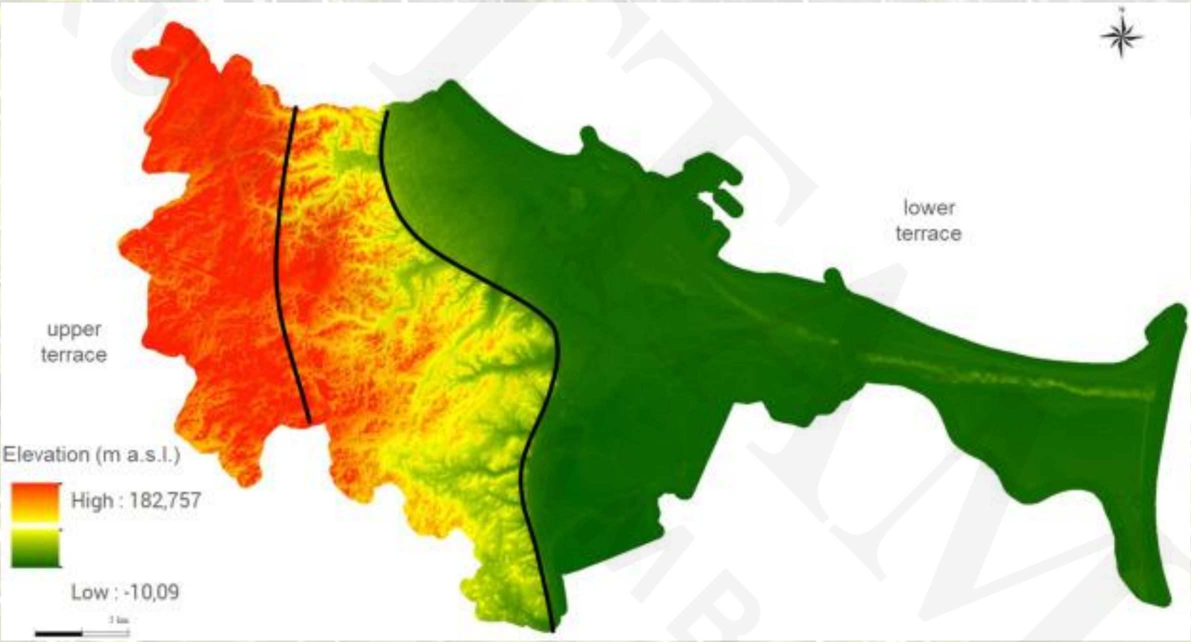

Fig 2: Hypsometric map of Gdańsk, Poland cited by (Kasprzyk et al., 2022)

Fig-2 shows a map which illustrates high and low-elevation areas, revealing the direction of precipitation and its influence on rain garden performance. Apart from this, key information such as the area, purpose and retention capacity of each rain garden was documented in the table below:

No.	Object	District	Type	Area	Retention capacity	Purpose	Construction year
1	3 Maja St.	City	Ground	758.7	98.2 m^3	Main streets	2020

		centre		m^2		crossroads	
2	Bishop O'Rourke Square	Wrzeszcz	Ground	200.86 m^2	56.3 m^3	Roof, street, pavements	2018
3a	eMOCja Center	Stogi	Ground	25.1 m^2	2.3 m^3	Roof, parking lot	2020
3b			Box	4.9 m^2	1.2 m^3	Roof	2020
4	Lastadia st.	City centre	Ground	325 m^2	108 m^3	Parking lot	2020
5	Kaczeńce	Stogi	Ground	449 m^2	224.5 m^3	Warehouse roof	2018

Table 1: Summary Data of Selected Rain Gardens. (Kasprzyk et al., 2022)

Fig-3: Graph showing Infiltration Curve from Kaczeńce rain garden. (Kasprzyk et al., 2022)

The Infiltration Curve (Fig-3) was plotted using data from Kaczeńce rain garden using which the infiltration rates were determined for two rain gardens (Table-2).

Rain garden	Logger	Slope	R^2	k_1 (mm/h)	k_2 (m/day)
eMOCja Center	1st box	−38.809	0.763	24.4	0.586
	2nd box	−28.433	0.715	22.2	0.534
	3rd box	−28.595	0.724	23.7	0.569

	4th ground	−42.621	0.723	29.5	0.707
	5th ground	−36.600	0.682	17.5	0.420
Kaczeńce	1st ground	−38.326	0.993	22.0	0.528
	2nd ground	−39.926	0.993	17.7	0.426

Table 2: Hydraulic Performance of eMOCja Center and Kaczeńce Rain Gardens. (Kasprzyk et al., 2022)

Using the data from Table 2, the Average volume of stormwater runoff was estimated for all rain gardens and parameters such as catchment area and infiltration volume were analyzed (Table 3).

