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Full Length Research Paper

An inventory of rainwater harvesting technologies in Swaziland

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Rainwater harvesting involves water collection from surfaces on which rain falls and storing it for later use. Although water supply shortages are a global problem, not much has been done to exploit the rainwater harvesting benefits in Swaziland. A descriptive study using structured questionnaire was conducted to identify rainwater harvesting technologies used in Swaziland. Purposive sampling was employed in targeting 714 households practising rainwater harvesting in four ecological zones. Results indicated technologies consisting of a catchment, conveyance system and storage reservoir. Reservoirs comprised drums, buckets, metal tanks, trailed bowsers, and polyvinyl chloride (PVC) tanks. Roof catchments with aboveground reservoirs were utilised by 99.6% households, whereas roof catchments with underground reservoir was used by 0.1% household and 0.3% used ground catchments. The lowveld had the highest (31.1%) households using corrugated sheets roof catchments; whereas the highveld and middleveld had 26.6 and 21.6% households using this catchment. The Lubombo Plateau used diverse catchments materials; 20.7% corrugated sheets, 0.1% grass (bamboo) and 0.3% vegetated ground catchments. The water stored per household ranged from < 100 L, to > 1,000 L. Technologies cost ranged from < E100 (< $13.37), to > E1000 (> $133.71). It was concluded that there is potential for increasing water harvesting in the regions where practised.

Key words: Potable water, rainwater harvesting, roof catchments, water quality, water-harvesting technologies.

INTRODUCTION

Water is essential to man, animals and plants; without water, life on earth would not exist. An adequate supply of safe water is a prerequisite for major, socio-economic development of a community. Despite this, water supply shortages are becoming a problem of global proportion (Preston, 2008). Factors such as the amount of time spent in the collection of drinking water, and a substantial reduction in the incidence of disease, can contribute to development, provided the time and energy gained are utilised economically (Mwendera, 1988; Economist.com, 2008) . Safe, drinking water is important in the control of many diseases, such as diarrhoea, cholera, typhoid, infectious hepatitis, and amoebic and bacillary dysentery (Hofkes, 1981). One reason safe drinking water is of paramount concern is that 75% of all diseases in developing countries arise from polluted drinking water (TWAS, 2002).

It is estimated that river flow, together with the annual turnover of groundwater account for less than 40% of the rain, which falls on the world's land surface (Pacey and Cullis, 1986). The remaining water is lost through evaporation from the soil, pools, marshes, lakes and by transpiration from the leaves of growing plants. Despite this loss, freshwater resources are vital for meeting basic human needs and inadequate protection of the quality and the supply of freshwater can set important limits to sustainable development (UNEP, Undated). In some of the drier regions of the world, water collected in rivers could be low and depended on shared water resources between countries. Though this is the case, such water could be vital in meeting the per capita basic need of 20 to 50 L of water, which should be free from harmful contaminants (SIWI, 2010). Where water supplies are inadequate developing countries could be affected by two types of water scarcity; physical (where water consumption exceeds 60% of the usable supply) and economic (where a country physically has sufficient water

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resources to meet its needs, but additional storage and transport facilities are required (Postnote, 2002). The economic scarcity could mean embarking on large and expensive water-development projects. However, for many countries, specifically in sub-Saharan Africa, where Swaziland is located, it will be difficult to mobilize the necessary financial and other resources to increase water supply to adequate levels.

Availability of adequate and clean water for household uses is an enormous problem for rural households in developing countries (Mwendera, 2006). Women who are usually overburdened by a host of domestic chores have to walk long distances daily in order to fetch water for their households. Such water supplies are usually polluted during the rainy seasons, with the result of high incidence of water-borne diseases. Rainwater harvesting is the practice of collecting and using precipitation from a small catchment area such as roofs, artificial surfaces at ground level, and land surfaces with slopes less than 50 to150 m in length. It has the potential of meeting water needs of rural communities (Pacey and Cullis, 1986; Sustainable Earth Technologies, 2003).

