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# Domestic rainwater harvesting to improve water supply in rural South Africa

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**Abstract**

Halving the proportion of people without sustainable access to safe drinking water and basic sanitation, is one of the targets of the 7th Millennium Development Goals (MDGs). In South Africa, with its mix of developed and developing regions, 9.7 million (20%) of the people do not have access to adequate water supply and 16 million (33%) lack proper sanitation services. Domestic Rainwater Harvesting (DRWH), which provides water directly to households enables a number of small-scale productive activities, has the potential to supply water even in rural and peri-urban areas that conventional technologies cannot supply. As part of the effort to achieve the MDGs, the South African government has committed itself to provide financial assistance to poor households for the capital cost of rainwater storage tanks and related works in the rural areas. Despite this financial assistance, the legal status of DRWH remains unclear and DRWH is in fact illegal by strict application of the water legislations. Beyond the cost of installation, maintenance and proper use of the DRWH system to ensure its sustainability, there is risk of waterborne diseases. This paper explores challenges to sustainable implementation of DRWH and proposes some interventions which the South African government could implement to overcome them.


*Keywords:* Domestic rainwater harvesting; Rural South Africa; Water supply; Sustainable

## 1. Introduction

South Africa is one of the signatories of the Millennium Development Goals. With its mix of both developed and developing regions, 3.7 million people have no access to any form of water supply infrastructure and an additional 5.4 million people who have some access have to be brought up to a basic level of service (Info, 2006). Domestic rainwater harvesting (DRWH) is an alternative for South Africa to meet the Millennium Development Goals of halving, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation (MDG 7, Target 1), and provide free the first six kilolitres of water consumed monthly to poor households (households with less than USD 112 income/month). Rainwater harvesting (RWH) describes the small-scale concentration, collection, storage, and use of rainwater runoff for productive purposes. DRWH is one of the broad categories of RWH where water is collected from rooftops, courtyards and similar compacted or treated surfaces, stored in underground tanks (UGTs) or aboveground tanks (AGTs) and used for domestic purposes, garden watering and small-scale productive activities. DRWH is not new in the region, rooftop RWH is a major source of drinking water in the rainy season especially in KwaZulu-Natal and the Eastern Cape (Duncker, 2000). The practice is currently spreading in rural South Africa, especially with the financial assistance provided by the Department of Water Affairs and Forestry (DWAF) to resource poor households for the capital cost of rainwater storage tanks and related works. There is a direct link between the provision of clean water, adequate sanitation and improved health (Gleick, 1996), and often inadequate water supply is pointed as a factor contributing to poor sanitation. Improving the quantity

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and quality of water supply improves the level of sanitation. Sanitation is an important public health measure which is essential for the prevention of diseases. With regard to sanitation services, in South Africa, 16 million people (3.9 million households) are without adequate sanitation services (Info, 2006). Water plays a major role in laying the foundation for economic growth, not only by increasing the assurance of supply, but also by improving water quality and therefore human health (Phillips et al., 2006). There are two categories of storage reservoirs for DRWH, surface or aboveground tanks (common for roof collection) and sub-surface or underground tanks (common for ground catchment systems). As the level of adoption increases some critical aspect of DRWH such as the health implication, the sizing of the storage tank and the management strategy need consideration. Apart from the most spoken advantage of enabling small-scale productive activities (brewing, small-scale food production, household construction, etc.); DRWH also has the adverse potential impact to spread a number of water related diseases if proper measures are not taken. The immune systems of HIV-positive people are susceptible to a wider range of common illnesses and diseases than individuals whose immune systems are not compromised by HIV and AIDS (Ashton and Ramasar, 2002). As funds are made available for the widespread of DRWH, there is a need to explore its potential to improve the rural water supply. This paper presents the current state of DRWH in South Africa and seeks to highlight the challenges to overcome for its sustainable implementation.

## 2. The RWH Pilot programme

As part of the efforts of the South African government to halve the number of food insecure households, financial assistance is provided for the implementation of storage tanks. During the Demonstration Phase of its Pilot Programme, DWAF has constructed, through implementing agents, 64 underground tanks (UGTs) (Fig. 1) in 26 villages distributes in 4 provinces, namely Eastern Cape, Limpopo, KwaZulu-Natal and Free State. (De Lange, 2006).