Rain garden	Impermeable catchment area	Rain garden area	The sum of the precipitation period	Storm water runoff	Maximum filling (obtained)	Average filling (calculated)
	m^2	m^2	mm	m^3	mm H_2O	mm H_2O
eMOCja boxes (total)	75.0	4.9	3.52	0.264	56.00	53.88
eMOCja ground	140.0	25.1	3.52	0.493	11.08	19.63
Kaczeńce	2696.5	449.0	3.59	9.680	80.50	21.56

Table 3: Infiltration Capacity Determination of rain gardens (Kasprzyk et al., 2022)

Notably, from Table 3, a substantial impact of varying rain garden sizes is evident. The third rain garden, being the largest, displayed a filling capacity four times higher than the estimated value.

Next is the Floral Biodiversity Impact Assessment, where Shannon Evenness and Shannon Diversity indexes for all rain gardens were calculated shown in (Table 4).

Rain garden	Shannon Evennes index (D)	Shannon Diversity index (H)
3 Maja St.	0.837	3.110
O'Rourke Square	0.909	3.205
eMOCja Center	0.963	3.100
Lastadia st.	0.943	3.631
Kaczeńce	0.929	3.275

Table 4: Biodiversity Index Values for rain gardens planting. (Kasprzyk et al., 2022)

The index values fall within the range of 0.84 to 0.96, indicating commendable performance in terms of solving urban challenges and affirming the efficacy of ecosystem services according to (Castellar *et al.*, 2021 cited by Kasprzyk et al., 2022) and (Pedersen Zari, 2015 cited by Kasprzyk et al., 2022).

Furthermore, this assessment included a compilation of dominant plant species found in the rain gardens (Table 5). The study noted that these species are hydrophytic, resilient to periodic flooding, and effective in removing heavy metals, pollutants, and oil derivatives from water.

Rain garden	3 Maja St.	O'Rourke Square	eMOCja Center	Lastadia st.	Kaczeńce
Dominant plant species	▪ *Iris pseudacous* ▪ *Glyceria maxima* ▪ *Phalaris arundinacea* ▪ *Acorus calamus* ▪ *Phragmites australis*	▪ *Iris sibirica* ▪ *Hemerocaliss* ▪ *Anemone hybrid* ▪ *Hosta sieboldiana* ▪ *Darmera peltate*	▪ *Deschampsia caespitose* ▪ *Lysimachia nummularia* ▪ *Hemerocaliss* ▪ *Myosotis scorpioides* ▪ *Glyceria maxima*	▪ *Lysimachia nummularia* ▪ *Iris sibirica* ▪ *Deschampsia caespitose* ▪ *Carex muskingumensis* ▪ *Myosotis scorpioides*	▪ *Phragmites australis* ▪ *Phragmites humilis* ▪ *Rosa 'Rugby'* ▪ *Glyceria maxima* ▪ *Iris sibirica*
Total species number (S)	41	34	25	47	34
Total plant number (N)	4654	3913	783	4107	1248

Table 5. Dominant plant species used for rain garden planting. (Kasprzyk et al., 2022)

The pivotal segment focused on Thermal Imagery and remote sensing data (Fig-4).