Swaziland is a land locked county in Southern Africa, which lies within the latitude and longitude of 26°30 S and 31°30 E, respectively. It covers an area of 17364 square kilometres, with a population estimated at approximately one million. Swaziland has a sub-tropical climate receiving almost 75% of its annual rainfall during the months of September to March (Government of Swaziland, 1995).

Despite the fact that Swaziland is a well-watered country, with a mean annual rainfall that ranges from 550 to 625 mm in the lowveld, and 850 to 1400 mm in the highveld, water is one of the major constraints to development (Government of Swaziland, 1997a). It is known that a high proportion of the population residing in rural and peri-urban areas does not have access to safe and clean water (Government of Swaziland, 1977b). National health statistics in the country show that some infant mortality is related to water-borne diseases, which is a reflection of the poor quality of water (Government of Swaziland, 2002). According to the 1991 Demographic and Household Survey, only 28% of the rural residents had access to safe potable water as opposed to about 89% in the urban areas (Government of Swaziland, 1997b).

According to SIWI (2010), almost one-tenth of the global disease burden could be prevented by improving water supply, sanitation, hygiene and management of water resources. It is concluded that such improvements reduce child mortality and improve health and nutritional status in a sustainable way. Swaziland is a well watered country, but lacks the infrastructure to provide safe drinking water for domestic use in the rural areas. This is exacerbated by the scarcity of information on how to exploit the water supply and health benefits of rainwater harvesting in the country. Therefore, this study was conducted to identify and categorise the technologies used for harvesting rainwater for domestic purposes, and to determine the costs of such technologies in Swaziland. The study could provide insights and potable water options that could be utilized by communities located in the rural areas not covered by reticulated rural water supply schemes and the drier regions of Swaziland such as the lowveld and some areas of the Lubombo Plateau. Rainwater harvesting, particularly rooftop rainwater harvesting is relatively safe for domestic use than most surface water sources such as rivers. Furthermore, the main advantages of a rainwater system are that the quality of rainwater is comparatively good, it is independent and therefore suitable for scattered settlements and the owners/users can construct and maintain the system (Rahman, 2006).

METHODOLOGY AND SAMPLING

The research was carried out during the dry season after the rainy or water harvesting period (September to January, 2007). The study was descriptive in nature, whereby primary data were collected through documentary analysis of official records or desk search. Secondary data were collected using structured questionnaire, personal interviews, and field observations. Purposive sampling procedure was used in order to target those households practising rainwater harvesting technologies, due to lack of data on households involved in rainwater harvesting. The sample population included rural households practising water harvesting in all the four ecological zones of Swaziland, namely highveld, middleveld, lowveld and Lubombo Plateau. The highveld is humid and temperate with an average annual precipitation of 1,000 to 2,300 mm. The middleveld and Lubombo Plateau are subtropical with an average annual precipitation of 900 to 1,150 mm. The lowveld is tropical and semiarid with an average annual precipitation of 500 to 900 mm. (Figure 1). These four ecological zones formed the geographical area where the study was conducted.

Since rainwater harvesting is practised more in the drier lowveld than any other region, more rural areas were selected from this ecological zone or region than the other three. There were 30 sample areas; 12 in the lowveld, six in the middleveld, six in the highveld and six in the Lubombo Plateau. In each rural area, 25 households that harvested rainwater were randomly selected for interview. This then led to an eventual sample size of 714 households (instead of the originally proposed 750) due to problems encountered with one of the chiefdoms. Bereavement in one of the chiefdoms as per cultural norms prevented the data collection because the communities (Households) were in mourning.

