A Study into Reducing Utilities Bills by a Rainwater Harvesting Method at the University of Namibia (UNAM) Rundu Campus

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ABSTRACT

Shortage of water provision sources has become a major problem for many growing cities all over the world due to climate change. Hence, adoption of different water conservation techniques at different institutions and communities is paramount. Rainwater harvesting (RWH) becomes an excellent technique of water conservation for future needs. We have reviewed the different methods to harvest water and propose the use of a rooftop rainwater harvesting structure for the University of Namibia (Rundu) campus located in Kavango East region. Different parts of the RWH system were reviewed based on standard guidelines. It was observed from the analysis that implementation of RWH system can resolve the water scarcity problems during rainy season by storing a huge quantity of approximately 105 840 litres per month in a year. The implementation of this initiative can help reduce considerably the water utility bill and the energy use required for water pumping and treatment.

Keywords: Rooftop rainwater harvesting, innovation, Sustainability, Water scarcity**.**

INTRODUCTION

Many developing and developed countries are facing water scarcity due to climate change. This situation is also worsened by the rapid population growth, industrialization and urbanization resulting in high demand of water supply (Remmert, 2020). In Namibia, all bulk water assets are regulated by NamWater that determines and levies tariffs on a full cost-recovery basis for water supplied according to Section 7(1) (a) of the Namibia Water Corporation Act. Even though a lot of effort has been put in place to supply the people with water, the cost of water for Namibians has increased drastically. We have recently experienced an acute crisis in the quantity and quality of water in Rundu. Actual pumping of water is below the capacity due to unpaid bills. In addition, the water distribution lines are very old, inadequate, and faulty. Huge wastage of water is an important reason of the crisis. Construction works, car washing, watering gardens, toilet flushing and even production in mills and factories are done with water meant for drinking. The problem is so severe in some areas that people do not get the minimum required quantity of water for drinking. Scarcity of safe water is the main reason for the outbreak of diarrhea and other intestinal diseases in the city, which have assumed epidemic proportions (Lugeretzia, 2017). Considering the problems of water scarcity that many are likely to face soon or are already facing, we have delimited our study at UNAM Rundu Campus. Water is consumed a lot through different ways on Campus for watering of grass, flowers, seedbeds by the agriculture students, bathing, washing, cooking, in the kitchen and flashing toilets. This increases the water costs especially during dry season. Therefore, alternative water supply options are becoming significantly important to avoid water scarcity and reduce the costs. Rainwater harvesting (RWH), an alternative water supply option, is a common practice in countries with high annual precipitation (Jokisch et al., 2016). Rainwater harvesting (RWH) is a technology used for collecting and storing rainwater either from the rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as using complex techniques such as underground check dams. In this paper, different methods of harvesting rainwater are reviewed, opportunities and possibilities of utilizing rainwater harvesting at UNAM Rundu Campus as a secondary source are explored. The most suitable method and sites for harvesting rainwater are proposed. The monetary value of harvested rainwater is also determined.

LITERATURE REVIEW

2.1 Methods of rainwater harvesting (RWH)

Rainwater harvesting is a way of collecting rainwater from rooftops and above-ground impervious surfaces that is stored in catchment tanks for other use.

2.1.1 Rooftop Rainwater Harvesting

Rooftop harvesting is a system of catching rainwater where it falls, the roof becomes the catchments and rainwater is collected from the roof of the buildings. This method is simple, less expensive, eco-friendly, very effective and very useful if implemented correctly. It can either be stored in a tank or diverted to an artificial recharge system to meet the commercial needs through storage in the tanks (Morey et al., 2016).

2.1.2 Surface Runoff Harvesting

In urban areas, rainwater flows away as surface runoff that can be caught and used for recharging aquifers by adopting appropriate methods. This is the method of collecting rainwater flowing along the ground during the rain and it is collected to a tank below the surface of the ground for irrigation and other purposes. The main objective of surface runoff rainwater harvesting is to meet the ever-increasing demand of water, to reduce water pollution, soil erosion and flooding of roads (Larrauri, 2019) (Larrauri and Shumaker, 2019)

2.1.3. Dams: Dams are barriers that are built to trap water. Rainwater can collect directly in them. Water collected in dams is mostly used for irrigation purposes or treated and then distributed for household use (Chowdhury et al., 2016). They can also be used to harvest a lot of water because of the way in which they are designed. The construction of the dam requires a large space, and the area must be free from underground utilities and electrical lines. Yet, Rundu Campus has all this installed. The treatment and distribution of the collected water cost is expensive, making it not appropriate to be used in the campus.

