Rain water harvesting and Artificial Recharge in Africa: Review

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Abstract: The report tries to highlight the growing popularity of rainwater harvesting and artificial recharge in Africa in relation to increasing demands and exploration of groundwater. Several techniques are identified as methods for water harvesting and recharge but those associated with collection devices, catchment areas and conveyance systems are given more attention for example check dams and recharge pits. Scarcity of groundwater data and lack of awareness of groundwater phenomenon is still a hindrance to intensive artificial recharge projects.
[Mupenzi, J.P., Lahai, L., Tafadzwa, L. M., Lie, Y. and Jiwen G. **Rain water harvesting and Artificial Recharge in Africa**, Nature and Science 2011;9(4):41-45]. (ISSN: 1545-0740). http://www.sciencepub.net.

Key word: Groundwater, Rainwater harvesting and artificial recharge

1. Introduction

Water is a crucial resource with great implications for African development. The freshwater situation in Africa, however, is not encouraging. Of the estimated 800 million who live on the African continent, more than 300 million live in water-scarce environment (AU/NEPAD, 2006). Because of semi-arid and arid conditions, especially in southern Angola, Namibia, Botswana, western South Africa, and western Zimbabwe, all have lower recharge rates and hence tend to place a higher value on their water resources than the humid countries. In these areas, groundwater recharge may be limited and probably largely localized to line and point sources such as streambeds and dam basins, respectively (Xu and Beekman, 2003). In Southern African nations, especially in those within the arid and semi-arid areas, there is a greater need of and access to reliable source of water supply (ADELANA et al., 2008). North Africa is the most water-stressed region in Africa, and freshwater availability will become an even more important issue in the coming decades, it is also threatened with seawater intrusion, resulting from over-exploitation of groundwater resources in coastal areas (UNEP, 2008). As indicated figure 1(WHYMAP, 2008), North Africa has the highest groundwater mining activities indicated by the red circles.

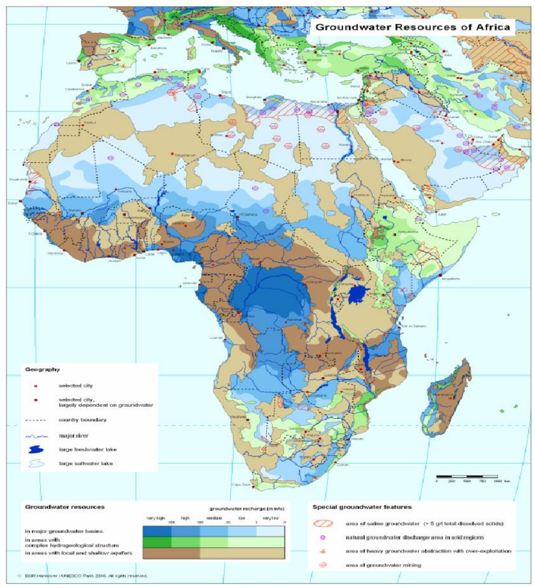

Figure1 Groundwater resources of Africa

Groundwater is of particular importance in Africa, where numerous countries rely on a combination of hand-dug wells and public boreholes for their drinking water. Although groundwater use is generally less visible than surface supplies, it increasingly provides the main source of agricultural irrigation in rural areas, as well as a vital safety net for dry-season food security (ADELANA et al., 2008). From the Groundwater Dependency data of Southern Africa countries shown in table 1, dependency is moderate to major in semi-arid and arid countries (ADELANA et al., 2008). However, with increase in population and the need for development, the situation for groundwater dependency will continue to grow at an alarming rate.

Table 1 Situation of Groundwater dependency in Southern African countries

Member state	Rural	Urban	Agri	Industry	overall dependency
Angola	2	2	2	1	2
Botswana	3	2	3	3	3
DR Congo	1	1	1	1	1
Lesotho	2	2	1	1	1
Malawi	3	1	2	1	2
Mauritius	1	2	2	2	2
Mozambique	2	2	1	1	2
Namibia	3	3	3	3	3
Seychelles	2	2	1	1	1
South Africa	3	2	2	2	2
Swaziland	2	1	1	1	1
Tanzania	3	3	3	1	2
Zambia	2	2	1	2	2
Zimbabwe	2	2	1	2	2

Indication scale: 1= minor, 3 =moderate, 3 =major

Where there is no surface water, or where groundwater is inaccessible due to hard ground conditions, or where it is being over exploited recharge alternatives should be implemented. In a very simplified sense, if a society is threatened or subjected to water scarcity it should respond by attempting to get and store more water using simple, inexpensive and traditional concepts.

2. Methodology

This used the documentation method for getting all information regarding Rain water harvesting and Artificial Recharge in Africa.

