An ACP-EU Technology-Transfer Network on Rainwater Harvesting Irrigation Management for Sustainable Dryland Agriculture, Food Security and Poverty Alleviation in sub-Saharan Africa

AFRHINET BASELINE SURVEY REPORT FOR ZIMBABWE

Compiled by

MENAS WUTA, GEORGE NYAMADZAWO AND BLESSING MAGONZIWA

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About AFRHINET

AFRHINET is a three-year project which focuses on fostering the knowledge and use of rainwater harvesting technologies for supplemental irrigation in rural dry lands of sub-Saharan Africa. The project focuses on the implementation of integrated capacity-building activities, the development of re- search and technology-transfer centres, and the setting-up of a transnational network of multivariate relevant actors. The action of the project takes place in Ethiopia, Kenya, Mozambique and Zimbabwe.

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LIST OF ACRONYMS

RWH	Rainwater harvesting
RWHI	Rainwater harvesting irrigation
ZINWA	Zimbabwe National Water Authority
DDF	District development fund
DAMI	Department of Agricultural Mechanisation and Irrigation Development
DOI	Department of irrigation
EMA	Environmental Management Agency
SSA	Sub Sahara Africa
Ha	hectares
NGO	None Governmental Organisations
GEF	Global Environmental Facility
MAMID	Development
MTRID	Ministry of Transport and Infrastructural Development
MOHCC	Ministry of Health and Childcare

1. Analysis of political and institutional framework in the field of rainwater harvesting and/or small-scale irrigation

1.1 Introduction

In Zimbabwe, the political and institutional framework for RWHI interventions for smallholder farmers draws together a number of stakeholders with different roles, responsibilities and interests. It is important to understand the obligations and concerns of each stakeholder and its linkages to RWHI activities. The government, through various ministries and departments owns and control both surface and groundwater sources. However, there is very little control on the water which is harvested in small reservoirs because RWH is mainly done on a small-scale or at household level. Several institutions are in charge of small-scale irrigation and rainwater harvesting. Institutions that are involved in RWHI in Zimbabwe are housed in different Ministries and Departments and are not well coordinated. Ministries involved in irrigation development include: The Ministry of Environment, Water and Climate; the Ministry of Agriculture and Mechanisation and Irrigation Development (MAMID); the Ministry of Transport and Infrastructural Development (MTRID); the Ministry of Local Government, Public Works and National Housing, Ministry of Finance; Economic Development and the Ministry of Health and Childcare (MOHCC). The departments through which they operate are outlined in section 1.5.

Key policies related to irrigation

The Zimbabwe Water Act number 31/1998, 22/2001, 13/2002, 14/2002, and the Environmental Management Agency (EMA) Act of 2007, mention the importance of RWH in irrigation development. However, on the ground there seems to be very little RWH interventions for irrigation development in small-scale farming areas (Motsi et al., 2004; Mugabe 2004). Currently, the Government is developing an Agricultural Mechanisation and Irrigation policy which specifically addresses several RWH technologies and their importance in irrigation development. It is possible to develop and implement rainwater harvesting systems in Zimbabwe for irrigation at both small and large-scale. In Zimbabwe, half of the country's agricultural land (16.4 million hectares) lie in the dry Agro-ecological Regions III, IV and V (Vincent and Thomas, 1960) and home to 1.2 million households (see Appendix 2). These regions are characterized by low levels of rainfall (FAO 2000). In addition, the distribution is highly erratic and variable both spatially and temporally. These factors contribute to an inadequate water supply for crop production. Poor rainfall years, dry spells and droughts exacerbate the incidence of crop failure. Thereby, increasing water and food scarcity, and poverty. Under these circumstances, linking rainwater harvesting and small-scale irrigation can play an important role in improving crop yields and food security (Nyamadzawo et al. 2013). Irrigation has the potential to improve farm incomes by enabling a higher cropping intensity, improving the crop quality and crop yields (African Union 2003).

Whereas large-scale irrigation schemes are already established and actively promoted by the Government, small-scale irrigation schemes are few. In addition, the Government has not spent significant efforts to promote RWH for small-scale irrigation. However, NGOs have actively promoted small-scale irrigation. Technologies such as micro irrigation **or** micro-agricultural water management, which can be used in smallholder farming areas in to enable large numbers of poor rural people to improve their food security, nutritional status and incomes, thereby contributing to agricultural growth, are not widely implemented and (Merrey and Sibanda 200x). However, they may have the potential to enable supplementary irrigation for millions of people and to achieve household food security through home garden micro-irrigation. RWHI may have the potential to bridge the dry season in rural drylands of Zimbabwe as a supplement of rain-fed crop production. Consequently, the rainwater harvesting interventions are not widely recognised in water policy or in investment plans, despite the broad base of cases identifying multiple benefits for development and sustainability (UNEP 2009).

1.1.1 Definition of rainwater harvesting and small-scale irrigation generators

In most rural arid and semi-arid areas, including SSA, water availability plays a critical role in supporting food security and livelihoods (Baguma et al., 2010). Most of sub-Saharan African countries in general and Zimbabwe in particular, lie in water-scarce river basins Gwenzi et al., 2015. These authors also stated that where freshwater resources are available, poor distribution of portable water has resulted in water shortages. However, rainwater harvesting in both urban and rural areas represents an under-utilized resource currently excluded in existing water policies in SSA (Gwenzi and Nyamadzawo, 2014).

RWH involves the collection, storage and subsequent use of rainwater for domestic, agricultural and other livelihood activities where and when it falls (Ngigi et al., 2005; Jebamalar and Ravikumar, 2011). Rainwater harvesting consists of a wide range of technologies used to collect, store and provide water with the particular aim of meeting demand for water by humans and/or human activities (Malesu et al. 2005; SIWI, 2001). It also includes the collection and storage of local surface runoff for productive purposes, i.e. irrigation, livestock, agroforestry, domestic, etc. Rainwater harvesting for domestic and agricultural uses is a very old practice dating back to 4500 BC in the Middle East and India (Sivanappan, 1997). The practice originated in arid and semi-arid areas, but increasing water demand for industrial and domestic uses is forcing most developing countries (Jebamalar and Ravikumar, 2011) to consider RWH as a supplemental water source. RWH may reduce the impacts of drought, storm water runoff, and peak flow levels, as well as reliance on ground and surface water. In addition RWH may lower non-point source pollution, allow groundwater recharge, and promote water conservation and sustainable practices. RWH may also be considered a key adaptation strategy to the impacts of climate variability and change (Barron, 2009).

RWH can be classified in two major categories: in-situ (in field) water conservation practices, small basins, pits, bunds/ridges- and ex situ runoff-based systems -catchment and/or storage- (UNEP 2009). The storage system is usually used in supplementary irrigation and involves either direct taping of rainwater or diversion of water from storage works and seasonal rivers. At present, there are very few documented cases of RWH for supplemental irrigation in SSA, but this trend may change in the near future due to potential of using rainwater for small-scale irrigation in rural arid and semi-arid regions (Merrey and Sibanda 200x; UNEP, 2009). Advantages of rainwater harvesting includes; low-cost technology: relatively cheap materials can be used for construction of containers and collecting surfaces, low maintenance costs and requirements, collected rainwater can be consumed without treatment, if a clean collecting surface has been used (African Union, 2003).

1.1.2 Definition for small-scale irrigation

Small-scale irrigation is the application of water to crops at a small-scale (<0.12 ha) (African Union, 2003) in order to enable multiple cropping. The crops are usually used for household food requirements. Any excess is sold locally or at the nearest market. Small-scale irrigation can also refer to a group of farmers irrigating together and sharing the same water source and supply line, though the farmers have individual control over their plots (FAO, 2000). RWHI by means of small-scale irrigation generators may be generated from various sources: Roof-tops, large rock outcrops (Dwalas), dead level contours, groundwater dams (sub-surface and sand dams), tied ridges, bunds (in situ) and Berms (integrating rainwater harvesting with road infrastructure), groundwater, subsurface dams and alluvial aquifers (UNEP, 2009; Gwenzi et al. 2014).

The most common small-scale irrigation method is the use of a watering can/bucket. It can also be used canals, irrigation pipes with or without sprinklers. Some farmers use flood irrigation, though it is not popular because it is inefficient because of the associated transmission losses canal irrigation and flood irrigation to reduce transmission losses (Nyamadzawo et al. 2013). A few of the farmers use water pumps. The principle behind small-scale irrigation is the management of risks associated with rain-fed agriculture and the provision of safety nets (AU Report, 2003). Each farmer practicing small-scale irrigation has the potential to feed 70 others for 3 months with a bonus of cash income and greater crop and food diversity (AU Report, 2003).

1.1.3 Operation of RWHI systems

1.1.3.1 Components of RWHI system

A basic RWHI system should consist of an adequate catchment area, a storage facility, a conveyance system, and a delivery system for subsequent irrigation purposes. Rainwater is collected from the catchment area, e.g. an impermeable surface like a roof via guttering and down-spouts, a road, or the micro-catchment area of a seasonal riverbed. The water is transported and filtered by different mechanisms until it is finally stored for subsequent use. A pump may be installed to deliver water from the storage unit to the point of use. However, gravity can also be used as a main conveyance mechanism. However, in most smallholder farming areas in Zimbabwe, there is no electricity supply and few resources to pump water, therefore, most of the harvested water is usually run by gravity to the point of use. In some cases, the harvested water is conveyed to the point of use using watering cans.

1.1.3.2 Water supply systems for RWHI

Water supply systems can be classified into four supply chain components which are;

a) Water sources: Rivers, seasonal wetlands (dambos), surface dams, sand dams, underground dams, shallow alluvial aquifer, roof water or underground/borehole water.
b) Abstraction method: Pumping (electric, fuel or solar energy), gravity, manual .
c) Water storage: Examples: Metal tanks, Plastic tanks or bricks/concrete walled holding tanks. In some cases, storage may be skipped when water is directly pumped directly from the source to the point of use.
d) Conveyance: This is the transport of the water from the source to the point of application. Examples in clued the use of buckets, polypipes, metal pipes, cement pipes, concentrate lined canals, clay lined canals, and flooding.

The difficulty with describing water supply systems is that at every stage of the supply chain, there are a wide range of options. Thus, there are at least 6 water source options including rivers, dams, rain water, wells, boreholes, mine shafts, sand dams etc.. There are at least 8 pumping technologies on the market in Zimbabwe: Examples: electric, fuel or solar energy pumps, gravity pumps and manual pumps (Nazare 2014). In addition, there are more than five water conveyance methods: Examples: poly-pipes, metal pipes, cement pipes, concentrate lined canals, clay lined canals and flooding (Nazare 2014). Finally there are at least 5 storage methods for water: Examples: metal tanks, Plastic tanks or bricks/concrete walled holding tanks. The end result is that a huge number of permutations (supply chains) that can be created resulting in a wide variety of solutions for providing water supplies. It is considered more efficient to describe the supply chain components and then create supply systems to cater for specific situations and clientele (see section 5.3.1.4).