2.1.4. Underground Tanks: These are also ideal for collecting rainwater. They are made by digging into the ground and creating a space which is then cemented to reduce water infiltration (Berhane, 2018). The top is also sealed, and water is acquired through pipes directed into the tank, and to get water out, pumps are used. Underground tanks are ideal for harvesting rainwater because the rate of evaporation is reduced since they are built underground where sunlight does not really penetrate (Campisano et al., 2017). However, there are underground utilities such as sanitary sewers and water supply pipes placed underground, around the campus. This may take time to locate a place free of all these utilities in the campus and construct the underground tank.

Study area

The University of Namibia Rundu Campus is situated in Kavango region at the far northern part of the country which receives about 600 mm of rainfall per year (Mwinga et al., 2018). This is the part of the country which receives high rainfall compared to rest of the country, which makes it easy to harvest rainwater. The campus consists of various edifices like administrative block, Science block, Central library, lecture halls, kitchen, dining hall student hostel blocks (females & males), gym hall, and staff houses. All these structures are supplied in water by the Rundu Municipality and an average of 150 kl are consumed per month. The use of rainwater harvesting would help to reduce the cost of water during raining season. The different methods discussed are very effective and can aid in the collection of a lot of water even for commercial activities while others are only suitable for harvesting water meant for domestic use. However, after carefully studying the different methods, based on the context of the study area, the appropriate method to be used at Rundu campus seems to be the Rooftop system. This is because it is an alternative that can be easily installed and maintained, does not need large areas to work like dams and underground tanks. It could also provide water directly to institution and lastly, it renders water of good quality and if properly maintained it is not harmful to human health, unlike dams which may breed mosquitoes and cause other waterborne diseases if not treated.

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METHODOLOGY

A preliminary survey is carried to examine the buildings and to verify the rooftop area. The population and the water consumption within the campus is recorded by a detailed inquiry. The data collected from the bills is used to determine individual building unit water demand. The potential of Rooftop Rainwater Harvesting (RTRWH) is calculated using equation (4.1) for selected buildings. The mass curve technique is adopted to estimate the volume of the tank and detailed design plan is discussed. An explicit study on the economic aspects is done to find the efficiency of the RTRWH system.

The descriptive stepwise procedure used in this study is shown in Figure 1.