3. Results and Discussions

3.1 Concepts of rainwater harvesting and artificial recharge

Rainwater harvesting is one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand (Yongxin, 2006). There are two main techniques of rain water harvesting namely storage of runoff on surface for future use and recharge to groundwater and shallow aquifer (MacDonald and J Davies, 2000). As rainwater harvesting gains popularity among African countries so does artificial recharge as a way to counteract water shortages. Artificial recharge can be used for a number of reasons: integrated water management, seasonal storage and recovery of water, long-term storage or water banking, emergency storage or strategic water reserve, short term storage, enhancement of well field production, restoration of groundwater levels, compensation for over-draft, reduction of pumping cost, stoppage or reduction of the rate of land surface subsidence, and improvement of groundwater quality to agricultural or municipal standards (SAI, 2009). Other objectives of artificial recharge are to reduce land subsidence, to store water, to improve the quality of the water through soil-aquifer treatment or geo-purification, and to use the aquifer as water conveyance systems (Raju, et al., 1994). Artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that obtaining under natural conditions of replenishment (Raju, et al., 1994). Artificial groundwater recharge systems are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources (Moegiadi, 2000;Yahya , 2009.).

Table2 Properties of artificial groundwater recharge

Method of AGR	Conditions of use	Advantages	Disadvantages
Wells	a thick impervious Layer between Surface of the soil and aquifer	Inexpensive	Clogging up at infiltration surface
Dam	suitable Geomorphology	For low permeable-soil	Sediment accumulation High Evaporation
Spreading	available land High permeability	low maintenance cost	suspended sediments

Moegiadi (2000) described an artificial recharge system as any man-made scheme or facility that adds water to an aquifer. The author further stated that rain water harvesting is essential because:-

1. Surface water is inadequate to meet human demand that has to depend on ground water.

2. Due to rapid urbanization, infiltration of rain water into the sub-soil has decreased drastically and recharging of ground water has diminished.
3. Over - exploitation of ground water resource has resulted in decline in water levels.
4. To enhance availability of ground water at specific place and time.
5. To arrest sea water ingress.
6. To improve the water quality in aquifers.
7. To improve the vegetation cover.
8. To raise the water levels in wells and bore wells those are drying up.
9. To reduce power consumption.

Rainwater harvesting is a simple and low cost water supply technique that involves the capturing and storing of rainwater from roof and ground catchments for domestic, agricultural, industrial and environmental purposes (Yahiya, 2009). SAI (2009) described the different types of rainwater harvesting technique used in Africa for artificial recharge.

3.2 Gabion

A gabion which is a semi permeable barrier made of boulders in a mesh of steel wires and anchored to the stream bank, to slow but not stop, the flow of storm water in a small watercourse, so as to enhance water infiltration to groundwater and help prevent soil erosion.

3.3 Recharge pits and trenches

Recharge pits and trenches are constructed for recharging the shallow aquifers and / or avoiding runoff damages. Pits are generally 1 to 2 m wide and 2 to 3 m deep. Trenches are generally 0.5 to 1m wide and 1 to 1.5 m deep and 10 to 20 m long depending upon availability of water. Both are filled with boulders, gravels & coarse sand to filter and increase water infiltration and to minimizing evaporation. This is an ideal solution of water problem where there is an inadequate groundwater supply or surface resources are either lacking or insignificant (Moegiadi, 2000; Bancy et al., 2005; SAI, 2009). To improve the quality of groundwater through dilution since rainwater is bacteriologically safe and free from organic matters. When open well are dried up, it is possible to use them for recharging groundwater in diverting upstream runoff inside the well (SAI, 2009).

3.4 Check dams

Check dams which are small, temporary or permanent dams constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows for a certain design range of storm events. A check dam can be built from logs of wood, stone, pea gravel-filled sandbags or bricks and cement. Allow groundwater recharge and sediment to settle out (Raju, et al., 1994 ; Bancy et al., 2005; SAI, 2009). Surface runoff can also be used for recharging groundwater, which will positively impact on springs and shallow wells.

Table 3 Artificial recharge sites in Southern Africa

site	Operational status
Windhoek	newly
Polokwane	10 yrs old
Omdel	5yrs old
Atlantis	20yrs old
karkams	5yrs old
calvinia	Recently tested

It should be noted that artificial groundwater recharge is affected by quantity, quality and reliability and the sources are storm runoff, rainfall harvesting, river flows and water releases from dams (ADELANA et al., 2008). Factors to consider in all schemes of artificial recharges are also complex. These include quantity, quality and timing of available water for recharge, the department and storage capacity of aquifers, local hydrological conditions, native groundwater quality, and land availability (Bancy et al., 2005). The Rivers have more consistency than storm runoffs. Storm runoff is usually collected in an impoundment basin from which controlled release of water into recharge basin take place after settling of the bulk of the suspended solids. A perfect example is Omdel scheme located on Omaruru River Namibia. They are two physical characteristics which determine aquifer suitability for artificial recharge namely permeability and storage the later is South African secondary aquifers concern. These aquifers during the natural recharge period are normally full and only have space for recharge during dry periods (Murray and Tredoux, 1998).