Results of the DWAF RWH Demonstration Phase, November 2005–July 2006, and subsequent analysis and planning for expansion, has shown that the total cost of delivering a homestead rainwater tank of 30 $m^3$, is not expected to exceed ZAR 22,800 (Table 1) during the expansion and roll-out phases. The isolated cost of material and labour for the construction of the rainwater tank, which amount to ZAR 13,000 is unaffordable for the populace.

In its RWH pilot programme, DWAF only considers UGTs which collect rainwater from the ground, and totally disregards aboveground tanks (AGTs) which collect rainwater from rooftops. Furthermore, it is inappropriate to use the same tank size for different locations since the rainfall, the water requirement and the availability of alternative water sources differs from one site to another. Even though water stored in UGTs in not potable, some households use it as drinking water after putting in some drops

Table 1
Total DWAF investment per household (De Lange, 2006)

| Description | Cost in Rand | Cost in USD |
|---|---|---|
| Material and labour per 30 $m^3$ rainwater tank | 13,000 | 1806 |
| Facilitation, sustainability inputs, household training and production establishment, coordination with local authorities, construction and project implementation management, etc. | 7000 | 972 |
| Value added tax @14% | 2800 | 389 |
| Total | 22,800 | 3167 |

USD 1 = ZAR 7.2 (FNB, 2006).

Fig. 1. 30 $m^3$ RWH underground tank constructed by under the DWAF demonstration phase (Picture by Papenfus).

of bleach (Duncker, 2000), raising the question of the quality of the water. Furthermore, about 67,000 UGTs and AGTs are already being used as main source of water (Census 2001). Since it is impossible to monitor what the harvested water will be used for, it makes sense to consider the possible adverse effects of the use of DRWH on health.

## 3. Literature review of the potential impact of DRWH on water-related diseases

The main advantage of DRWH is to provide water right at the household, suppressing the burden of having to walk long distances to fetch water. The quantity of water delivered and used for households is an important aspect of domestic water supplies, which influences hygiene and therefore public health (Howard and Bartram, 2003). In the South African context, the quality of the water takes another dimension when one considers the HIV/AIDS epidemic (one of the worst in the world) that shows no evidence of a decline with the number of people infected with HIV estimated at 5.5 million (UNAIDS, 2006). The Strategic Framework developed by the government in 2003 states:

> Lack of access to water supply and sanitation constraints opportunities to escape poverty and exacerbates the problems of vulnerable groups, especially those affected by HIV/AIDS and other diseases. A key focus of South Africa's water services policy should be on ensuring access of the poor to adequate, affordable and sustainable levels of defined basic water supply and sanitation services (DWAF, 2003).

Newborn, young children, elderly, incapacitated people or people living under unsanitary conditions are those at greatest risk of water-related diseases. Table 2 below, gives a classification of water-related diseases. Water-borne diseases remain a cause for concern in both developing and developed countries worldwide (Duncker, 2000).

Table 2
Classification of water-related disease (Eisenberg et al., 2001, citing Bradley, 1974)

| Category | Comments |
|---|---|
| Water-borne diseases | Caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses; includes cholera, typhoid, amoebic and bacillary dysentery and other diarrhoeal diseases |
| Water-washed diseases | Caused by poor personal hygiene; includes scabies, trachoma and flea-, lice- and tickborne diseases in addition to the majority of waterborne diseases, which are also water-washed |
| Water-based diseases | Caused by parasites found in intermediate organisms living in water; includes dracunculiasis, schistosomiasis and some other helminths |
| Water-related diseases | Transmitted by insect vectors which breed in water; includes dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever |

Currently, drinking water quality provision in many rural areas is substandard (Mackintosh and Colvin, 2003). The impact of water-borne disease in South Africa is significant. Pegram et al. (1998) estimates that about 43,000 South Africans die every year from diarrhoeal disease and the annual public and private direct health care costs incurred due to diarrhoea alone are at least ZAR 3.0 billion. DRWH has the potential to supply water of better quality at household level, therefore reducing the water related diseases but further studies are required on the subject. In South Africa, few data on quality of water sources and associated health problems are available, since limited surveys have been conducted (Nevondo and Cloete, 1999). The same lack of data is observed worldwide on the quality of DRWH (Dillaha and Zolan, 1984).