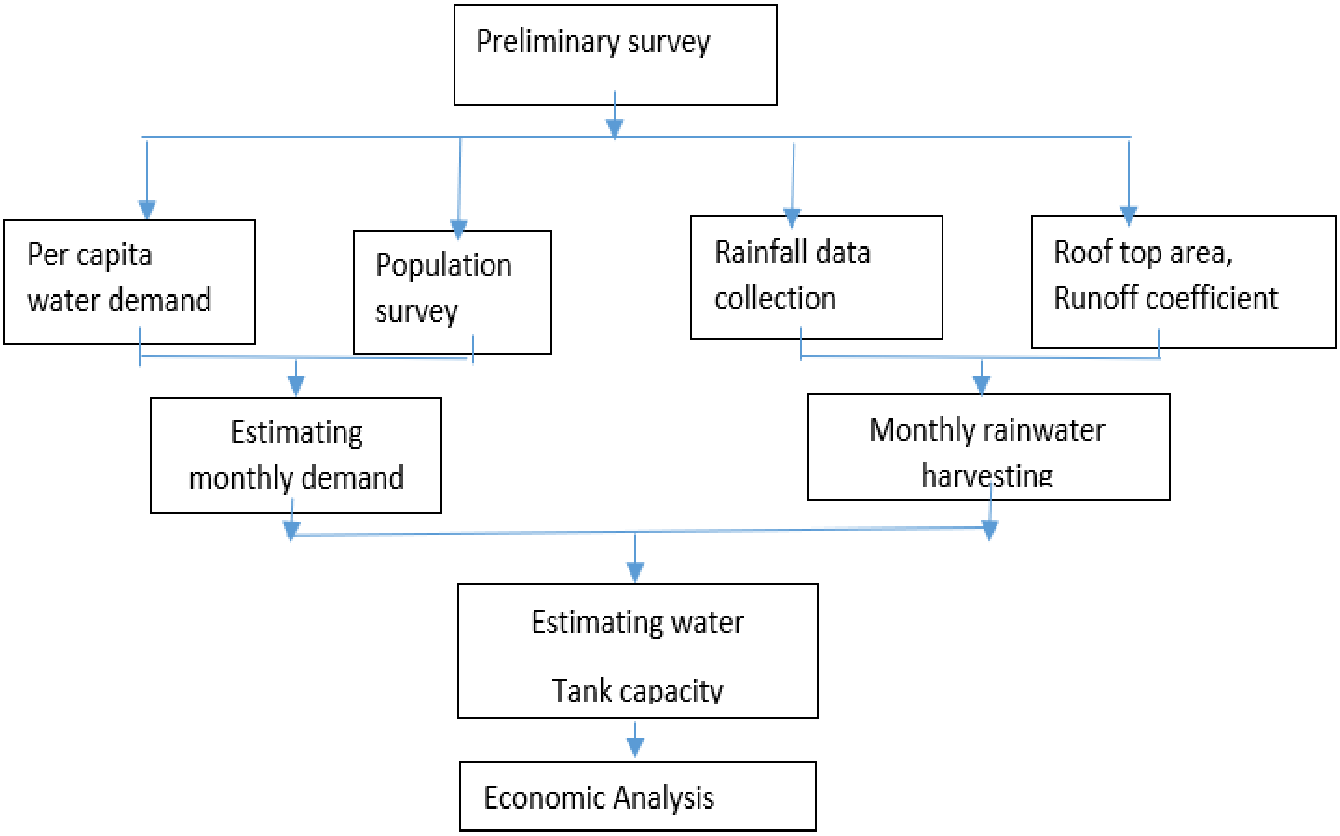

Figure 1: Study methodology flow chart

Collection calculation

The RTRWH potential is calculated using the equation below:

$$Q= CIA \tag{4.1}$$

Where Q is the total discharge from the roof (m^3s), C indicates the coefficient of runoff, I is the intensity of rainfall (mm), and A represents the total rooftop catchment area. Generally, the value of runoff coefficient depends on the properties of roofing materials (Mao et al., 2021). The common values of runoff coefficient are presented in Table 1.

Table 1. Runoff coefficient values for various roof types

SI. No	Type of roof	Runoff coefficient
1.	Galvanized iron sheet	0.90
2.	Asbestos sheet	0.80
3.	Tiled roof	0.75
4.	Concrete roof	0.70

Data sets and data collection

The areas which were identified to use more water on the campus are the students' hostels, the dining hall (kitchen) and the gardens. There are a total of five students' hostels with 28 rooms each, a common room, a laundry, bathrooms, and toilets. Each hostel is divided in two parts with 14 rooms, a laundry, bathrooms, and toilets. 2 tanks will be set at strategic collection points at the junctions of gutters in each hostel, 2 tanks at the kitchen, 2 tanks at science building and 4 tanks for the gardens.

Model selection and description

A rainwater harvesting system is shown in Figure 2 below. This shows how the collection surface captures rain and directs rainwater to storage. This may include filtration processes to remove debris and dust from runoff. The storage device stores the water until it is required. It is then transported to where it will be used. If water will be used for drinking, there may be additional filtration. Uses of rainwater may include drinking, washing, flushing toilets, irrigation etc.