RESULTS AND DISCUSSION

Water harvesting technologies

The majority (99.6%) of the 714 households studied harvested water using roof catchments to aboveground (Figure 2) reservoir technologies. Out of the remaining 0.4% households, only 0.1% household harvested water using roof catchments to underground reservoir technologies, and the other 0.3% used vegetated ground

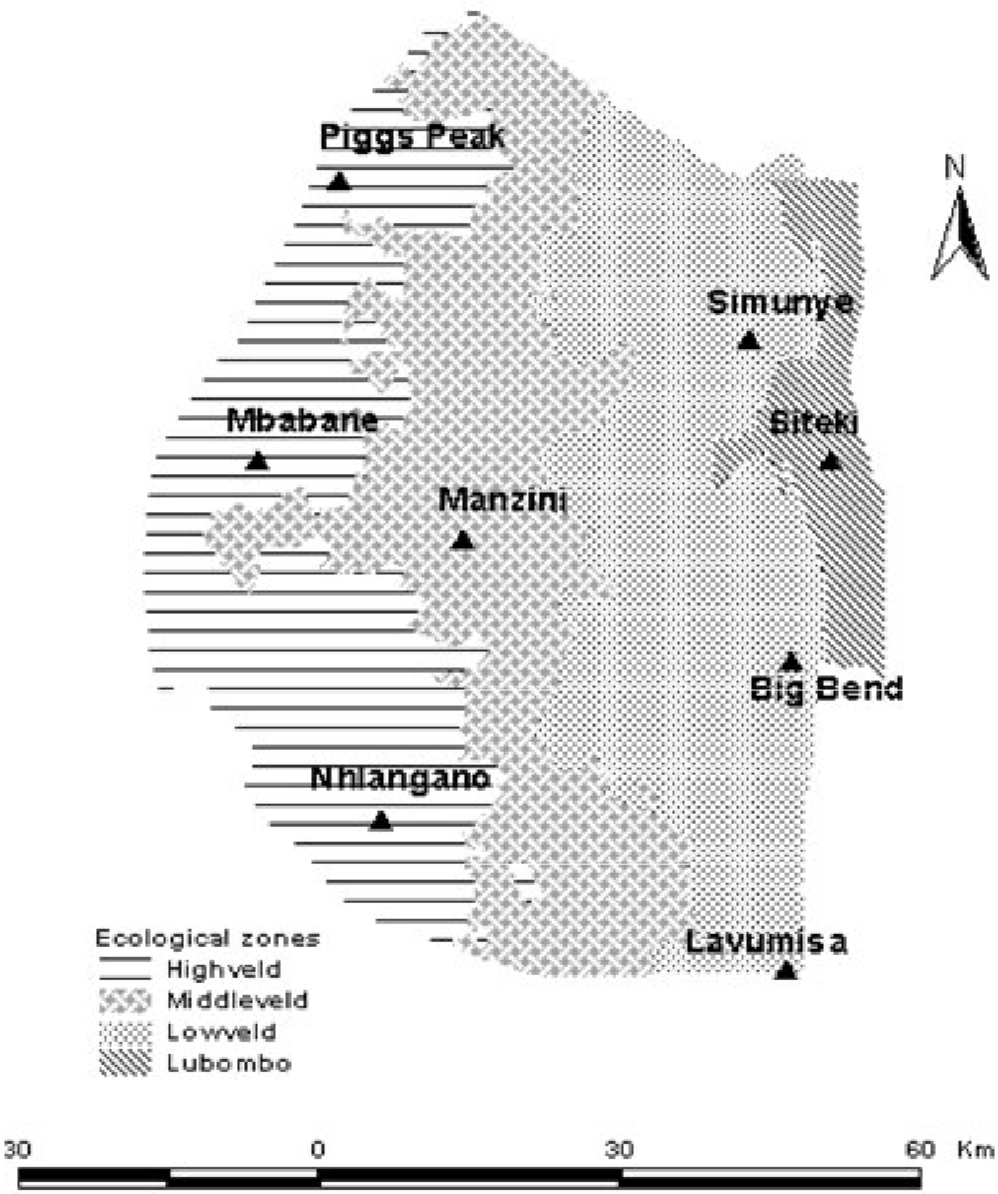

Figure 1. Map showing the ecological zones of Swaziland and major towns.

