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The Revolutionary Government of Zanzibar

In Collaboration with

Millennium Development Goals - MDG Centre, Nairobi Kenya

United Nations Development Programme (UNDP), Tanzania and

World Agroforestry Centre – ICRAF, Nairobi, Kenya

An Assessment of Rainwater harvesting Potential in Zanzibar

May 2007

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Executive Summary

The report provides results of an assessment of rainwater harvesting potential in Zanzibar. The study was commissioned by the MDG centre based in Nairobi Kenya, facilitated by UNDP Tanzania and carried out in collaboration with the Government of the Zanzibar. The methods used in the study include review of available government policy documents and reports, interviews with key government informants, field visits to sites selected by the government and GIS mapping of rainwater.

The Government is resolute on developing and facilitating a favourable environment for developing water resources in Zanzibar. Useful studies have been done on both surface and groundwater. However, no attempt has been made by government to develop an Integrated Water Resources Management plan. The result is lack of coordinated approach to water resources management within the government circles. Government is also lagging behind most nations that have at least initiated IWRM plans. It is strongly recommended that the responsible government ministry should take the lead in facilitating the development of IWRM plans for Zanzibar. This would institute a systematic approach to the development of water resources with rainwater at the centre of it all and with the involvement of all actors, including government, NGOs, private sector, communities and external partners/donors.

The study has revealed that Zanzibar receives a colossal volume of rainwater amounting to 4 km3. Of this total, Unguja and Pemba receive 2.4 km3 and 1.5 km3 respectively. Unguja utilises 33 MCM (1.3%) for domestic water supply and irrigation. Pemba correspondingly utilises 9.2 MCM (0.6%). Groundwater recharge amounts to 588.7 MCM (24.0%) and 117.7 MCM (7.7%) for Unguja and Pemba respectively. However, the rainwater that runs off to the Indian Ocean amounts to 881.3 MCM (24%) for Unguja and 797.4 MCM (52.3%) for Pemba. Total evapo-transpiration is 40% of the total rainfall for both islands i.e. (974.6 MCM and 610.0 MCM for Unguja and Pemba respectively). This water balance was verified and found to be accurate using GIS methods. The only disparity was the lower runoff value of 443.3 MCM for Pemba. ICRAF could not determine the probably cause of this difference.

Several approaches and technological options have been recommended for Zanzibar in this report. With regards to the approach, awareness creation would be an important entry point to the promotion of RWH. This campaign could be spear headed by HE President Karume. The President indicated to the study team that he would be interested in being the patron for the campaign. Another important area is capacity building or enabling communities to implement RWH structures. There needs to be a capacity building centre setup to nurture the interests of water harvesting in the country.

With support from Sida, the Rainwater Harvesting Association of Tanzania (RHAT) was formed in the year 2002. RHAT provides leadership in management of RWH knowledge i.e. research and development, networking and capacity building in Tanzania. There is a window of opportunity for Zanzibar to forge ties with the existing association which has further affiliation with SEARNET and the Global Water Partnership. These linkages would facilitate transfer of RWH knowledge and experiences within and outside Zanzibar.

This report has also presented technological options applicable to Zanzibar. The technologies are mainly focussed on enhancing groundwater, capturing runoff and collecting rainfall in-situ. Due to high dependency on groundwater, there is reason to inculcate in the minds of Zanzibaris, the concept of recharging groundwater. Pemba has numerous rivers which could be used to harness runoff. The ideas in this report are generic and need to be adapted to the site specific conditions through detailed surveying and designing.

To initiate RWH activities, Zanzibar needs to invest US$ 6,420,000 over a period of eight years. Such an investment would create annual water storage per capita of 1624 m3. This amount exceeds the 1500 m3 minimum international bench mark. This investment would go towards improving policies on IWRM, training all key stakeholders, setting up demonstrations and scaling up sites and monitoring and documentation of the entire processes

Introduction

This study was requested by HE Amani Adied Karume, President of Zanzibar. The terms of reference were prepared and commissioned by the MDG centre based in Nairobi in collaboration with UNDP Tanzania to explore the prospective of improving water availability and management in Zanzibar through application of rainwater harvesting and management technologies.

Zanzibar is comprised of two island; Unguja of 1658 km^2 and Pemba of 985 km^2. The islands are located 40 kilometres off the mainland Tanzania coast, 5 degrees and 6 degrees south of the Equator. The 1999 census estimated the population of Zanzibar at 916,000. According to the Household Budget Survey report release in September 2006, 49% of the population lives below the basic needs poverty line. The report further found that the incidence of poverty was higher in rural compared to urban areas. Agriculture is the main occupational activity, employing more than a quarter of the total labour force in Zanzibar. In the year 2000, agriculture contributed 36% Gross Domestic Product (GDP) and about 90% of the total foreign exchange earnings. However, agriculture is propelled by poor smallholder farmers producing under rain fed conditions using traditional methods. According to Johnson 1994, both islands are fertile due to the rich soils derived from weathering of main sedimentary rock sequence. Zanzibar is also endowed with high mean annual rainfall of up to 1900mm. Water balance studies conducted by the Ministry of Agriculture, Natural resources, Environment and Cooperatives (MANREC) and JICA suggest that Zanzibar looses on average 50% of the total rainfall received through runoff via rivers to the sea. Only 24% in Unguja and 7% in Pemba ends up in groundwater. Given that Zanzibar's main water sources is groundwater, there is great need to introduce rainwater harvesting technologies in order to improve water availability, especially for agriculture which takes up the largest proportion of the island's water.

In order to create a vibrant and stable agriculture sector, there needs to be improvement in utilization and management of all available water resources on the island. There is increasing appreciation by government to explore the use of rainwater to increase water availability in all sectors.

Background

Authority

This assessment report has been prepared in accordance with a request to Professor Jeffrey Sachs[1] by HE Amani Adied Karume, President of Zanzibar. The request was made during a meeting held on 8th January 2007. President Karume outlined the developmental challenges facing Zanzibar and emphasized the continuing commitment of the Government to supporting a vibrant agricultural sector to complement the rapid growing tourism and industrial sectors. During this meeting President Karume requested Professor Sachs to facilitate technical support in rainwater harvesting and other approaches to improving water resources management in the agriculture sector.

The MDG Centre in Nairobi, Kenya, provides scientific, technical and policy support to governments and other partners in East and Southern Africa. The MDG Centre plays a unique role in linking global and national commitments with the rich, multi-sectoral field experience being generated by the Millennium Villages Project and other related community-level initiatives that contribute towards the MDGs. The MDG Centre focuses on innovative ways and means to achieve impact at scale. This requires: (1) identification of best practice across the key sectors, (2) critical analysis of results from the MVP and related activities with a view to wider understanding and application, (3) design and adaptation of implementation mechanisms at district and other "meso" levels, (4) accurate costing of resource requirements, and (5) political and public sensitization to practical opportunities for achieving the MDGs. The Centre operates in close partnership with and receives partial financial support from UNDP.

Under the overall direction of Professor Jeffrey Sachs, The MDG Centre commissioned an assessment of potential for water harvesting in Zanzibar. The assessment was

[1] Professor Jeffery Sachs is the United Nations special advisor to the Secretary General and Founder of the Millenniums Villages and Millennium Promise projects

undertaken by an experienced Water Resources Specialist based at the World Agroforestry Centre (ICRAF) in Nairobi Kenya. The assessment comprised three stages undertaken between 19th March and 30th April:

1. Initial visit to Zanzibar including review of water resources strategy documents and technical reports, field visits in both Unguja and Pemba, and consultations with Government officials (Zanzibar, 2 weeks)
2. Preparation of draft report, including conclusions, recommendations and investment concept note (Nairobi, 2 weeks).
3. Discussion of report with Government of Zanzibar authorities, workshop on follow up actions and investment plans, and finalization and formal presentation of the report (Zanzibar, 1 week).

Objectives of the study

Under the technical direction of the Director of The MDG Centre, East and Southern Africa, and with the administrative and logistical support of UNDP Tanzania, the following objectives created:

1. Review and summarize strategy documents and technical reports related to rural water utilization in Zanzibar, with special reference to rainwater harvesting.
2. Through field visits to both Unguja and Pemba, assess the extent, impact and challenges of past and on-going rainwater harvesting investments in Zanzibar.
3. Drawing on local experience and best practice elsewhere, identify technical options (and unit costs) for rainwater harvesting in rural Zanzibar, taking account of different farming systems and variations agro-ecological conditions.
4. Undertake a rapid diagnosis of specific rainwater harvesting options for the proposed Millennium Village in Micheweni.
5. Drawing on the assessments, prepare one or more draft project concept notes for rainwater harvesting investments in Zanzibar.

Present, discuss, revise and submit the final assessment report (including the investment concept note) with the Government of Zanzibar.

Overview of the problem

During the last decade, the Southern and Eastern Africa Rainwater Network (SEARNET) with support from the Regional Land Management Unit[2] (RELMA) has been promoting rainwater harvesting in Eastern and Southern Africa. SEARNET has nine member countries including Kenya, Uganda, Ethiopia, Tanzania, Rwanda in East Africa, and Botswana, Malawi, Zambia and Zimbabwe in Southern Africa. In each of these countries, there is a national network constituting membership of government, NGOs, community and individuals. Between the years 2002 and 2006, a Global Water Partnership Associated Programme (GWP-AP) entitled "A Network for green water harvesting in Eastern and Southern Africa and South Asia[3]" championed awareness creation, policy research, and capacity building activities on rainwater harvesting activities in 18 countries. By the end of the first phase of the programme in December 2006, the following problems were still outstanding in the ESA region:

- Poor access to and availability of water in the region due to inadequate water harvesting infrastructure – water storage falls below 1700 m^3/capita/year (international minimum).
- Extremely low agricultural production – less than one tonne per hectare due to intra-seasonal dry spells and drought; this has been exacerbated by climate change and weather risk – these could be mitigated through supplementary irrigation and in-situ RWH and ground water recharge
- Poor management of rainwater – flooding, erosion, ecosystems, pollution

At national level, limited resources are allocated for applying Rainwater Harvesting (RWH) technology. Also, the inadequate coordination among key actors in the sector causes over-lap and duplication of activities. Most national governments in Eastern and Southern Africa (ESA) only allocate money for conventional water supply systems such as boreholes and dams as a means of water for agricultural, industrial and domestic use.

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[2] RELMA was a Sida funded unit based in Nairobi Kenya. The programme ended in December 2006.

[3] GWP-AP was implemented by RELMA and Centre for Science and Environment based in New Delhi, India

However, such systems are often centralised, expensive and benefit mainly those in urban areas. Although RWH has proved effective in both rural and urban settings, the governments have paid little or no attention to including this in their national economic development strategies and action plans. Thus, improving water management and governance are catalytic entry points for efforts to help developing countries fight poverty and hunger, safeguard human health, reduce child mortality, promote gender equity, and manage and protect natural resources.

The problem analysis has high relevance to Zanzibar as shall be shown in this study.

Definition of rainwater harvesting

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. When surface run-off is collected in reservoirs, it can be used for the management of floods and droughts. Surface run-off can also be used for recharging groundwater, which will positively impact on aquifers, springs and shallow wells. Rainwater harvesting yields numerous social and economic benefits, and contributes to poverty alleviation and sustainable development;

Rationale of RWH

RWH can AUGUMENT water supply in all sectors; Rainwater harvesting increases food production - For instance, according to studies carried out in Zambia, maize yield can be tripled with RWH through Conservation agriculture; RWH minimizes the risk of crop failure during droughts and floods; RWH eliminates women's burden of collecting water for domestic use. The time saved can be used for other productive activities; RWH gives opportunity for the girl child to attend school; It provides a relatively safe and clean source of drinking water thus minimizing incidences of water borne diseases; When applied at watershed level, it improves the environment and minimizes the effects of drought and floods; RWH is a decentralized water supply system encouraging community participation and self reliance. Local communities who have an enormous capacity to invest labour and time can do it; the systems are varied and can therefore be built according to the ecological characteristics of the particular region or locality.

Methodology

Several methods and tools were to assess elements within the scope of this study

Literature review

Government policy documents and reports were obtained from key Ministries for review. During the literature review, special attention was paid to identifying specific government policy statements or pronouncements on RWH, assess sectoral and institutional arrangements for implementation of policies and their impacts on water management especially in agriculture.

Interviews with Senior Government Officials, Farmers and Traders

Semi-structured discussions were conducted with key government Principals Secretaries and their supporting staff to get their views and experience on RWH. The proceedings of the interviews were recorded on a Sony M-470 micro-cassette voice recorder and later reviewed for in depth analysis of the view points.

Field Visits

The host Ministry of Finance and Planning organised several field visits to rural farming areas in Unguja and Pemba to access ongoing activities on RWH. A series of digital images were taken using a Sony DSC-P200 7.2 mega pixels camera. The images were captioned and used in analysing the current practices on the ground. The images were also included in this report to highlight important observations. During the field visits, accompanying senior government officials and farmers were interviewed and their voices recorded on a Sony voice recorder.

Random inspections

A series of random visits to selected places, such as the small holder black smiths and traders in hardware, were made to collect information on the production, supply and demand of roof catchment RWH components. Walks were made along the streets of Zanzibar Stone town to observe existing installations on water harvesting.

GIS Mapping of Rainwater Harvesting potential in Zanzibar

The GIS database of RWH potential in Zanzibar was developed using Arc GIS and Arc view software, by utilizing both vector and raster (gridded) available databases. The major variables identified for prioritizing RWH in the GIS were **rainfall, topography, soils, and land suitability and population density**. See appendix for detailed mapping criteria.

Literature review

Historical Background

Zanzibar is well known as the infamous centre of slave trading and as a point of call for ships sailing around the Cape to ports in India, the Gulf and the Far East. During the then Arab administration, staple foods such as rice and wheat flour including sugar were imported and paid out of the lucrative spice revenues. From the Sultans era up to current times, the general public of Zanzibar has enjoyed free domestic water supply. However, times have now changed. The international donor community is generally mounting pressure on developing nations to privatise all urban and rural water supply utilities in order to sustain their ever rising operation and maintenance costs. Most African countries, including mainland Tanzania, have succumbed to such pressure resulting in the establishment of water supply and sanitation companies that collect revenues from water users to pay for the services. According the information gathered during the study, in the year 2008, Zanzibar will introduce tariffs for water.

Growing Demand for Water in Zanzibar

According to Johnson 1994, Zanzibar's expanding demands for the growing agricultural, industrial, urban and rural water supply were recognised as early as the 1980s. He reported fears in some circles regarding the extent to which surface and groundwater resources could be exploited without exceeding their sustainable threshold. Because Zanzibar, more specific Unguja mainly depends of groundwater, the main concern he cited was the unwise development and over pumping of groundwater leading to falling water tables, seasonally drying up of springs and river beds and seawater intrusion into more sensitive coastal aquifers. It was on this basis that Johnson carried out several hydro geological studies to generate knowledge for future development and planning of groundwater.

The islands are well known for producing cloves, nutmeg, cinnamon and other spices. Other important agricultural products include coconut palm, rice, sugar, cassava, vegetables and

Government Policy on Rainwater Harvesting

Available policy documents were reviewed to gain insight on the existing policies on rainwater harvesting in Zanzibar. More emphasis was placed on understanding the agricultural policies which are the main focus of this study.

During consultation meetings with key government informants, it was clear that there is no clear and coordinated government approach to harvesting and managing rainwater in Zanzibar. There are however, impressive sectoral efforts especially in the Ministry of Agriculture, Natural Resources, Environment and Cooperatives (MANREC) and Ministry of Water to deliberately encourage rainwater harvesting.

Sectoral efforts to promote RWH

MANREC has a vision to promote agricultural transformation from predominantly rural based subsistence to modern economy. High dependency on rain fed crops and prevalence of agricultural and animal diseases are some of the major constraints to achieving higher agricultural productivity in Zanzibar.

The Water policy of MANREC recognises that agricultural production is mainly rain fed, but a lot of rainwater is lost through surface runoff. The policy further states that efforts to contain rainwater losses have been constrained by lack of water harvesting and storage techniques. Management of water has also been a major constraint. MANREC therefore hopes to address this problem by promoting the private sector to develop technologies for water harvesting and storage.

Irrigation Master plan

The Irrigation Master plan (MANREC, November 2006) attaches great importance to harvesting and storing rainwater for irrigation purposes. The eight existing irrigation schemes covering 76 ha in Pemba primarily utilise streams flow whereas the four schemes covering 268 ha in Unguja exclusively rely on groundwater. The general approach used in the existing irrigation schemes is capital intensive (US$23,000/ha as reported by FAO). This top down approach has led to collapse of most of these schemes. Other constraints include inadequate maintenance of existing irrigations structures, lack of funds and technical skills, shortage of qualified staff in the field of water management, lack of effective water users associations and lack of water harvesting and storage techniques.

MANREC is rethinking this approach and has embarked on a participatory approach involving farmers at all stages of planning, implementation, operation and maintenance of the irrigation schemes. MANREC is seeking funding for implementation of this well thought of irrigation master plan. It must be mentioned that donors are very sceptical about funding such proposals due to failure of similar mammoth irrigation projects in the 1970s and 1980s. Besides there is still a global debate as to whether irrigation should supersede upgrading of rain fed agriculture. Studies[4] have shown that irrigation alone cannot produce enough food to feed sub-Saharan Africa.

Surface Water Availability

Zanzibar has both perennial and ephemeral rivers. As shown in figure 1, Pemba has exceedingly higher river density than Unguja. The discharge from these rivers is reduced drastically during the dry season. However, during the rainy season (Masika) all these rivers flood rapidly having discharge several times more than the available water during the low flow periods. This water rapidly drains to the Indian Ocean or disappears into the coral limestone locally called "Pokezi".

According to Srivastara 1999, no river discharge data were available in Zanzibar till July 1997. In his assessment of surface water availability, Srivastara set up temporary gauge discharge sites and observed the river flow for a very short period of time. He further

[4] Find reference here

calculated run off in these rivers using Rational and CWC empirical formulae. After assessing several river basins in Unguja, Srivastara concluded that damming rivers and diverting the water to cropped land could irrigate large parcels of land in Unguja. River Mwera and Kipange had enough water to irrigate 585 ha of crops during the Masika and vuli periods.

Given that large proportions of the total annual rainfall runs off through the river system, it would be practical to explore ways of capturing this river flow and utilising it for agriculture production and other uses.

