Demonstrating Education for Sustainable Development through Rainwater Harvesting in Institutions of Higher Learning in Kenya: The Potential at Kenyatta University

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Abstract

The challenge of water scarcity is increasing in most countries of the world with potentially severe negative effects on human well-being and sustainable development. This paper reports on the hirtherto untapped potential of rainwater harvesting across public universities in Kenya, using Kenyatta University as the case study. Roof catchment footprints were mapped quantified using Geographic Information System procedures. Rainfall data was obtained from the university meteorological station and analysis for general trends from 2005 to 2017. Volumes of harvested water were calculated by obtaining the product of actual area of the roof catchment and rainfall received in millimetres. Results show that mean monthly rainfall ranged from 15-180 mm, averaging 75 mm. Annual and monthly totals, including rainfall days fluctuate a lot and have been declining since 2005. All roofs have gutters and drainage pipes but lack rainwater storage tanks. Therefore, significant quantities of harvested water are immediately lost as runoff water. For example, the Central Administration Complex, the Post-Modern Library and the Business Services and Student Centre roof catchment loss on average 290,800, 465,300 and 289,700 litres per month respectively. The socio-economic and ecological effects of such avoidable loss cannot be overemphasized. As centres of excellence in leadership education, universities can demonstrate sustainable water resource management as envisaged in the UN framework of education for sustainable development by integrating the complete rainwater harvesting infrastructure particularly appropriate plastic tanks in new project design and implementation, and when auditing all old buildings. To mainstream such environmental stewardship in strategic management requires the establishment of an environmental office in the university anchored on ISO 14001:2015 certification. Here-in is the discussion on leadership gap this article hopes to kindle.

***Keywords*: Rainwater Harvesting, Roof Catchments, Universities, Sustainable Development**

Introduction

Background

Despite water being a basic human right and having multiple sources of abstraction (Haque *et al.* 2016; Hughes 2019), its availability and quality globally is declining. This will add to the already worsening situation of human well-being as the world grapples with the effect of climate change and poor water conservation and management practices. According to UNESCO (2023), 2 billion people (26% of the population) do not have safe drinking water and 3.6 billion (46%) lack access to safely managed sanitation. From a rural development perspective, World Vision (2023) estimates the number of people who lack access to clean water at 771 million. This water shortage is bound to increase especially in cities if concerted effort to mitigate it is not given the seriousness and urgency it deserves. The situation is likely to be worse in developing nations, in particular Africa, where environmental performance standards tend to be marginalised.

Sustainable access to safe drinking water in Africa will remain a pressing challenge if deliberate efforts are not employed to address water stewardship. Estimates already show that Sub-Saharan Africa accounts for 40% of people in the world without access to potable water (Sojobi *et al.* 2016). But what Africa and Kenya in particular is doing to avert this scenario is little if any. It is no wonder that UN-Water (2021), estimated the people living in water-stressed countries at 2.3 billion, of which 733 million live in high and critically water-stressed countries. FAO (2020) estimates the people living in agricultural areas with high to very high, water shortages or scarcity at 3.2 billion of whom 1.2 billion people live in severely water-constrained agricultural areas. Unfortunately, more countries are drifting from water stress status into water scarcity status as a result of a myriad of factors, which are largely anthropogenic in nature. There is no doubt that this will undermine the already severe challenge of food insecurity, especially in the dryland agro ecosystems in Africa.

Locally, Kenya is classified as a water scarcity nation and highly vulnerable to climate change and its impacts (UNEP,2002; UNICEF, 2022). Growing water demand and water scarcity have turned into a notable challenge in the country with about 28 million Kenyans lacking access to safe water and 41 million lacking access to improved sanitation (Water.Org, 2023). In urban areas such as the greater Nairobi, only about 40% of the inhabitants had direct access to piped water (Herrero *et al*. 2010). The rest obtained water from vendors and boreholes whose quality is never guaranteed. This dismal performance 60 years since independence indicates that more intentional strategies are need as the nation responds to sustainable development goal number 6. Relying on metered water alone in places with a high population density like in institutions of learning is unsustainable and risky in the context of health and sanitation. Investment in alternative sources of water in the context of integrated water resources management merits consideration in pursuit of sustainable development.