catchments to harvest water (Table 1). Out of the 711 households that used roof catchments to aboveground reservoir technologies, the region with the highest number of households in this category was the lowveld, with 30.8% households, followed by the highveld, with 26.6% households. The middleveld and the lowveld had less number of households using roof catchments to aboveground reservoirs, with 21.4 and 20.6% of the households, respectively. The lowveld was the region with the highest (0.3%) proportion of households, which used roof catchments to underground reservoir technologies, while the Lubombo Plateau had the least (0.1%). This can be attributed to the low (500 to 900 mm) rainfall received by this region compared to the others (methodology and sampling). The scarcity of water in this region could be the main reason which made households to harvest and store rainwater during summer (rainfall season) for immediate and future use. The low rainfall received by the lowveld does not make it ideal for rainwater harvesting. This is exacerbated by the poor coverage of the region by the rural water supply reticulation and the distant sources of water such as streams and rivers, which may not be safe.

Water harvesting catchment's materials

The water harvesting catchment materials used by the

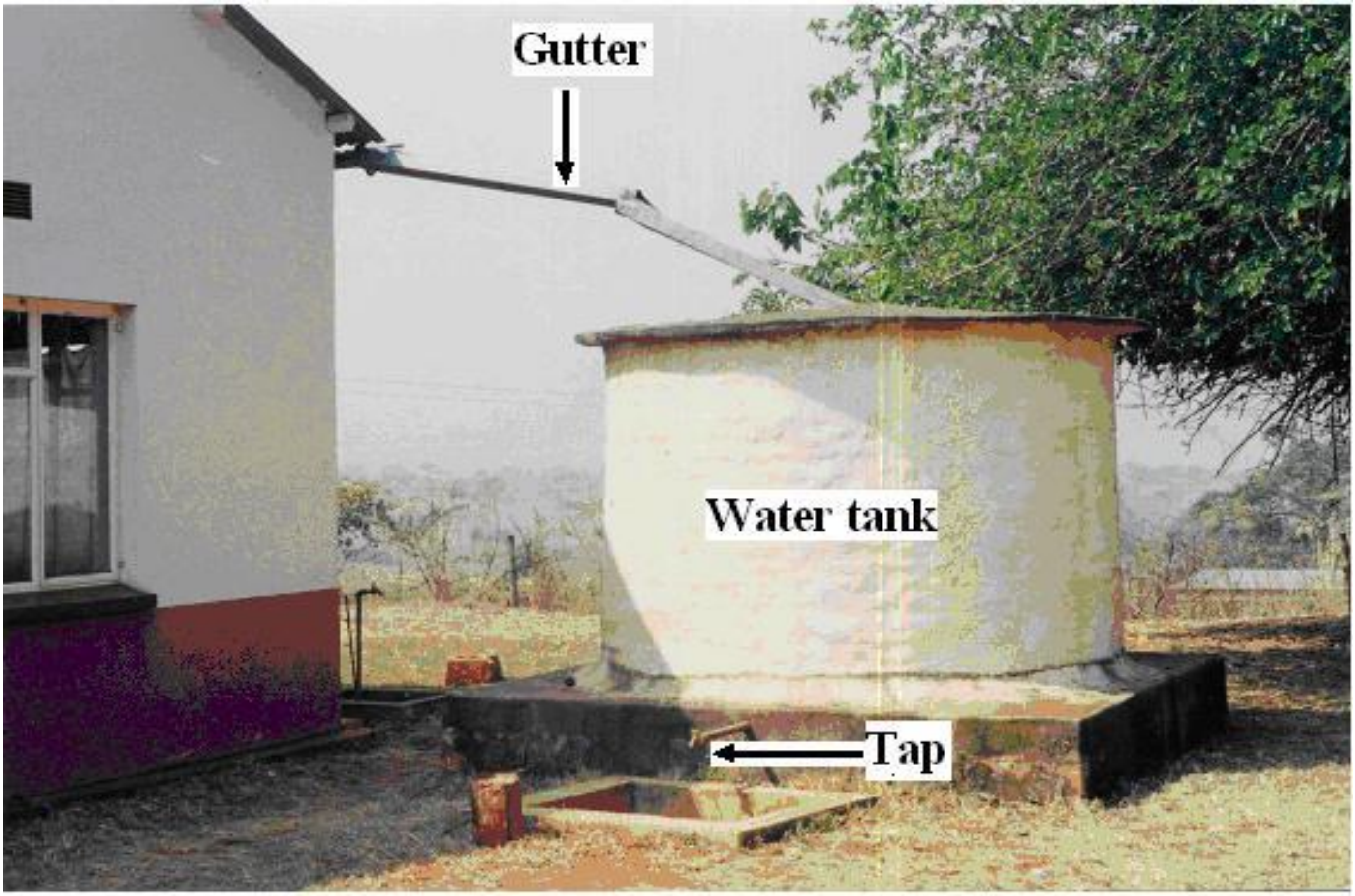

Figure 2. A rainwater harvesting technology consisting of a roof catchments, conveyance gutter and an above ground storage tank.

Table 1. Water harvesting technologies used by households in the ecological zones (N=714).

Ecological zone	Roof catchment to aboveground reservoir		Roof catchment to underground reservoir		Total	
	N	%	N	%	N	%
Highveld	190	26.6	-	-	190	26.6
Lowveld	220	30.8	2	0.3	222	31.1
Middleveld	154	21.4	-	-	154	21.6
Lubombo Plateau	147	20.6	1	0.1	148	20.7
Total	711	99.6	3	0.4	714	100

N - Number of households, - No data.