The health implications of widespread use of DRWH are divided into two aspects, namely (Vasudevan et al., 2000):

- Concerns regarding water quality and possible direct health implications due to contaminants.
- Insect vector breeding related to water storage and health implications arising out of it.

### 3.1. The quality of DRWH

Available literature presents different conclusions on the quality of water harvested from rooftops. While some studies report that rainwater from rooftops generally meets the international guidelines of drinking water (Sazakli et al., 2007; Zhu et al., 2004; Handia et al., 2003; Dillaha and Zolan, 1984) other studies reports that chemical and/or microbial contaminants are often present in level exceeding international guidelines of drinking water (Abbott et al., 2006; Vasudevan and Pathak, 2000; Nevondo and Cloete, 1999; Yaziz et al., 1989). The quality of the harvested and stored rainwater depends on the characteristics of the considered area, such as the topography, the weather conditions, the proximity to pollution sources, the type of the catchment area, the type of water tank and the handling and management of the water (Sazakli et al., 2007; Zhu et al., 2004; Vásquez et al., 2003; Gould, 1999).

UGTs collect surface runoff and have therefore a contamination path very similar to those of other water bodies. In the case of rooftop RWH, even though the nature of water collection process seems to prevent the pollution of rainwater, it is wrong to assume that the harvested water reaches the drinking water standard. Fig. 2 shows the contamination paths for DRWH systems collecting water from rooftop.

The sources of contamination of rooftop RWH tanks include; dust from the soil, leaves from trees, repellent insects, chemical deposits, and bird droppings. The maintenance of DRWH system mainly consists in periodical

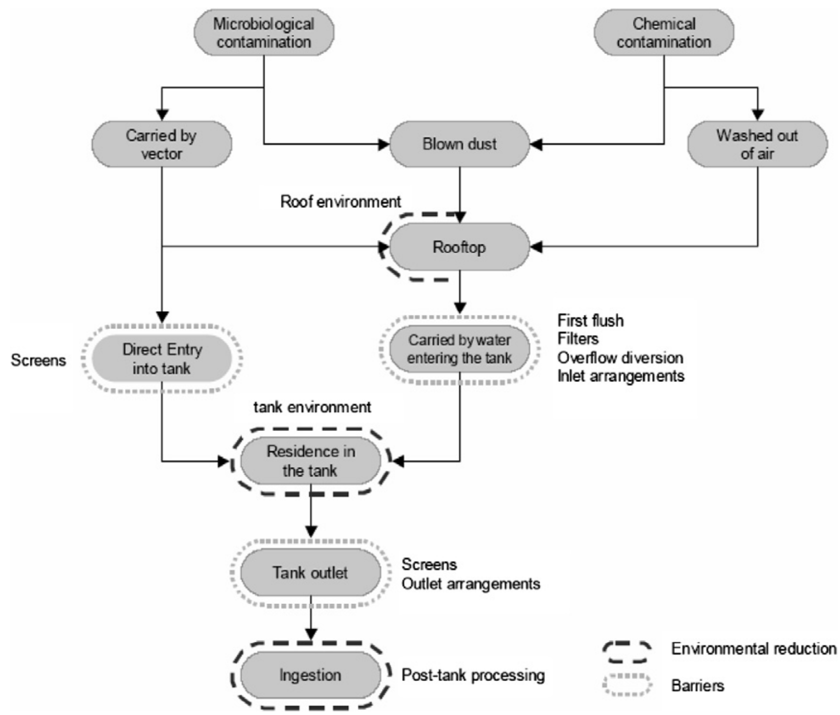


Fig. 2. Contamination paths DRWH systems collecting water from rooftop.

cleaning of the catchment area and the interior of the water storage tank (Sazakli et al., 2007; Dillaha and Zolan, 1984) as well as the diversion of the first millimetres of rains. Since it is impracticable to clean the roof surface, the best way of preventing pollutants and contaminants from getting into the storage tank is by either diverting or flushing the first millimetres of rains. Martinson and Thomas (2005) developed a methodology that enables to estimate the amount of rain to flush for any type of roof. This implies that in a country such as South Africa where the rainfalls are erratic and unevenly distributed, the first millimetres of rain after each dry spell will have to be either diverted or flushed. At present, no diverting devices are installed on the AGTs implemented in rural South Africa. Such a diverting device coupled with regular cleaning of the water storage tank will improve the water quality. Another maintenance procedure is the periodic addition of a disinfectant such as chlorine to the cistern to kill existing bacteria (Dillaha and Zolan, 1984).