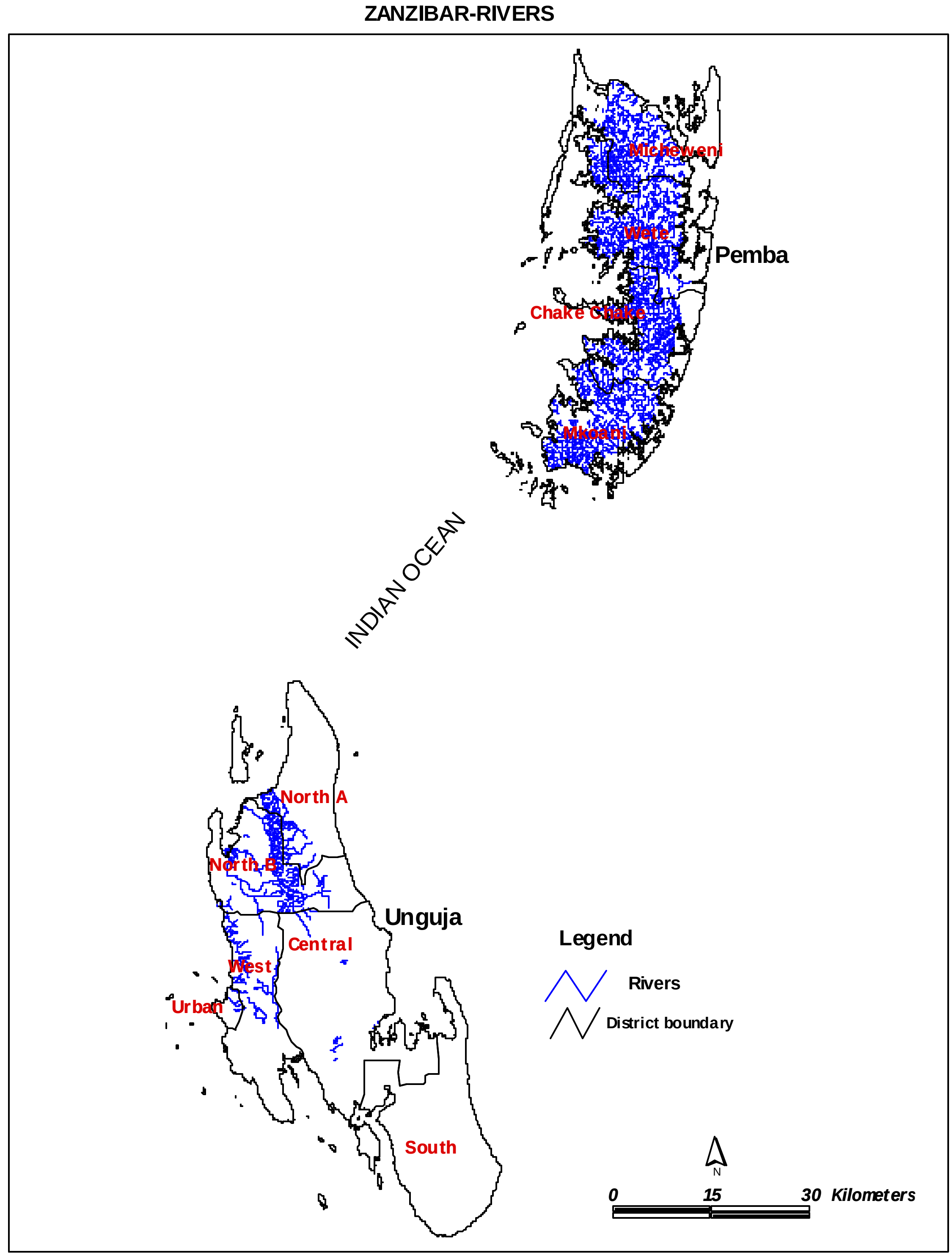


Figure 1 Rivers of Zanzibar. Source: ICRAF GIS Unit 2007

MANREC has attempted to compute the surface water availability

At the Irrigation department headquarters in Zanzibar, there exists keen interest in supporting rainwater harvesting activities. The department has qualified personnel all trained in soil and water engineering and irrigation disciplines at Cranfield University in the United Kingdom. Since agriculture is the focus of this study, it will be appropriate to initiate a rainwater harvesting unit within the department of irrigation.

Ministry of Water Construction Energy Lands and Environment

During this study, no water policy document was made available for review. However, reports on groundwater and surface water were reviewed. The review focussed mainly on understanding the function of the Ministry of water in managing and monitoring groundwater resources. To a limited extent the review looked at the role of government in provision of water for domestic use.

Groundwater Recharge, Abstraction and Monitoring

Given that Zanzibar, especially Unguja, is heavily dependant on groundwater, it is crucial that the Ministry of water plays a critical role in managing recharge areas and monitoring groundwater abstraction. A report by HALCROW, 1994, presents monitoring data on groundwater levels and quality and surface water flow in rivers. This data was collected by the Zanzibar Water Resources Development Project implemented in 1994.

From this data one sees a strong relationship between the rainfall amount and groundwater level and quality. At the onset of Masika, the groundwater level is low and as the season sets in, the groundwater level rapidly increases. The electrical conductivity of the water also goes down reflecting an improvement in the water quality.

The challenge here it to ensure that catchment areas, which are necessary for sustaining this natural process of groundwater recharge are maintained, and that abstraction does not exceed the recharge process.

Rainwater harvesting and Groundwater recharge

Rainwater is the primary source of water for recharging groundwater. The recharge process either occurs naturally or can be done artificially using a variety of methods. As the natural land cover is transformed to give way for other landuse types, the natural recharge process is affected and if not check could result in the depletion of groundwater. It was reported during the mission that monitoring of groundwater had been abandoned by the Ministry of Water. It was observed that catchment areas are encroached resulting in deterioration of the water quality and quantity. Plate 1 shows construction of urban dwellings in the catchment area of the main spring providing domestic water supply to Zanzibar town. There is urgent need for the government to redress the two issues if sustainable abstraction of groundwater is to be maintained.

Plate 1 Spring Catchment Encroachment in Zanzibar
(Photos by Maimbo M. Malesu, March 2007)

Rainwater Harvesting and Domestic Water Supply

Rainwater can be collected and safely used for domestic water supply.
Urban areas have higher proportion of households (91%) using piped water compared to 59% of the rural population.

Rainwater harvesting and the Millennium Development Goals

This study was partly commissioned by the MDG centre to assist the government of Zanzibar to accelerate the attainment of MDGs. This section explains the contribution of RWH to the MDGs. In principle, RWH contributes to goals number 1, 3 and 7.

Rainwater harvesting for poverty alleviation

Goal 1: Eradicate extreme poverty and hunger

More than one billion people still subsist on less than one dollar a day. Many regions fall short of achieving the target. Problems of poverty are inextricably linked with those of water. Rainwater harvesting improves water availability, its proximity, its quantity and its quality. Improving the access of poor people to water has the potential to make a major contribution towards poverty eradication. The collection of rainwater for supplementary irrigation has proved extremely valuable to deal with rainfall variability particularly at household and community level. This has led to improved agricultural production, enhanced food security and poverty reduction.

Rainwater harvesting and gender

Goal 3: Promote gender equality and empower women

Two thirds of the world's illiterate people are female, and the rate of employment for women is only two thirds that of men. It has however been shown that water-related enterprises such as agricultural development projects, have a far greater success rate when women are involved than when they are excluded.
According to the World Water Development Report, many girls are prevented from attending school because they are in charge of collecting domestic water. The lack of sanitation facilities worsens the situation.

Rainwater harvesting is a decentralized water supply system that eliminates women's burden of collecting domestic water. Rainwater collected and stored at the homestead enables women and the girl child to use the time saved on education and other income generation activities.

Rainwater harvesting for water accessibility

Goal 7: Ensure environmental sustainability

Environmental resources are at risk. For example 50% of the entire world's wetlands have been lost since 1900. Environmentally sound policies are needed to ensure the sustainability of our ecosystems.

Rainwater harvesting when practiced at watershed level, significantly improves the environment. As the water supply increases in the watershed, communities are able to engage in more crop production including tree planting activities that lead to increase in the proportion of land area covered by forest, which help to maintain biodiversity. Rainwater harvesting can also be used to recharge ground water resources that are presently dwindling at an alarming rate.

Rainwater harvested from rooftops supplies relatively clean water, which when filtered, treated and stored, provides a safe and clean source of drinking water. In most settings around the globe, the ratio of existing conventional water supply systems to rainwater harvesting potential is 1:20. Take the example of Kisumu city in Kenya, where water supply between 1969 and 1999 remained constant at 20 MCM per day. Within the same period, the city's population grew ten times resulting in water supply deficit of 12.3 MCM per day. Rainwater harvesting potential on the other hand is 390 MCM day.

Rainwater Harvesting and Integrated Water Resources Management

Integrated Water Resources Management (IWRM) is founded on the Dublin Principles. These guiding principles were agreed upon by world leaders in June 1992 during a United Nations Conference on Environment in Rio de Janeiro. In the year 2002, during World Summit on Sustainable Development (WSSD) held in Johannesburg 2005, all nations agreed to develop IWRM plans by 2005. There has been slow progress in the achievement of this commitment. Only a few countries have completed these plans.

Rainwater is the primary source of water and therefore should be the starting point for IWRM planning. Before working out the water policy and legislative framework, the financing and incentives structure and creating an organisational framework, It would be rational to first consider the total available water i.e. rainwater potential, gain a good understanding of how this rainwater partitions and thereafter, allocate this water to the various demands in a sustainable manner. IWRM provides the framework for doing exactly that.

Zanzibar is one of the nations that have not adhered to the commitment of creating IWRM plans.

Dublin Principles

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

2. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.

3. Women play a central part in the provision, management and safeguarding of water.

4. Water has an economic value in all its competing uses and should be recognized as an economic good.

According to Global Water Partnership's definition:

"IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

The three main components of IWRM are:

Policy and Legislative Framework: Setting goals for water use, protection and conservation and preparation of a national water resources policy.

- Policies with relation to water resources
- Water policy translated into law
- Water rights
- Legislation for water quality
- Reform of existing legislation

Financing and Incentives Structure: Financial resources to meet water needs

- Investment Policies.
- Grants and internal source
- Loans & equity

Creating an Organisational Framework:

- Reforming institutions for better governance
- Transboundary organisations for water resource management
- National apex bodies
- River basin organisation
- Regulatory bodies and enforcement agencies
- Service providers and IWRM
- Strengthening public sector water utilities

Private sector support to RWH

The private sector plays a critical role in the provision of good and services for rainwater harvesting. Roof catchment systems, for instance, require the right quality roof materials such as galvanised iron sheets or clay tiles for collection of good quality water. Other components such as gutters, down pipes and hardware materials for construction of ponds and tanks are all dependant on the private sector.

During a snap survey in Zanzibar stone town, it was discovered that that there were no suppliers of gutters, a component required in roof catchment systems. Even the Fundis[5] interviewed confirmed that there was no demand for gutters in Zanzibar Stone town.

The private sector if provided with favourable conditions could play a significant role in the development of RWH. This is an area the government could create job opportunities for the Zanzibaris.

Plate 2 Local Fundi in Zanzibar Stone Town

Community participation in RWH

Rainwater harvesting is a local specific and decentralised water supply system requiring the full participation of the community. Most rural based agricultural RWH interventions require strong community organisation. Communities must be mobilised and trained on construction, operation and maintenance of RWH systems (See Plate 3 and 4). Cost sharing schemes could also be formulated to make the RWH systems affordable to the communities. In Kenya, for instance, communities use either micro-finance systems or “Merry-go-round” schemes to finance RWH. Enabling communities to implement RWH through training will form a major part of the investment required to initiate water harvesting activities in Zanzibar. It was discovered during the study that communities are not accustomed to RWH concepts. Awareness campaigns will also be required to interest communities to invest in RWH.

[5] Fundi is the local name for craftsman

Plate 3 Women constructing a Ferro-cement tank in Kabale, Uganda

Plate 4 Proud owner of Ferro-cement tank in Kajiado, Kenya

Results

This section reports on the key findings of the study.

Water Resources Potential in Zanzibar

Rainfall

Zanzibar has two reliable annual wet seasons. The Masika rains from the south falls through March and May, and the Vuli rains from northeast during November and December. Average rainfalls for north Unguja are 1,800 mm and for south Unguja 1500 mm. Pemba generally receives higher rainfall than Unguja, at 2000 mm on average.

GIS mapping of rainfall

The results of GIS mapping of rainfall are given in figure 2 below. The mapping is based on satellite data collected over a period of five years. The data sets are refined to 20 m^2 resolution. The results are comparable to annual average rainfall recorded between 1950 and 1993 at 25 weather stations located throughout Zanzibar (See Table 1).

Table 1 Rainfall Stations and Records of Average Annual Rainfall

Unguja			Pemba		
Station	Average annual rainfall	Duration of Observation	Station	Average annual rainfall	Duration of Observation
H. Mchana	1,587	1950-91	Chake Chake	1,797	1952-90
Chwaka	1,470	1951-55	Chambani	1,531	1950-88
Kisauni	1,636	1952-92	Kigomasha	1,584	1950-91
Kisongoni	1,297	1950-91	Limbani	1,960	1950-86
Kizimbani	1,857	1950-92	Mtambile	1,891	1950-91
Makunduchi	1,453	1950-92	Mkoani	1,812	1950-91
Mkokotoni	1,863	1951-71	Ole	1,542	1950-91
Mkwajuni	1,946	1950-91	Wesha	1,912	1950-91
Muongoni	1,567	1950-91	Wete	1,571	1950-92
Mwera	1,642	1950-91	Mtanga Fwani	1,751	1950-91
Selem	1,515	1950-91	Karume	1,716	1974-92
Tunguu	1,265	1955-93			
Victoria Gardens	1,459	1951-91			
Pangani	1,626	1966-93			

Source: Zanzibar Water Resources Development Project (ZWRDP), Annex B 1994 in MANREC Irrigation Master Plan Volume II: Appendices page D-18

According to figure 2, Unguja has an equal North-South divide in annual mean rainfall regime. The northern part has higher mean annual rainfall ranging from 1600 mm to 1800 mm whereas the southern part ranges from 1200 mm to 1400 mm.

Pemba has an East-West divide in annual mean rainfall regime. The western part, with relief of 30-90 metres above sea level, generally receives higher rainfall than the eastern lower side with relief of -18-30 metres above seas level. Mkoani district, located southeast of Pemba, receives the highest annual mean rainfall of between 1800 mm and 2000 mm.

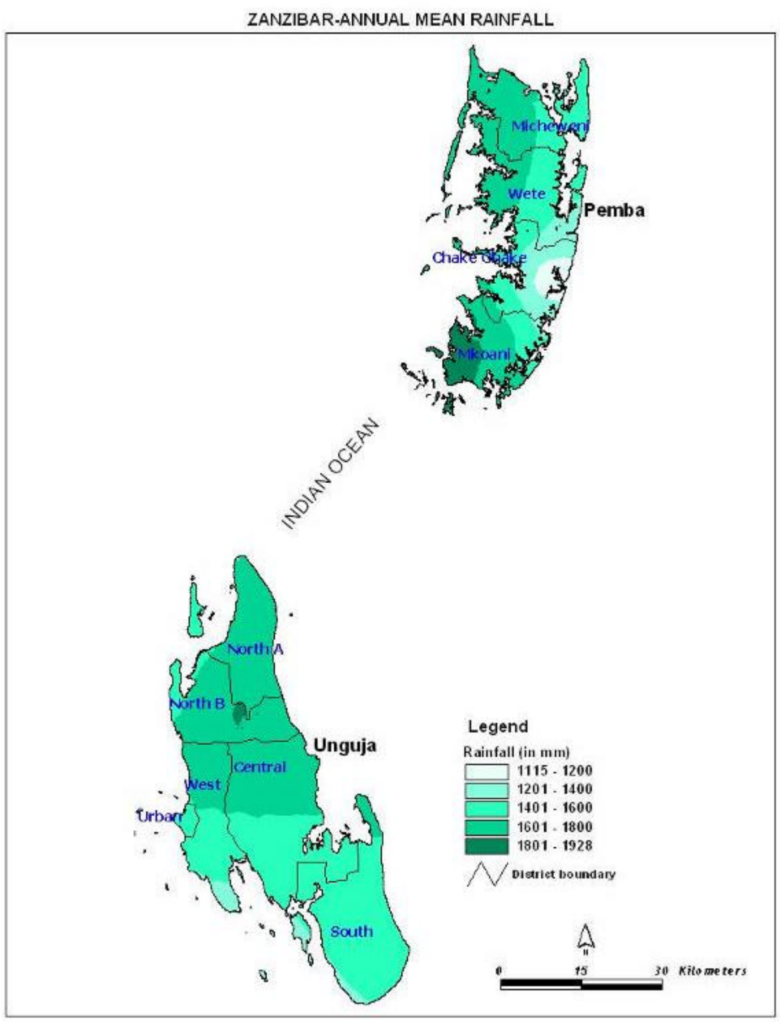


Figure 2 Zanzibar Mean Annual Rainfall (Source: ICRAF GIS Mapping Unit)

Microscopic Water Balance in Zanzibar

Rainwater in Zanzibar is well appreciated as the primary source of water. Water balance Calculations by the JICA study team that prepared the irrigation master plan estimated the total rainfall received in Unguja and Pemba to be 2,444.6 MCM and 1525 MCM respectively. Of this total rainfall, Unguja utilises 33 MCM (1.3%) for domestic water supply and irrigation. Pemba correspondingly utilises 9.2 MCM (0.6%). Groundwater recharge amounts to 588.7 MCM (24.0%) and 117.7 MCM (7.7%) for Unguja and Pemba respectively. However, the rainwater that runs off to the Indian Ocean amounts to 881.3 MCM (24%) for Unguja and 797.4 MCM (52.3%) for Pemba. Total evapo-transpiration is 40% of the total rainfall for both islands i.e. (974.6 MCM and 610.0 MCM for Unguja and Pemba respectively). See Figures 4 and 5 illustrating the water balance for Unguja and Pemba respectively.