1.1.4 Methodology used for data collection

1.1.4.1 Data collection

To generate an in-depth insight into RWHI in the smallholder farming areas of Zimbabwe, , several methods of data collection were used and these included the use of questionnaires (Appendix 1), key informant interviews, informal interviews and direct observations. Survey data were collected using a structured questionnaire survey from October 2014 to December 2014. The data on households was obtained from the district administrators' offices and from the Agritex field extension supervisor. To manage expectation, farmers were not asked to give figures of income earned, because of the fear that they would under report their incomes, as some would expect some financial benefits from the study (Mabeza and Mawere 2012).In addition survey questionnaires were also administered to organisation that are involved in promoting irrigation in small-scale areas (NGOs), equipment traders and stakeholder such as government departments and Ministries.

In addition the study also utilised the available literature. The materials examined during this review included both published (including World Wide Web articles, journal articles and books, paper maps, aerial photography, and unpublished material, academic material (including peer reviewed material, MSc and PhD theses), national inventories, and non-governmental material, draft reports, newsletter articles, conference proceedings and consultancy reports.

1.2 Economic framework of the rainwater harvesting and/or irrigation market

Economic feasibility is the major consideration in national policy development for RWHI (FAO, 2000). Reliable information is required to guide the planning process of any RWHI systems. This will ensure that the development of the system will be done after careful analysis of the projects' feasibility and circumvent development of unsustainable ventures with high maintenance and operational costs. In most countries where roof based RWHI systems are privately owned, users are forced to pay all of the costs and provide their own labour in RWH system construction. This principle is defined as self supply, as improvements to household or community water supplies are fully financed by the owners themselves (http://rural-water-supply.net/en/self-supply). In addition, in rural arid and semi-arid areas of Zimbabwe, labour is a major cost affecting the adoption of RWHI technologies (Mutekwa and Kasangaya 2006). Therefore, there is a need to use low cost and locally available resources in the construction of RWHI systems. Women are in charge of household maintenance, and water supply for them is an important chore; therefore their input and participation in the development of RWHI's national policies is required.

Women produce most of the food in Africa; therefore increasing their productivity and incomes will directly improve the well being of children as well. Improving women's access to water, land, markets and information is not simply a matter of social justice; it is an imperative (Merrey and Sibanda 200x)

In addition, there is need to develop and implement market linkages between farmers and traders, as market-driven individualized micro-AWM technologies will be attractive investments to produce high value crops for markets and nutritious vegetables for home use. Such technologies may lend themselves to gender equity since women can acquire and use them, and may also reduce labor costs for over-burdened women (Merrey and Sibanda 200x). There is also need to develop and adopt effective public-private partnerships (PPPs), community-managed systems (CMSs), and the operations, private models for funding and operation and management of RWHI projects (Safe water netwok 2004). With limited financial support from government, and foreign aid, water users should be informed and motivated to commit their own share of the cost and labour for the construction and operation of their rainwater catchment system (UNEP, 2009). There is need to establish policies and cost–sharing strategies (including subsides) to be provided together with technical know-how and capacity building (UNEP, 2009). Examples include the sourcing of locally available raw materials for use in the construction of RWHI infrastructure, provision of labour for construction activities.

1.2.1 Institutional framework of RHWI sector under the Ministry of Environment Climate and Water

In Zimbabwe, the Department of Irrigation (DOI) is a key stakeholder in RWHI. However, there are other many stakeholders associated to self-supply and small-scale irrigation. Currently, there is no framework that solely focuses on small-scale irrigation or RWHI. The DOI is involved in both the small- and large-scale irrigation sectors with the corresponding structures to the provincial level (Figure 1). The Zimbabwe National Water Authority (ZINWA) is another important stakeholder in water resources management because it is responsible for the costing, allocation and the distribution of water from all sources inclusive of rivers and dams. ZINWA does not charge for water used by most small-scale farmers who harness weir and small dams which holds less than 5 m^3 of water.

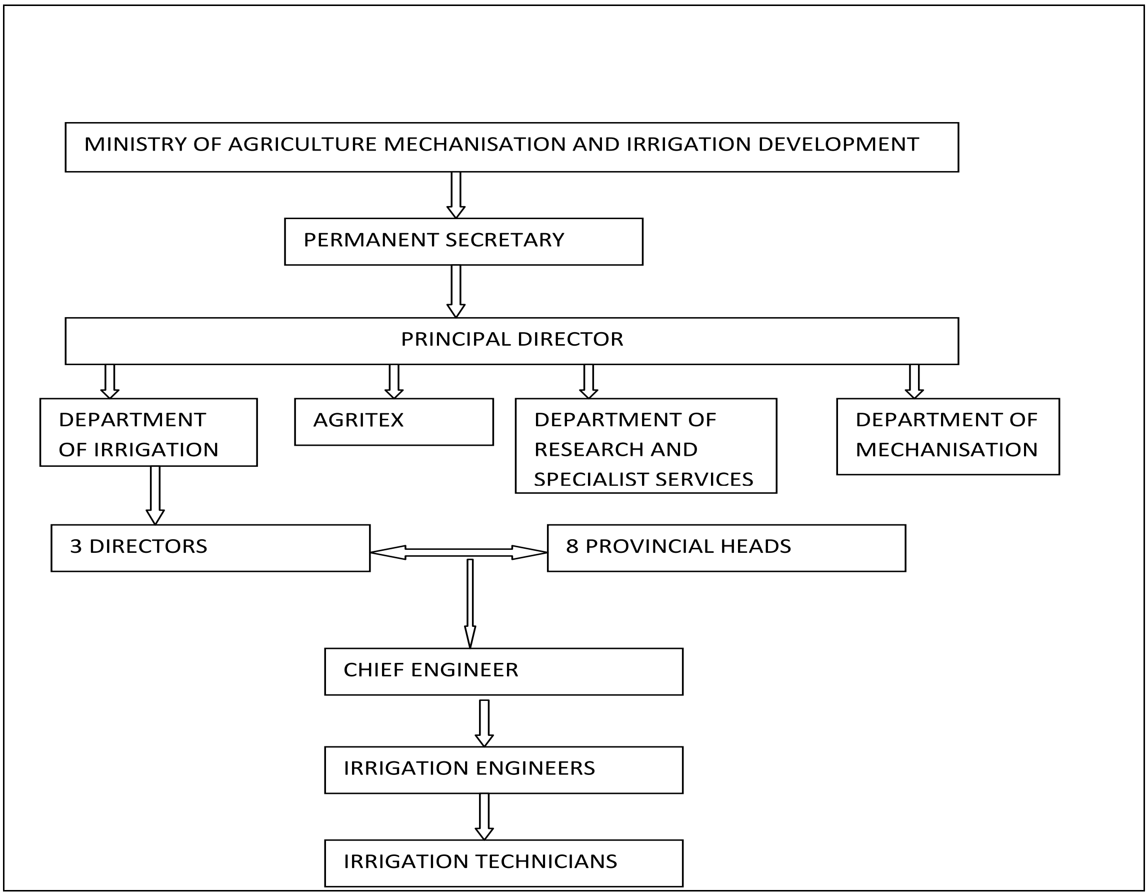


Figure 1. Organogram for the Department of Irrigation (DOI). **[AFRHINET Zimbabwe , 2015**]

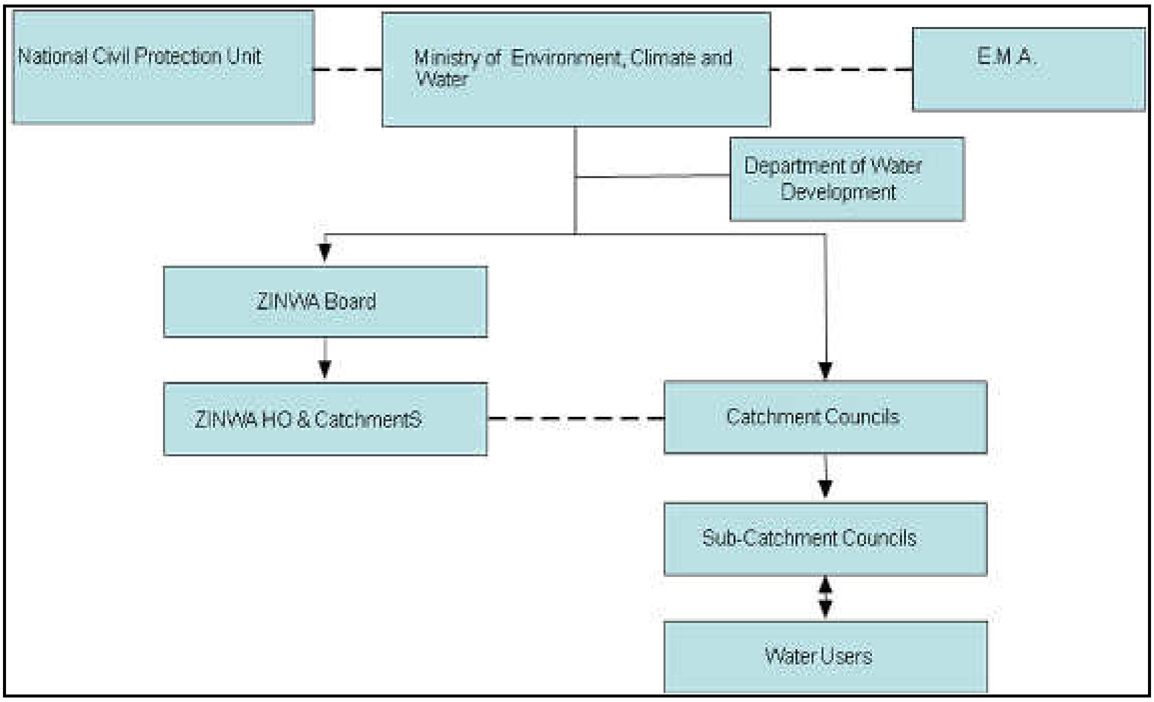


Figure 2. Institutional framework for the Ministry of Environment, Climate and Water. **[ZINWA, 2015]**

1.2.1.1 Policy makers

The Parliament of Zimbabwe is the major policy maker in Zimbabwe. The policies are then implemented by the different Ministries. In addition, water resources are governed by several Acts, Statutory Instruments and the National water policy and the climate change strategy. Catchment councils, which fall under the Zimbabwe National Water Authority (ZINWA), are also important policy makers. Catchment councils govern river outline plans, and surface and groundwater permits (storage and abstraction).

1.2.1.2 Regulator and Supervision

ZINWA is currently the *de facto* regulator in the water sector. ZINWA formulate the policies and regulate them at the same time. However, it is planned the creation of a Water and Waste Services Regulatory Unit (WWSRU) in the National Water Policy of 2012, but to date the unit has not been established. Sub-catchment Councils also play a supervision role as they monitor water abstractions with the support from ZINWA and enforce the water permits. ZINWA supervises the construction of any private or public large-scale dam.

1.2.1.3 Involved organisations in the operation of the water systems operation

Irrigation schemes in Zimbabwe are operated using different models:

(i) Operated by ZINWA at the water storage and supply level and farmers are responsible for the infield operations.