households were mainly (99.6%) roof catchments, with only 0.3% being vegetated ground catchments. The roof catchments materials were found to be in five categories, according to the four ecological zones as shown in Table 2. The roof catchment materials included: corrugated sheets, grass or bamboo, vegetation, polyvinyl chloride (PVC) plastics and tiles.

The lowveld had the highest (31.1%) number of households using roof catchment materials that were made of corrugated sheets. It was followed by the highveld with 26.6% households, while the middleveld had 21.6% households. The Lubombo Plateau was the only region, which used diverse catchment materials. These comprised corrugated sheets (20.7%), grass or bamboo (0.1%) and vegetated ground catchments (0.3%). The vegetated catchments were ground catchments where water harvesting was conducted in a small scale by a few households. There were no households that used ground catchments to harvest rainwater in all the other regions.

Table 2. Water harvesting catchments material used by households in the ecological zones (N = 714).

Ecological zone	Catchment material										Total	
	Roof catchments								Ground catchment			
	Corrugated sheets		Grass/ Bamboo		Tiles		Plastic (PVC)		Vegetated			
	N	%					N%N%N%		N	%	N	%
Highveld	190	26.6	-	-	-	-	-	-	-	-	190	26.6
Lowveld	222	31.1	-	-	-	-	-	-	-	-	222	31.1
Middleveld	154	21.6	-	-	-	-	-	-	-	-	154	21.6
Lubombo Plateau	145	20.7	1	0.1	-	-	-	-	2	0.3	148	20.4
Total	711	99.6	1	0.1	-	-	-	-	2	0.3	714	100

N - Number of households, - No data.

Table 3. Water harvesting catchments size used by households in the ecological zones (N = 714).

Ecological zone	Catchment size (m^2)								Total	
	< 20		20-50		50-100		> 100			
	N	%	N	%	N	%	N	%	N	%
Highveld	52	7.3	65	9.1	62	8.7	11	1.5	190	26.6
Lowveld	71	9.9	117	16.4	30	4.2	4	0.6	222	31.1
Middleveld	63	8.8	54	07.6	22	3.1	15	2.1	154	21.6
Lubombo Plateau	50	7.0	60	08.4	13	1.8	25	3.5	148	20.7
Total	236	33.0	296	41.5	127	17.8	55	7.7	714	100

N - Number of households.