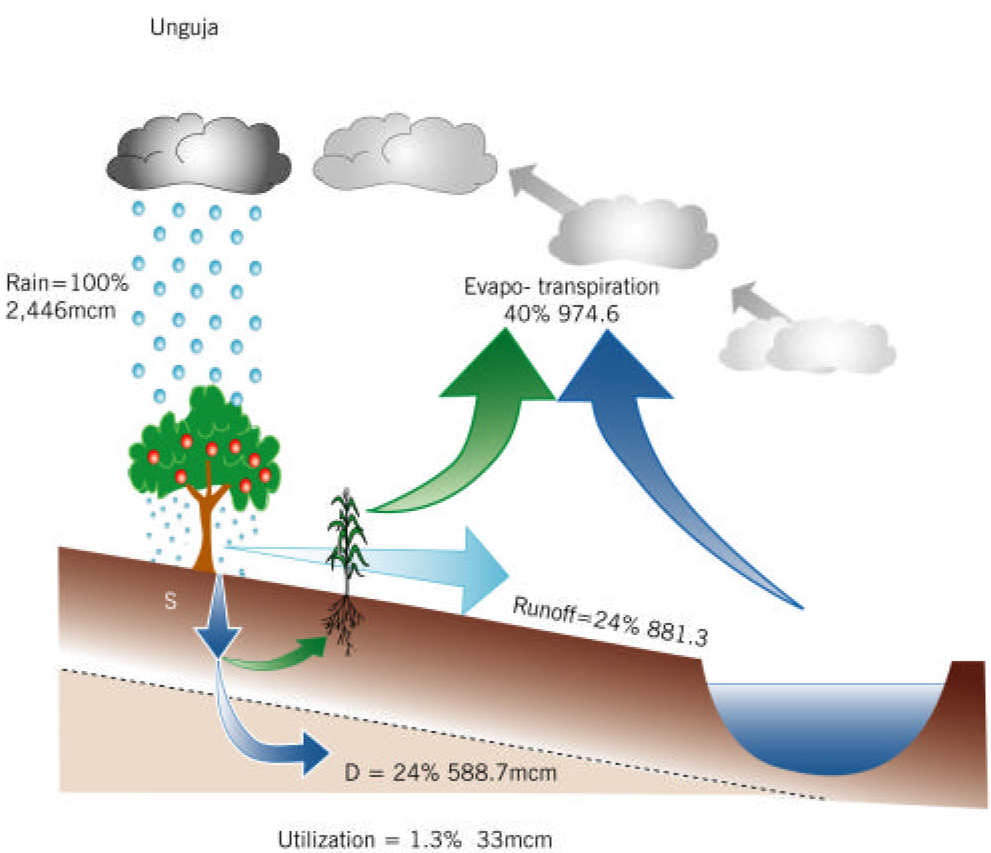


Figure 3 Unguja Microscopic Water Balance Adapted from ZWRDP, 1994

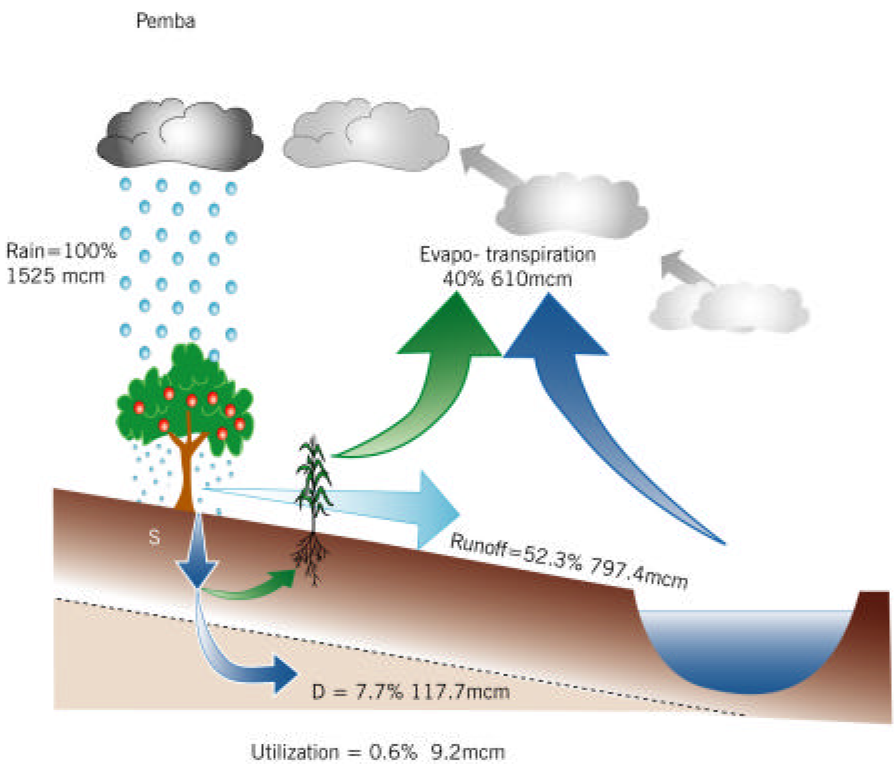


Figure 4 Pemba Microscopic Water Balance, Adapted from ZWRDP 1994.

Verification of Water Balance using GIS Mapping Methods

The GIS mapping done at ICRAF indicates that Zanzibar receives a total annual rainfall volume of 3827 MCM. Compared to the value computed by the JICA team, this value is lower by 142.6 MCM or 3.59%. The difference could be attributed to the total area of the islands used in the calculation at ICRAF. In this study, the wetlands and marshlands at the periphery of the island boundary or land masses submerged in the ocean were left out of the calculation.

The runoff values calculated for Unguja and Pemba are 785 MCM and 443.3 MCM respectively. The runoff value obtained by ICRAF for Pemba is lower than one provided in the irrigation master plan (797.4 MCM) because the river line area is excluded from this calculation.

In this study the evapo-transpiration rate of 40% is adopted from the JICA study for both islands.

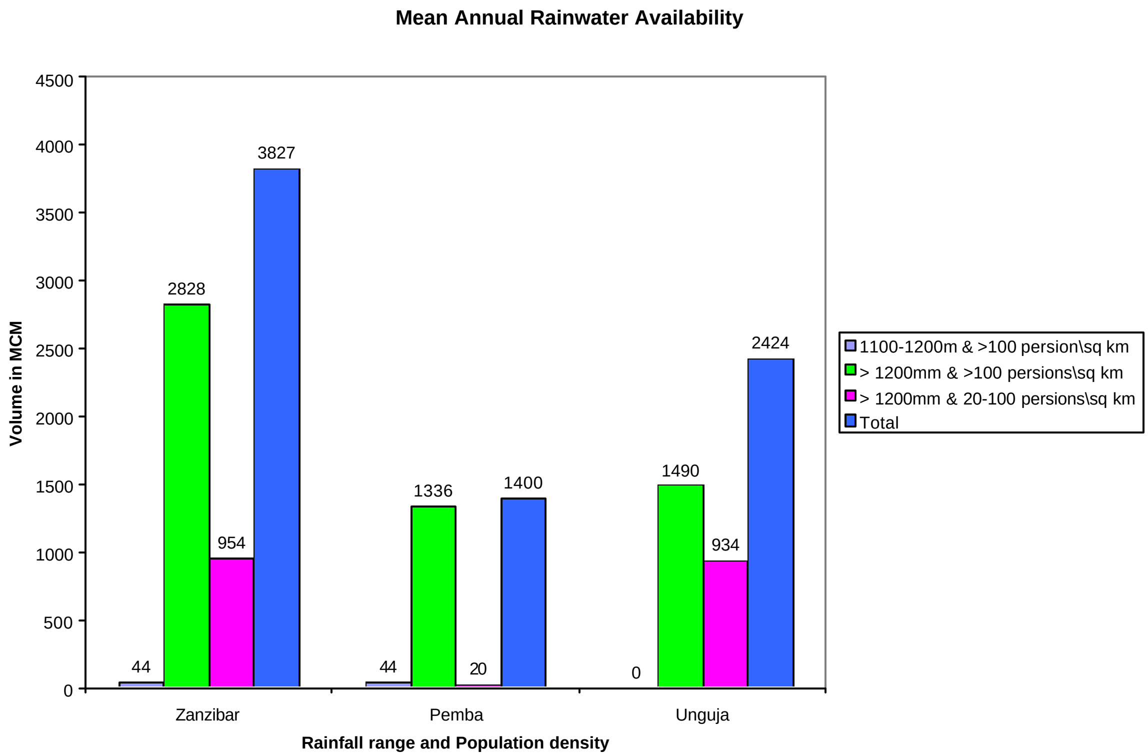
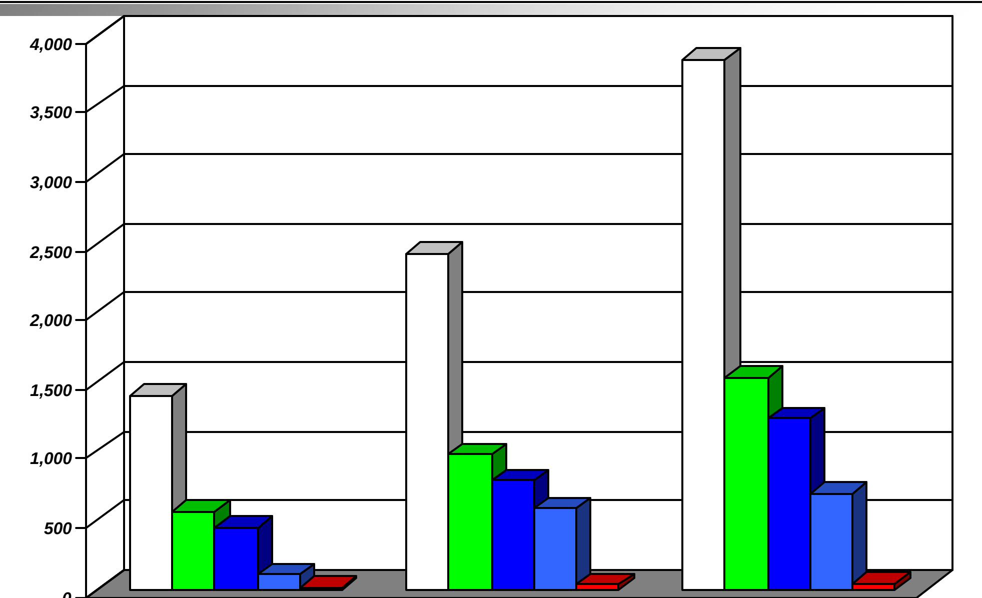


Figure 5 Mean Rainwater Availability by Population density in Zanzibar

It is interesting to note that, according to figure 5, that the area in Zanzibar receiving more than 1200 mm of rainfall and population density greater than 100 persons per square kilometre receives 2828 MCM of rainwater or 74% of the total rainfall. The southern part of Unguja generally has lower population density of 20-100 persons per square kilometre and receives 24% of the total rainfall. The remaining 1.2% of the rainwater falls in a densely (>100 persons/Km^2) populated area in central Pemba.



	Pemba	Unguja	Zanzibar
Total Rainwater	1,400	2,424	3,824
Evapotranspiration	560	970	1,530
Runoff	443	785	1,229
Groundwater	108	582	690
Current Use	8	32	40

Figure 6 Rainwater portioning and water utilisation in Zanzibar

As illustrated in Figure 6, the current utilisation of rainwater in Zanzibar is way too low (1%). It will take great effort and investment on the part of the government, private sector and general public to fully utilize both the green and blue water. The green water or evapo-transpiration proportion of the rainfall could be tapped through increasing forest cover, grassland and cropland whereas blue water involves harvesting runoff for agricultural, domestic and industrial water supply. Utilising Agroforestry interventions on cropland maximises the use of green water.

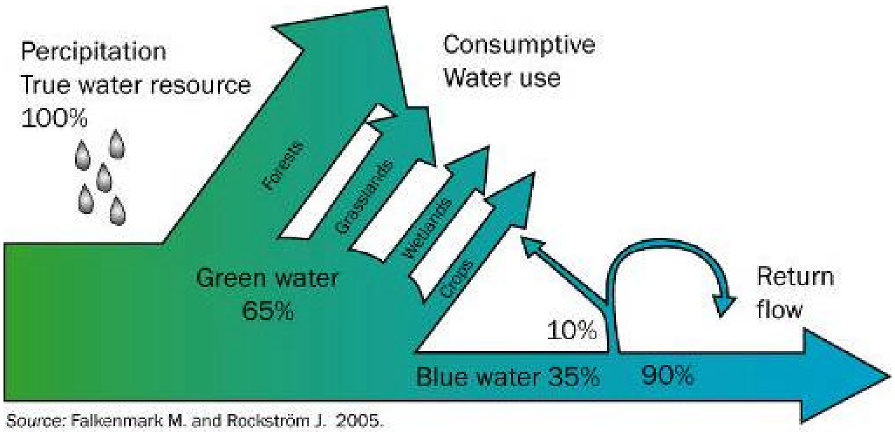


Figure 7 Global Rainwater Partitioning

Water requirements to meet Humans needs

According to Table 2, the human annual water requirement to meet dietary needs, domestic water supply and industrial requirements is given as 1500 m^3 per capita per year. Food production accounts for the largest proportion (86.67%). Industry and domestic take up 10% and 3.3% respectively. This shows that Agriculture needs careful planning in order the meet dietary requirements of any given population.

Table 2 Human annual water need

Water for humans	Human annual need (m^3/p/yr)	%
Diet	1300	86.67
Domestic	50	3.33
Industry	150	10.00
Total	1500	100.00

Figure 8 shows the relationship between the water requirements for diets and the Gross Domestic Product (GDP). Rich nations with high GDP generally have higher water requirements to meet dietary requirement than the poorer nations which use less than 1000m3/capita/year.

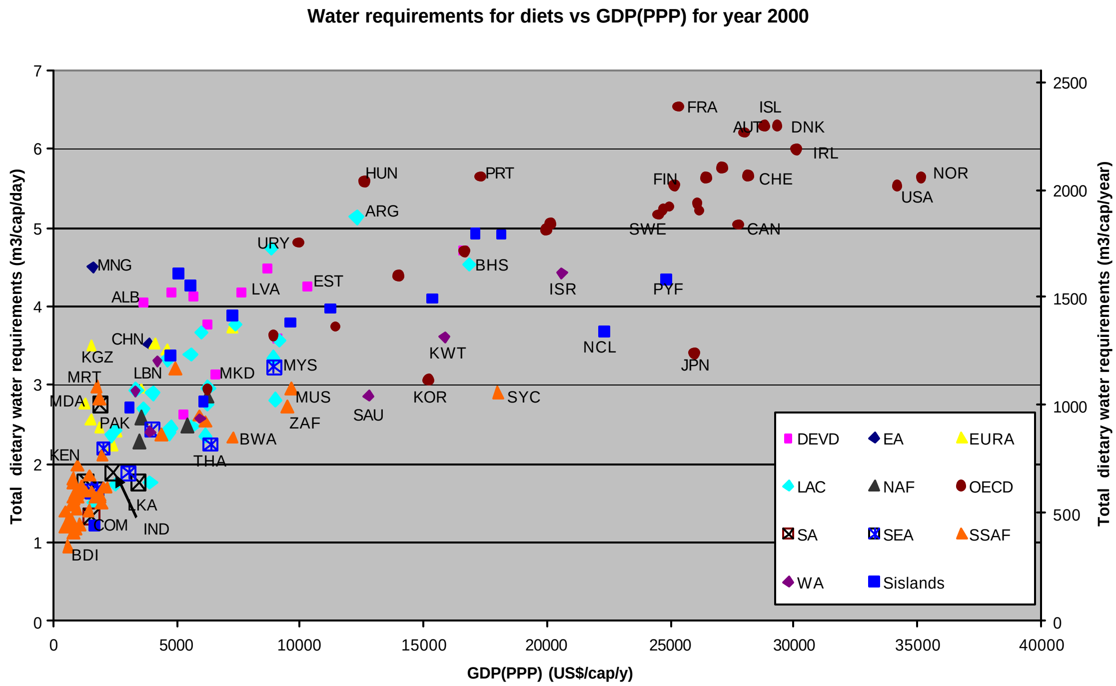


Figure 8 Water requirements for diets versus GDP/capita/year (Source SEI, 2006)

Basing on the water balance for Zanzibar and the human annual water need ($1500m^3$), simple calculations were done to determine the population size that could be supported by the available water resources on Unguja and Pemba islands. The first scenario in Table 3 examines 100% precipitation. Although it is not practically possible to capture all the rainwater received, this analysis presents an interesting picture. It shows that the total rainfall can support threshold populations of 1.6 million and 1 million on Unguja and Pemba respectively.

Table 3 Total rainwater scenario at $1500m^3$/capita/year

Location	Total Rainfall	Population
Unguja	2,444,600,000	1,629,733.33
Pemba	1,525,000,000	1,016,666.67
Total	3,969,600,000	2,646,400.00

Table 4 shows the population coverage by the current water use at 1500m3/capita/year. This second scenario suggests that the current water use (domestic and irrigation) can only meet human annual water need of 28,133 people. For the sake of argument, the human annual water need was reduced to 500m3/capita/year (see Table 5) to take into account that Zanzibar is still a developing nation with a low GDP. The resulting population coverage was still at a low of 84,400 people. There are two important implications of this scenario. The first one suggesting that a large proportion of the population of Zanzibaris lives far below the basic human standard of living. This conclusion is supported by results of the household budget survey of September 2006 which found that about half of Zanzibaris live below basic needs poverty line. The study further found that more that one half of household's income is spent on food. This then leads to the second implication that Zanzibar relies a great deal on imported food produced from outside the islands.

Table 4 Current water use scenario at 1500m^3/capita/year

Location	Current Water Use	Population
Unguja	33,000,000.00	22,000.00
Pemba	9,200,000.00	6,133.33
Total	42,200,000.00	28,133.33

Table 5 Current water use scenario at 500m3/capita/year

Location	Current Water Use	Population
Unguja	33,000,000.00	66,000.00
Pemba	9,200,000.00	18,400.00
Total	42,200,000.00	84,400.00

The third analysis considers the groundwater recharge proportion of the rainwater. It is assumed here that groundwater abstraction should never exceed the annual recharge rate otherwise that would be considered mining of the resource. According to Table 6, annual groundwater recharge can support the water needs of 470,933 people i.e. 392,467 and 78,467 in Unguja and Pemba respectively. This analysis shows that the current water use from groundwater could be expanded 18 times in Unguja and 13 times in Pemba without mining the existing groundwater resources.