(ii) Operated by farmers from the storage works through the supply system(s) to the infield works.
(iii) Operated through various formal or informal partnerships with government or non-government organisations.

The DOI usually plans and set up the irrigation schemes. They also design and commission irrigation systems. However, with regard to most small-scale irrigation schemes, ZINWA operates the storage component and leaves the transmission and infield systems to the farmers. The department of Agricultural, Technical and Extension Services (AGRITEX) officers provide extension and knowledge support services to farmers. Several schemes have been operated by farmers with technical assistance from NGOs' and/or International aid organizations such as Care international, Global Environmental Facility (GEF). Examples include Tongara Refugee camp, Nyanyadzi, Nyamajura, and Himalaya. These schemes were developed by the government and are either farmer operated or NGO operated. Other programmes that are also funded by NGO's include nutrition gardens which are aimed at supporting child-headed households and other most-vulnerable local community members (HIV/AIDS, elderly, women-headed, etc.).

1.2.1.4 Planning in the small-scale irrigation sector

ZINWA carries out water resources planning for the small-scale irrigation in liaison with other government departments and stakeholders. ZINWA also plans and calculate limits on water abstraction from dams and areas that can be irrigated during certain periods. DOI carry out the planning and construction of irrigation projects. Private and NGO's stakeholders can also plan the development of small-scale irrigation in liaison with ZINWA and the Ministry of Agriculture and its departments.

1.2.2. Environmental Issues

Environmental issues are handled by the Environmental Management Authority (EMA). However, the Water Act also addresses water quality control and environmental protection. Water resource management should be consistent with environmental approaches, and as such, any proposal for the use, management or exploitation of water resources, needs to give adequate consideration to: (a) the protection, conservation and sustenance of the environment; and (b) the right of access by members of the public to places of leisure or natural beauty related to water or water bodies. There is a provision that users will pay for the water if they exceed a certain threshold, and also if anyone discharges polluted water.

Surface water in Zimbabwe is usually of good quality for irrigation and conductivity is usually less than 500 micro Siemens/cm (FAO 2015). Groundwater tends to be more variable in quality, with some being saline, sodic or saline sodic (FAO 2015). Current knowledge about the quality of groundwater in the country is limited. However, in most large-scale farming areas chemical analyses of water are done before the implementation of drip irrigation systems, while chemical tests are rarely done for surface and sprinkler systems (FAO 2015).

There is a general increase in the use of agrochemicals in the country due to the intensification of crop production both at small-scale and commercial scale. The use of agrochemicals is an occupational risk for irrigation farmers and increases the risk of contamination of both surface water and groundwater resources (FAO 2015). However, data on water analysis showing agrochemical levels in natural water sources both in small-scale and large farming areas in Zimbabwe is currently not available and it is thus difficult to establish the extent of pollution due to irrigated agriculture.

Even though the Water Act allow for permits for discharge or disposal into water upon an application by any interested person and subject to prescribed standards of quality and any operative outline plan, ZINWA may issue permits authorizing the discharge or disposal and specifying the quantity and quality of the discharge or disposal concerned. It may also impose a fee in relation to the discharge or disposal concerned, under the Water Fund established under the Zimbabwe National Water Authority Act of 1998. The fee will be applied to the cleaning up of any water pollution and the alleviation of its environmental effects on one hand. And research related to water pollution and its control on the other.

1.2.3 Current Strategies to Promote RWHI

ZINWA promotes small-scale irrigation through a competitive water pricing (see Table 1). In addition, ZINWA has given farmers, after prior registration, waivers on permits for the development of small dams or weirs that harness less than 5 m^3 of water. Small-scale farmers are not charged for using water, and for constructing small dams. In addition, ZINWA gives waivers for water charges in privately constructed dams until the cost of construction have been recovered.

Some NGO’s have also been promoting RWHI. Examples include Africare, who was promoting irrigation in Zvishavane (Masvingo Province), GEF (Musana, Mashonaland Central Province), Care international, USAID, Oxfam Gb and FAO Some private companies have also been playing an important role in the development of RWHI. Currently, locally made plastic water storage tanks are available at competitive prices. This has enabled farmers to harvest and store water easily. The DOI has also been promoting RWHI. However, their major constraint has been lack of funds, which has severely reduced their operations.

Figure 2. An example of a small-scale dam. **[ZINWA 2015]**

Table 1. Price for water, in m^3 for the different farming enterprises. [Mandizi**ba 2015]**

CATEGORY	PRICE ($/ML/YEAR)
Industry/Commercial Estates	9.45
Commercial-A2	6.82
Local Authorities	6.00
Farmers-A1	5.00
Farmers-small-scale	4.50

1.2.4 Conflict resolution

The most common conflict at small-scale level is water abstraction rights. At times, upstream users may extract more water at the expense of downstream users. In some cases, some commercial borehole users may extract water for commercial uses, i.e. bottling. Thus, this may result in shallow wells drying out. If there is any case of conflict and disagreement with regard to water use rights, one can appeal to the catchment council (Figure 2). If one is not satisfied with the ruling or decision of the catchment council, one can appeal to the Administrative court (see Appendix 1).

1.2.5 Policy framework with regard to RWHI

1.2.5.1 Ministries related to RWHI

a. The Ministry of Environment Water and Climate

i) The Department of Environmental Management Agency (EMA), is responsible for the regulation of environmental flows and management of wetlands, including vleis (seasonal wetlands).

ii) ZINWA is in charge of major dams and water resources in the country. It is a water planning and bulk supply parastatal agency. It works in cooperation with Councils, who has the responsibility of managing river systems and enforcing laws and regulations at the local level.

iii) The Department of Water Development (DWD) is in charge of the overall formulation of national policies and standards for the planning, management and development of the nation's water resources. This department is the policy and regulatory unit on water within the Ministry.

b. The Ministry of Agriculture and Mechanisation and Irrigation Development (MAMID)

This ministry is responsible for the overall development and implementation of the government's policy on agriculture and irrigation, which also include RWHI. The Ministry is directly or indirectly involved through several departments and parastatal agencies:

i) The Department of Research and Extension Services (AREX) is responsible for the provision of extension services to small-scale farmers on matters related to irrigation. In addition, the research unit of AREX is responsible for soil surveys and soil testing for irrigation development.
ii) The Agricultural and Rural Development Authority (ARDA) is a parastatal agency responsible for the operation of government-owned irrigated estates and farms on behalf of the government. It works closely with the Department of Irrigation and also AREX, especially on soil testing.
iii) The Grain Marketing Board (GMB) is a parastatal agency in charge of marketing the country's strategic grain crops such as maize. All controlled crops such as maize and wheat from irrigation schemes are sold to the GMB at prizes that are gazetted by the government. In addition, the GMB also administers the government input credit scheme for irrigators and usually the beneficiaries should sell the crops to the GMB.
iv) The Department of Irrigation (DOI) is a new department in the Ministry of Agriculture and Rural Development. The mandate of the department is to manage all irrigation activities in the country which include planning, identification of schemes, designing, construction, operation and management of existing irrigation schemes.
v) The Department of Agricultural Mechanisation mainly involves in soil and water conservation works (in situ-harvesting).
vi) The Department of Research and Specialist Services (DRSS) through the Chemistry and Soil research Institute is involved in soil analysis for farmers and in assessment of soils for suitability for irrigation.

c. Ministry of Transport and Infrastructural Development (MTRID)

This Ministry is involved rural resources management and water development programmes. The District development fund (DDF) is responsible for the development of rural infrastructure such as roads, dams and boreholes at district level. The DDF also provides tillage services to irrigators and offers a nationwide public works facility for maintaining public infrastructure including boreholes and small dams. It also plans and constructs small irrigation schemes, but under the supervision of the Department of Irrigation.

d. The Ministry of Local Government, Public Works and National Housing

This ministry works through the Rural District Councils in mobilising local communities, farmer selection and irrigation plot allocation in smallholder irrigation developments.

e. Ministry of Finance and Economic Development

The Ministry of Finance and Economic Development has a key role in availability of resources and funding for development activities such as irrigation. It also coordinates externally sourced development finance for irrigation development. It is the Ministry which funds all the other ministries and departments.

g. The Ministry of Health and Childcare (MOHCC)
Is responsible for the regulation of water quality standards.

1.2.5.2 Policies and Strategies on RWHI

Irrigation development is one of the major priorities for agricultural development in Zimbabwe. The Zimbabwe Agenda for Sustainable Socio Economic Transformation, ZIMASSET, is Zimbabwe's midterm economic blueprint for the period October 2013 to December 2018 and it spells out the government's priorities in water resources and irrigation development. ZIM ASSET, 2013 emphasizes the role of promoting RWH and small-scale irrigation for rural development. One entry point to achieve full development of the country's water resources is the construction of dams to provide water for irrigation for both large-scale and small-scale irrigation schemes.

Section 3.12 of ZIMASSETstates the Government's focus in the support of irrigation, "In order to stimulate agricultural productivity and safeguard food security, Government will recapitalize and capacitate AgriBank and the Grain Marketing Board (GMB), the Agricultural Marketing Authority (AMA) and the Agricultural Rural Development Authority (ARDA). While the Plan will ensure that the Presidential Input Support Scheme focuses on supporting the vulnerable groups at household and community level, it will also ensure that other farmers timeously access affordable inputs. Policies will also be put in place to promote contract farming initiatives.

Irrigation development has been considered of high importance to the country by all successive governments in Zimbabwe (FAO, 2015). Before the independence in 1980, the then colonial government invested heavily in dam construction and irrigation infrastructure but this mainly benefited the large-scale commercial farmers. However, from 1980 onwards, the new government focused on irrigation development for the small-scale farming sector. This was done through the promotion of farmer-, government and joined-managed smallholder schemes.

The government has embarked on an aggressive large- and medium-size dam construction programme in the country in order to increase the capacity for irrigation and other purposes. Total capacity of current dams is about 103 km^3, but this includes 50% of Lake Kariba on the Zambezi River which is shared between Zambia and Zimbabwe and accounts for 94 km^3 of this capacity. Not taking into consideration this shared dam, total capacity of the dams in the country is 9 km^3. The total area under small-scale irrigation is 11.861 ha and this is 8% of the total irrigated area]. In addition, there are two new irrigation schemes. These were developed after the land reform which increased the area under small-scale irrigation. The reform has split up commercial farms, most of which had irrigation facilities, and has formed tow ushered in two new groups of farmers: A1, who irrigate small areas at times with shared infrastructure, and A2, who are commercial irrigators. In some cases, the A2 farmers also share irrigation infrastructure. This new categories of farmers have an estimated of 69. 714 ha and this is % of the total irrigated area.