Flood water harvesting using a series of dams on the perennial rivers traversing the semi-arid regions of Kenya can alleviate the suffering of people and animals caused by drought (Reliefweb, 2023). Such an investment is however capital intensive and out of reach for ordinary resource-poor rural and urban communities. Similarly, desalination of ocean water is also expensive and generally not a priority for government. However, for having a wastewater treatment plant, every town in Kenya has the potential to reclaim substantial quantities of clean water from domestic effluent, and harness it for peri-urban irrigation agriculture and limited domestic uses. This has been demonstrated in water scarcity countries like Israel at Shafdan (Israel21c, 2022) and Changi Water Reclamation plant in Singapore (World Economic Forum, 2022), where waste water treatment ends at tertiary treatment, thus making millions of litres of clean water available for various purposes. In Kenya, waste water treatment ends at secondary effluent, which is re-discharge into river systems thus re-polluting them (Kitulu et al., 2020; Citizen TV, 2019), besides wasting all the financial investment in the treatment process and facility. Comparatively, rainwater harvesting stands out as a practical and achievable alternative to improve water security where existing water supply is inadequate, or where there is abundant annual rainfall that is wasted as runoff, or in highly contaminated and saline coastal areas, and in dry regions with inherent low and erratic annual rainfall (Opare 2012; Ghis and Schondermark, 2013; and Samaddar *et al.* 2014). Of concern would be the suitability of the water due to the type of roof, type of storage tank and air quality (Zdeb et al., 2020). Depending on the intended use of the water, requisite treatment such as chlorination remains an affordable measure for all times (Gakungu, 2013). Instead of harvesting rain water, most universities rely on metered and borehole water to meet their demand. Borehole water is pumped to an elevated steel tank from where the water flows to various application points by gravity. Based on his study in Umoja of Nairobi, Nyakundi et al (2020) caution on borehole water carrying the risk contaminated with *E coli* thus posing a direct risk to human health.

Opportunities for rainwater harvesting in Kenya are envisaged in the mandate of various authorities and agencies established by the 2010 constitution and the Water Act of 2016 (Republic of Kenya, 2010; 2023); and most important Sustainable Development Goal 6 (UNEP 2019). Despite the availability of such blue prints, UNESCO (2023) observed with concern that the world is still off track in achieving this goal, and billions of people and countless schools, businesses, healthcare centres, farms and factories do not have the safe water and toilets they need. The call by UNESCO on this world water day was for the global community to draw the necessary conclusions and to see water as a vital and common good of humanity. There is therefore a strategic management gap when universities with occasional to frequent water shortages allow free and clean rainwater to be disposed away as runoff. By virtue of their mandate in societal transformation, universities can play leading roles as champions in education for sustainable development through capacity and competence building of stakeholders in water resource stewardship.

Research Objective

The main objective of this study was to quantify the potential of roof-based rainwater harvesting at Kenyatta university and recommend measures of causing universities to invest in rainwater harvesting from their vast roof catchments in pusuit of education for sustainable development.

Methodology

Study Area Characteristics

This study was conducted in 2019 at Kenyatta University situated to the north of Nairobi City in Kenya. Figure 1 shows the location of the university including the various zones in which the study roof catchments are situated. Being a typical public university in Kenya, the water resource use model is similar and hence representative of all other public universities in the country.