In Nigeria work by Efe (2006) revealed that thatch, aluminium, asbestos, corrugated iron sheets, and open surfaces produced rainwater, which had most of its physiochemical and biological characteristics generally below the World Health Organization (WHO) threshold. Unfortunately this work did not state the WHO threshold values referred to, but it concluded that the rainwater harvested should be stored for human consumption and for other uses, but water treatment was needed to regularise the pH, TSS, iron concentration, and colour.

Different conclusions have been made on the quality of water harvested from roof tops (Kahinda et al., 2007). Generally, water collected from roof catchments is usually of acceptable quality for domestic purposes (Anonymous, undated). However, the quality of the harvested and stored rainwater could depend on the characteristics (such as the topography, weather conditions, the proximity to pollution sources, catchment area, the water tank, the handling and management of the water) of the considered area (Sazakli et al., 2007; Zhu et al., 2004; Vasquez et al., 2003). Simple roof rainwater management like the "first flush" usually provide safe drinking water with low organic contents, even for rainwater collected immediately after rainfall (Zhu et al., 2004).

Water harvesting catchment size

The roof catchments ranged in size from < 20 m^2 to > 100 m^2 (Table 3). Thirty three percent of the sampled households had roof catchments that were less than 20 m^2, while the largest number of households (41.5%) had roof catchments with sizes between 20 and 50 m^2. Roof catchments with surface areas of between 50 and 100 m^2 accounted for 17.8% of all the catchments, and only 7.7% had catchments areas above 100 m^2.

Water collection and gutter systems

Table 4 shows the four groups of catchment water collection systems identified by the households. There were PVC gutters, metal gutters, corrugated iron sheets and no device at all each making 32.5, 43.4, 16.8 and 7.3% households, respectively.

The conveyance technologies that were used to take water from the roof gutters to the storage tanks comprised: (i) down-pipes; (ii) used 2 L plastic soda containers; (iii) wooden sticks; and (iv) free fall (Table 5). The low cost of the free fall method was probably the main reason why it was the most popular (76.1%), even

Table 4. Catchment water collection devices used by households in the ecological zones (N=714).

Ecological zone	Catchment collector								Total	
	PVC gutter		Metal gutter		Corrugated iron sheets		None			
	N	%	N	%	N	%	N	%	N	%
Highveld	64	09.0	102	14.3	10	1.4	14	2.0	190	26.6
Lowveld	75	10.5	74	10.4	61	8.5	12	1.7	222	31.1
Middleveld	47	06.6	58	08.1	37	5.2	12	1.7	154	21.6
Lubombo Plateau	46	06.4	76	10.6	12	1.7	14	2.0	148	20.7
Total	232	32.5	310	43.4	120	16.8	52	7.3	714	100

N - Number of households.

Table 5. Conveyance devices used by households in the ecological zones (N = 714).

Ecological zone	Conveyance devices								Total	
	Down pipe		2 L plastic soda container with hose pipe		Wooden stick		Free fall			
	N	%	N	%	N	%	N	%	N	%
Highveld	75	10.5	8	1.1	-	-	107	15.0	190	26.6
Lowveld	38	5.3	14	2.0	2	0.3	168	23.5	222	31.1
Middleveld	66	9.2	2	0.3	-	-	154	21.6	154	21.6
Lubombo Plateau	30	4.2	2	0.3	2	0.3	114	16.0	148	20.7
Total	209	29.3	26	3.6	4	0.6	543	76.1	714	100

N - Number of households, - No data or zero.

.though it is not an efficient method of conveyance. This is in contrast to the work of Sigwane and Kunene (2010) which reflected the free fall as the least (19%) conveyance system used by the community studied. The down pipe technology is an efficient conveyance method, but its high cost might be the reason why it became the second in terms of popularity, as it was used by 29.3% households. The 2 L soda containers were the least (3.6%) used conveyance device, followed by the wooden sticks, which were used by only 0.6% of the households.