The anticipated growth within the Agricultural Sector will be underpinned by the following sectorial assumptions: Improved agricultural infrastructure to militate against drought through rehabilitation and expansion of irrigation projects and increased construction of dams. The following dams are also set to be complete by December 2018 according to ZIMASSET:

a) Tokwe- Mukorsi dam in Masvingo Province
b) Gwayi-Tshangani Dam in Matebeleland North Province

c) Mutange in Midlands Province
d) Semwa Dam in Mashonaland Central Province
e) Marovanyati dam in Manicaland Province
f) Kunzvi Dam in Mashonaland East Province
g) Chivhu Dam in Mashonaland East Province
h) Tuli –Manyange Dam in Matebeleland South Province
i) Bindura Dam in Mashonaland Central Province
j) Dande Dam and Tunnel in Mashonaland Central Province
k) National Matebeleland Zambezi Water Project
l) Shavi Dam in Midlands Province

1.2.5.3 Relevant Laws and Acts for RWHI

General Laws which govern irrigation are enshrined in the constitution of Zimbabwe, which enshrines the right to access to water for basic needs.

- The Water Act outlines the institutional management of the water sector based on equitable and sustainable management of water resources.
- The water act also governs water use for small-scale irrigation.
- The Technical Standards Outline dictates that dam designs need to be approved, inspected and monitored by a government approved Engineer

:

The Water Act (1976)
The water act was first published in 1976 and its main object was to govern water rights to public water. It was amended in t998, 2001 and 2002.

The Water Act 31/1998, 22/2001, 13/2002, 14/2002.
According to these amendments, all water in Zimbabwe is vested in President, and as such, there is no private ownership of water. Therefore, no person shall be entitled to ownership of any water in Zimbabwe and no water shall be stored, abstracted, apportioned, controlled, diverted, used or in any way dealt with except in accordance with this Act.

The Water Act:
(i) Allocates water permits.
(ii) Creates Catchment and Sub-catchment councils, who can allocate water use permits and can limit quantity of water abstracted for irrigation.

1.2.6 Analysis of potential opportunities for RWHI

RWH and irrigation can improve agricultural production, food security and improve the livelihoods of people in the small-scale farming sector (Shimada 1994; Orr and Ritchie

2004). Even in the wetter regions of Zimbabwe such as NRs I and II, mid-season drought spells are common making supplementary irrigation necessary. In the smallholder farming areas, irrigation is also used to extend the growing season of certain crops or ensure the early planting of such crops as tobacco. With RWHI, farmer may be able to do multiple cropping in a single year. Instead of only depending on rainfed staple crop production, farmers may also be able to grow a variety of crops which include horticultural crops for both home consumption and for income generation thus enabling diversification of produce (Shimada, 1994). RWHI has the potential to improve small-scale household food security. RWHI is also important and benefit the most vulnerable communities like elderly or women-headed households in the small scale farming areas as they would irrigate their crops without putting much effort. In small-scale farming area where smallholder farmers largely depended on irrigation for crop production, horticultural gardens provided the single largest source (80%) of income to meet household needs (Dambo Research Unit, 1987; Mabeza and Mawere, 2012). Mabeza and Mawere (2012) also reported that 85.4% of the households in Seke depended on income from small-scale irrigation in dambos (seasonal wetlands). RWHI may also improve income generation by means of the introduction of high-value crops, for example, in Zimbabwe crops grown under irrigation constitute almost half of the total value of the crops marketed (FAO, 2015). In addition, RWHI may enhance the diversification of income generating activities as farmers can also get additional income from irrigated crop in addition to their already existing sources.

1.2.7 Analysis of potential barriers for RWHI

In Zimbabwe, the development of irrigation schemes is fragmented under different Ministries and Government departments as shown in section 1.2.5. This has resulted in inefficiencies and at times, conflicts between departments which have negatively impacted RWHI. Generally, most people may not understand the principles of RWHI, and some of them never practiced them. Hence, awareness of RWHI must be increased amongst practitioners e.g., academics, scientists, makers and policy makers (UNEP 2009; Awulachew et al. 1995). This can be achieved through establishing of Research and Transfer Centres, and demonstration centres. In addition, initial development costs may be high and unaffordable for most smallholder farmers, as there is need for the of small dams and other water storage facilities which are out of reach of is most cash strapped small holder farmers. In addition, the lack of a technology matching the available financial resources, high initial cost of implementing the technology, lack or inadequate access to financial resources, inappropriate land tenure, unfavourable local geology and insufficient capacity among the local communities may also reduce the uptake of RWHI technologies (Republic of Kenya 2013).

The lack of adequate institutional support, institutional set-up and accountability, issues which are not stable may result in confusion on mandate, and in some cases failure of RWHI due to lack of accountability (Awulachew et al. 1995). Some and consultation among stakeholders may result in the failures of RWHI (Awulachew et al. 1995). Science and technology actors should be involved in RWHI and avail technologies that are affordable to most of the smallholder farmers. Also, different cultural and traditional perceptions, like the taste of water of low mineral content, has resulted in failure or rejection of technologies such as RWH as flowing water is sometimes considered more pure than stored water or rainwater because of self purification (Kaleen L (1993).

1.3 Conclusions and recommendations

Investing in rural water development through RWHI may potentially reduce poverty and improve livelihoods through providing water for agriculture and livestock in arid and semi-arid regions of Zimbabwe. However, some of the factors which may limit the use of RWHI is the shortage of funding, lack of technical know-how, and lack of appropriate technologies. Hence, there is need to enhance access to institutional support services such as credit and extension. There is also the need to establish farmer training institutions in order to promote RWHI. In addition, there is also the need to improve related extension services. Availing market information on inputs and outputs may only achieve the desired impacts if an effective extension system is in place to guide farmers to understand the issues related to the optimum application rates of inputs, targeted planting dates and product quality. This may enable them adequately respond to market demands. Smallholders also need to be linked to markets for sustainable crop production. Capacity-building activities in RWHI should be promoted in schools, colleges and Universities and examples of building capacity include the like the establishing of Research and Transfer Centres, and the demonstration trials. This may involve training of farmers and providing information, both in print and electronic form to the farmers. It may also be recommended that the Government coordinates development and institutional reforms as a way to bring all irrigation functions under a single and stronger government department. In addition Science and Technology actors should play a major role in availing proven RWHI technologies to farmers at affordable prices.

2. Analysis of research and innovation needs in RWHI management

2.1 Introduction

The field of RWHI in rural arid and semi-arid areas of Zimbabwe has a great potential to improve crop yields and the livelihoods of local communities. However, most previous research has focused on commercial agriculture and little has been done to meet the requirements of the small scale farmers (FAO 2015). Prior to independence in 1980, most research focused on commercial farming. Even though there was an increased focus on small-scale farming areas after the independence, most of the research focused on soil fertility and conservation (FAO 2015). Research on RWH in smallholder areas has focused on in-field (in-situ?) water harvesting, especially in the drier parts of the country. This was because researchers believed that in-situ RWH showed a greater likelihood of success (Moist et al., 2004, Mupangwa, et al., 2006, Mutekwa and Kusangaya, 2006 and Munamati and Nyagumbo, 2012). Lack of consultation (Awulachew et al. 1995) and the absence of appropriate technologies has however, reduced the potential of RWHI because most people will not afford the available technologies (Republic of Kenya 2013). Therefore, there is currently the need to increase scientific and technical capacities on the use of RWH as supplementary irrigation or in-situ rainwater harvesting as it makes more water available to the plant roots during the dry season (Mutiro et al. 2006). In addition, there is also a need for the development and demonstration of appropriate low cost technologies for RWHI. Thus, other arid and semi-arid areas in the country may benefit from these technologies. Examples include the use of sand dams compared plastic water tanks for water storages. In most cases plastic tanks are more expensive relative to sand dams, hence they may not be appropriate from smallholder farming areas.

2.2 Available and planned institutions and main research areas

The Government of Zimbabwe has been trying to foster capacities on RWH and small-scale irrigation by means of the establishing of Institutions of Higher Education. These offer agriculture related degrees, diplomas and certificates (Table 2). In addition, the Government has also established agricultural polytechnic colleges, which offer technical certificates and Diplomas in agriculture. However, these institutions train mainly agricultural extension officers. There are also several farmer training centres that have been put up in the country. In addition, the Government is planning to establish a University in each of the country's' 10 provinces whose main focus will be training in agriculture and science and technology. The planned Universities include Manic land University of Science and Technology (Manic land Province); Mariner University of Science and Technology.

Table 2. Available institutions involved in agricultural training and research

University	Agricultural Colleges	Research Institutes	Vocational Training Centres
Africa University (AU)	Chibero	Agricultural Research Trust	
Bindura University of Science Education (BUSE)	Mlezu	Institute of Agricultural Engineering	
Chinhoyi University of Technology (CUT)	Gwebi	Makoholi tranining Centre	Makoholi Tranining Centre
Harare Institute of Technology (HIT)	Shamva	DRSS	Magamba Training Centre
Lupane State University (LSU)	Kushinga Phikelela	Tobacco Research Institute	Chaminuka Technical College
Midlands State University (MSU)	Blackforby		Honde Technical College
Great Zimbabwe University (GZU)			
National University of Science Technology (NUST)			
Solusi Univesity (SU)			
University of Zimbabwe (UZ)			
Women University in Africa (WUA)			
Zimbabwe Open University (ZOU Zimbabwe Ezekiel Guti University (ZEGU)			

(Mashonaland East Province); and Gwanda University of Science and Technology (Matebeleland South). The government is also planning to establish more Agricultural colleges and farmers training schools.

2.3 Main research outputs and outcomes

The major research outputs from the Government's initiatives include some innovation and technologies for smallholder farmers. The thrust of these institutes have been to increase the research and evaluation of relevant technologies specifically meant to increase crop yields in smallholder farming areas (e.g. fallowing and ridging, development of ox-drawn ridgers, development of farmer operated water pumps etc). The main thrust of research institutes in Zimbabwe has been on tillage and traction for small-scale farmers. Some books, research articles and manuals on small-scale irrigation have been published as a result of this research effort (Dambo Research Unit 1997;). However, relatively little effort has been put towards RWH, and the use of alluvial aquifers in seasonal riverbeds for water and food security in Zimbabwe: e.g., de Hamer et al. (2008), Motsi et al (2004) and Mpangwa et al (2006). Though some considerable research has focused on irrigation technologies for smallholder farming areas the major challenge have been technology transfer from the researchers to the farmers (Moyo et al. 2006). Most of the technologies that have developed have not been adopted by local communities due to poor linkages between research and the famers (Republic of Kenya 2013; UNEP 2009). In addition, some of these technologies have proven to be inappropriate for small-scale farmers (Moyo et al. 2006). Examples include some types of drip technology, which farmers ended up abandoning because the technology was not suited to their environment, e.g., drip irrigation kits which did not work well because of water shortages (Moyo et al. 2006). In addition, the farmers lack appropriate training to adequately use these technologies, they have poor capital and human resource endowment, are among the factors that negatively influence adoption of Rain water harvesting technologies (Murgor et al. 2013). Also, most of technical guidelines are not accessible to the farmers. The few that are accessible are mostly written in English and not vernacular language. This has resulted in little information filtering to the small-scale farming areas. There is also need to improve the capacity for academics, scientists, practitioners and policy-makers to teach and research on RWHI and to have it incorporated in the curriculum; hence our training materials and courses should cover these groups.