It should also be noted that as vegetation cover increases so doe's rates of infiltration and this has an impact on recharging shallow aquifers. One promising technology for rural farming systems is rainwater harvesting which is the process of interception and concentration of rainwater and runoff and its subsequent storage in the soil profile or in artificial reservoirs for crop production (UNESCO, 2006). Recharge is either natural that happen mainly via direct rainfall infiltration into permeable soils, but also from surface flow, or can be man-made (by contour ploughing, building bunds/dams, ponds, diversion channels, and wells to enhance recharge), or may be incidental (irrigation, wastewater disposal, leaky pipes in cities, or clearance of deep rooted vegetation).The benefit of surface tanks over sub-surface ones, which are partly or completely underground, is that water can be easily extracted through a tap just above the tank's base. This popularity was demonstrated in the Kusa area of Nyando District, Kenya, where Regional Land Management Unit (RELMA) was involved in a project to promote rainwater harvesting. In just six months, 113 above-ground tanks with capacities ranging from 3 m^3 to 23 m^3 for homes and 23 m^3 to 30 m^3 for institutions were constructed (Mati, 2001).

3.5 Pans and ponds

Pans and ponds are dug up to capture and store runoff from surfaces such as hillsides, roads, rocky areas and open rangelands. Pans have been used to harvest rainwater in many parts of East Africa. When well designed and with good sedimentation basins, pans can collect significant amounts of water for irrigating crops to augment rainfall. In a recent study by RELMA in Lare division of Nakuru district, Kenya, a 25 square kilometer area was randomly selected and using GIS technique the number and distribution of runoff ponds in the area were determined. A Quick bird image revealed 908 pond constructed by farmers in the location. This is the highest adoption of ponds RELMA has ever observed in Africa. The adoption of ponds has resulted in improved livelihoods of the communities through increased food and water security. It was concluded and recommended that ponds should be scaled up in areas of similar biophysical conditions.

3.6 Earth dams

Earth dams are perhaps the most widespread method of water harvesting, especially from river valleys. A dam can be constructed to collect water from less than 20 km2 for a steep catchment and 70 km2 for a flat one. In Tanzania, low earth dams called 'malambo' have been built, especially in Dodoma, Shinyanga and Pwani regions (Hatibu and Mahoo, 2000; Adelana and Xu, 2006).

3.7 Spate irrigation

Spate irrigation or diversion of flood flow from highlands into lowlands and 'wadis' has a long history in the Horn of Africa, and still forms the livelihood base for rural communities in arid parts of Eritrea and the upper rift valley in Ethiopia (Negasi, et al., 2000). An example of this is demonstrated at Lamza in Eritrea where vegetables are grown by irrigation, using water collected in a small dam of about 150,000 m^3(GHARP, 2009.).

RELMA has been promoting conservation agriculture in Sub Saharan Africa with notable successes in Zambia, Zimbabwe and Tanzania (Nyagumbo , 2000). Studies in Zambia demonstrated a network of centers' to diversify the use of animal-drawn implements to achieve conservation tillage (Adelana and Xu, 2008 ; Kaoma-Sprenkels, et al., 2000; Robins, et al.,2006; Adelana and Alan M, 2008.). In Zimbabwe, technologies such as no-till tied ridging are used. The ridges, made using animal traction, are about 20-25 cm in height and laid across the slope at 0.4-1% gradients. Other technologies include no-till strip cropping, where crops are grown in rows 3-9m wide, and pot-holing, infiltration pits (chimbatamvura) and fanya juu chini terraces. All these improve infiltration and reduce runoff though to a lesser extend it can also add to groundwater recharge. The USAID funded GHARP case studies projects in Ethiopia, Kenya, Uganda and Tanzania these revealed a number of promising and proven technologies. For example the projects implemented in Isinon, Kimalel and Wamani in Kajiado, Baringo and Laikipia districts respectively. These projects were promoted by partners in East Africa promoting rainwater harvesting these partners are Ethiopian Rainwater Harvesting Association (ERHA), Kenya Rainwater Association (KRA), Rainwater Association of Somalia (RAAS), Rainwater Harvesting Association of Tanzania (RHAT) and Uganda Rainwater Association (URWA).

4. Conclusions

Population increase in Africa will give rise to demand for more water through agriculture, livestock and domestic use and this will lead to a drastic increase in groundwater exploration and development. Data are scarce and to a large extent have not been gathered with any rigour over the last two decades. The reasons behind this change are complex. It is clear that although groundwater supports social and economic development in Africa (particularly in rural areas). The resource is not properly understood. It recognized that major gaps exist in knowledge of groundwater resources in Africa and that there is a need for African groundwater scientists, managers and policy makers to determine best practices and reduce inequities in capacity. For further studies, there is still need for intensive research, awareness, data collection and filling knowledge gaps in Africa as far as groundwater is concerned.

Acknowledgements

This study was financially supported by the State Key Development Program for Basic Research of China (973 program, Grant No. 2010CB951002); the Knowledge Innovation project of Chinese Academy of science (KZCX2–YW–334) and China Scholarship Council.

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3/4/2011