### 3.2. *DRWH as an insect vector*

Vasudevan et al. (2000) indicates that mosquito is the major insect vector, which needs to be considered in the context of DRWH. Mosquitoes cause various diseases (Table 3), among which malaria is the most common in South Africa.

Malaria transmission is a multifactorial phenomenon and climate is a major limiting factor of its spatial and temporal distribution, but many non-climatic factors may alter or override the effect of climate (Craig et al., 2004). Regions of South Africa affected by malaria are the lowveld region of Mpumalanga, Limpopo and the north-eastern parts of Kwazulu-Natal (Fig. 3). Malaria victims are mostly women and children and if uncontrolled, it becomes a major economic burden as most of the malaria risk areas in South Africa fall within some of the best tourism regions (DOH, 2003a).

Table 3
Diseases caused by mosquitoes

| Protozoan disease | Filarial disease | Viral disease |
|---|---|---|
| Malaria | Heart worm | Yellow fever<br>Dengue fever<br>Encephalitis |

The implementation of DRWH in those three provinces requires special measures to prevent the breeding of mosquitoes in the DRWH tanks. Preventive measures with regard to DRWH may be divided into three groups (after Vasudevan et al., 2000):

(i) Prevention of mosquito breeding in the surroundings of the tank. Chemical and biological measures may be employed to kill immature mosquitoes during larval stages:
  - Plants and aquatic plants that repel mosquitoes can be grown around the DRWH site.
  - A biological control of mosquito species using *Bacillus sphareicus*, *Bacillus thuringiensis* which contains proteins toxic for larvae of a variety of mosquito species can be used in existing depressions.

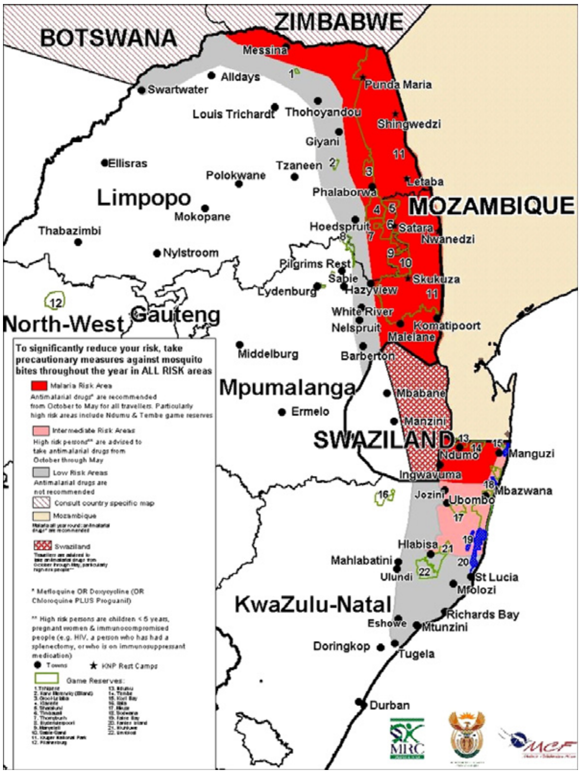


Fig. 3. Map of distribution of endemic malaria in RSA (DOH, 2003b).

- The larvae can also be killed by the use of extracts (oil layer), kerosene oil as well as the use of well tested chemicals. Oils and films disperse as a thin layer on the surface of the water which causes larvae and pupae to drown.

(ii) Prevention of mosquito breeding in the tank.
- The tank should be tightly closed, so that there are no openings for the entry of mosquitoes.
- Screen may be used (with hole size less than 1 mm) to bar entry of mosquito larvae in the tank.
- No stagnating water should be allowed around the DRWH site as mosquitoes might use it to breed.
- Gutter leading to the storage should have a free flow of water. Mosquitoes use as nurseries gutters with stagnant water.