2.4 Conclusions and/or recommendations

There is need for assistance in supplying simple technologies which meet the requirements for the small-scale farming sector. One major problem with RWH is the high costs associated to store adequate volumes of water e.g., in water tanks, (catchment area and riverbeds (de Hamer et al. 2008; Motsi et al 2004). Therefore, the development of alternative low-costs water storage facilities, like plastic tanks or seasonal riverbeds, may have a crucial role in the satisfactory development of RWHI. In addition, the costs of RWH systems are not affordable for local communities. Therefore, there is the need to identify technologies or strategies which allow the adoption and replication of these technologies. Unfortunately, there is a large gap between theory and practice in the field of RWH and researcher or developer of technologies and the small-scale farmers (Murgor et al. 2013). Training support, both to communities and private small-scale construction initiatives, may help. There is also need to develop technologies that are tailored, tested and suited to the arid and semi-arid conditions. Demonstration sites, so that farmers and other stakeholders can learn from seeing the RWH in practice, may be very useful. Currently there are very few examples of these initiatives. Finally, the preparation of manuals in both English and local languages may allow to increase the number of people who can benefit from the manuals. In addition, the materials should be distributed by electronic and print media.

3. Analysis of regional capacity and training needs in RWHI

3.1 Introduction

Food security in most smallholder farming systems of southern Africa mainly depend on cereal production, which is a rain-fed staple crop (Nyamadzawo et al. 2014). The majority of smallholder farming areas in Zimbabwe are located in semi-arid areas where rainfall is low, erratic and unreliable (Department of Metrological Services, 1981; Bratton 1987; Unganai, 1996). In the last years, the incidence and extent of mid-season dry spells, and onset and offset changes, have been attributed to climate variability and change (Branca et al. 2011; Phillips et al., 1998).). In most countries in sub-Saharan Africa, where high vulnerability to weather shocks already exists, are expected to be hit the hardest, with predicted decrease in agricultural productivity of between 15% and 35% (Cline 2007, IPCC 2007).

The Sothern Africa Development Community (SADC) member states occasionally experience unfavourable weather conditions, which make the region prone to severe droughts and floods, and their related consequences. Adverse weather in a number of SADC countries results into reduced planting and crop failure. This may result in serious food shortages especially in rural and peri-urban areas and therefore, undermine the food access to a significant percentage of the population. In addition, this also results in heavy human and economic losses (references). However, in Zimbabwe there is overdependence on rain-fed agriculture and low-value crops as most of the agricultural systems of southern Africa are predominantly rain-fed and irrigation systems are not well developed (Camberlin et al., 2009). Therefore, a low percentage of land is under irrigation (Manzungu 2003). The development of RWHI may have the potential to increase food security in smallholder farming areas. However, the storage of rainwater and small-scale irrigation development in the region has been hampered by the unavailability of skilled manpower, lack of technical know-how, unavailability of funding and inappropriate technologies (references).

3.2. Identification of regional existing capacities

At independence in 1980 the Zimbabwe recognised the role of irrigation in agricultural development, especially in improving the production of the smallholder farmers. The government then promoted small scale irrigation, which had been neglected by the previous colonial government. In addition, further steps were taken to develop new smallholder irrigation schemes and rehabilitate all the irrigation schemes, which were damaged and neglected during the Liberation War. In all, 155,500 ha are under irrigation and this total is about 8.5 percent of the total irrigated area. An additional 30 000 ha, of land is under micro-irrigation, in dambos (seasonal wetlands), though this is not normally included in official estimates by the government as irrigated land. The small-scale sector which is on government irrigation schemes or micro-irrigation, are potential targets for the development of RWHI, or and can benefit the implementation of RWHI.

Table 3. Area under irrigation in selected countries in the SADC region. (SADC 2001)

Country	**Arable land area (Ha)**	**Irrigable land (Ha)**	**Area under irrigation (Ha)**
Malawi	24 000 000	400 000	62 000!
Mozambique	36 000 000	-	7 500 * 45 000 was destroyed during war
Swaziland		90 000	49 860 *small-scale irrigation is 30% of this
Tanzania	-	29 400 000	200 000
Zambia	35 000 000	423 000	100 000
Zimbabwe	16 000 000	550 000	150 000

In the SADC region, there are several institutions that are involved in irrigation development. These included regional Universities in each member country, agricultural and technical colleges which are involved in the training of researchers, extension officers and farmers. Regional institutions can potentially play a significant role in RWHI. At regional level, there is a need for Agricultural related research institutions to collaborate in developing and sharing capacity to carry out research in RWHI efficiently and effectively. The region suffers from imbalanced distribution of human capital and financial resources (SADC, 2001). Therefore, some of the countries have more capacities than others: for example, in Zimbabwe has human capacity to carryout research, but their major constraints is the lack of finance and financial resources. This variation in access to resources and capacities has a direct impact on the ability to collaborate in research activities.

In addition a lot of NGOs' and international organisations such as the, Care International, Global Environmental Facility (GEF) also play a role in irrigation development in the small-scale farming sector in Zimbabwe and regional level. This is because they provide funding, technical experts to train both the farmers and extension staff on irrigation. Some of these NGO also partner national Agricultural research and training institutions such as Universities in the training of researchers and farmers. This has ensured that traditional technical water management skills are passed on to the beneficiaries. However, there is need for further training to develop the capacity of water sector professionals and institutions in the in Zimbabwe. Some of the skills that need to be developed include the development of the financial management capacity of water resources managers and professionals, extension officers, academics, Researchers and Scientists: (SADC, 2001). In addition, training programmes should recognise the impact of epidemics such as HIV/AIDS and Malaria on capacity development and institutional strengthening. Therefore, institutions involved in RWHI should collaborate and cooperate with the health sector and other related sectors in supporting measures to combat the pandemics in the region. An example of this initiative is the SADC transboundary initiative to fight malaria between Zimbabwe and Mozambique.

NGOs are actively involved in water development and management activities at regional, national and community levels throughout the SADC region. Some of the communities that are assisted by NGOs' do not have sufficient knowledge, skills and financial capacity to engage in small-scale irrigation (SADC, 2001). NGOs' provides support (empowerment) and facilitation to poor stakeholders, in terms of awareness raising, and skills training. NGOs' play an important role in capacity building and community empowerment in water supply, sanitation, public health, and agricultural production. This important role should be acknowledged and these organisations should be taken as development partners and not competitors by the government.

Again there is need to train academic, scientists, practitioners on water management issues, and to disseminate their research findings to communities. Poor dissemination of research findings has prevented some innovative RWHI innovation not to get to the farmers because of poor extension linkages between researchers and farmers. There is also need to engage policy makers to ensure that they integrate RWHI into the country's' irrigation development plans.

There is also need for gender mainstreaming in RWHI because X (references). Women play a central role in the provision, management and safeguarding of water (references). This is because most of women spend their time at home while men are at work or working in towns and cities (references). Therefore, they should be involved in the development and implementation of policies, processes and activities related to RWHI. Women should be included and empowered to fully participate in decision making at all levels of RWHI.

3.3. Identification of lacking capacities

The Government of Zimbabwe has been trying to foster capacities on RWH and small-scale irrigation by means of the establishing of Institutions of Higher Education. These offer agriculture related degrees, diplomas and certificates (Table 2). In addition, the Government has also established agricultural polytechnic colleges, which offer technical certificates and Diplomas in agriculture. However, these institutions train mainly agricultural extension officers. There are also several farmer training centres that have been put up in the country. In addition, the Government is planning to establish a University in each of the country's' 10 provinces whose main focus will be training in agriculture and science and technology. Constraints to capacity and training needs in the area of RWHI irrigation in Zimbabwe and the SADC region include: inadequate financing and institutional support, high operational costs, lack of credit facilities for small-scale farmers and inadequate and inaccessible markets and lack of training (Chifamba et al. 2013; Chozovachii 2012). Challenges faced by all these countries in the region include: the lack of internal funding from the national budgets, low participation of the private sector in smallholder irrigation development and top-down approaches where technologies are imposed to the farmers (African Union 2003). In addition, poor soil and water management have caused environmental problems like water logging and soil salinisation. The low levels of funding even from international organisations have hampered irrigation development and RWH in the smallholder farming areas (SADC 2001). Lack of proper defined markets, adequate market linkages and market information and transport services have seriously affected small-scale irrigation development (Chozovachii 2012). Thus many farmers produce crops which are not sold because lack of market (FAO 2015) or buying wrong irrigation equipment because of lack of information or training (African Union 2003). The lack of research and development of suitable and compatible technologies have also affected the development of RWH and small sale irrigation development as farmers sometime buy equipment that they cannot use.

In addition, there is also a fragmentation of policies on irrigation development and RWH in the region (Republic of Kenya 2013). This lack of a coherent polices actually impedes irrigation development because of conflict between departments, which may result in inefficiencies. Currently water storage capacity in Africa is under-developed, and is estimated to be 20 m^3/capita compared to between 2000-4000m^3/capita in developed countries (African Union 2003). Therefore, SADC water development policies should provide clear strategies to increase water storage development which can enhance small-scale irrigation. In the region, RWH techniques are well known, but the adoption rate is low. This may be due to several reasons among them: lack of government support and government subsidies, poor technology transfer, poor extension services (Chifamba et al. 2013). In addition, there are no or very few centres where demonstrations are available to farmers. Setting up demonstration sites may increase the uptake of RWH and small-scale irrigation technologies.

3.4. Conclusions and/or recommendations

There is a huge potential to develop RWHI and scientific, technical and human resources in Zimbabwe and the SADC region. Irrigation development has been hampered by the unavailability of skilled manpower, lack of technical know-how on the side of the farmers, the unavailability of funding and appropriate low-cost technologies. Even though some adequate technologies may be available, a lack of knowledge sharing platforms among experts and farmers has prevented the uptake of technology in the region. There is a need to train farmers so that they are aware of the full potential and benefits of RWH and irrigation development. There is also a need for more collaboration and networking between all relevant stakeholders among the regional member states to foster irrigation development in the region. In addition, it is required that extension workers are trained across the region. Also, there is a need to foster linkages between research institutions and extension units in order to foster the promotion, adoption and replication of new technologies.

It is required political will in order to provide more funds towards agriculture and farmers. Small-scale irrigation development should be prioritised within the agricultural sector. There is also need to educate the population on the link between irrigation and how it can help curtail the HIV/AIDS problems. There is also need for establishment of demonstration plots to convince both the farmers and stakeholders about the potential benefits of RWHI. The improvement of existing systems and policies is also required to improve irrigation in smallholder farming areas.

4. Analysis of technology-transfer and market-oriented needs in RWHI management

4.1 Introduction

Technology-transfer is the process of transferring innovative know-how from technocrats (researchers, extension officers) to the market place and direct beneficiaries (UCLA, 2015). Currently technological transfer is very poor in Zimbabwe and the SADC region because of several reasons, such as: lack of consultations between researchers, NGOs', equipment traders and farmers on appropriate irrigation equipment that is suitable for small-scale farming areas (African Union 2003). This has resulted in researchers developing technologies which the farmers refuse to adopt. The lack of interaction between farmers and technical advisers has resulted in poor technology transfer.