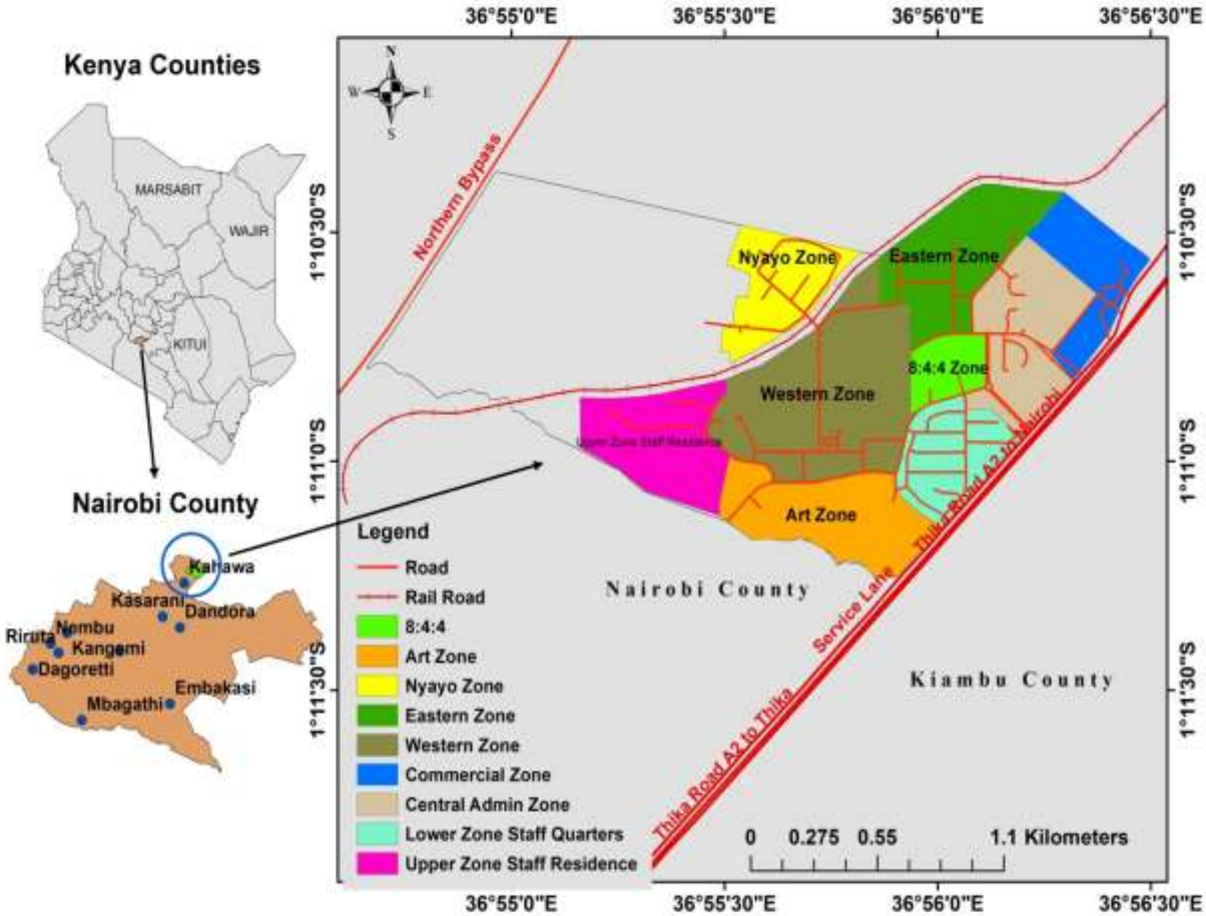

Figure 1: Study Catchments at Kenyatta University

Research Design

Spatial analysis using GIS was the main research design used. GIS maps environmental variables in a footprint orientation. Data generated is therefore 100 percent quantitative and within the ratio data measurement scale. By its nature GIS-based spatial analysis excludes sample sizes and sampling procedures. The scope of this work was restricted to mapping, hence the omission of a social survey there-in.

Data Collection and Analysis Methods

Spatial Survey

Geographic Information System procedures were used to map and calculate roof catchment footprints of major buildings in the University (Figure 1). The Kenya Data was obtained from World Resources Institute (WRI), KE Streets, places and Road points from Open Street maps. Clipping and extraction using query was undertaken to obtain the study area map i.e., University boundary Digitized shapefile. Google earth pro software was installed. The university residential areas and building roof tops were digitized in Google earth. An image from Google Earth for the study area extent for year 2018 was extracted from Google earth and georeferenced in ArcMap. Overlays were undertaken between the image and the digitized building polygons after having been converted from KML to shape files. The digitized images were used to prepare roof catchment maps on ArcGIS and estimation of their surface areas computed done.

Since GIS provides horizontal footprints, which are less than the actual ridged roof areas, a standard average roof ridge of 25^0 was used to adjust the footprint area by multiplying the footprint area with the factor of 1/cos Ø, where Ø is the roof pitch. Further, since the roof overhang should also be considered before applying the above factor, 15% allowance is commonly applied in construction engineering of buildings. Therefore, a more realistic roof catchment area would be: [Plane (footprint) area x 1.15)]/cos Ø, thus: 1.15A/Cos 25°. Potential rainfall harvest (m^3) was estimated as the product of actual roof catchment area (m^2) and rainfall received in metres.