(iii) If inspite of the above, eggs or larvae have entered DRWH, various ovicidal and larvicidal measures have to be considered.
- The measures practiced for killing bacteria may result in dying of mosquito eggs and larvae. These include high temperature, boiling and use of botanicals.
- Algal bloom both promote or discourage mosquito larvae depending on certain conditions. However, this is not recommended for AGTs since the water can be used for drinking.
- Measures for protection from mosquito biting should be undertaken.

In South Africa, residual spraying has proven to be effective in reducing the cases of malaria.

## 4. Sizing the DRWH storage tank

For a given size and location of DRWH system and operating strategy, there will be a limit on the water it can supply per day, per week or per year (DTU, 2001). The storage tank accounts for a large fraction of the cost of the DRWH system (Table 1). It is therefore critical to size it appropriately, and to get the maximum benefit out of it. Often the storage tank is either oversized or undersized. To find the optimum storage tank size, which will help reaching a certain reliability of supply, the following should be considered:

(i) The water availability:
- Rainfall distribution and intensity.
- Characteristics of the catchment area such as size and land cover.
- Alternative water supply. There are 10 different water sources in South Africa (Statistics SA, 2003): Piped water inside dwelling, Piped water inside yard, Piped water on community stand: distance less than 200 m from dwelling, Piped water on community stand: distance greater than 200 m from dwelling, Borehole, Spring, Rainwater tank, Dam/pool/stagnant water, River/stream and Water vendors.

(ii) The water requirement. South Africa has 5 seasonal rainfall regions (year round, winter, early summer, mid-summer, late summer, and very late summer). The water requirement varies from one rainfall region to another.

(iii) The technical constraints such as the limitation of space, lack of labour, rocks in the ground, etc. Factors that help in deciding whether the storage tank will be above-ground or underground are:
- The roof type and height. Rural household usually have thatched roofs that have a lower runoff coefficient (around 0.2) than corrugated iron sheets.
- The soil type. An AGT should not be built on expansive clay soils or sandy soils, and;
- The dimensions of the stand. In most peri-urban areas (informal settlements) of South Africa, there is no space for a storage tank.

(iv) Socio-economic constraints such as the lack of labour force, customs. About 67% of the 4.23 million of rural household (Statistics SA, 2003) are below the poverty line (income of less than ZAR 9600 per annum) and can not afford the cost of a rainwater tank.

Fig. 4 shows the water demand satisfied by a tank compared to its size. As it can be seen, economics of tanks are such that the benefit of a tank is not strictly proportional to its size. The reason for this is that a smaller tank will be filled and emptied (cycled) often whereas a larger tank will only be cycled rarely (DTU, 2001).

In rural areas where municipal water is available, when there is insufficient rains to fill the tank, the owners fill it

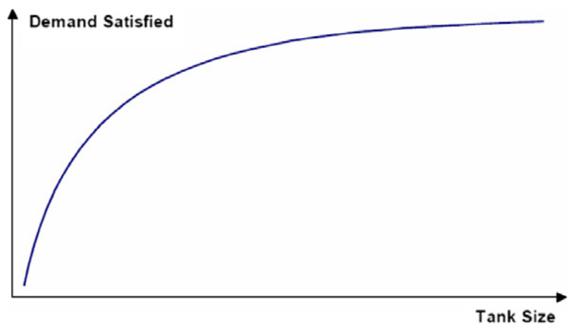


Fig. 4. Benefits of tank sizing (DTU, 2001).

with municipal water. In the case of AGTs, they first empty the tank to refill it with "fresh" water. If the non-governmental organisations (NGOs) look at this "municipal RWH" as a multiple use of the storage tank, the water authorities do not share their view especially because this "municipal water harvesting" practice continues even during the dry season and disrupts the water supply.

## 5. Legal aspect of DRWH

A review by Kahinda et al. (2005) of the National Water Act (Act No. 36 of 1998) and the Water Services Act (Act No. 108 of 1997) indicates that the current water legislations do not give a clear legal framework for the adoption of DRWH, making DRWH illegal by strict application of the law. If under the National Water Act, Section 22 (1) (c), DRWH is a permissible water use which does not require a license (Schedule 1), the Water Services Act, Section 6 (1) states that it will require an authorisation from the water services authority.