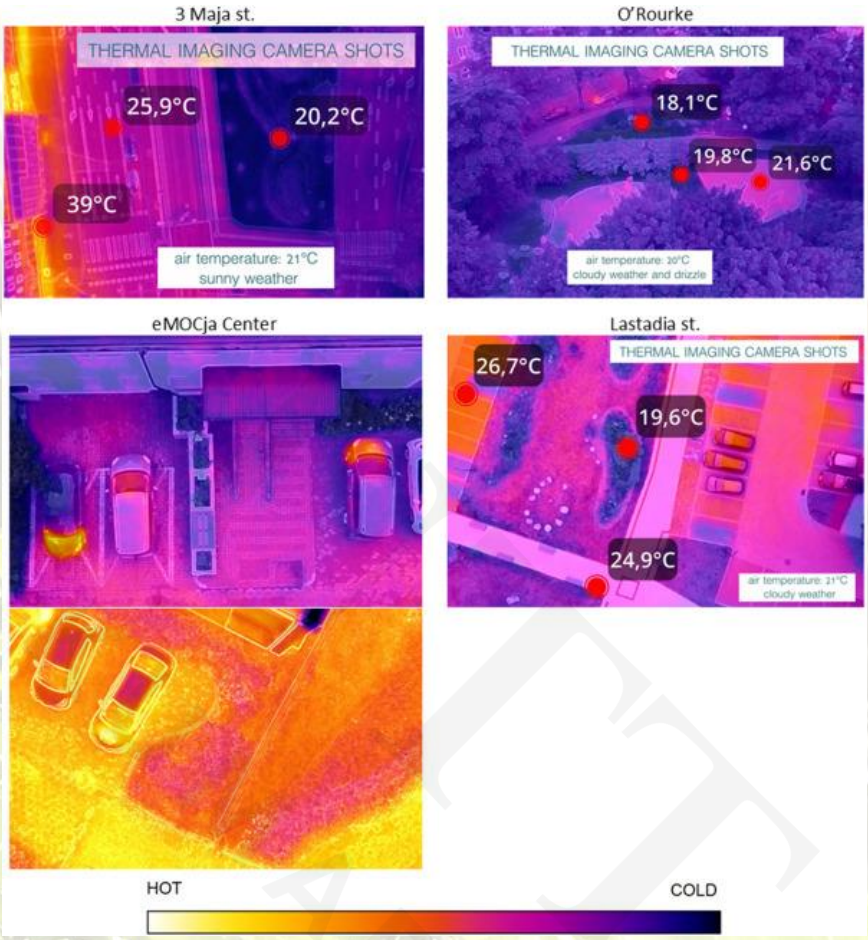

Fig-4: Thermal Imagery Camera Shots from Rain Gardens. (Kasprzyk et al., 2022)

The impact of rain gardens is vividly observed, depicting cooler temperatures in rain garden areas compared to others. This presentation, enhanced by a colour palette, effectively demonstrates the potential of rain gardens in mitigating the heat island effect.

Critical Discussion

General Structure & Clarity

The joint discussion of Results & Discussion enhances coherence, as discussing the numerous components and findings separately might have disrupted the content's flow. However, there are minor grammatical errors related to the use of articles, punctuations, conjunctions and helping verbs which could have been easily corrected with proofreading and the use of spell and grammar-checking tools. Apart from this, there was an error in stating the acronym. NBS (Nature-Based Solutions) was written instead of NBS in the following segment:

"NSB such as rain gardens may be introduced to existing urban spaces such as residential areas, main crossroads in the city centre, and even old towns." – Research Objects, third paragraph. (Kasprzyk et al., 2022)

Moreover, although five rain gardens were selected for the study (Table 1), infiltration data (Table 2) and Runoff data (Table 3) for only two (eMOCja and Kaczeńce) were presented without justification for excluding data from the remaining three rain gardens. This omission leaves a gap in the presented information.

Furthermore, the reference to the report European Environment Agency 2015 (cited by Kasprzyk et al., 2022) given in the introduction and the reference to the paper on Permeability of rain gardens in New Zealand (cited by Kasprzyk et al., 2022) used in the Hydraulic Efficiency section of the paper is broken which makes the citations invalid.

Aims and abstract.

The case study's objectives were clearly outlined in the abstract of the paper. Additionally, presenting the aims of the study as questions at the end of the introduction section effectively highlights the covered topics.

However, both instances mentioned these aims towards the conclusion of their respective sections. Placing this information within the first or second paragraph would have improved the paper's core focus.

Furthermore, in the Introduction section, the readers must reach the fourth paragraph to understand that the paper is primarily based on rain gardens which is an inconvenience that hampers the content flow. Lastly, a brief explanation of challenges in the abstract regarding the implementation of rain gardens would have clarified the vitality of the research and would have given a balanced perspective of both positive and negative arguments.

Academic context

Right from the introduction, the authors have considered the recommendation given by the Helsinki Commission cited by (Kasprzyk et al., 2022) to state the importance of stormwater management systems. This was followed by mentioning the significance of water-sensitive Urban Design, discussing the impacts of climate change on water balance, and the potential of NBS in addressing them etc.

Apart from this, they have also done a commendable job in consolidating technical specifications and components of the rain garden such as the Excess water flow directions, emergency flow system, settling tanks etc. Moreover, significant yet novel challenges such as microplastics in rain gardens were also addressed in the paper.

On the flip side, the values of the Floral Biodiversity Assessment (Table 4) didn't add much to the potential of rain gardens as a multi-functional NBS. For example, it expressed the strength and diversity of species in the rain garden (Table 5) but didn't provide any data on their growth rate, health, and condition after storms etc which is important to estimate the level of maintenance needed for efficient operation.