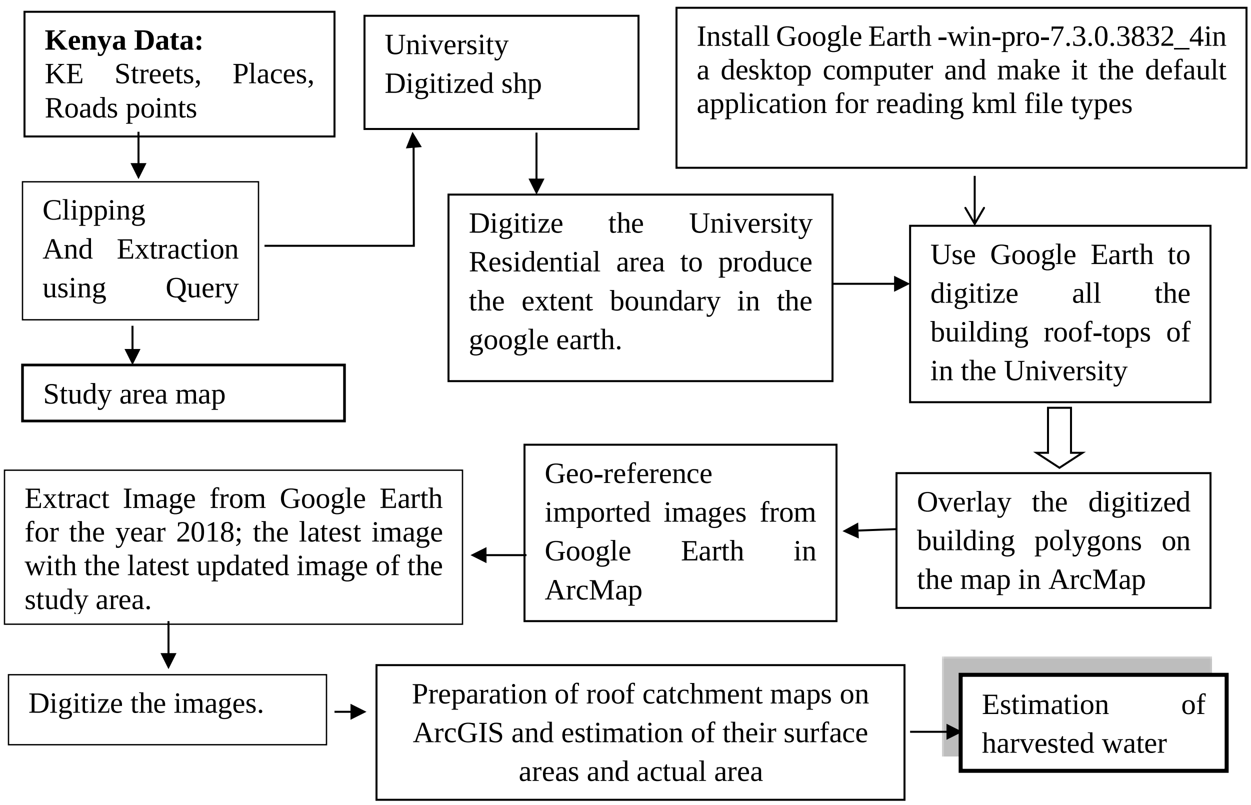

Figure 2: Steps followed in the estimation of roof catchments in the university.

Environmental Observations

The physical status of rainwater harvesting infrastructure was visually observed for the availability or absence of gutters, delivery pipes, discharges pipes and water storage tanks.

Results and Discussion

Seasonal Potential of Roof-Based Rainwater Harvesting

Monthly rainfall data from 2005 to 2017 suggests that the study area has a bimodal rainfall pattern with possibilities to plan and harvest water for two seasons (Figure 3). However, the annual and monthly totals, including rainfall days fluctuate a lot and have been declining since 2005 (Figure 4). The average monthly rainfall of 74.63 mm i.e., 0.075 m^3 (Table 1) has implications on water availability for competing uses on campus and hence the need for water harvesting and saving technologies. Physical observations of buildings revealed that no single roof catchment was connected to a water storage tank. Instead, drainage pipes were in place to safely discharge the harvested water into runoff drains. Where tanks were installed, they stored pumped from boreholes.

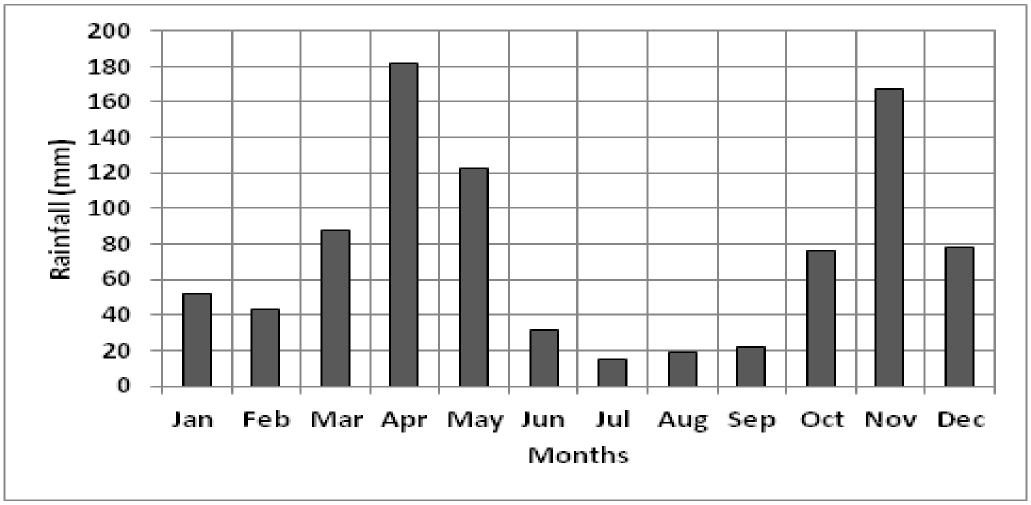

Figure 3: Seasonal rainfall distribution (2005-2017)