Table 6 Groundwater potential at 1500m3/capita/year

Location	Groundwater	Population
Unguja	588,700,000	392,467
Pemba	117,700,000	78,467
Total	706,400,000	470,933

According to table 7, runoff harvesting can support human annual need of 1,119,133 people on both islands. This water could be used for both rain fed and irrigated agriculture.

Table 7 Total Runoff scenario at 1500m^3/capita/year

Location	Runoff	Population
Unguja	881,300,000	587,533
Pemba	797,400,000	531,600
Total	1,678,700,000	1,119,133

Zanzibar's Opportunities and Challenges in Water Management

After holding several consultative meetings with key informants in the government, perceived challenges and opportunities in water management were identified.

Challenges

1. The total amount of water available for the ever growing population of Zanzibar is not well established and no serious attempts have been made to carry out an assessment;
2. There is heavy dependence on groundwater for domestic and agricultural use;
3. Despite receiving high rainfall, Zanzibar experiences water scarcity;
4. Communities are not accustomed to harvesting rainwater;
5. The best modalities of harvesting rainwater have not been established;
6. Integrated Water Resources Management plans are not in place. This has a negative implication on the planning and budgeting of water at the Ministry of Finance and Planning
7. There are no big rivers in Zanzibar. Numerous perennial streams exist and these facilitate rapid loss of runoff to the Indian ocean
8. The current focus of government has been of the development of water infrastructure. However, whether this approach will result in the achievement of set targets is not known by the government.

9. Agriculture contribution has declined from 35% - 23%. Recent years have seen a shift from agriculture economy to service economy (tourism industry) which is putting pressure on water resources. Tourists require 200 litres of water per day.

Opportunities

1. New long and short term development strategies in place to address non-income poverty which includes provision of clean and safe water
2. Government has placed high priority on the development of water resources
3. Ambitious targets to increase access to water in urban area from 75% to 90% and rural areas from 59% to 75% by 2010.
4. There are high expectations from government officials on the outputs of this study. Most documents/study reports on water resources are outdated. UNICEF has done lots of studies on water harvesting.
5. Emerging interest by donors (e.g. JICA) to revive collapsed government irrigation schemes. A new bottom up approach will ensure community ownership.

Past and ongoing RWH investments in Zanzibar

The level bunds are commonly practised in Unguja. These are level structures measured along the contour to impound surface runoff. Level bunds are measured using various methods. The cheapest method is the A-frame. The line level method is also relatively cheap and can be taught to farmers. There are also expensive methods such as using the dumpy level. As seen in Plate 5 below, level bunds require accurate measurement and maintenance for them to function properly.

Level bunds

Plate 5 Level bunds in Unguja

River diversions and surface irrigation

The most promising innovation seen in Pemba was the check dams and river diversion using surface canals (see Plate 6). The rice irrigation was very impressive and farmers are producing 4 tonnes per hectare. According to a key informant, the cost of investment for such a system is US$3000 per hectare.

Plate 6 River diversion and surface irrigation in Pemba
(Photos by Maimbo M. Malesu 2007)

Groundwater

Groundwater abstraction is wide spread especially in Unguja (see Plate 7). The abstraction methods used include boreholes and open shallow (15-20m). According to information gathered, almost every household in Unguja desires to own a well. Currently the government is overwhelmed with its role of monitoring both the quantity and quality of ground water. Groundwater recharge is not practiced.

Plate 7 Shallow wells in Unguja

Spring water

Springs are excellent sources of water for all purposes. The main source of domestic water supply to Zanzibar Stone town is a spring that was developed and protected in 1923 (see Plate 8). Up to present, this spring still has a good yielding capacity. However, there is need to protect the life of the spring by ensuring that all human encroachment in the catchment area is curbed.

Plate 8 Main spring in Zanzibar

Observed Challenges in the field

- Land degradation
- Soil Erosion (See Plate 9)
- Runoff Control/flooding
- Encroachment of groundwater recharge areas/catchment areas
- Upstream down stream conflicts
- Salt water intrusion
- Lack of govt., private, donor investment in RWH

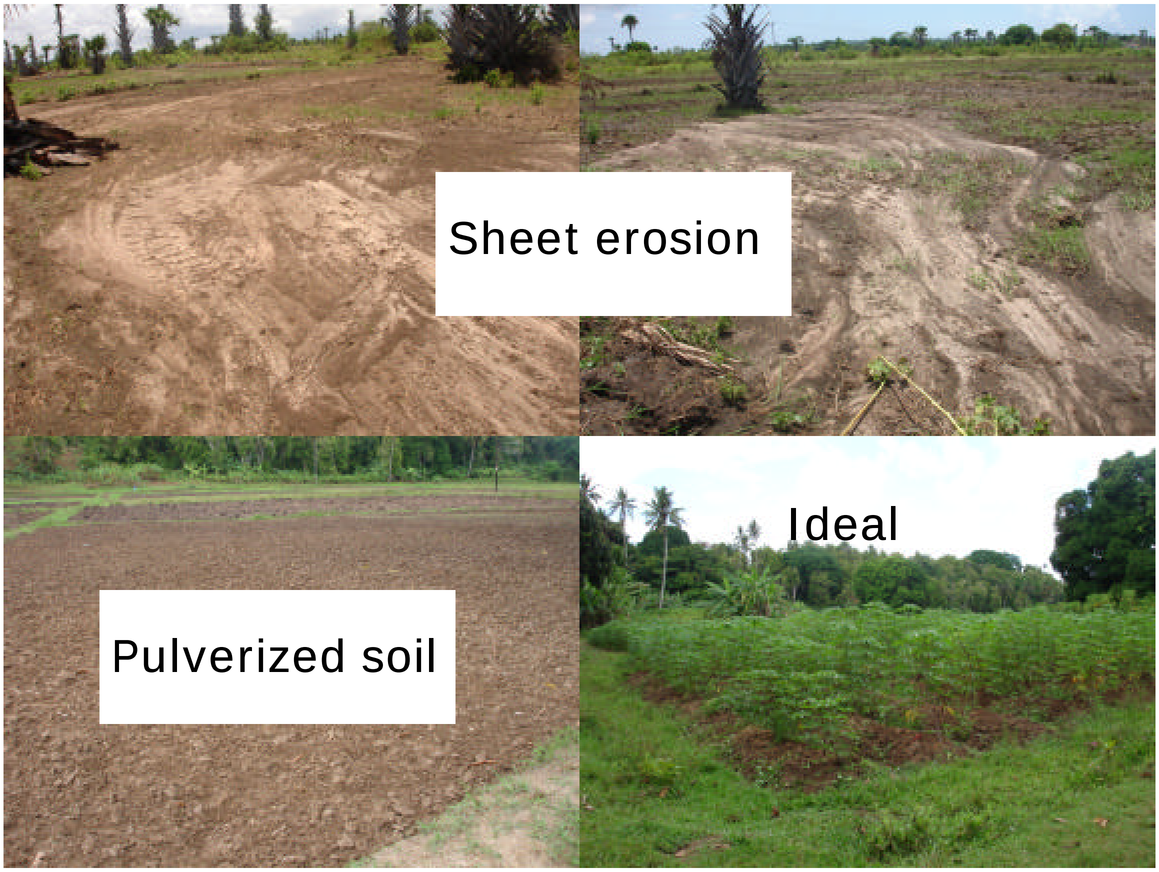


Plate 9 Sheet erosion in Ungula

Impacts of RWH Practices

- Increased production e.g. Rice yields 4 tonnes per hectare
- Improved water supply and sanitation
- Positive environmental impacts

Approaches and Technological Options

Approaches

Zanzibar requires appropriate approaches for the sustainable management of its rainwater resources. Four approaches are proposed as shown in Figure 9. The first approach would aim at promoting community awareness on the potential and appropriateness of rainwater management in addressing the water needs for tourism, agriculture, manufacture and domestic purposes.

The second approach would involve technical assistance and training of key stakeholders and rural communities on appropriate systems of rainwater management for domestic, service, agricultural, industrial and ecological use. This approach would be suitable for many institutions like tourist hotels and community based organizations, government and non-government agencies. The approach will entail empowerment of local artisans and community workers on the principles of rainwater management and skill train them on the technical aspects of construction, maintenance and operation of selected rainwater management systems.

The third approach would be applicable to the vulnerable rural communities that do not have sufficient labour and funds for constructing the rainwater harvesting systems. It would involve the creation of a seed money facility and a revolving fund mechanism (merry-go-round) to assist the vulnerable members of the community to hire artisans and materials for the construction of the proposed rainwater management facilities.

In these approaches, ownership and maintenance of the rainwater systems will be the responsibility of the system operators (either individuals or the communities). The users will be in charge of monitoring the performance of the systems and they will be capacitated to disseminate the technology to other areas of the country.

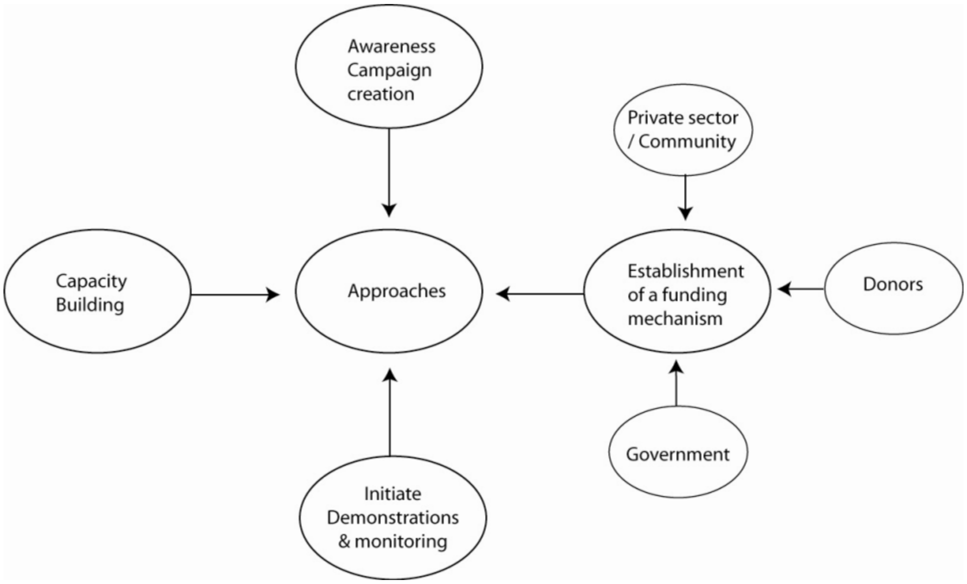


Figure 9 Approaches for instituting RWH in Zanzibar

Technological Options

There is a wide range of technological RWH options applicable to Zanzibar. Figure 10 illustrates short and long term storage systems for crop production, livestock and household/domestic use. The in-situ techniques are knowledge based are do not require capital investment. The runoff systems, however, require construction of storage structure such as check dams, tanks, ditches and terraces. The groundwater recharge systems also require construction of abstraction, storage and recharge structures such as wells, boreholes, subsurface dams etc. The roof catchment water harvesting systems require construction of either above or below ground storage tanks.

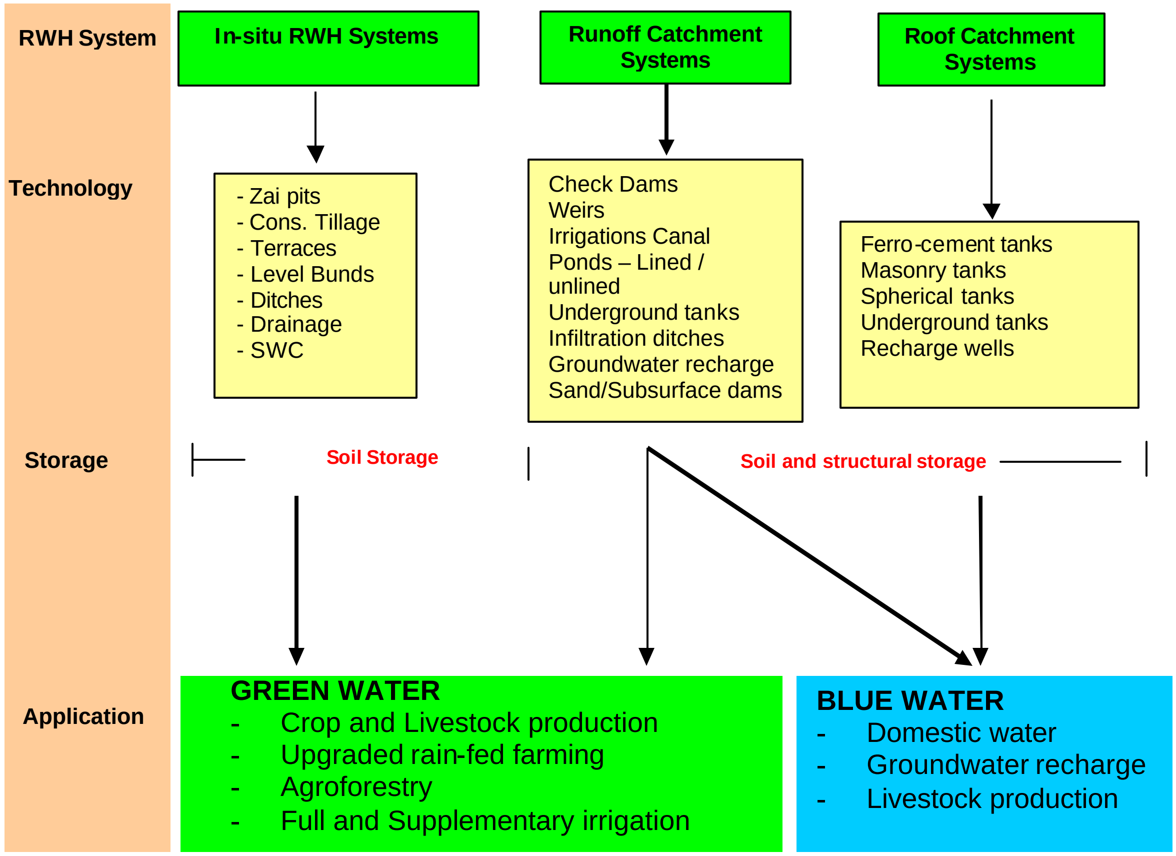


Figure 10 Technological RWH Options Applicable to Zanzibar

Artificial ground water recharge for borehole and well rehabilitation

Groundwater is the most common source of freshwater in Zanzibar. The challenge of over abstraction of ground water resources with the resultant drying and collapse of some boreholes and the danger of seawater intrusion to the underground aquifers could be managed by utilising the artificial ground water recharge technology in light of the favourable geologic conditions.

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 or replenishment. Any man-made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system (see figure 11). In Artificial recharge, infiltration basins or injection wells could be used to recharge groundwater water resources.

Application of artificial groundwater recharge technology would involve harvesting runoff and passing it through a siltation trough before allowing it to flow into a recharge facility. Two options exist for exploiting this technology:

Use of infiltration technologies: Where suitable conditions are created to promote infiltration of the largest possible volume of surface runoff to groundwater aquifers either through a permeable overlaying the aquifer or directly to the aquifer,

Injection technologies: based on pumping surface water directly into the groundwater aquifer.

Design Considerations

Three most important **components**, which need to be evaluated for designing the rainwater harvesting structure, are:

- Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water
- Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built up pattern of the area
- Hydro-meteorological characters viz. rainfall duration, general pattern and intensity of rainfall

Techniques

Pits: - Recharge pits are constructed for recharging the shallow aquifer. These are constructed 1 to 2 m, wide and to 3 m. deep which are back filled with boulders, gravels, and coarse sand.

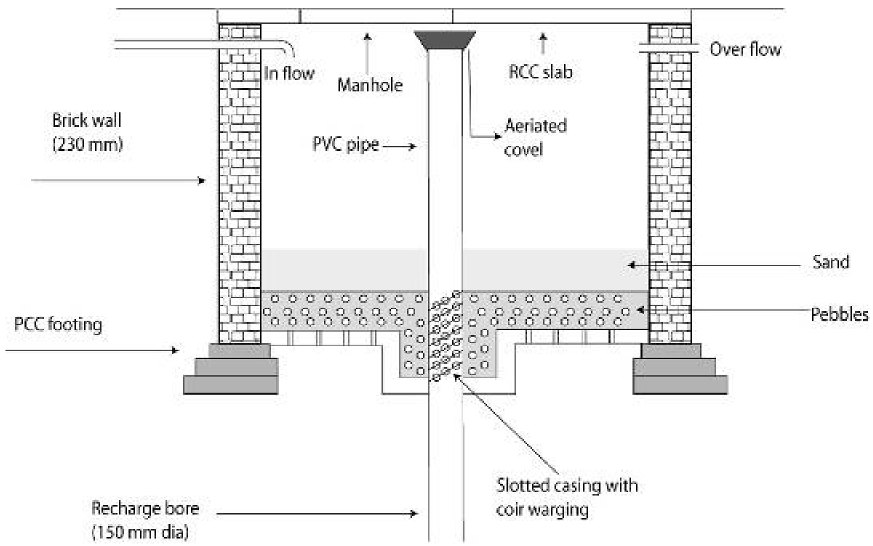


Figure 11 Recharge well for shallow water tables

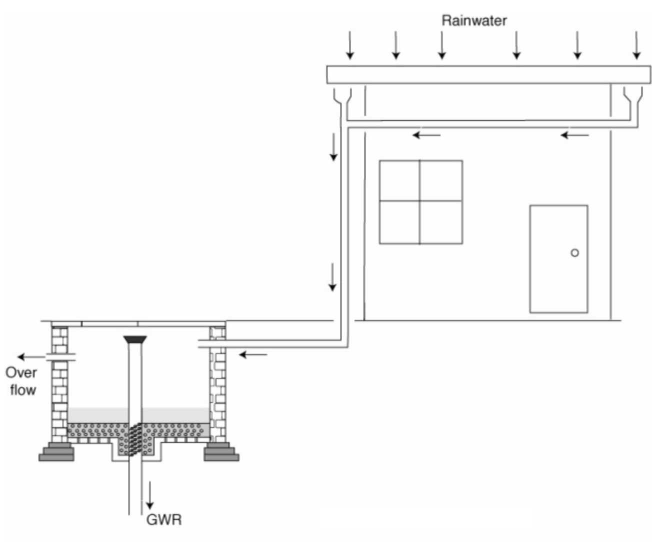


Figure 12 Groundwater recharge well with Roof catchment

This design is suitable for areas with shallow water level in hard rock as well as soft rock areas for individual houses, group housing societies, schools and small industrial set ups (See Figure 11 and 12).