Type and capacity of water storage systems

The types of storage reservoirs used by the 714 households studied comprised (i) plastic drums, (ii) metal drums of about 210 L, (iii) buckets of about 25 L, (iv) mortar and concrete tanks, (v) plastic (PVC) tanks, (vi) metal tanks, and (vii) bins (Table 6). Table 7 shows the reservoir storage capacities of the harvested water comprising five groups, namely: less than 100, 100 to 300, 300 to 500, 500 to 1000 L and greater than 1,000 L. The majority (31.5%) of the households had reservoirs, which could store between 100-300 L of the harvested water, followed by 26.5% households that stored water in reservoirs with capacities more than 1000 L. Less than a 1000, 300 to 500 and 500 to 1000 L capacity reservoirs were used by 15.3, 13.7 and 13% households, respectively. With adequate rainfall received, these storage capacities could improve the water supply quantities, which should benefit the households directly. Lessons could be learnt from the study by Kahinda et al. (2007) who observed that improving the quantity and quality of water supply could improve the level of sanitation. However, these capacities could only provide water to the households during the water harvesting season, rather than the whole year requiring contingency water supply sources. Increasing the tank capacities could sustain the household longer than is the case currently. In this regard lessons could be drawn from the work by Singwane and Kunene (2010) in Swaziland which indicated that harvested rainwater do not sustain families throughout the year due to small storage facilities, while those with big tanks (10 000 L) could not be sustained for long due to large family sizes.

The type of storage reservoirs used by the different communities reflected their interaction with the neighbouring corporate institutions, Non Governmental Organizations (NGOs), the seasonal nature of the rainwater harvesting, and financial capacity to purchase. The communities' closer to corporate institutions with fleets of vehicles used more 210 L drums for water storage, which are basically oil containers for the institutions' vehicles during their useful life. Technical

Table 6. Storage reservoirs used by households in the ecological zones (N = 714).

Ecological zone	Type of storage reservoir														Total	
	Plastic drum		Metal drum (210 L)		25 L plastic buckets		Mortar/ concrete tanks		Metal tank		Plastic (PVC) tanks		Bins			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Highveld	34	4.8	71	9.9	32	4.5	5	0.7	3	0.4	45	6.3	-	-	190	26.6
Lowveld	47	6.6	62	8.7	29	4.1	45	6.3	7	1.0	25	3.5	7	0.1	222	31.1
Middleveld	23	3.2	52	7.3	20	2.8	11	1.5	11	1.5	37	5.2	-	-	154	21.6
Lubombo Plateau	35	4.9	44	6.2	14	2.0	6	0.8	5	0.7	26	3.6	18	2.5	148	20.7
Total	139	19.5	229	32.1	95	13.3	67	9.4	26	3.6	133	18.6	25	3.5	714	100

N - Number of households , - No data

Table 7. Reservoir storage capacity used by households in ecological zones (N = 714).

Ecological zone	Reservoir storage capacity (L)										Total	
	< 100		100 - 300		300 - 500		500 - 1000		> 1000			
	N	%	N	%	N	%	N	%	N	%	N	%
Highveld	27	3.8	75	10.5	20	2.8	15	2.1	53	7.4	190	26.6
Lowveld	28	3.9	68	09.5	32	4.5	51	7.1	43	6.0	222	31.1
Middleveld	18	2.5	38	05.3	19	2.7	18	2.5	61	8.5	154	21.6
Lubombo Plateau	36	5.0	44	06.2	27	3.8	9	1.3	32	4.5	148	20.7
Total	109	15.3	225	31.5	98	13.7	93	13.0	189	26.5	714	100

N - Number of households.

advice and financial assistance from NGOs resulted in some communities using the mortar and concrete tanks. The temporary that is (when it rains) harvesting of water resulted in the utilization of the smaller storage devices such as the 25 L buckets. The bigger and more sustainable PVC and metal tanks were utilized by those households that had permanent water harvesting systems and therefore practiced rainwater harvesting through out the rainy season. In all cases the water storage devices reflected the capacity of the household to either purchase them or fabricate one like the case of the mortar and concrete tanks.