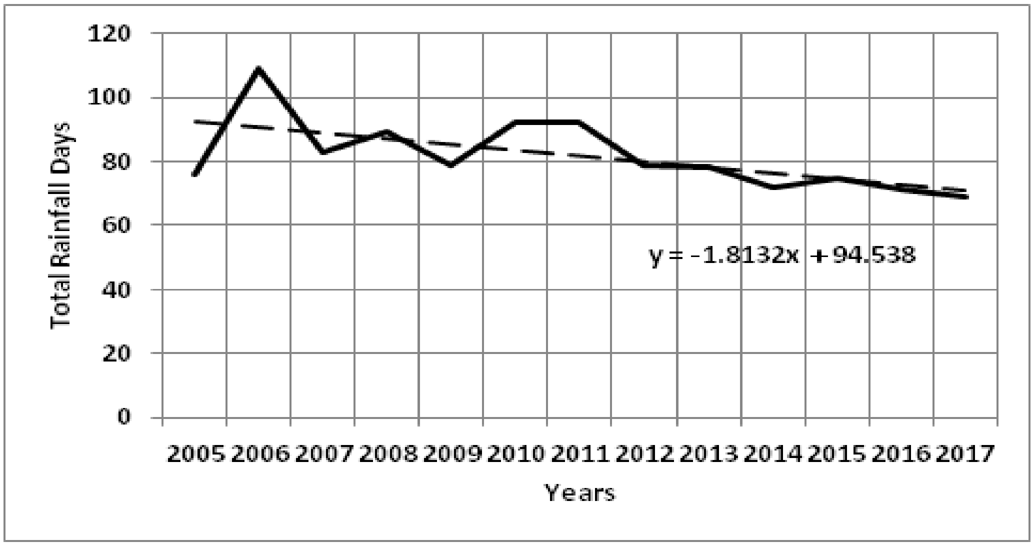

Figure 4: Time Series for Rainfall Frequency (2005-2017)

Table 1. Rainfall Data for Kenyatta University (mm) (2005-2017)

MONTH	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	MEAN MONTHLY (MM)
Jan	19	9.6	29.4	70.9	63.9	149.9	6.3	0	49.2	8	8	180.2	87.5	52.5
Feb	21.1	33.9	29.4	21.2	38	151.7	71	4.5	0	128.5	40.8	12.4	15.5	43.7
Mar	50.9	96.9	43.6	204.9	84.6	257.9	92.6	4.2	69.4	167.6	22.8	9.6	36	87.8
Apr	163	323.6	252.5	178.3	63.1	112.7	73.4	250.7	375.9	52.1	234.4	182.9	79.6	180.2
May	241.8	68.3	66.2	15.6	96	230.7	102	186.7	30.4	45.4	143.6	238.6	140.1	123.5
Jun	22.1	11.7	47.2	1.5	7.1	23.5	39.1	59.3	16.3	85.4	77.1	18	4	31.7
Jul	13.5	3.1	43.3	74	6.2	7	0	5.3	8.8	12	8.2	0	11.6	14.8
Aug	1.7	22.1	26.1	8.4	3.9	14.5	12.3	31.2	22.5	71.2	8.3	32.3	20.2	21.1
Sept	6.4	34.1	31.5	45.6	1.2	1	64.3	38.5	11.7	0	0	0.3	15.8	19.3
Oct	22.7	24	73.1	150.1	97.7	65.8	96.6	135.6	0	44.4	125.9	4.8	153.7	76.5
Nov	85.8	404.6	128.7	197.4	49.7	57.1	237.2	126.5	89.3	137.7	429.2	83.8	143.9	167.0
Dec	1.1	114.6	36.8	2.8	93.2	71.1	51.7	220.5	78.3	40.3	231.7	18.4	45.6	77.4
Total	649.1	1146.5	807.8	970.7	604.6	1142.9	846.5	1063	751.8	792.6	1330	781.3	753.5	74.63

Source: Weather Station, Department of Geography, Kenyatta University

Notes:Mean monthly rainfall = 74.63 mm is in this paper approximated to 0.075 m), 1 m^3 (CM) = 1000 litres; 1000mm = 1 m