Trenches: - These are constructed when the permeable layer is available at shallow depth. The trench may be 0.5 to 1 m. wide, 1 to 1.5m deep and 10 to 20 m long depending up availability of water. These are back filled with filter materials (see Figure 13).

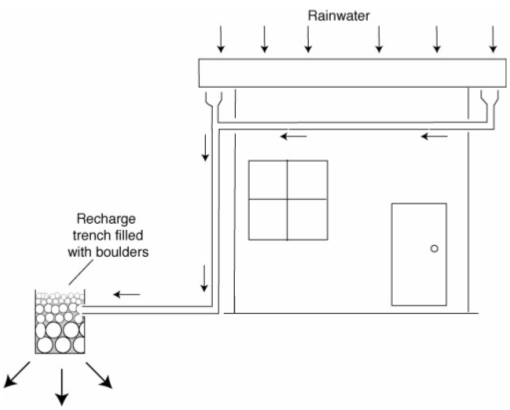


Figure 13 Groundwater recharge using trench filled with boulders

This design is suitable for areas with shallow water level in hard rock as well as soft rock areas for large group housing societies, schools and small industrial sheds.

Dug wells: - Existing dug wells may be utilised as recharge structure with water passing through a filter media before being allowed into the dug well.

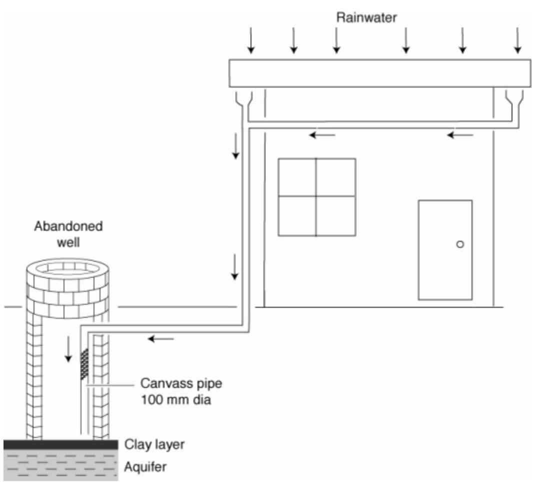


Figure 14 Dugs out wells used as recharge facility

This design is suitable for areas with shallow (5 to 15 m) water level in hard rock as well as soft rock terrain for individual houses, group housing societies, schools and small industrial sheds

Hand pumps : - The existing hand pumps may be used for recharging the shallow/deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps.

This design is suitable for areas with moderate to deep water level in both hard rock as well as soft areas for individual houses, group housing societies, schools and small industrial sheds.

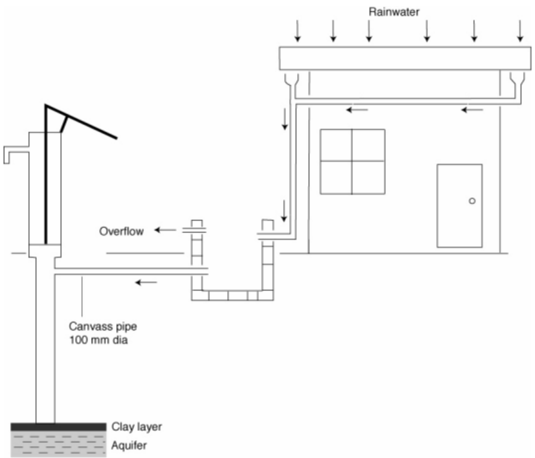
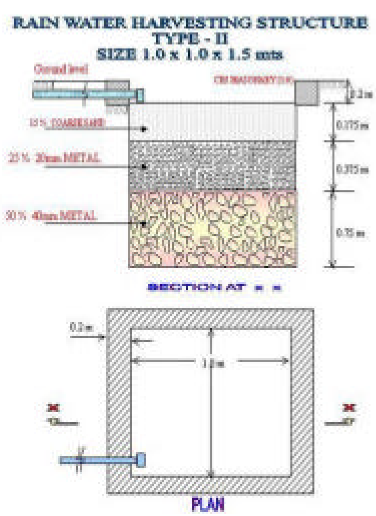


Figure 15 Recharging grounwater using existing Hand pump

Recharge wells : - Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking the recharge wells.



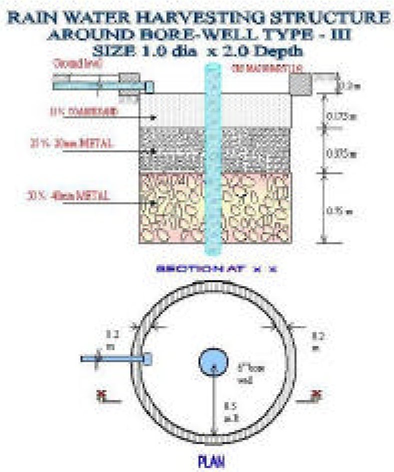


Figure 16 Filtering medium for Groundwater recharge structures

Recharge Shafts: - For recharging the shallow aquifer, which is located below clayey surface, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed and back filled with boulders, gravels & coarse sand.

This design is suitable for areas having shallow water level in hard rock and soft rock areas with shallow water level, suitable for group housing societies, schools and small industrial sheds.

Lateral shafts with bore wells: - For recharging the upper as well as deeper aquifers lateral shafts of 1.5 to 2 m wide & 10 to 30 m long depending upon availability of water with one or two bore wells is constructed. The lateral shafts are back filled with boulders, gravels & coarse sand.

Well-tank and borehole well: is a combination of a well-tank and borehole well structure adapted to provide water supply directly from the rain storage while the excess is used to augment borehole storage. The borehole is drilled to groundwater level and the well tank, which is 0.5 to 1 m away from the borehole, is drilled to a depth such that the static level of the borehole is at least 6 m higher. This difference in elevation provides a sufficient water level in the well to permit easy abstraction of the stored water. This water depth in the well tank is maintained by the construction of a junction between the well tank and the borehole at the bottom of the well tank at the static water level.

Spreading techniques: - Best suite in areas where the permeable strata starts from the top. The water is spread in streams by making check dams, bunds, cement plugs, gabion structures or percolation ponds and allowed to infiltrate through.

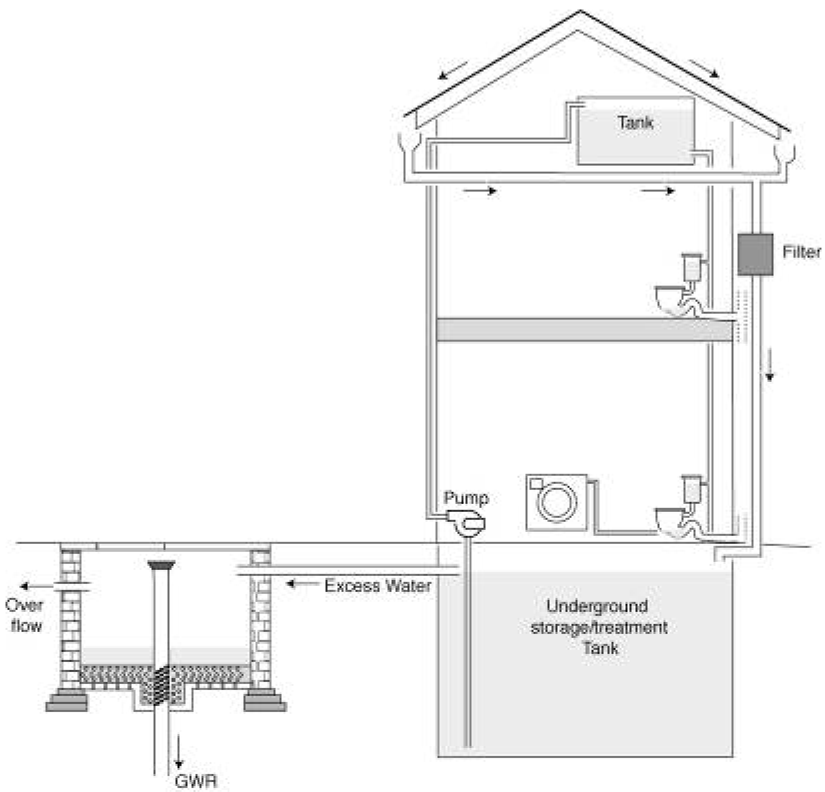


Figure 17 Roof Catchment with underground storage and overflow for groundwater recharge

Suitability

The Pokezi phenomenon is a clear sign of accelerated natural recharge of the ground water resources to impede the salt intrusion by the Indian Ocean waters. It demonstrates the existence of a great potential in harnessing the technology to maintain the groundwater levels for sustainable groundwater exploitation and maintaining environmental resilience. The technology can be applied widely in the Southern parts of Unguja and the Eastern parts of Pemba Islands. It could also be adapted as an integral part of the rooftop rainwater harvesting by instituting it in the building codes as a mandatory component of any housing structure.

Generally, artificial recharge technologies are considered suitable in situations where groundwater represents the main component of the available water resources. This situation pertains in most parts of Zanzibar.

Expected impacts

Use of artificial groundwater would be mitigation against seawater and brackish water intrusion and thereby sustain supplies of fresh water over a long period

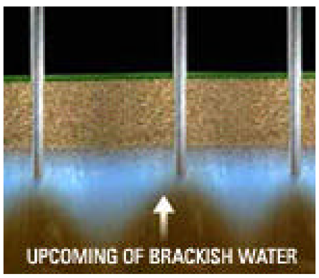


Figure 18 Saltwater Intrusion

Accelerated use of ground water recharge would reduce flash flood occurrence in the low-lying areas.

Groundwater recharge as a storm water management technology ensures reliability of water supplied from nearby wells

Runoff collection using in-stream structures

Small dams for supplemental irrigation, water supply and groundwater recharge

In-Stream weirs or check dams could be constructed across the small streams that cover the landscape of Zanzibar and used to increase the retention time of runoff flows during flash floods. The stored water could then be harnessed by gravity through buried pipe collectors laid at the bottom or adjacent to the streambed or drawn through canals to feed agricultural field crops or domestic and livestock water supply systems.

Design Considerations

The structures should be constructed across the entire width of the watercourse so that a small lake is formed behind them. The dams should be built on the higher upstream regions of the rivers where the watercourse is narrow and deep. The dams should be equipped with spillways to allow the release of floodwater into the river course downstream of the dam after the lake water level reaches a certain height.

Intake structures from these dams should be sited and designed to maximize water quantity, maximise water quality and optimise water pressure in the demand areas. They should also be designed to divert sediment and organic matter. The small dams could be designed and constructed in a cascading manner along the course of the rivers in areas that are geologically sound and with minimal environmental effects. Hydro geological studies should be carried out to select suitable intake sites, to establish the command area that can feasibly be irrigated and to ensure a balanced downstream upstream apportioning of the water resource. The hydrological studies should be used to inform on safe designs of the dam in their lifetimes.

Suitability

Small dams and hill reservoirs are suited for storing irrigation and drinking water in areas with high rainfall like Zanzibar. Pemba Island is most ideal for this technology as it has favourable topographical and geological formations and a high density of streams. The implementation of this technology would require enforcement of appropriate land management policies to reduce soil erosion from the catchments in order to reduce the effects of sediment settlement in the dams.

Possible layout

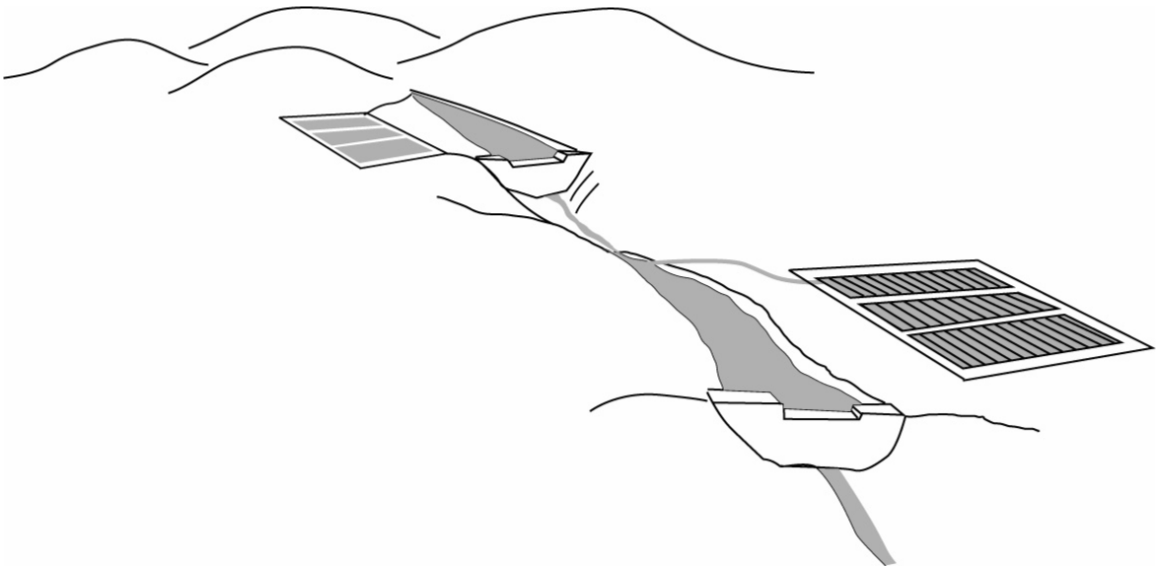


Figure 19 Lay out of Check dams

Expected impacts

Large quantities of the surface water that that ends up flowing to the ocean will be retained to recharge aquifers spread on the streambeds.

Increase capacity storage capacity making water available for diverse uses

Flood mitigation

Runoff collection using surface structures

Ponds and pans

Ponds and pans are naturally occurring or excavated water storage structures without a constructed wall. They usually store surface runoff, even though there are examples of constructed ponds storing roof water.

Excavated ponds come in sizes from 200 to 500 m^3 for households to over 10,000 m^3 for communities. They can easily be started with a small capacity and expanded over the years by digging them deeper and wider. In areas with impermeable soils and suitable topography, the only cost would be labour for construction.

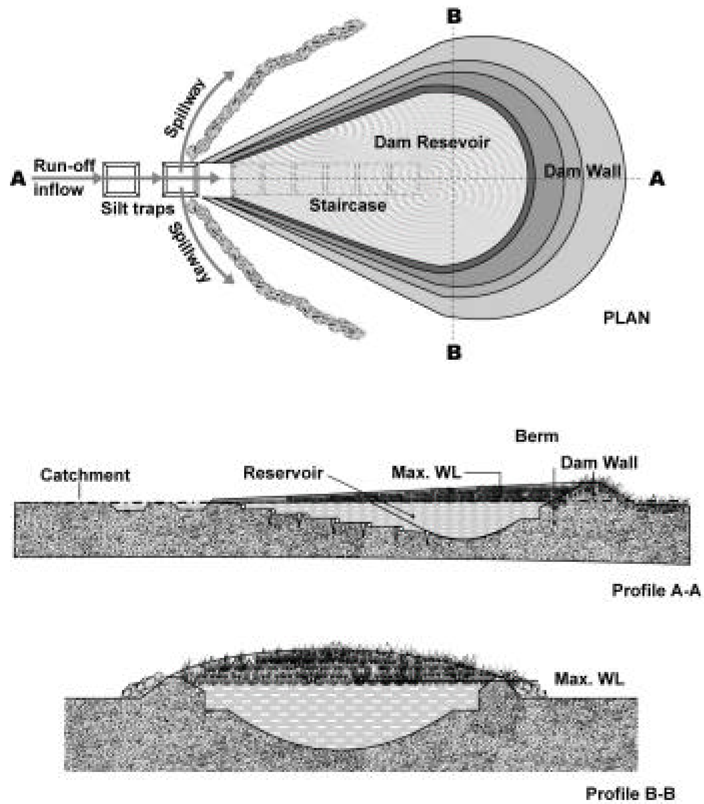


Figure 20 Charco dam

Design considerations

Ponds should be situated at a low point in the catchment area to collect water that flows naturally by gravity. The catchment area can consist of any type of surface such as cropland, grasslands, and road surfaces or a compound around homesteads. The structure can be of any shape although circular designs are the most common. Their sizes depend on the water demand, allowance given for silting, the catchment area, area available for pond construction and the soil type. Most ponds are normally preceded with silt traps to reduce sediment inflow into the ponds. In areas with porous soils, a lining membrane should be added. This could be achieved through blanking with clay soil or by lining using an appropriate membrane material.