Farmers are not sufficiently part of the process of choosing the technology suited to their circumstances, especially when schemes are being developed or rehabilitated. In addition, technical advisers lack skills, commitment and back-up to interact meaningfully with the farmers (African Union 2003). Also, farmers have no irrigation experience or have had inadequate exposure to technologies to debate the options. In addition, most of the traders do not do market and research on their products, they do not provide back-up services and spares. This has resulted in farmers refusing to adopt some technologies. Some of the irrigation equipment is costly and the pricing is above the reach of many farmers (African Union 2003). For example, currently in Zimbabwe, the cheapest solar pumping unit costs US$2500. Even though the solar pumping system is a sustainable option for irrigation (references), the initial investment is very high and is well above the reach of many small-scale farmers in Zimbabwe. As such, this technology is unlikely to be adequately transferred to the market and adopted by small-scale farmers. Manufacturing of equipment specifically suited to small-scale farmers is probably also hampered by the low demand.

There is lack of market information and transfer to the market and as a result farmers are short changed and they earn very little from their produce. In addition, there, poor infrastructure, lack of inputs and credit. Hence there is need for development of commodity specific marketing information and infrastructure in order for small scale irrigation farmers to effectively enter and compete on the open market (African Union 2003). In addition, markets are unreliable especially during the rainy seasons when people are self sufficient and reliant. In such times argues that produce are bought at very low prices thus affecting producer's income (Makumbe 1996).

To improve technology transfer, famers should be trained to use RWH and irrigation equipment and to maintain and repair them. Farmers should also be part of the decision making on the technology that they require and is suitable for their region. If RWHI management is to make an impact in the small-scale farming areas, it should be part of life such that it can be passed on from one generation to another. Thus, RWHI should be instilled into farmers so that it is part of a culture. RWHI facilities should be constructed, operated and maintained by farmers themselves as this increases the commitment of farmers. Famers should be willing implementers of the irrigation programmes while government and NGO officers take the technical advisory role. In addition, local available resources should be used to bring RWHI systems into being in the farmer's locality. Local farmers should also be empowered and trained to develop their potential through building dams, diversion of streams and rivers, harvesting water from bare rocks, and other currently available water storage systems. Farmers should be trained and given skills to identify potential diversion or water harvesting sites, construction of diversion or water harvesting structures and layout of irrigation fields and canals. Training should also be provided on equity issues to reduce conflicts over water and to settle conflicts that arise in an amicable manner using local structures.

4.2 Identification of what has been achieved in terms of technology-transfer and market-oriented products

Some limited success has been achieved in the field of technology transfer and market-oriented products. The Government of Zimbabwe has established farmers training facilities where farmers learn about new irrigation technologies. However, the number of farmers that have been enrolled is very limited (FAO, 2015). In addition, the government has also established a master farmer scheme, where excelling farmers are trained further and given agricultural skills. The farmers can be target farmers for could and training course in RWHI. There has been effort to foster linkages between research, extension and farmers to increase technology transfer, but with limited success because of budgetary constraints (African Union 2003). This has been done through several platforms which include agricultural shows, farmer field days, farmer field schools, sites visits and tours. Some market oriented technologies have also been developed. These are mainly low cost, locally adapted technologies. Examples include the treadle pump for small-scale irrigation (FAO 2015a), planting pits (for infield water harvesting) and infiltration pits which are dug along contours to harvest rain water (a farmer innovation from Masvingo), (Motsi, et al. 2004). Technologies that have been successfully transferred in arid and semi-arid regions of Zimbabwe are mainly in-situ water harvesting technologies. All the cases transferred in Zimbabwe are shown in Table 4.

Table 4: Technologies successfully researched and/or transferred

Researchers/Organisation	Technology researched and/or transferred	Area where transferred
Motsi, Chuma & Mukamuri (2004)	Tied ridges, infiltration pits and *fanya juus*	Mudzi, Gutu and Chivi
Mugabe (2004)	Infiltration pits	Chiredzi
Munamati & Nyagumbo (2010)	Dead-level contours	Gwanda
Mupangwa, Love & Tomlow (2006)	Tied ridges, infiltration pits and *fanya juus*	Mzingwane catcment, Limpopo Basin
Mupangwa, Tomlow & Walker (2011)	Dead-level contours & Infiltration pits	
Mutekwa & Kusangaya (2006)	Tied ridges, infiltration pits and *fanya juus*	Ngundu, Masvingo
Mutekwa, Kusangaya & Chikanda (2005)	Tied ridges, infiltration pits and *fanya juus*	Chivi, Masvingo
Nyagumbo, Munamati, Chikwari & Gumbo (2009)	Dead-level contours	Gwanda

In Zvishavane region, there are successful examples of RWHI technology transfer. Typical examples are farmers who have managed to construct rainwater harvesting structures from bare rocks and also transmission structures to fields for irrigation.

4.3 Technology transfer needs

To enhance technology transfer, there is a need for consultation among farmers so that researchers can develop suitable technologies. The types of technology available to famers may not be user friendly and may also limit the possibilities for local manufacturing and/or trading. An example are some of the low-cost pumps which are imported into the country which do not have back up services and spares. Most small-scale farmers bought them but they have already dumped them because they cannot repair or service them. This has caused significant financial losses among farmers and traders. There is need to increase capacity building, educating and training of farmers in irrigation management. At times, there is inadequate experience for management by the users resulting in poor performance of irrigation schemes. In addition, the operation and maintenance often receives inadequate attention from users as it is left often to government (FAO 2015). Hence, there is a need to empower farmers and training them in operation and maintenance of irrigation equipment. Improved accessibility to equipment can help in technology transfer (Nhundu and Mushunje, 2010). Access to equipment, design and installation capacity, spares/maintenance support, training, finance and enabling government policies would help promote improved RWHI management. In addition, adequate technical training of salesmen and dealers would enhance their contribution to RWHI as they could properly advise farmers on the right equipment to buy. Provision of technical RWHI support and spares supplies should be encouraged. The provision of literature and manuals in local languages so that information about irrigation technologies can reach many farmers should also be supported. Improving marketing information about irrigation technologies, the provision of local back-up services and spares can also help in technology transfer. There is also need to share experience and material for farmer training in the country and across the region. There should be improvement in farmer evaluation of new equipment, such as diesel and petrol pump technologies. Technology that should be promoted should be environmentally friendly, such as solar powered pumping systems, and treadle pumps. The use of water harvesting techniques at all scales should be encouraged.

4.4 Conclusions and/or recommendations

Currently there is a basket of technology that small-scale farmers can use for irrigation in the small farming areas. However, the lack of appropriate technology transfer platforms has hindered the development of small-scale irrigation schemes. Technology transfer is the key to the success of RWHI management. The biggest challenge has been lack of linkages between researchers, industries/traders and the farmers to foster this transfer. Poor technology transfer has resulted in the rejection of some noble innovations by farmers. It is therefore recommended that the current technology transfer approach should be revised. There should be increased consultation with farmers so that researchers can develop suitable technologies. There should be increased capacity building, education and training of farmers and extension officers in irrigation management. Improved accessibility to appropriate farmer evaluated equipment can also help in technology transfer. Competitively priced solar powered irrigation systems should be promoted in small holder farming areas because diesel and petrol pumps are expensive to run.

5. Analysis of available practices and technologies in RWHI

5.1 Introduction

There a several RWH and small-scale irrigation technologies which are currently implemented in Zimbabwe. However, availability of resources, implementation costs, the intended use of the harvested water, and the storage capacity of the technologies determine their use (de Hamer 2008). Even though the technical capacity to develop RWH and small-scale irrigation is available in the country, there are socio-economic conditions that prevent their full utilization and exploitation such inadequate funding and costly irrigation equipment (Nhundu and Mushunje 2010). Especially, the severe economic crisis in Zimbabwe has caused the migration of most technical capacity and human resources to other countries (Nyanga et al. 20112). The inflationary environment that eroded the value of irrigation funds, labour shortages and lack of relevant irrigation services (Mhundu and Mushunje 2010). The rate of unemployment has increased over 70%, which has resulted in reduced income to invest on the farms (UNDP 2012). In addition, the closure of industries has reduced the number of suppliers and increased the cost of equipment that can be used for RWH and small-scale irrigation and most farmers were not well-appraised on the institutions offering the irrigation services (Mhundu and Mushunje 2010). It is expected that as the economic conditions in the country improve, (industries open, employment increases), the costs associated with RWHI will decrease. In addition, it is expected that there will be more available resources to invest in RWHI. The central government is a key stakeholder because they have the capacity to fund the development of infrastructure: dams for small-scale irrigation, availing loans for small-scale irrigation, and capacity building and development of irrigation services.

5.2 RWHI practices and technologies

5.2.1 RWHI in the small-scale farming sector

Approximately 13.000 ha of irrigation land in Zimbabwe if found in the small-scale irrigation sector (FAO 2000). Currently 6000 ha are in use. The remainder 8 000 ha require rehabilitation. In the long term, 97.500 ha can be developed for irrigation in small-scale farming areas (FAO 2000). Small-scale prívate irrigation schemes are individually run schemes of less than 2 ha. The individual farmer is responsible for water supply to the farm and all farm operations. These farmer investors are driven by a strong profit motive and are predominantly located in peri-urban areas or in close proximity to urban areas.

There are communities of small-scale farmers that share the same water pump and delivery line and there is usually, there is one pump station and delivery line. The scheme area is usually below 50 ha. Each farmer has a land holding averaging 0.5 ha (FAO 2000). The water supply can be gravity fed or pumped. These groups tend to be better organized in operation and management of their systems. Investment in the group schemes are mainly from government and NGOs. The projects have usually a top-down approach (either government or NGO). This type of group schemes form the bulk of the communal and old resettlement schemes (FAO 2000). They are the main contributors to agricultural production for the country and food security in rural arid and semi-arid areas (FAO 2000).

Government managed, farmer managed and jointly managed smallholder irrigation schemes in Zimbabwe (Source: AGRITEX estimates, 1998, FAO 2000).

	Total	Number of irrigation schemes					
Province	area (ha)	Total	Government managed	Jointly managed	Farmer managed	Surface irrigation	Sprinkler irrigation
Matebeleland South	1 234	21	16	3	2	19	2
Masvingo	2 796	37	22	3	12	32	5
Manicaland	4 248	29	5	13	11	25	4
Midlands	695	34	13	6	15	30	4
Matebeleland North	169	8	4	4	0	8	0
Mashonaland East	378	35	0	0	35	5	30
Mashonaland Central	659	8	0	2	6	0	8
Mashonaland West	821	15	1	2	12	8	7
Total	11 000	187	61	33	93	127	60
Percentage		100	32	18	50	68	32

Examples of irrigation schemes, sizes and number of beneficiaries (Source: Farmers and Extension Workers at schemes, (FAO 2000).