Selected Premises and their Potential in Rainwater Harvesting

The catchment areas/zones selected for this study are those which often have a high student population and hence high-water demand especially for sanitation purposes. The potential harvests indicate that with suitable and adequate storages, these zones can be water secure for much of the year with minimum strain on metered supplies and hence cost to the university (Tables 2 and Table 3). There is no doubt that each block at the University can yield significant water from its roof. By virtue of its expansive total area, the roof catchments at the referral hospital can yield an average of 2029 m^3 of water per month. For a whole year the yield would be 24,348 m^3. The central administration Complex can yield on average 290 m^3 per month or 3480 m^3 per year. The combined twin towers have a potential yield of about 102 m^3 per month or 1224 m^3 per year. Each hostel at the Nyayo complex can yield on average 143 m^3 per month or 1716 m^3 annually. The management innovation needed is to direct the harvested water to strategically placed storage tanks. In this study, the recommended smallest water tank was of 20,000 litre capacity to maximise on value for money given the high costs of plastic tanks in Kenya. As also observed by Parker et al., (2013), increased adoption of rainwater harvesting calls for reduction in the cost of storage tanks if many people in low-income countries are to benefit from it.

Instead of having a plastic tank per block, which would add to total costs, tailor made tanks could be strategically placed to store water from more than 2 roof catchments. To enhance environmental aesthetics and limit environmental intrusion, the university could specify its requirements in terms of colour, height, diameter and any other variable like patterns on the tank surface. Where land space is not limiting appropriate underground tanks can be constructed accompanied with strategically placed above ground mega storages where water is to flow to various points of application by gravity. Compared to the total direct and indirect cost of supplying metered water, the university will save in the long run and most importantly demonstrate its core function of competence-based learning and education for sustainable development. Currently most building lack tanks that would store water harvested from their vast roofs (Plate 1 and 2). This applies across public universities and many other institutions of learning, including those with severe water shortages. It is thus plausible to affirm that design and construction of buildings deliberately ignores water harvesting, which is indicative of low or poor environmental awareness within strategic planning in learning institutions. Education for sustainable development was meant to solve such knowledge gaps. Suffice is to observe that EfSD has not been embraced and mainstreamed in all learning subjects as envisaged (UNESCO, 2021

Plate 1: Gutters and discharge pipes, but no tanks on a newer building at main campus

Plate 2: Gutters and discharge pipes, but no tanks on an old building at main campus

Table 2. Estimated roof areas and monthly water harvests from selected zones at Kenyatta University Main Campus

SN	NAME	FOOTPRINT AREA M2 (A)	ACTUAL AREA (B) = 1.15A/COS 25O) M2	EST VOLUME = 0.075B (M3)	EST VOLUME (LITRES)
	1. 844 Zone				
1	Old Library	4834	6135	460	460,000
2	College of Education Block	1832	2325	174	1754,000
3	844 Blocks	2867	3639	273	273,000
4	Science Zone 39	1125	1428	107	107,000
5	Students Computer Centre	992	1259	94	94,000
	2. Church Blocks				
6	Catholic Cathedral	977	1240	93	93,000
7	University Chapel	551	699	52	52,000
8	Foreign Languages Department	1871	2374	178	178,000
	3. Eastern Zone				
9	Admissions Block	405	514	39	39,000
10	Hostel category 1 (7 units)	9505	12064	905	905,000
11	Hostel category 1 (11 units)	5512	6996	525	525,000
12	Mathematics Department	594	754	57	57,000
	4. Nyayo Zone				
13	Nyayo Hostels (6 units)	9028	11459	859	859,000
14	School of Economics	2580	3274	246	246,000
15	School of Engineering	1948	2472	185	185,000
	5. Western Zone				
16	Geography Department	836	1061	80	80,000
17	History Department	609	773	58	58,000
18	Hostels (6 units)	7427	9427	707	707,000
19	Ngong Hostels (2 units)	1264	1604	120	120,000
20	7. Shopping Centre Units	1017	1290	97	97,000

Notes: Mean monthly rainfall across the years = 74.63 mm (0.075m); 1 m^3 (CM) = 1000 litres; 1000mm = 1 m

Table 3. Estimated roof areas and monthly rainwater harvests from other premises at the Main Campus

SN	NAME OF ZONE	FOOTPRINT AREA IN M2 (A)	ACTUAL AREA (B) = 1.15A/COS 25O) M2	EST VOLUME 0.075B (M3)	EST VOLUME (LITRES)
1	Alumni Building	953	1209	90.7	90,700
2	Arts Complex A (Twin Towers)	539	684	51.3	51,300
3	Arts Complex B (Twin Towers)	541	686	51.5	51,500
4	Chandaria Innovation Centre	880	1117	83.8	83,800
5	Central Administration Complex	3056	3877	290.8	290,800
6	Centre for International Programmes	888	1126	84.5	84,500
7	Directorate Complex	1279	1622	121.7	121,700
8	Health Unit	1065	1351	101.3	101,300
9	Int. Language and Culture Centre	2461	3122	234.2	234,200
10	Kenyatta University Funeral Home	2827	3587	269.0	269,000
11	Amphitheatre	2071	2627	197.0	197,000
12	Business Services and Student Centre	3045	3863	289.7	289,700
13	KU Convention Centre	1699	2155	161.6	161,600
14	OML Lecture Halls	1892	2401	180.1	180,100
15	Graduate School	2927	3714	278.6	278,600
16	Post Modern Library	4889	6204	465.3	465,300
17	KU Referral Hospital	21323	27056	2029.2	2,029,200
18	School of Hospitality and Tourism	896	1137	85.3	85,300
19	UNI-City Mall	11264	14293	1072.0	1,072,000