Cost of water harvesting systems

The estimated costs of the water harvesting technologies (Table 8) ranged from less than E100 ($13.37) to more than E1000 ($133.71). While only 0.6% households from the Lubombo Plateau could not estimate the cost of the technologies, 61.8% of the 714 households estimated the costs in the range of less than E100 ($13.37). This low cost was attributed to the size of the system employed by the household for drinking water purposes only. Only 20.3% households estimated the costs to be between E501 ($66.99) and E1, 000 ($133.71), while 13.4% households estimated the costs to be between E100 ($13.37) and E500 ($66.86), whereas 28 (3.9%) households estimated the

Table 8. Cost of household water harvesting technologies used in the ecological zones (N = 714).

Ecological zone	Technology cost (E)[1]										Total	
	< 100		101-500		501-1000		> 1000		Unknown			
	N	%	N	%	N	%	N	%	N	%	N	%
Highveld	145	20.3	29	4.1	6	00.8	10	1.4	-	-	190	26.6
Lowveld	100	14.0	31	4.3	79	11.1	12	1.7	-	-	222	31.1
Middleveld	107	14.9	19	2.7	23	03.2	5	0.7	-	-	154	21.6
Lubombo Plateau	89	12.5	17	2.4	37	05.2	1	0.1	4	0.6	148	20.7
Total	441	61.8	96	13.4	145	20.3	28	3.9	4	0.6	714	100

1 - $US 1.00 = E7.4788 (Ned bank, Swaziland Limited, 2008), N - Number of households, - No data.

water harvesting technologies to be greater than E1000 ($133.71).

Generally, the cost of the system is moderate in view of the fact that the catchments (roof) and the conveyance (gutter and down pipe) were available. These costs were absorbed during the construction stage of the buildings in most cases. The storage facility was the single cost that was associated with the water harvesting in most of the households studied. On the basis of this, it could be deduced that water harvesting could be afforded by households in Swaziland. Farolfi et al. (2007) concluded that rural households indicated more willingness to pay for water quality and quantity improvements.

Most people in rural areas rely on river and collective tap water, whilst private tap is mainly found in urban areas (Farolfi et al., 2007). However, in rural areas, in spite of substantial investments, coverage levels remain low (30%) largely because of poor maintenance of existing water systems (Government of Swaziland, 2003). It could therefore be concluded that surface water sources such as streams provide the contingency supplies when there is no rain.

Government support is currently enshrined in the draft national water policy which has one of its five objectives as; to ensure access to adequate and good quality water for all citizens (Department of Water Affairs, Undated). In this policy promoting rainwater harvesting is addressed under water for food security within water resources for agriculture. The Water Act, 2003 (Act No. 7 of 2003) once fully operational could potentially provide a conducive environment for Government intervention through the National Water Authority. Other than these policy statements and the rural water supply, there is no tangible support that government provides for household water harvesting initiatives.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The water harvesting technologies used by the 714 households studied were found to be three phased: (i) a catchment, (ii) conveyance and (iii) storage reservoir. They were categorised into two groups, identified as roof catchment to ground storage reservoir (99.6%), and roof catchment to underground reservoirs (0.4%). In the ecological zones with rainwater harvesting technologies made up of roof catchments with aboveground reservoirs, and roof catchments with underground reservoirs, there is potential for increasing these, due to the relatively low capital costs involved. The estimated costs of the water harvesting technologies on Table 8 ranged from less than E100 ($13.37) to more than E1000 ($ 133.71). Only 0.6% households from the Lubombo Plateau could not estimate the cost of the technologies used.

Recommendations

Due to the low cost of the rainwater harvesting technologies and the quality of the harvested water, enabling policies and tangible support should be established to encourage communities (especially those located in low rainfall areas like the lowveld, as well as those with very few alternative clean water sources) to practise rainwater harvesting. This should complement the rural water supply coverage, particularly the low rainfall areas where rainwater harvesting is a challenge. Further research should be conducted to determine or assess the quality of the harvested water over time at predetermined sampling points in each of the four ecological zones of Swaziland.

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