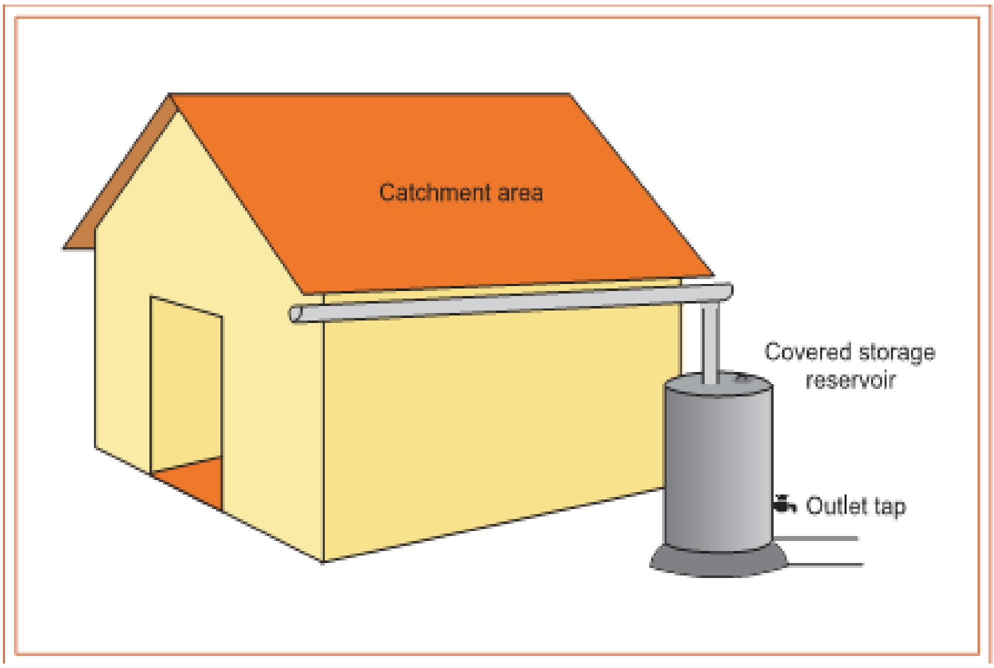

Figure 2: Rainwater harvesting model.

A rainwater harvesting system consists of four main components.

- The **cistern** — or water storage tank — stores runoff for later use.
- The **gutter system** collects runoff from the rooftop and directs it into the cistern.
- The **overflow pipe** allows excess runoff to leave the cistern in a controlled manner.
- The **outlet pipe**, which is sometimes connected to a pump, draws water from the bottom of the cistern for use.

It is important to consider all these components and how they work together before installing a rainwater harvesting system. The cistern is the primary component, it is selected and located based on anticipated water needs. The local plumbing codes might affect the installation, and periodic maintenance will be required.

RESULTS AND DISCUSSION

Water quality analysis

The quality of the harvested water may be affected by parameters such as the location of the buildings, the roof cover material, and the periodic cleaning of the roof (Chiang, 2013). About 10 samples of rainwater were collected from the roof top of selected buildings to be analyzed. The characteristics are given in Table 2. The test showed that our samples are in the range of the drinking water standards in Namibia. However, if the water

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is to be used for human consumption, the analysis recommends the use of a filtering unit to trap the roof sediments before entering the storage tank. The recommended minimum frequency for bacteriological analysis of drinking water is once every three months.

Table 2: Harvested water quality (Shivute, 1956)

x	Parameter	unit	Range	Namibian standards
1	pH		5.4-7	6-9
2	Total Dissolved Solids (TDS)	mg/L	30-83	500
3	Total Suspended Solids (TSS)	mg/L	00-28	25
4	Calcium (Ca)	mg/L	10-41.5	150
5	Magnesium (Mg)	mg/L	0.2-0.4	70
6	Chlorine	mg/L	16-53	250
7	Electrical conductivity	mS/s	45-158	150

Rainfall statistics

Figure 3 shows the rainy period of the year in Rundu lasts for 6 months, from October to April with a sliding 31-day rainfall. The month with the most rain in Rundu is January and the month with the least rain is July (Weather and climate, 2022).