Scheme	**Area (ha)**	**Number of female plot holders**	**Number of male plot holders**	**Total number of plot holders**	**Plot size (ha)**	**Average dyland area (ha)**	**Full time or part time irrigation**
Chitora	9	0	18	18	0.5	Nil	Full time
Longdale	7.5	2	13	15	0.5	Nil	Full time
Mambanjeni	78	100	68	168	0.3 - 0.5	Nil	Full time
Murara	18	12	24	36	0.5	Nil	Full time
Mzinyathini	32	20	61	81	0.4	Nil	Full time
Ngezi Mamina	216	30	124	154	0.5 - 1.5	Nil	Full time
Oatlands	5	8	4	12	0.4	4	Part time
Principe	60	10	50	60	1	0.4	Full time
Rozva	21	8	25	33	0.5 - 1	1	Part time
Wenimbi	34.2	2	20	22	1.55	8	Full time
Total	480.7	192	407	599			

Rural horticultural crops are similar to crops grown in urban/peri urban gardens. However, in rural irrigation schemes, the types of crops are different due to the larger distance to markets and they are usually for household consumption, with a little surplus for the local market. The crops are mostly irrigated manually, i.e. bucket irrigation using surface water from streams and groundwater from shallow wells (Nyamadzawo et al. 2014). The investment levels for these gardens are very low. Some of the areas that need improvement are access to funds, provision of extension services, access to markets and other technical support services (Chifamba et al. 2013; Chozovachii 2012). As the area equipped for irrigation is expected to increase, there is a need for sustainable alternative sources of water for irrigation and energy for pumping (African Union 2003). This is one of the key objective of the AFRHINET project.

There are also a group of farmers in urban and peri-urban areas that implement horticultural crops (Bell et al. 1987). The farm holdings are usually a few hundred square meters (Bell and Roberts 1991). These lands are usually close to market areas. Individual farmers invest in the development of the schemes mainly for income generation with a clear focus on vegetable production. Water supply for these schemes is mainly groundwater from shallow or deep wells (Bell et al. 1987; Nyamadzawo 2014). The distribution of the water is made usually by buckets (Nyamadzawo 2014) or motorized pumps. The average size of garden at each farm is between 0,2-0.5 ha (Nyamadzawo 2014; FAO 2000). These farms are a major source of fresh produce that is sold in urban areas (Mabeza and Mawere 2012).

5.2.2 RWH Technologies

RWH technologies currently implemented in Zimbabwe can be divided in four systems: roof catchment systems, rock catchment systems, ground catchment systems, check and sand dams (Figure 3). These systems can be used to supply water during periods of scarcity (de Hamer et al 2008). The type of RWH system to use is dependent on the environment; available resources and intended purpose of the harvested water, rainwater harvesting interventions to date are primarily to increase crop/fodder/food/timber production, or to provide domestic/public/commercial supplies of water (UNEP 2009).

5.2.2.1 Rock catchments

Just as the roofs of buildings, rock outcrops can also be used as collecting surfaces for RWH and the structures built to collect wáter are called rock catchments (Peterson 2006). Reservoirs of rock catchments may be a tank built ne the rock catchment of a rock catchment dam built on rock surface. Runoff water gravitate into the reservoir naturally or is diverted by garlands which are build by rock and mortar. For rock catchments, a significant proportion of water can be obtained from sloping rock where collecting channels drain into pipes that lead to tanks. If access to the catchment area by wildlife, livestock and humans can be prevented, a protected rock catchment may collect water of high quality, as long as the surface is cleaned before rainfall is collected.

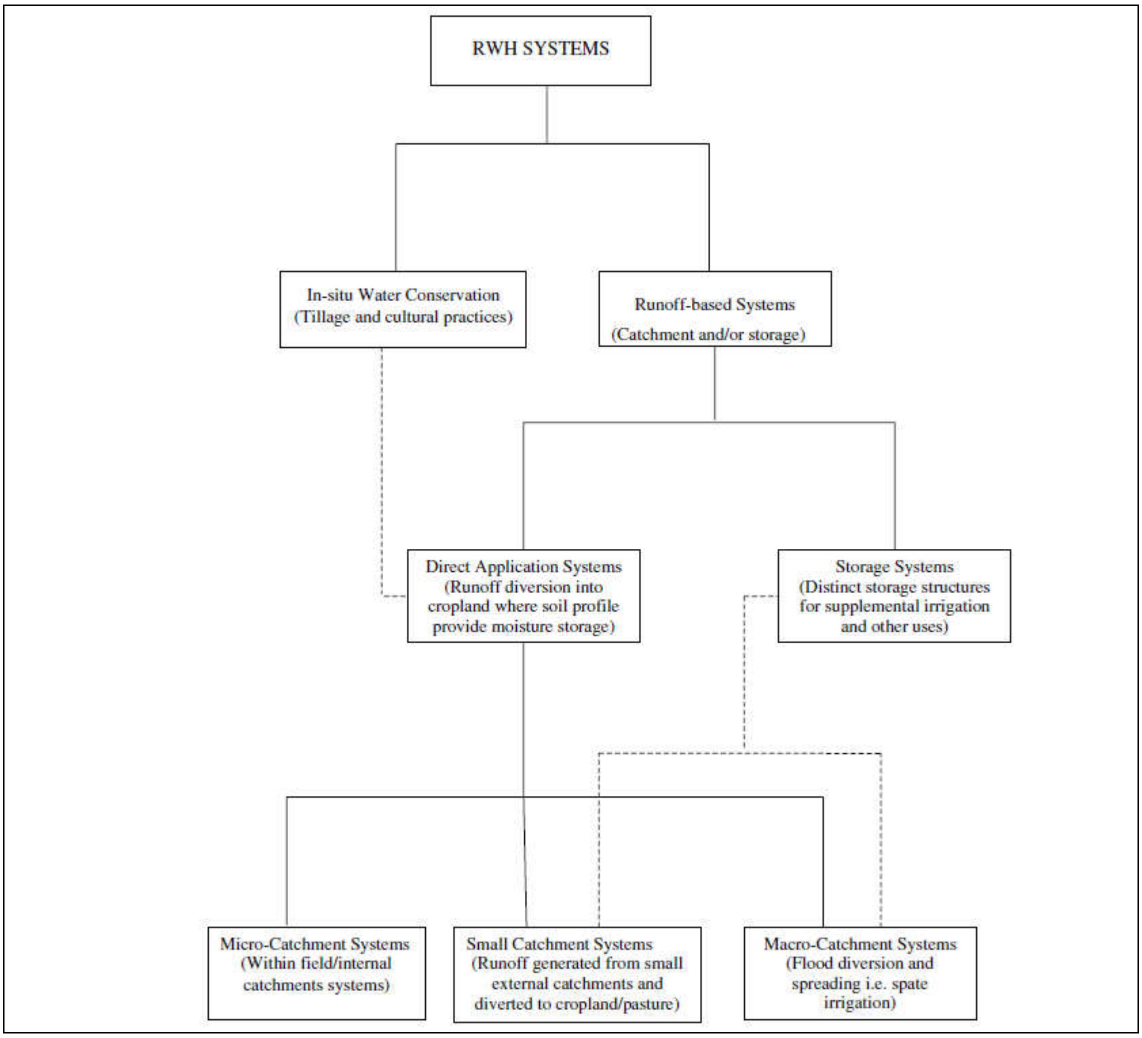


Figure 3. The type of RWH systems that can be exploited in Zimbabwe. Source: Ngigi (2003)

Rock catchment systems can also be likened to roadside diversion a ditch which collects runoff from the road (Figure 5) (Ngigi 2003). Cut-off drains deliver rainwater run-off from roads onto farmland where it sometimes creates erosion and deep gullies. This runoff water can be collected in roadside ponds, water into ground tanks, small earth dams or land for seasonal irrigation (infonet-biovision.org, 2015).

Figure 5. Roadside diversion ditches can be used to collected runoff water which can collect in roadside ponds. Sources, E. Nissen-Petersen, Kenya.

5.3 Ground-catchment systems

5.3.1. Small-scale surface dams

These are small dams or weirs that are constructed across streams and rivers to capture surface flow. Surface dams are artificial, usually formed by constructing a dam across a river or by diverting a part of the river flow and storing the water in a reservoir. Small scale surface dams can be constructed using earth or masonry with rocks. Earth dams are among the cheapest ways to store rainwater available. The sizes of the reservoirs vary from lakes to small pond-like water bodies. In most small-scale farming areas of Zimbabwe, most of the small surface dams/wells are constructed within the individual farmer gardens for the provision of water for irrigation. The water is stored in the reservoir and can be used for small-scale irrigation, and for other domestic uses.

Surface dams are quick and easy access to a water source, they avail drinking water and water for other uses, they increased potential for sustained agricultural irrigation, provide water storage for use during low-flow periods, increased protection of downstream river from flooding events. The disadvantages include, relatively high construction and maintenance costs, displacement of local populations after the dam fills up, maybe sources of conflicts especially in small-scale farming areas.

5.3.2 Natural potential

There is a great potential for the construction of more surface dams and irrigation for small-scale irrigation development in Zimbabwe, but the biggest challenge is the lack of financial resources. There are also some small-scale irrigation schemes that have been planned, e.g. Zambezi valley, Matebeleland water project, but have not been implemented because of lack of resources and also because irrigation development is not a priority in Zimbabwe.

5.3.3 Technological capabilities (construction and services)

The technological know-how for dam construction is available locally and the government has set up department that are responsible for construction of small-scale dams and maintaining rural water supplies (http://www.ddf.gov.zw/water). The main mission of the DDF are to provide and maintain sustainable Rural Water Supplies and Maintenance in Communal and Resettlement areas so as to uplift the living standards of the rural people. Their function include; (i) Surveying and designing for the construction of small earth dams and village irrigations. schemes for land identification, clearance, construction of canals and or laying out all laterals, (ii) Construction of small earth dams (9m wall), (iii) Construction of village irrigation schemes for land identification, clearance, construction of canals and or laying out all laterals, (iv) Construction of pump stations and installations of optimum pumps, and (v) Providing professional and technical advice on irrigation regimes (http://www.ddf.gov.zw/water).

5.3.4 Groundwater dams

Ground water dams

The primary objective of this technology is to preserve or increase groundwater resources. Artificial surface groundwater recharge refers to different groundwater recharge techniques that release water from above the ground into the groundwater aquifer via soil percolation. With direct groundwater recharge, water moves from storage aboveground to the aquifer via soil percolation. This method can make of techniques such as infiltration basins to enhance the natural percolation of water into the ground. The other method that can be used is the spreading basin method, where spreading of water in surface basins excavated in the existing terrain takes place. In This method tolerates more turbid water than other recharge methods (O'HARE et al. 1986). Recharge shafts, pits and basins can also be used and they all vary in shape and sizes.