Suitability

Ponds and pans are mostly built in areas with flat slopes or inclined slopes. They can find ready and useful application in the southern regions of Unguja and the eastern coasts of Pemba. They could be used to provide water for livestock, supplemental irrigation of fruit crops and to nature tree, vegetable and fruit nurseries. Ponds could be adapted from the mainland Tanzania's *charco* dams (see Figure 20) or Kenya's *silanga*

Layout

Plate 10 Runoff Pond in Machakos district in Kenya

Plate 11 Rectangular plastic lined pond in Machakos Kenya

Expected impacts

- Improved accessibility to water by reducing the distance travelled to less than 100 m for household based systems**.**

- Increased productivity of the land and labour force through utilisation of stored water on land based production.
- Increased farm incomes

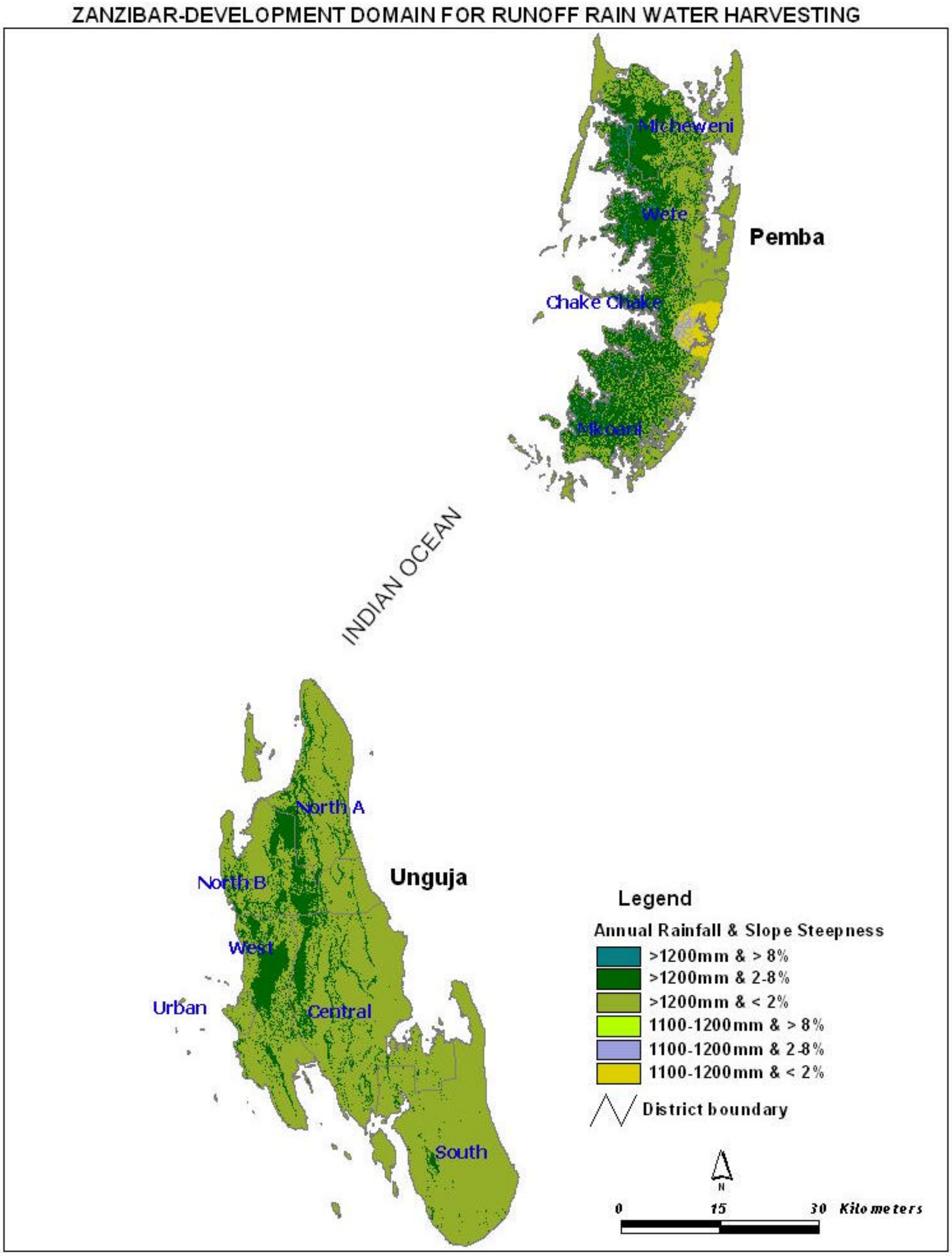


Figure 21 Development Domains for Runoff Catchment Systems

Rooftop rainwater harvesting

A rainwater harvesting system consists of a rainwater catchment surface, conveyance system and a water storage tank (Figure 22). Rooftop rainwater harvesting systems can serve households or communities. Household systems generally catch rain from rooftops of homes and store it in tanks. Important considerations in these systems are the roof size, rainfall, water demand and costs. Roofs can be of aluminium, galva nised iron, concrete, shingles tiles or mud. Conveyance systems usually consist of gutters and drain pipes that deliver the water from the roof to the storage tanks. The storage tanks are used to store water and should be made of inert material. Reinforced concrete, Ferro cement, fibreglass, polythene, or stainless steel is suitable materials.

Figure 22Rooftop rainwater harvesting

Design considerations

Important factors to consider in designing the tank include provision for adequate capacity, sloped bottom for ease of cleaning, grit trap, provision of a manhole for ease of access for cleaning, a vent for ventilation and protection against insects and pests. The quantity of water available from rainwater harvesting system depends on the size of the catchment, the rainfall, the size of the storage tank, the guttering size and efficiency and the water use regime.

Suitability

Rooftop rainwater collection systems have been extensively used by most Small Island Developing States especially where rainwater catchment systems augment the groundwater supplies. This technology is suited for the island of Zanzibar and could be adopted at household and community levels both in the urban and rural areas. Ferro cement tanks could find wide adoption and application in Zanzibar and would be cost effective in meeting the water demands at the household levels.

Plate 12 Wide spread Roof Catchments in Zanzibar town

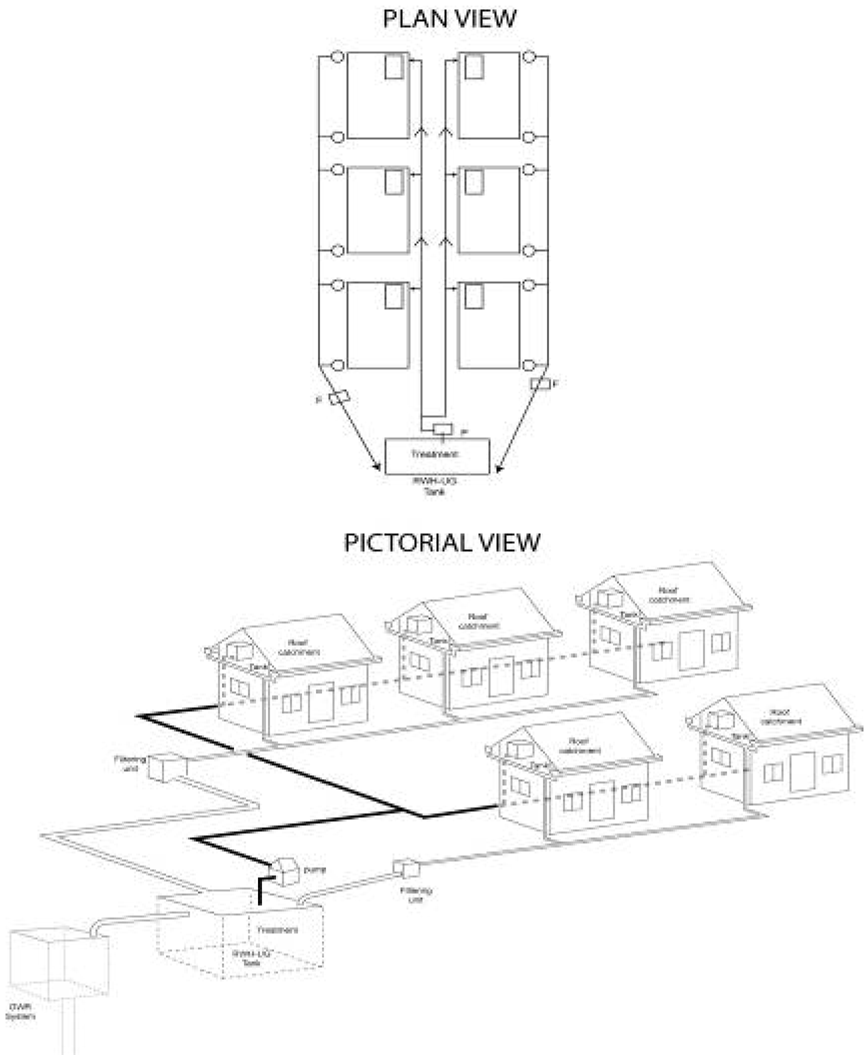


Figure 23 Plan and pictorial vi ew of an estate storage and groundwater recharge facility

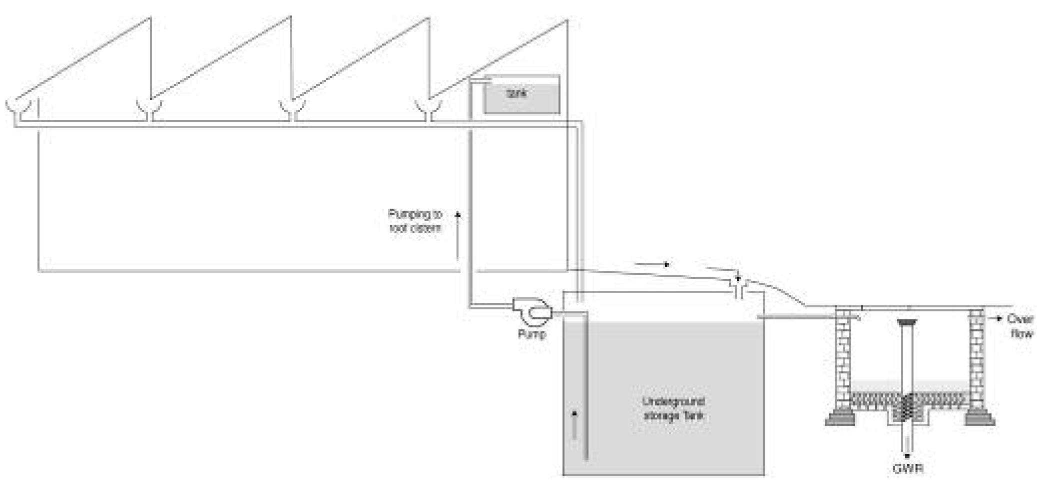


Figure 24 Factory with Underground storage and recharge facility

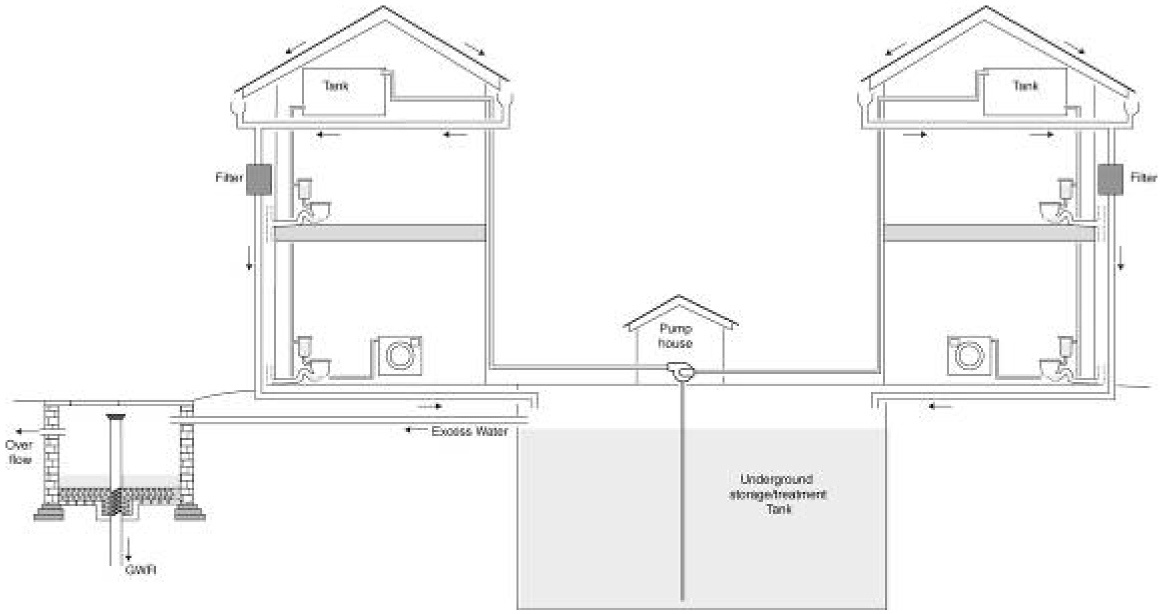


Figure 25 Estate with central storage tank and groundwater recharge facility

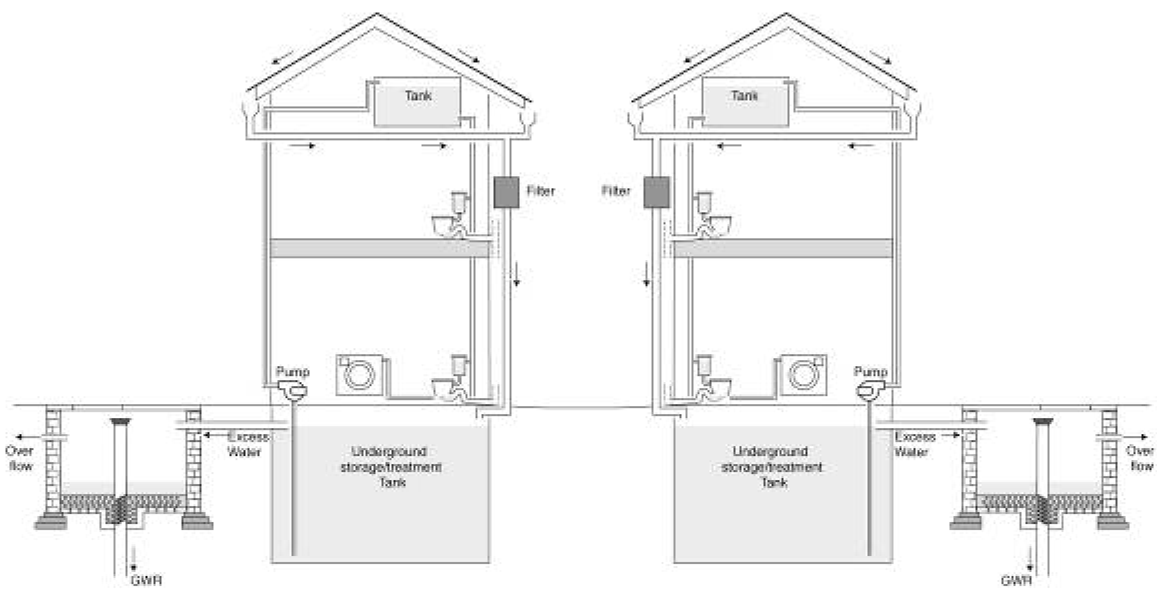


Figure 26 Estate with independent underground storage tanks and recharge facilities

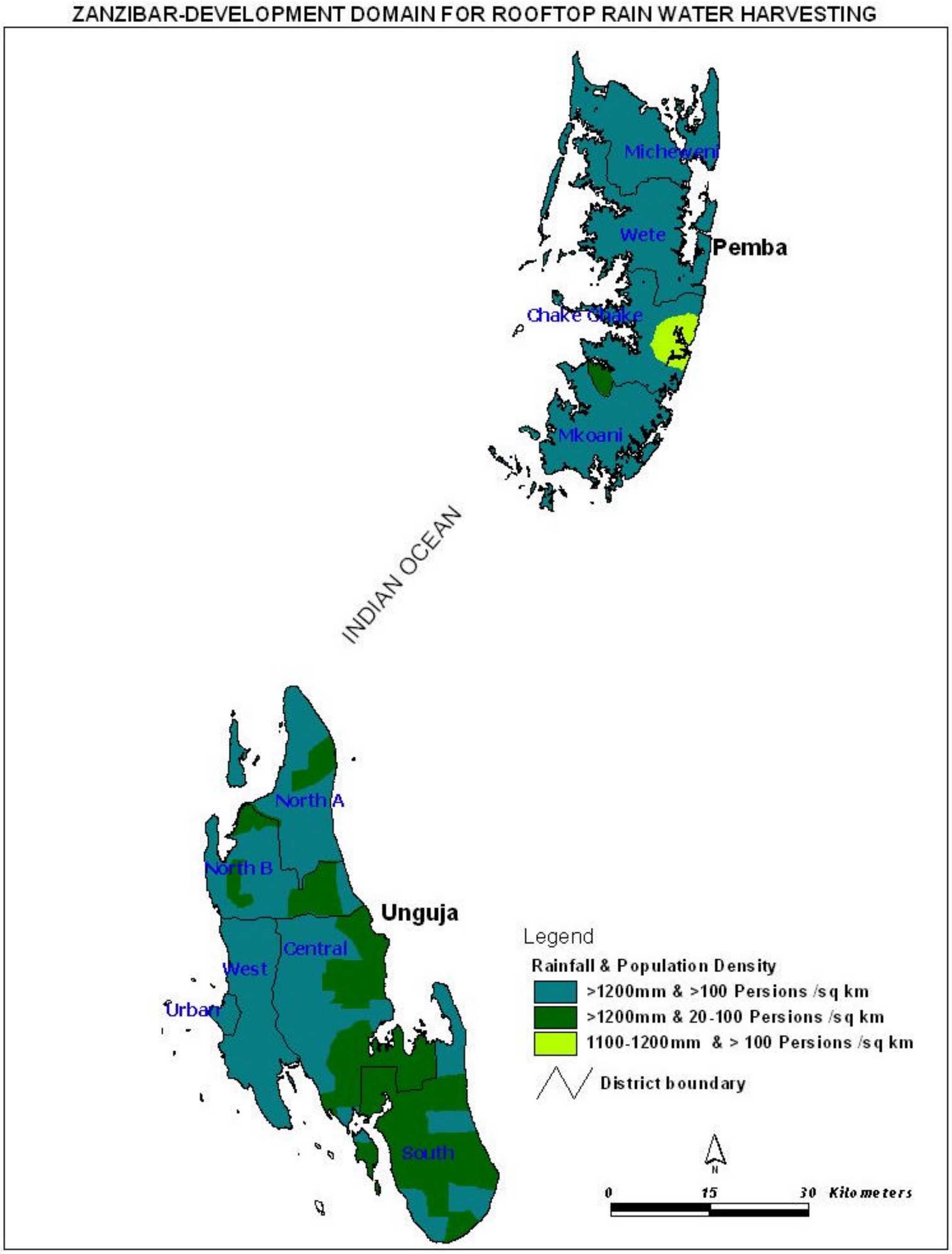


Figure 27 Development domains for Roof Catchment Systems

In-situ Water Harvesting for agriculture

Crop and livestock production can be improved substantially by concentrating rainwater where it is needed, as well as by supplementary irrigation at critical stages of plant growth. Two options that are suited for Zanzibar are considered here.

Zai Pits

Pitting (digging holes of various sizes for growing crops) has been practiced as a method of water harvesting and conservation for both micro-catchment and external catchment systems. In East Africa, farmers have always grown crops such as bananas, coffee, tea and many types of fruit tree in pits. However, they still consider pits for field crops such as maize, millet and beans as a novel technique.

Since the annual rainfall is nearly 1,000 mm, the farmers plant about 15-20 seeds of maize per pit and the yield per pit is more than double that of those on conventional tilled land

Design Considerations

The Zai utilizes shallow, wide pits that are about 0.6 m in diameter and 0.3 m in depth. During excavation, the soil is thrown down slope to form a small embankment. To improve fertility, farmers place manure or compost in the bottom of the pit before planting four to eight seeds of a cereal crop, for example, maize (Figure 28). *Zai* pits are effective because they are one technique that harvests water, conserves moisture and improves fertility

Suitability

Suitable for areas with moderate to high rainfall and therefore could be adapted to Zanzibar conditions.