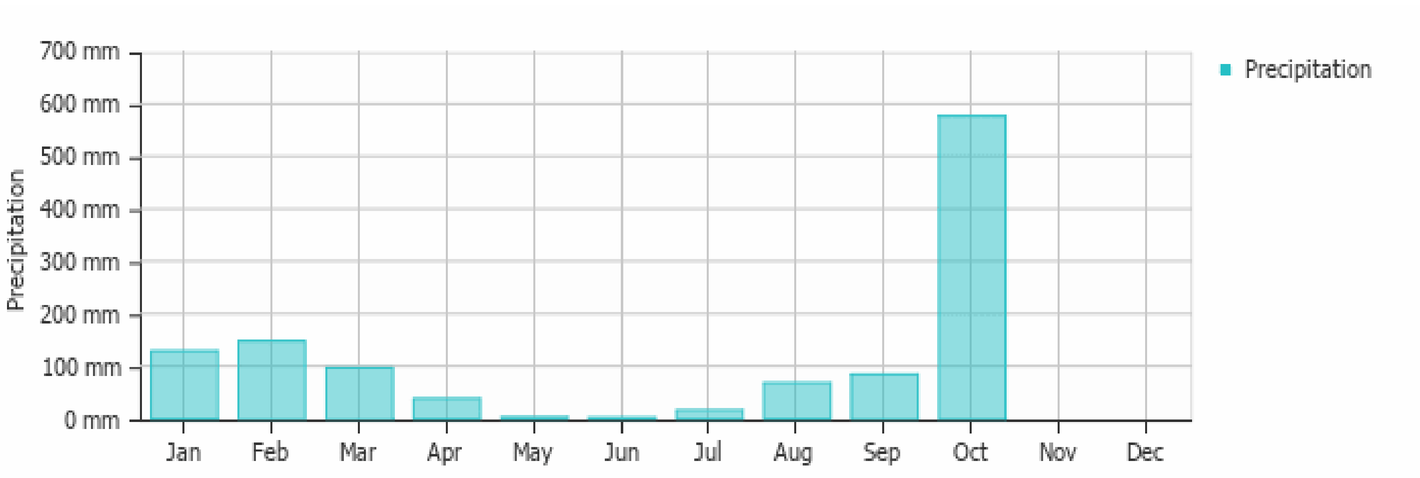

Figure 3: Average precipitation (rain) in Rundu, Namibia in 2021.

Water demand and cost

The major determining factors for water demand are the population of the campus and the purpose of water usage. Usually, it is challenging to estimate the water demand in universities since people are involved in diverse activities. However, the water demand data for each month at Rundu campus has been obtained from the finance office. The average monthly consumption obtained from the Municipal water bills is approximately 2 500 m^3. To calculate total water costs, we break up the usage into the different tariff categories. In the 0-15 m^3, 15m^3 of water was used, in the 16-30 m^3 category, 15 m^3 of water was used, in the 31-60 m^3, 30 m^3 of water was used, in 61-100 m^3, 40 m^3 was used, in 101 and above, 2400 m^3 was used. In total (15m^3+15m^3+30m^3+40m^3+2400 m^3 = 2500 m^3. Now we calculate how much the number of m^3 used in each category cost according to the tariffs:

15 m^3×NAD 22.66 = NAD 339.90

15 m^3× NAD 25.78 = NAD 386.70

30 m^3 × NAD 26.80 = NAD 804.00

40 m^3 × NAD 35.16 = NAD 1406.40

2400 m^3 × NAD 40.00 = NAD 96000.00

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For a month, the campus uses approximately 2500 m^3 and it costs NAD 98937.00. The municipality charges are shown in Table 3:

Table 3: Water demand and cost per month

Quantity Range (m³)	**Units (m³)**	**Tariffs (NAD)**	**Value (NAD)**
0–15	15	22.66	339.90
16–30	15	25.78	386.70
31–60	30	26.80	804.00
61–100	40	35.16	1,406.40
101 and above	2,400	40.00	96,000.00
TOTAL	**2,500**		**98,937.00**

Rainwater harvesting potential

The annual rainwater harvesting potential of the catchment areas (kitchen, 5 hostels, Sciences laboratories and gardens was estimated using equation (4.1) above. The value of runoff coefficient was taken as 0.9 from Table 1. It was observed that the 5 hostels have the highest daily rainwater harvesting potential of 1 700 litres. The rainwater harvesting potential estimated from selected building units are presented in Table 4. We see that during raining season, with the identified sites, we will be able to harvest approximately an average of 105 840 litres per month.

Table 4: Rooftop rainwater harvesting potential (m^3) for selected building units.

Building unit	Roof area (m^2)	RWH potential (l/day)
Kitchen	552	820
5 Hostels	5×224	5×340 = 1700
Sciences Laboratory	2 ×150	2×220 = 440
Garden 1	72	108
Garden 2	66	60
Garden 3	140	400

Positioning and potential of storage tanks

For the present study, seven main tank locations were identified and recommended. To meet the growing water demand and the identified RWH potential as discussed previously, 12 potential storage tanks with their capacity to hold the rainwater were chosen. To minimize the project cost, the proposed tank positioning was determined based on gravity flow of harvested water by reducing pumping head and pumping distance.