Notes: Mean monthly rainfall across the years = 74.63 mm (0.075m); 1 m3 (CM) = 1000 litres; 1000mm = 1m

Conclusions

The potential for rainwater harvesting from the expansive university roof catchments is huge but untapped. Most roof catchments have gutters and discharge pipes but lack water storage tanks. The few available tanks next to buildings store water obtained from boreholes. As a result, significant quantities of rainwater are conveniently lost as drainage and runoff water. The university system thus forfeits the economic, social and ecological benefits that such water could otherwise deliver. In particular environmental aesthetics through irrigation of flowers and lawns is lost, while sanitation levels of toilets and washrooms may easily be compromised, thus undermining the learning environment. From a strategic management perspective, the absence of storage tanks for rainwater harvesting is indicative of lack of its prioritization in project design and implementation. This absence also communicates existence of gaps with respect to environmental performance standards and resource stewardship. For not demonstrating rainwater harvesting and saving technologies, the university undermines its core role as a centre of excellence in leadership education for sustainable development.

Recommendations

1. There is need to invest in storage tanks of appropriate capacities, and strategically position them to enhance access to water for various purposes within the university. The choice for design and colour of the tanks can be deliberate in order to minimise environmental intrusion and enhance spatial environmental aesthetics. This can be achieved through negotiations with relevant partners in industry and government. Zero rating of plastic tanks would make them more affordable and therefore accessible to more institutions and people.

2. To nurture a culture of natural resource stewardship, policy should obligate universities to obtain ISO 14001:2015 certification, which would provide the assurance that the university and its employees monitor, measure and mitigate negative impacts on resources including water, based on a robust environmental management system.

3. Demonstrating rainwater harvesting would also show that universities are walking the talk when it comes to education for sustainable development, thus contributing to the development of future stakeholders with acceptable environmental conservation and management consciousness and ethos.

4. UNESCO in partnership with the National Environment Management Authority could also promote the mainstreaming of environmental resources stewardship in universities by establishing a yearly award that recognises the best performing university and calling out the least performing.

References

Citizen TV (2019). GARBAGE RIVERS | Effluent in Nairobi and Athi Rivers. https://www.youtube.com/watch?v=YnSvnwYjjI4 (Retrieved 6 February 2023)

FAO (2020). The State of Food and Agriculture. Overcoming water shortages in agriculture. https://www.fao.org/3/cb1447en/cb1447en.pdf (Retrieved 2nd June 2023).

Gakungu J N (2013). Qualitative Assessment of Rainwater Harvested from Roof Top Catchments. Kenya Engineer. https://www.kenyaengineer.co.ke/qualitative-assessment-of-rain-water-harvested-from-roof-top-catchments/ (Retrieved 10 March 2023).

Ghis E, Schondermark P (2013) *Investment feasibility analysis of rainwater use in residences.* Water Resources Management, 27, 2555–2576.

Haque M, Rahman A, Samali B (2016) *Evaluation of climate change impacts on rainwater harvesting.* J. Clean. Prod. 137, 60–69.

Herrero M, Ringler J, Van de Steeg P, Thornton T, Zhu E, Bryan A, Omolo J, Koo A, Notenbaert (2010) *Kenya: Climate variability and climate change and their impacts on the agricultural sector, ILRI report to the World Bank for the project* "Adaptation to Climate Change of Smallholder Agriculture in Kenya.

Israel21c (2022). How Israel Used Innovation to Beat Its Water Crisis. https://www.israel21c.org/how-israel-used-innovation-to-beat-its-water-crisis/ (Retrieved 30 March 2023)

Kitulu N, Nzeve J, Waswa F, Kitur E and Shitanda D. (2020). Irrigation Water Quality Analysis of Mitheu Stream in Machakos Municipality, Kenya. *African Journal of Environmental Science and Technology*. Vol. 14(9), pp. 241-249, September 2020. DOI: 10.5897/AJEST2020.2849