The DWAF RWH pilot programme falls under the Agriculture Water Use Development Finance, a sub-directorate of the DWAF directorate Water Resources Finance and Pricing. The financial assistance to resource poor farmers that funds the programme is supplied in terms of sections 61 and 62 of the National Water Act (Act No. 36 of 1998), which empowers the Minister to make available various types of grants or subsidies. There is a need of a clear policy that will provide a framework which will enable the sustainable use and upscaling of DRWH.

## 6. Discussion and conclusion

The review performed on this study shows that although DRWH appears to be one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand (Sazakli et al., 2007), it should not be looked upon as the panacea for water supply.

The sustainability of the DRWH requires close cooperation between the government, the private sector (NGOs and Scientists) and the rural households (Fig. 5) but also an integrated system approach where the quantity/quality of the water supplied as well as the associated costs of implementation are considered. A sustainable DRWH system is one that is implemented after considering not only the physical attributes (rainfall, location and catchment characteristics) and the socio-economic attributes in its design but also the quality of the rainwater and the alternative water sources.

To increase the water security of rural households, all potential water sources should be evaluated with respect to number, location, yield, dependability, and quality. Because of the unreliable rainfall, it is necessary to investigate the existence of other sources near a particular site that can be developed to insure water supplies that are more reliable. For years, untreated roof runoff has been widely used for drinking purposes with very few recorded or reported serious health problems. Rainwater collected from ground catchment systems is generally subject to high levels of microbial contamination and has to be treated before being consumed. It is necessary when designing the DRWH systems to prevent or minimize breeding of mosquitoes and avoid or reduce pollution and contamination. To further enhance rural water security, multiple water sources should be utilised depending on the season and geographic location.

Although extensive work has been done on the costing of water storage tanks (AGTs and UGTs), more work is needed on the sizing and design. The following need to be considered:

- The size and the design of the water storage tank cannot be standard considering the five rainfall regions of South Africa. A methodology developed by White (1993) incorporates the mean annual rainfall (MAR) and the percentage deviation from MAR, to determine area required to collect enough rainwater to provide an individual with water for a year in the various rainfall regions.

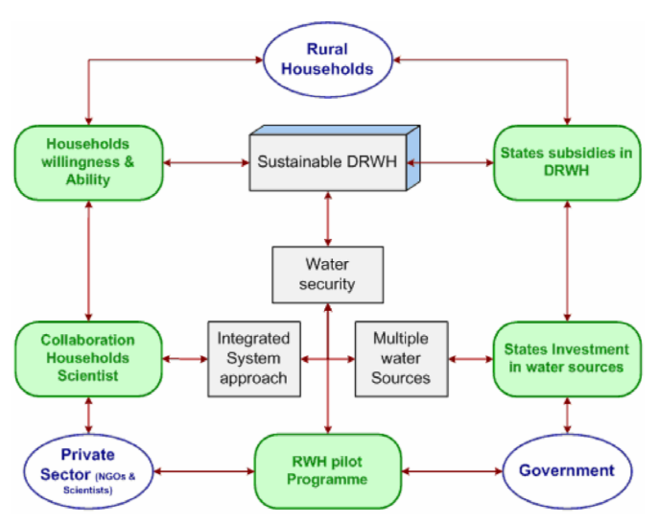


Fig. 5. Cooperation between all the stakeholders.

- There is a need to investigate the health related risks of the widespread use of DRWH especially in malaria prone areas. The RWH pilot programme currently disregards this aspect.
- By only financing UGTs, the government does not exploit the potential of DRWH to provide free the first six kilolitres of water consumed monthly to poor households. Financing AGTS will however require investigating the suitability of the rainwater collected for drinking purposes.
- Guidelines on the operation and maintenance of DRWH systems need to be written and disseminated to rural communities. The experience gained from the RWH pilot programme will be very valuable in incorporating the local experience in the guidelines.
- The water legislations should be clear on DRWH to facilitate its implementation by NGOs.

To account for first three points raised above, they should be a particular design and size of water storage tank for each DRWH ecotopes. DRWH ecotopes are areas with same physical and socio-economic characteristics (rainfall region, MAR, percentage deviation from MAR, soil type, similar alternative water sources and similar water requirement).

DRWH has the potential to improve rural water supply in rural South Africa but only an integrated system approach will likely guarantee its success.

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