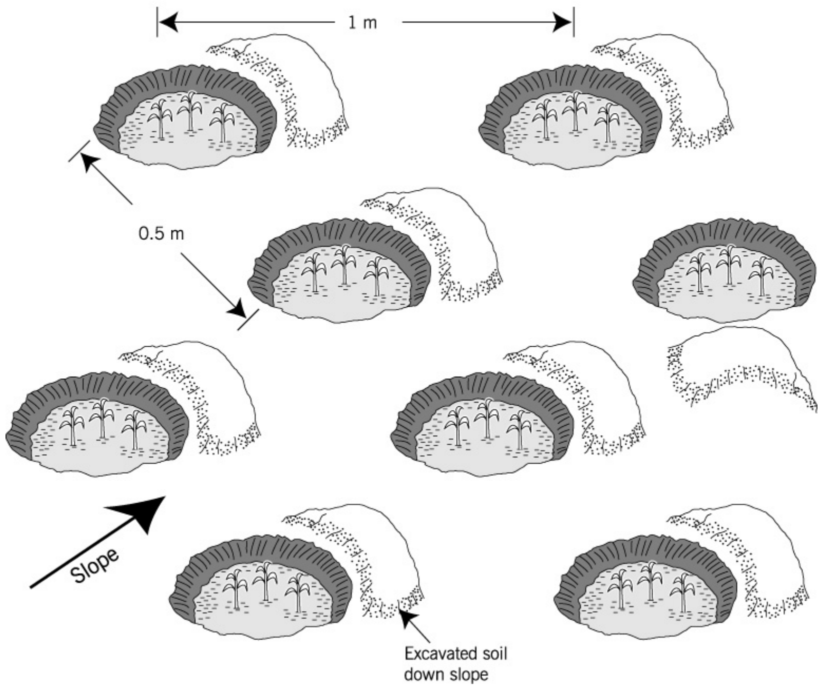


Figure 28: Zai Pit

Earthen bunds

Earthen bunds are structures constructed to pond runoff water. The most common are within-field runoff harvesting systems. Within-field systems tend to require less mechanization, relying more on manual labour and draught animals. In design, earthen bunds follow the contours, and have spillways at 20 m intervals to control the application of surface water to each crop section. Bunds are constructed at 15–20 m intervals and the catchment to cultivated area ratio ranges from 5:1 to 20:1. There is a distinction between bunds meant for within-field water harvesting and those meant for conventional soil and water conservation. In the runoff harvesting system, a 'catchment' is maintained within the terrace to provide runoff that will add to the natural rainfall, while under conventional bunding, the whole terrace is cultivated.

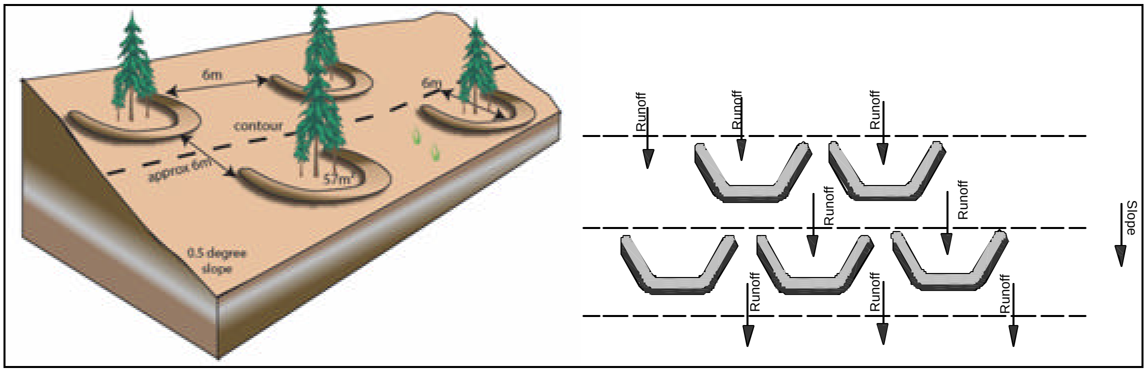


Figure 29: Earthen Bunds (contour, circular, trapezoidal)

Conservation Tillage

Conservation tillage is defined as any tillage practice to minimize the loss of soil and water, and which leaves at least 30% mulch or crop residue on the surface (see plate 13) throughout the year. However, with respect to small-scale farmers, conservation tillage is defined as any tillage system that conserves water and soil while saving labour and traction. Conservation tillage aims to reverse the trend towards lower infiltration in farming systems due to compaction, formation of soil crusts and lower water holding capacity due to oxidation of organic materials (due to excessive cultivation of the soil). From this perspective, conservation tillage qualifies as a form of water harvesting, as it impedes runoff and stores soil water in the crop root zone. Unlike conventional tillage systems based on soil inversion to help water infiltrate the soil and allow roots to penetrate easily, conservation tillage covers a spectrum of non-inversion practices from zero-tillage to reduced tillage that aim to maximize soil infiltration and productivity by minimizing water losses (evaporation and surface runoff) while conserving energy and labour.

Plate 13 Pot holing and crop residue management in conservation farming

Plate 14 Conservation farming plot at GART in Zambia

Plate 15 Yield of 10 tonnes per hectare off Conservation farming plot in Zambia

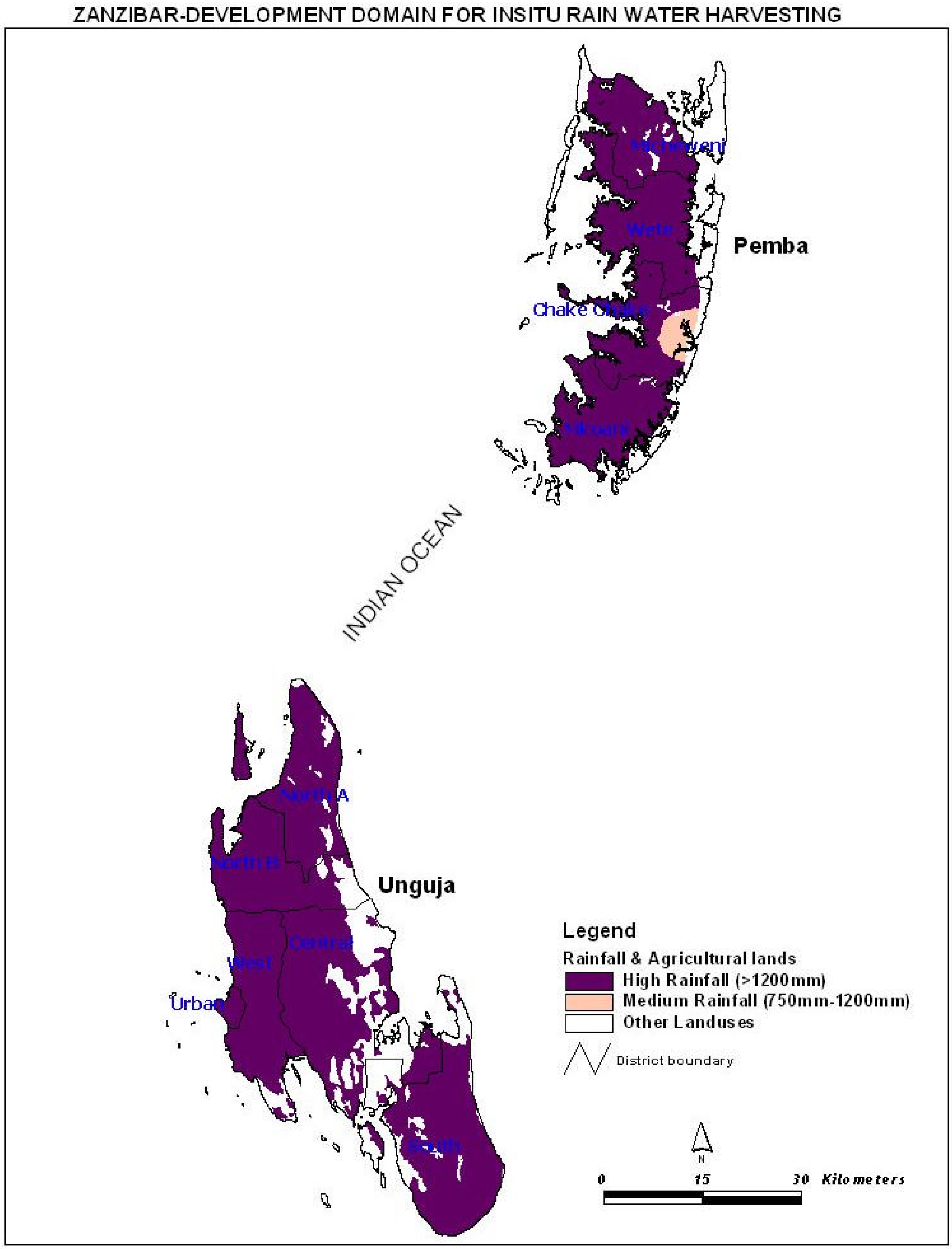


Figure 30 Development domains for in-situ RWH in Zanzibar

Water application technologies

Water lifting options

Rope and washer

The rope-washer pump consists of a rope with knots or rubber washers, whose diameters are slightly less than the diameter of the pipe, placed at intervals along it (Figure 31). During operation, the pipe is inserted into water and the rope drawn upwards through the pipe by means of a winding drum with a crank. Water is also drawn up and discharged at the top. Friction is kept low by allowing leakage between the washers and the pipe stem.

Suitability

This technology is appropriate for all domestic uses and micro-irrigation or garden irrigation uses. The pump can pump high volumes with a low lft. The technology is suitable for abstraction of water from shallow wells of up to 10 m depth or from rivers and streams.

Impacts

The introduction of this technology will lead to savings in time for drawing water and reduction of drudgery in watering gardens and micro-irrigation systems.

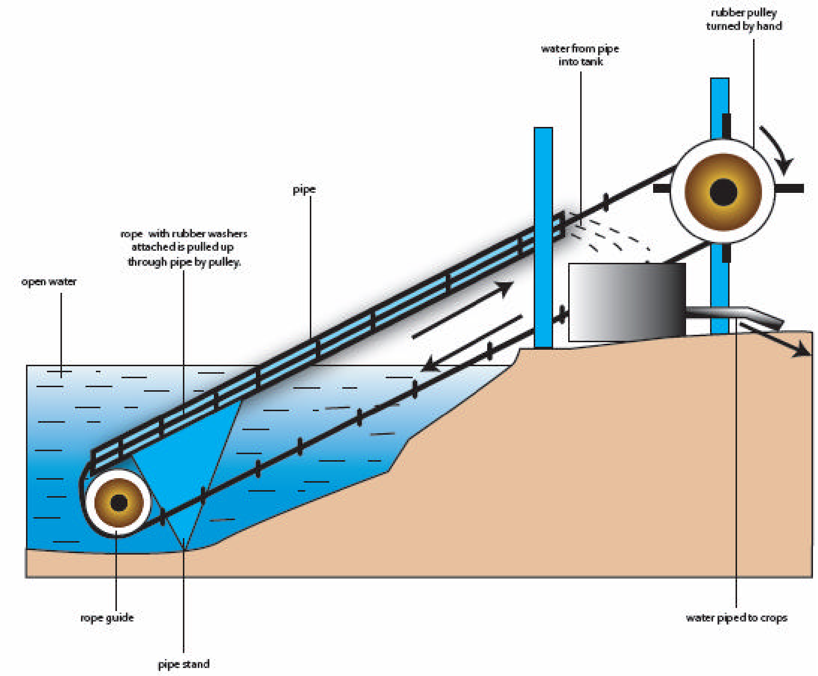


Figure 31 Rope washer pump

Treadle pump

The foot operated treadle pump is an easy to use and productive water-pumping device with an output of 0.6 to 0.8 l/s at a lift of 4.6m (Figure 32). For small-scale farmers, the technology works as a land augmenting intervention-providing farmers with a capacity to raise crops during the dry seasons.

Figure 32 Treadle pump

Wind pumps

A wind turbine is a device that taps the renewable kinetic energy of blowing wind, which converts it to useable mechanical, electrical or thermal energy. A variety of windmills are currently available, either commercially or in the form of working prototypes that could be readily manufactured. This includes both vertical & horizontal-axis rotational machines. Currently manufacturers concentrate more on the horizontal axis machines, usually associated with water pumping and electrical power generation.

Considering the wind regimes attainable in Island countries, the use of wind-operated pumps could provide the much-needed energy to pump water for domestic and irrigation purposes.

Figure 33 Wind pump

Some of the probable applications of wind energy are: -

- Pumping fresh water, for irrigating fields, domestic use, livestock breeding and other agricultural needs
- Powering agro-processing tasks, such as grinding corn, wheat & sugarcane and threshing and winnowing.
- Pumping saline water in salt works, and
- Generation of electric power (for modest rural electrification purposes), such as heating, lighting, and cooking.

Water application techniques

Drip Irrigation

Drip irrigation systems allow the more efficient use of water in agriculture. The technology improves the growth rates of high value crops by delivering moisture directly to their root zones. In this method, water is applied frequently with volumes of water approaching the consumptive use of the plant thereby minimizing losses. The technology could be adapted to augment the pond water storage systems in applying water to fruit tree crops like mangoes. Drip or trickle irrigation has a wide range of application from orchards to green houses and has also future potential of row crops. Stand-alone systems that utilize bucket storage are available and could be adapted to cover areas as small as 10 m2 to 500 m2 for use in garden tree crop farming. Such systems could be adapted for use in the marginal areas of Zanzibar and Pemba.

Investment Cost for initiating RWH in Zanzibar

This section presents results of the initial cost of setting up RWH technologies in Zanzibar. All the technologies included were carefully matched to the bio-physical environment or what is referred to in this section as the development domain. Table 9 shows that Zanzibar would need US$ 6,420,000 to initiate major training and demonstration of appropriate RWH systems recommended in this study.

The detailed workings of the RWH investments are provided in the appendix.

Table 8 Summary of Investment cost for initiating RWH activities in Zanzibar

Summary	Total Cost US$	Potential Target HH	Actual Target HH	Storage m^3
In-situ RWH systems	2,500,000	152,216	49,828	Not computed
Roof Catchment Systems	1,200,000	185,951	9,298	31,612
Runoff Catchment Systems	2,400,000	184,828	10,452	32,040,373
Artificial groundwater recharge	320,000	Not computed	3,000	Not computed
Total	6,420,000		69,577	32,071,985

This investment would create an annual storage per capita of 1624 m3.

In-situ RWH Systems

The in-situ development domain covers an area of 1978 km2 and has a total of 152,216 households. Conservation tillage (CT) has the widest application in this domain. The number of households targeted for CT is 50,000. The total farmer training cost for conservation tillage is US$ 916,000. For demonstration purposes only 2,225 households will be targeted for techniques such as Zai pits and Earthen dams at a cost US$ 45,000. Terracing is restricted to a very small development domain of 25.2 Km2 located in Pemba only. The training cost for 1938 farmers is US$ 39,000. It must be mentioned that the actual terracing cost is US$600 per hectare. Therefore, the farmer contribution for terracing 2519 hectare in this development domain is US$1,500,000.

Roof Catchment Systems

The roof catchment systems have a potential development domain area of 2417 Km2. This covers approximately 185,951 households.

Type of Tank	Unit Storage m^3	Target HH	Cost per m^3	Total Cost US$
Ferro Cement	8	4649	38	560,000
Masonry	10	2789	40	420,000
Underground	10	1860	32	220,000
Grand Total		9298		1,200,000

Table 9 Costs of initiating Roof catchment systems in Zanzibar

Runoff Catchment Systems

The run-off systems suitable in Zanzibar include check dams, lined and unlined ponds or Charco dams[6]. The proposed investment cost for these systems is US$ 2,400,000. Check dams are mainly suitable in Pemba with slopes greater than 8%. This development domain has an area of 407.7 km2 with a potential to harvest 0.6 km^3 of rainwater. There are 31,359 households living in this domain. Only 10% of the total was considered for initiating the development of check dams at a cost of US$ 1,584,000. Such an investment would yield rainwater storage of 0.031Km3. In impermeable soils, unlined ponds can be

[6] Charco dams are common on the mainland Tanzania, especially in the Pangani river basin.

constructed. 6, 316 ponds with a unit capacity of 100m3 can be constructed at a cost of US$ 316,000. The cost of lining 1000 ponds with a capacity of 50m3 is US$ 500,000

Artificial Groundwater Recharge

The cost of setting up 2000 shallow groundwater recharge wells is US$ 300,000. This investment is targeted for the urban areas where ground water abstraction is currently the highest. In the rural areas 1000 infiltration basins would cost US$ 20,000 to set up.

Conclusions and Recommendations

1. The Government is resolute on developing and facilitating a favourable environment for developing water resources in Zanzibar. Useful studies have been done on both surface and groundwater. However, no attempt has been made by government to develop an Integrated Water Resources Management plan. The result is lack of coordinated approach to water resources management within the government circles. Government is also lagging behind most nations that have at least initiated IWRM plans. It is strongly recommended that the responsible government ministry should take the lead in facilitating the development of IWRM plans for Zanzibar. This would institute a systematic approach to the development of water resources with rainwater at the centre of it all and with the involvement of all actors, including government, NGOs, private sector, communities and external partners/donors.

2. MANREC, with the help of JICA, has developed an excellent Irrigation master plan. The master piece describes in detail sites that are suitable for expanding or developing irrigation in Zanzibar. This master plan should be strongly linked to the result of this study as the documents are complementary. It would therefore follow that the Irrigation department is best placed to facilitate implementation of agricultural rainwater harvesting interventions recommended in this study report. There should be a water harvesting unit established within the irrigation department to provide leadership in RWH.

3. Zanzibar has a very high potential for developing roof catchment RWH systems. The Ministry of Local government should be charged the responsibility of ensuring that new and olds building are fitted with gutters, down pipes and water storage and groundwater recharge facilities. This entails the enactment of a law that will make it binding to harvest rainwater from roofs. The government could provide incentives to encourage investment.