Nyakundi. V, G. Munala, M. Makworo, J. Shikuku, M. Ali and E. Song'oro (2020). Assessment of Drinking Water Quality in Umoja Innercore Estate, Nairobi. Journal of Water Resources and Protection. DOI:10.4236/jwarp.2020.121002. https://www.scirp.org/journal/paperinformation.aspx?paperid=97640 (Retrieved 10 March 2023)

Opare S (2012) *Rainwater harvesting: An option for sustainable rural water supply in Ghana*. GeoJournal, 77, 695–705. https//doi.org/10.1007/s10708-011-9418-6

Parker, A., Cruddas, P., Rowe, N., Carter, R., & Webster, J. (2013). Tank costs for domestic rainwater harvesting in East Africa. *Proceedings of the Institution of Civil Engineers: Water Management*, *166*(10), 536-545. https://doi.org/10.1680/wama.11.00113 (Retrieved 3 June 2023)

Reliefweb (2023). Kenya 2022 Drought Response in Review. https://reliefweb.int/report/kenya/kenya-2022-drought-response-review (Retrieved 10 March 2023)

Republic of Kenya (2010). The Constitution of Kenya 2010. http://www.parliament.go.ke/sites/default/files/2023-03/The_Constitution_of_Kenya_2010.pdf (Retrieved 4th June 2023)

Republic of Kenya (2023). The Water Act (2016), https://wasreb.go.ke/downloads/Water%20Act%202016.pdf (Retrieved 10 March 2023)

Samaddar S, Murase M, Okada N (2014) *Information for disaster preparedness: A Social network approach to rainwater harvesting technology dissemination*. International Journal of Disaster Risk Science5:95–109.

Sojobi AO, Balogun II, Oyedepo BO (2016) Assessment of rainfall variability, rainwater harvesting potential and storage requirements in Odeda Local Government Area of Ogun State in South-western Nigeria. *Cogent Environmental Science 2*(1): 1138597. https://doi.org/10.1080/23311843.2016.1138597

UNEP (2002). https://www.unep.org/resources/report/vital-water-graphics-overview-state-worlds-fresh-and-marine-waters (Retrieved 2 June 2023)

UNEP (2019). Sustainable Development Goals. https://www.unenvironment.org/explore-topics/sustainable-development-goals (Retrieved 3 December 2019)

UNESCO (2021). Sustainable Development Goals - Resources for educators. https://en.unesco.org/themes/education/sdgs/material#:~:text=Education%20for%20Sustainable%20Development%20(ESD,achievements%20of%20all%2017%20SDGs (Retrieved 3 June 2023)

UNESCO (2023). Press release. Imminent risk of a global water crisis, warns the UN World Water Development Report 2023. https://www.unesco.org/en/articles/imminent-risk-global-water-crisis-warns-un-world-water-development-report-2023#:~:text=Globally%2C%202%20billion%20people%20(26,Water%20Conference%20in%20New%20York (Retrieved 2nd June 2023)

UNICEF (2022). Water Crisis in the Horn of Africa. https://www.unicef.org/media/126006/file/water-crisis-horn-africa-2022.pdf (Retrieved 2nd June 2023)

UN-Water (2021). Water Scarcity. Facts and Figures. https://www.unwater.org/water-facts/water-scarcity (Retrieved 2nd June 2023).

Water.Org (2023). Kenya's water and sanitation crisis. https://water.org/our-impact/where-we-work/kenya/#:~:text=With%20a%20population%20of%2053,lack%20access%20to%20improved%20sanitation (Retrieved 2nd June 2023)

World Economic Forum (2022). Singapore is leading the way in recycling wastewater. https://www.weforum.org/agenda/2022/11/singapore-wastewater-recycling-water-stressed/#:~:text=Singapore%20is%20recycling%20its%20wastewater%20so%20it's%20clean%20enough%20to,of%20countries%20facing%20water%20challenges. (Accessed on 30th March 2023)

World Vision (2023). Global water crisis: Facts, FAQs, and how to help. https://www.worldvision.org/clean-water-news-stories/global-water-crisis-facts (Retrieved 2nd June 2023).

Zdeb, M, Zamorska, J, Papciak, D, and Slys, D. (2020). The Quality of Rainwater Collected from Roofs and the Possibility of Its Economic Use. Resources. *Resources*, *9*(2), 12; https://doi.org/10.3390/resources9020012. https://www.mdpi.com/2079-9276/9/2/12 (Accessed on 10th March 2023)

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The authors confirm that there is no conflict of interest over this article.

Author Contributions

1. The first author did the primary research as part of her Masters study programme at Kenyatta University. As required by the Commission for University Education and the university author one extracted and prepared the first draft of this article from the unpublished thesis.

2. Author two was the primary supervisor for this master's research. He reviewed all drafts of the extracted paper and guided its content and form based on journal requirements. Author two also agreed to be the author of correspondence.