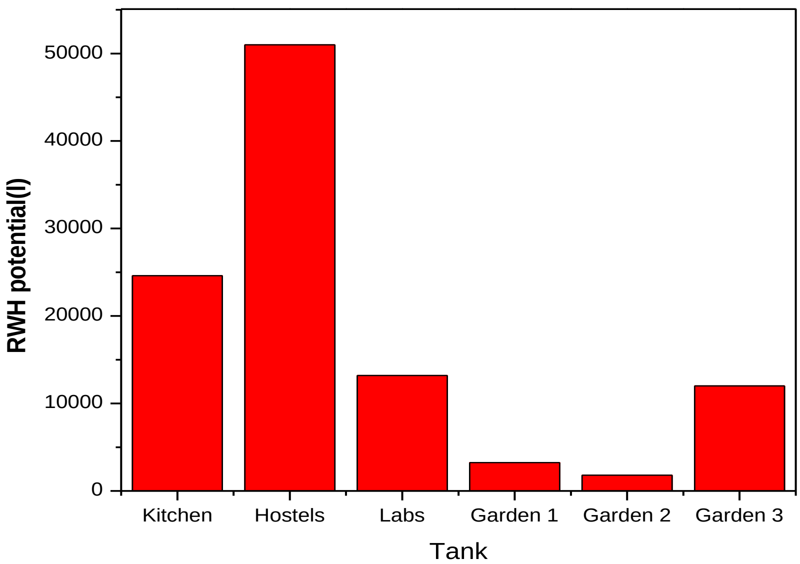

Figure 3: Rainwater harvesting potential for selected storage tank.

The quantity of rainwater harvested from each of the twelve tanks is shown in Figure 3. Highest estimated yearly storm water inflow will be from the five hostels tanks with 51 000 litres, followed by the kitchen with 24 600 litres, the laboratories with 13 200 litres and the gardens. During the season, 150 000 litres of rainwater can be collected. If the twelve water tanks are always full for 6 months, the price of water could be reduced drastically.

Cost estimation

Generally, 95% of the total rainwater harvesting project cost is solely due to the purchase of tanks, accessories, and the installation of pipes (Abdulla and Al-Shareef, 2009). The size of the tank to be installed mainly depends on water demand. A detailed estimation of cost considering local rate is given in Table 3. The harvested water does not need large treatment units since it is already free from various contaminants (Chiang, 2013). Looking at the total cost excluding the installation, the system is feasible as the harvested water can directly be used for activities such as gardening, washing, and cleaning. This will drastically reduce the total monthly bills during raining season. The conventional water supply during this period can only be used for drinking, cooking and laboratory purposes.

Table 3: Cost estimation of storage tanks.

Tanks	Capacity (l)	Cost (NAD)
5 Hostels	5× 10 000	5 × 12 000 = 60 000
2 Kitchen	2×10 000	2 × 12 000 = 24 000
2 Science	2 × 5 000	2 × 5 000 = 10 000
3 Gardens	3 × 5 000	3 × 5 000 = 15 000
		TOTAL = 109 000

CONCLUSION

We have analyzed different methods of harvesting rainwater. Various factors that enable and constrain rainwater harvesting were critically reviewed. The rooftop harvesting system is found to be the appropriate method for harvesting water. The establishment of such system will help to reduce the consumption of water. With the selected catchment areas, it was observed from the analysis that the potential of implementing RTRWH system with 12 tanks will provide approximately 105 840 litres per month that is enough to cover the monthly cost of water on Campus. The Buildings in Rundu campus have corrugated iron rooftops and gutters readily installed, all that is required needs to be installed are the filters, drainage pipes and water tanks. The water tanks can be purchased locally, for instance in Agra and Build it, which is cost effective. The overall quality of rainwater was quite satisfactory and implied that the system could be sustained during critical periods, as well as normal periods. Additionally, the system is cost effective, as large amounts of money can be saved per year. Moreover, increased awareness on water crisis has led rainwater harvesting to be proposed as a community facility. The small and medium residential and commercial construction can adopt this system as sustainable option of providing water. It is almost the only way to upgrade one's household water supply without waiting for the development of community system. The system could become a good alternative source of water supply in Rundu town to cope with the ever-increasing demand and should be accepted and utilized by the respective authorities as well as by the city dwellers.

List of abbreviations

RTRWH: Rooftop Rainwater Harvesting.

RWH: Rainwater Harvesting.

UNAM: University of Namibia

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