Evaluation of sample sizes

While the research focused on a 10-day precipitation duration, extending this timeframe to a yearly data set for example a time interval of 5 years (Jeon *et al.*, 2021) or testing with a controlled runoff from fire hydrants (Venvik and Boogaard, 2020 cited by Kasprzyk et al., 2022) could have provided a more comprehensive understanding of the rain garden's performance.

Moreover, the infiltration data (Table 3) was collected only from two rain gardens: eMOCja Center and Kaczeńce as they were closest to the monitoring station. However, incorporating data from all five rain gardens would have improved the sample size and have given more significant results.

Evaluation of Methodology

The authors located the rain gardens in the map (fig-1) but didn't correlate the effect of elevation on the performance of rain gardens with the Hypsometric map (fig-2). Hence both the maps were not utilized properly.

Furthermore, the reference (Schlumberger Water Service, 2014 cited by Kasprzyk et al., 2022) given in infiltration capacity determination is a user manual of the device and not a scientific paper mentioning the use of pressure transducers. Hence the use of pressure transducers is not justified. Apart from this, (Venvik and Boogaard, 2020 cited by Kasprzyk et al., 2022) to compare the infiltration rates in Table 2, adopted a better methodology for infiltration rate determination than the main paper. They considered both small-scale (lab-based) and large-scale (field-based) tests which gave comprehensive outputs to better judge the performance of rain gardens.

Apart from this, in the main paper, the method adopted for thermal imagery can be considered appropriate and significant data (Fig-4) was produced which gives this paper the edge over other research papers in terms of explaining the secondary benefit of cooling by rain gardens.

The paper also considered the seven Urban Circularity Challenges (UCC) from (Atanasova *et al.*, 2021 cited by Kasprzyk et al., 2022) as a parameter for judging the potential of rain gardens as NBS where the authors provided comprehensive discussion with regards to all UCCs.

Clarity of data

A decent amount of significant data is provided in the research however they are not thoroughly consistent. While the thermal imagery data is well-presented, there's a lack of information regarding measurement timing, intensity, and location-based breakdown. Notably, Bishop O'Rourke Square's rain garden among the five is omitted from the thermal images (Fig-4), creating ambiguity, and hindering a clear assessment of the rain gardens' performance.

Apart from this, in the section on Infiltration Capacity Determination in the main paper, the reference (Boogaard et al., 2014; Boogaard and Lucke, 2019; Venvik and Boogaard, 2020 cited by Kasprzyk et al., 2022). added is poorly referenced as multiple sections are taken from them and the specific part referred to is not mentioned. This adds to ambiguity in methods adoption.

Evaluation of Interpretation

The arguments and insights given about rain gardens based on UCCs can be considered a valuable consideration to the research field, but the authors have not proposed anything from their research as a contribution. All the information provided is based on interpretation and citations of other research papers.

The section on future challenges is dealt with an impressive amount of details in the paper which helps in understanding the severity of the problems and amplifies the necessity of rain gardens. Apart from this, the paper also didn't include any information regarding the ponding time of rain gardens. which could be an important parameter for rain gardens in case of extreme precipitation (Burszta-Adamiak *et al.*, 2023) and in some cases where it can encourage mosquito breeding. (Zhou and Guo, 2022).

Lastly, the authors didn't emphasize the importance of technical parameters considered in the research and their method of determination. This was remarkably discussed in the paper (Greksa, Blagojević and Grabić, 2023) on rain gardens in Serbia.

Conclusion

In conclusion, the authors highlighted the impact of multiple factors on the performance of rain gardens. Moreover, the data on urban heat island effect mitigation became the key highlight of the research. Apart from this, they also mentioned the significant addition in aesthetic value and biodiversity enhancement feature of rain gardens. Lastly, it also touched upon the emerging research area of challenges in terms of poly-fluoroalkyl substances and other new pollutants on which further research can be directed.

Overall, the research excels in presenting impactful data, offering valuable insights, and delivering well-founded arguments. However, the paper is poorly referenced as many of the cited papers are either not available or accessible which hampers the credibility of the paper and the possibility of replicating the methodology in future papers. As the paper is relatively new (published in August 2022), this is a severe drawback and cannot be overlooked. Nevertheless, the paper has 15 citations, and the findings and contributions significantly advance the understanding of the potential of rain gardens and their multifaceted benefits. Hence, it can be considered as a forward step in the right direction which can act as building blocks for future research.

Word Count: 1999 (Excluding Tables, Figures, Captions, and Bibliography)

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