4. Zanzibar is endowed with high annual rainfall of up to 2000 mm. The GIS mapping work by ICRAF convincingly demonstrated that in volumetric terms, the annual rainfall amounts to 4 km^3. This volume of water can support a population of 2.6 million people living in a developed country with a GDP/capita/year of over US$ 20,000. At its current population of 1 million inhabitants, Zanzibar could expand agriculture to a level that 100% of its food requirements could be met locally. However, the capacity to utilise this rainwater is unbelievably low. The current water utilisation stands at 1% of the available water. Zanzibar lacks the technical capacity to harness this huge rainwater potential. There is need for renewed investment in rainwater harvesting.

5. Several approaches and technological options have been recommended for Zanzibar in this report. With regards to the approach, awareness creation would be an important entry point to the promotion of RWH. This campaign could be spear headed by HE President Karume. The President indicated to the study team that he would be interested in being the patron for the campaign. Another important area is the capacity building or enabling communities to implement RWH structures. There needs to be a capacity building centre setup to nurture the interests of water harvesting in the country.

   With support from Sida, the Rainwater Harvesting Association of Tanzania (RHAT) was formed in the year 2002. RHAT provides leadership in management of RWH knowledge i.e. research and development, networking and capacity building in Tanzania. There is a window of opportunity for Zanzibar to forge ties with the existing association which has further affiliation with SEARNET and the Global Water Partnership. These linkages would facilitate transfer of RWH knowledge and experiences within and outside Zanzibar.

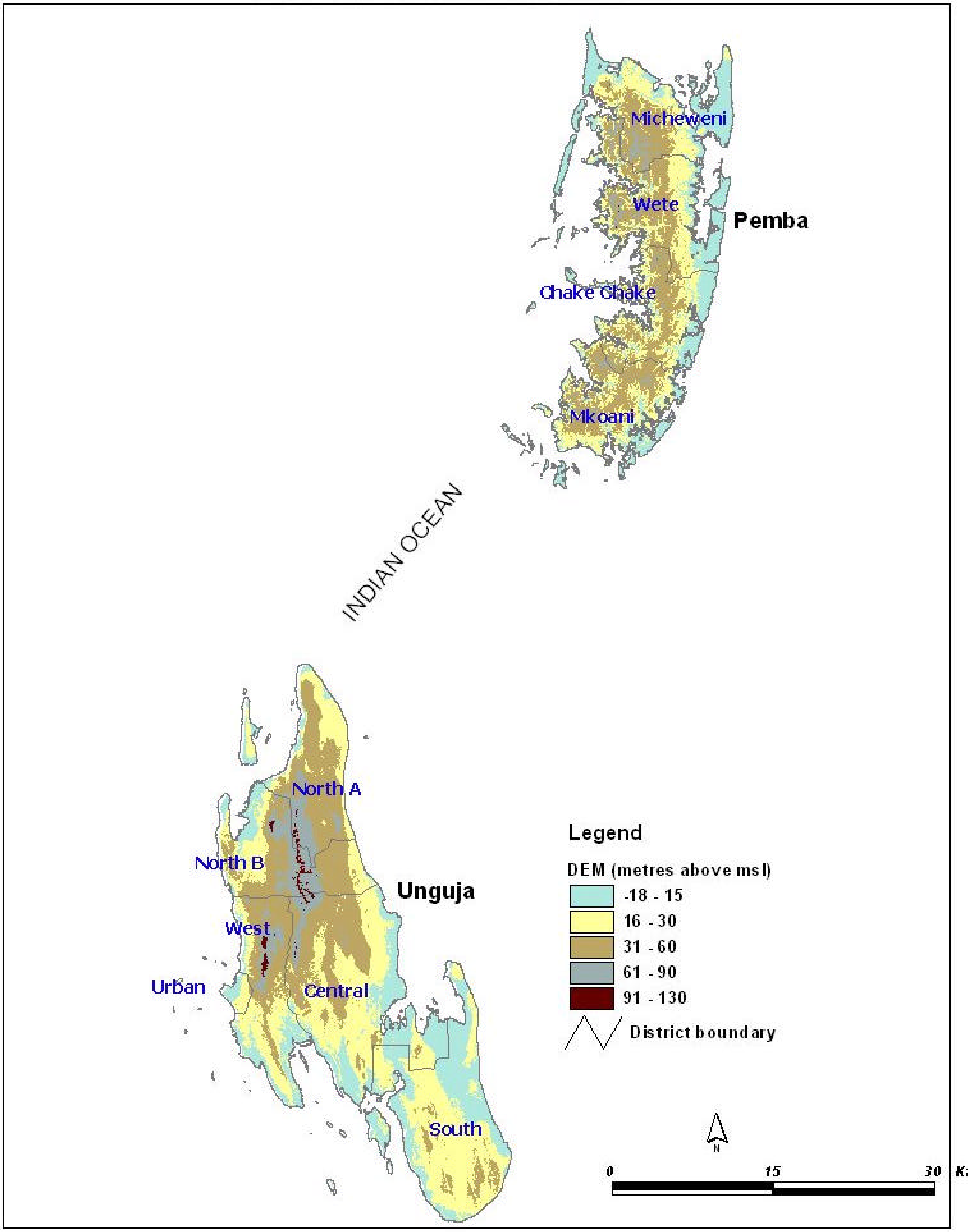
   This report has also presented technological options applicable to Zanzibar. The technologies are mainly focussed on enhancing groundwater, capturing runoff and collecting rainfall in-situ. Due to high dependency on groundwater, there is reason to inculcate in the minds of Zanzibaris, the concept of recharging groundwater. Pemba has numerous rivers which could be used to harness runoff.

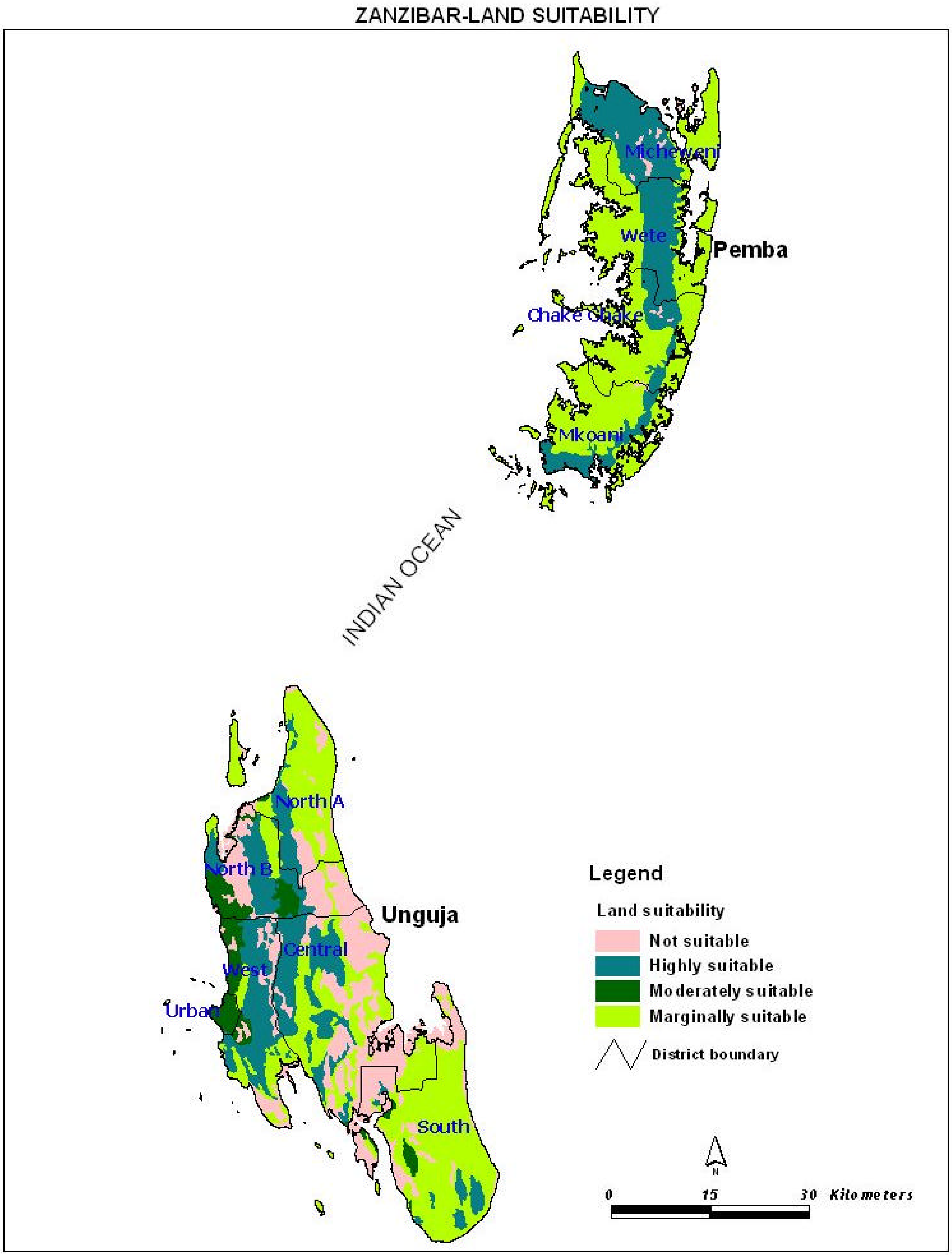
The ideas in this report are generic and need to be adapted to the site specific conditions through detailed surveying and designing.

6. To initiate RWH activities, Zanzibar needs to invest US$ 6,420,000 over a period of eight years. Such an investment would create annual water storage per capita of 1624 m3. This amount exceeds the 1500 m3 minimum international bench mark.
7. The short visit to Micheweni brought to light a very sensitive, relatively drier environment that needs detailed studies to be able to come up with practical RWH solutions. However, all technological options given in this report are applicable in Micheweni. Further studies should be conducted to gain better understanding of the needs and aspirations of the local communities in Micheweni. The community visited was very sceptical about our field visit. The District Commissioner was very positive the visit to Micheweni and pledged support for any future development plans in the area.

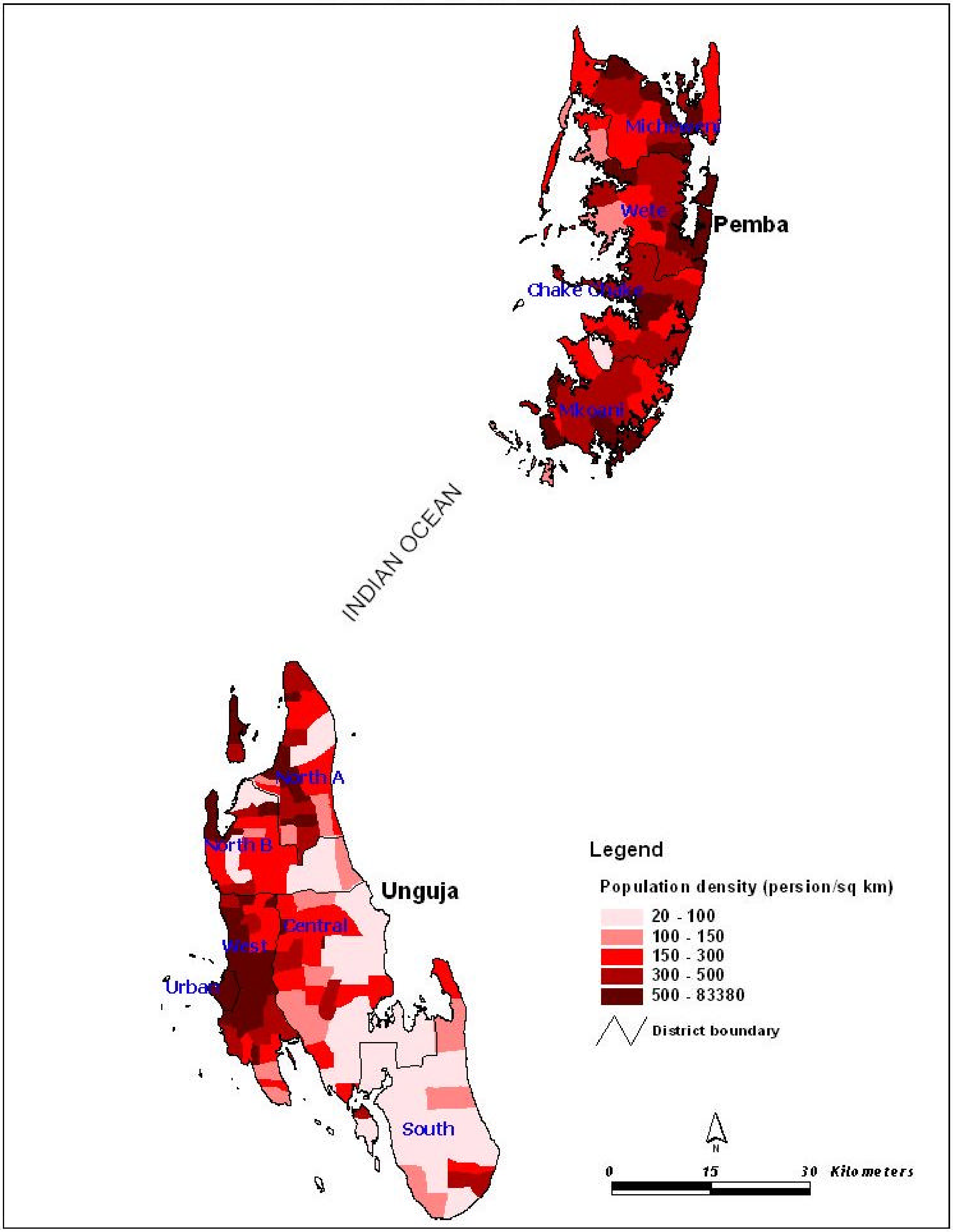
Base maps

ZANZIBAR-DIGITAL ELEVATION MODEL




ZANZIBAR-LAND SUITABILITY
Micheweni
Wete
Pemba
Chake Chake
Mkoani
INDIAN OCEAN
North A
North B
Unguja
Central
West
Urban
South
Legend
Land suitability
Not suitable
Highly suitable
Moderately suitable
Marginally suitable
District boundary
0
15
30
Kilometers

ZANZIBAR-POPULATION DENSITY



Rainwater Harvesting Value

	Zanzibar (all islands)			Pemba		Unguja	
Main type	**Classes**	**area-m2**	**Volume-m3**	**area-m2**	**volume-m3**	**area-m2**	**Volume-m3**
Rooftop	1100-1200m & >100 persion\sq km	37,938,800.00	44,208,250.40	37,938,800.00	44,208,250.40	0.00	0.00
	> 1200mm & >100 persions\sq km	1,767,947,600.00	2,828,002,892.00	843,582,000.00	1,335,553,482.40	922,849,200.00	1,490,292,705.20
	> 1200mm & 20-100 persions \sq km	611,472,800.00	954,479,458.80	12,490,800.00	20,481,976.40	598,827,200.00	933,760,642.00
	Total	**2,417,359,200.00**	**3,826,690,601.20**	**893,963,200.00**	**1,400,187,768.00**	**1,521,676,400.00**	**2,424,053,347.20**
Runoff	1100-1200mm & slope <2%	27,595,600.00	11,070,332.48	27,706,400.00	11,051,043.04	0.00	0.00
	1100-1200mm & slope 2-8%	10,088,000.00	3,542,432.52	10,082,000.00	3,540,338.28	0.00	0.00
	1100-1200mm & slope >8%	14,000.00	4,947.00	14,000.00	4,947.00	0.00	0.00
	>1200mm & slope <2%	1,723,648,400.00	891,864,094.20	443,488,000.00	228,827,722.92	1,278,718,000.00	662,155,621.96
	>1200mm & slope 2-8%	616,229,600.00	310,460,648.00	381,311,200.00	188,252,892.36	235,033,600.00	122,077,649.92
	>1200mm & > 8%	25,182,400.00	12,784,885.72	22,852,800.00	11,601,774.16	2,325,600.00	1,179,796.04
	Total	**2,402,758,000.00**	**1,229,727,339.92**	**885,454,400.00**	**443,278,717.76**	**1,523,496,800.00**	**785,413,067.92**
Insitu	High Rainfall (>1200) & agriculture	1,949,879,600.00	3,112,457,116.80	699,562,000.00	1,115,029,801.20	1,249,493,600.00	1,996,270,544.00
	Medium Rainfall (750-1200) & agriculture	28,924,400.00	33,657,152.80	28,924,400.00	33,657,152.80	0.00	0.00
	Total	**1,978,804,000.00**	**3,146,114,269.60**	**728,458,400.00**	**1,148,654,761.60**	**1,249,493,600.00**	**1,996,270,544.00**

Note: Different areas in Rooftop and Runoff is attributed to population values missing from some islands, which have slope values.

For Runoff, the following coeffients are used: Agricultural land = 0.3, Forest land = 0.5; Grassland = 0.4 and Urban =0.7

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Appendix

List of People met

1. His Excellency Amani Abeid Karume, President of Zanzibar
2. Dr George Simpeho, Country Coordinator, Tanzania, UN Millennium Project
3. Mr. Khamis M. Omar, Principal Secretary, Ministry of Finance and Economic Affairs (MOFEA),
4. Ms. Rahma M. Mshangama, Principal Secretary, Ministry of Agriculture, Livestock and Environment (MALE)
5. Mr. Tahir M. K. Abdullah, Director of Planning, Ministry of Water, Construction and Land
6. Mr. Mohammed Abdalla Hamad, Senior Planning Officer, Ministry of Finance and Economic Affairs, Department of Sectoral Policy and Project Development
7. Ms. Zeinab Pandu, MOFEA
8. Saada M. Salum, External Aid Coordinator, Ministry of Finance and Economic Affairs
9. Rujia Masheko Ali, Executive Engineer, Department of Water Development
10. Mr. Mchenga A. Mchenga, Irrigation Engineer, Ministry of Agriculture, Livestock and Environment
11. Mariam Hassan, Principal Geologist, Department of Water
12. Mr. Juma Abdulla Ali, District Commissioner, Micheweni, Pemba 255 (077) 3194455
13. Joseph Meza, MOFEA
14. Ramadhan Aseid Ramadhan, Director of Irrigation, Ministry of Agriculture, Livestock and Environment (MALE)
15. Dr. Hamed, MOFEA
16. Mr. S. A. Saleh, Ministry of Foreign Affairs, Tanzania
17. Munira H., UNDP, Zanzibar
18. Saada Mkuya, MOFEA
19. Ameir M. Khamis, MOFEA
20. Khamis Haji Jeiha, Regional Advisor, MORALSD