Sand dams

A sand dam is a reinforced concrete wall built across a seasonal river bed; 2 to 4 metres high and up to 90 metres across. A pipe can optionally be built into the dam, going up to 20 metres upstream (Maddrell and Bown, 2011). During the rainy seasons, water floods the valley and flows over the dam and in the process sand particles settle in the reservoir, while the lighter silt is washed downstream. Sand accumulates upstream of the dam, resulting in additional ground water storage capacity (Figure 6a and 6b). They obstruct the groundwater flow of an aquifer and stores water below ground level. The topographical conditions govern to a large extent the technical possibility of constructing the dams as well as achieving sufficiently large storage reservoirs with suitable recharge conditions and low seepage losses. This system is suitable for rural areas with semi-arid climate in order to store only seasonally available water to be used in dry periods for livestock, minor irrigation as well as for domestic use. Ground water dams can be built with locally available material and labour. However, building the dam still requires relatively high investments, labour intensive and specific expertise is needed. Before starting a ground water project in an area, the community must be intensively involved to create a feeling of ownership, which has proven to be the key factor in successful construction and maintenance of ground water dam. Communities can cover about 40% of the overall construction costs by being involved in the construction of sand storage dams and through provision of labour and locally available raw materials and management groups. The other costs can be covered by NGOs or government departments.

Ground water dams can be grouped into different types, for example;

i) **Stone-masonry dam:** A dam built of concrete blocks or stones. Local artisans can easily construct this type of dam. A stone-masonry dam is durable and suitable for any dam height. The dam is cheap when construction materials are available within the dam area.
ii) **Reinforced concrete dam:** A dam consisting of a thin wall made of reinforced concrete. It is a durable structure, relatively expensive but suitable for any dam height.

5.3.5 Natural potential-Ground water dams

Currently there are very few ground water dams that have been constructed in the country. Examples of ground water dams can be found in Umzingwane catchment (de Hamer, 2008) and Birchenough Bridge along the Save River in Zimbabwe. However, there is a huge potential for ground wáter dams. Using satellite imaging, Moyce et al (2006) reported that the alluvial aquifers in Mzingwane extend laterally outside the active cannel of the river, and individual alluvial aquifers have been measured with area ranging from 45 ha to 723 ha in the channels and 75 ha to 2196 ha on the plains. The estimated water resources potential ranges between 175 000 m^3 and 5 430 000 m^3 in the channels and between 80 000 m^3 and 6 920 000 m^3 in the plains (Moyce et al. 2006) and such a water resource can potentially support irrigation ranging from 18 ha to 543 ha for channels alluvial aquifers and 8 ha to 692 ha for plain alluvial aquifers. In semi arid areas of Zimbabwe, most rivers are seasonal these aquifers can be used to provide water for domestic use, livestock watering and dip tanks, commercial irrigation and market gardening. In this situation, the use of alluvial aquifers of non-perennial rivers can provide an important additional water resource (Moyce et al. 2006). The advantages of ground water dams include; the provision of reliable source of water, study from Umzingwane estimated that 62% of stored water can abstracted, while only 38% is lost due to evapotranspiration (de Hamer et al. 2008) Evapotranspiration losses were low because at depths >0.9m evaporation becomes negligible (Borst and DeHaas, 2006).

Technological capabilities (construction and services): Though there is an availble of information or estimates of water storage and the number of ground water dams in Mzingwane catchment, there are few such studies that have been carried out in other semi arid areas. This has been attributed to several factors among them; lack technical capacity, e.g., satellites to carry out the mapping, lack of financial resources to carryout comprehensive studies and also to construct ground water dams. Although the technical capacity and skill to carry out the construction is available locally, lack of financial resources and funding from the central government has resulted in a few of these dams being constructed. The lack of information dissemination on ground water dams, especially in rural areas and among extension officers has also resulted in a gap and may be in the poor uptake in ground water dams. This gap can potentially be filled by the work that AFRHINET is carrying out.

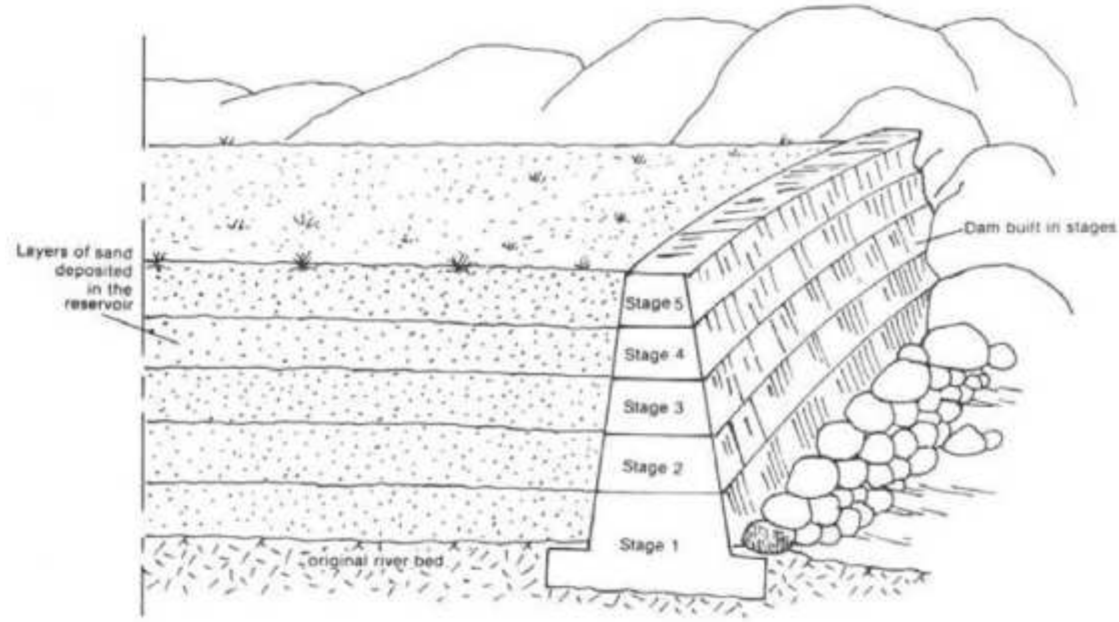


Figure 6 a. An example of a sand dam. Source: Nilsson, 1988

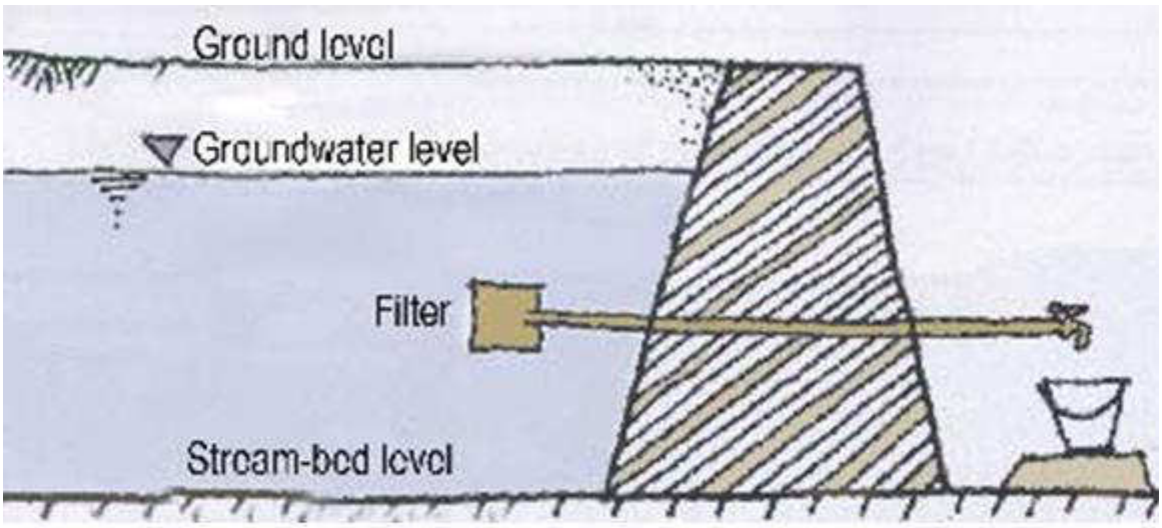


Figure 6b. Schematic drawing of a ground water dams. Source: Nilsson, 1988

5.3.6 Small-scale irrigation development

Small-scale irrigation in Zimbabwe is generally deficient and total of 187 smallholder scale schemes in the smallholder farming areas have been rehabilitated (FAO 2010). The area under irrigation was high before the land reform programme but it declined significantly following the land re-distribution program (UNDP, 2012). This has been as a result of multiple factors which include power shortages, lack of government support, lack of funding has also seen small-scale irrigation schemes failing to rehabilitate and replacing old equipment (Mhundu and Mushunje 2010). This has resulted in some of the irrigation schemes shutting down for example Nyanyadzi irrigation scheme at

Birchenough Bridge. Inadequate funding and costly irrigation equipment, poor management and leadership conflicts have also contributed to failing of some small-scale irrigation schemes because (Nhundu and Mushunje 2010).

Using all available internal renewable water resources (i.e. without including water from the Zambezi and Limpopo border rivers), the irrigation potential for the country is estimated at 600.000 ha, (FAO 2000). However, to date only 150 000 ha in total are under irrigation nationally and of this less than 13 200 ha (11%) are in the smallholder farming areas (FAO 2000).

Though irrigation can be beneficial to small-scale farmers, some smallholder schemes have failed and are under-utilized due to poor management, lack of inputs and irrigation experience by farmers (Mupawose 1984). Some of the most important factors which affecting performance of irrigation schemes in Zimbabwe included; improper planning, as some schemes were planned without involving the farmers. Schemes which were planned by consultants without Participatory Rural Appraisal (PRA) experience performs badly as shown by the Ngezi, Mamina, Mambanjeni and Rozva irrigation schemes (FAO, 2000). The lack of cooperation among farmers, especially in areas such as marketing, and transport hiring has resulted in poor performance of some irrigation schemes. The type of management is also important in the performance of the schemes. All farmer managed schemes, generally did well compared to government managed schemes which perform badly. In addition, for government run schemes farmers do not feel a sense of ownership and they are not worried about efficient utilisation of resources (FAO 2000). The type of irrigation technology is also important, whether sprinkler or surface, affects the labour inputs and leisure time for the farmers. Farmers on surface irrigation schemes complained of the high labour demands of the irrigation leaving very little time for other important activities like weeding, spraying and organizing marketing of produce compared to sprinkler irrigation (FAO 2000). Other factors included the strength of Irrigation Management Committees, Reliability of water supply, cropping patterns where schemes, which concentrate on high value crops, were doing better than those cultivating traditional grain crops, marketing, and availability of spares for capital items (FAO 2000). Other factors affecting small scale irrigation as described by FAO (1997) include: Relatively high cost of irrigation development, Inadequate physical infrastructure and markets, poor investment in irrigation, Lack of access to improved irrigation technologies, lack of cheap and readily available water supplies, poor resource base of farmers, fragmented and small size of land holdings, unsecured or lack of land titles, high interest rates and poor transportation and marketing facilities.

5.3.7 Description of small-scale irrigation systems

Small scale irrigation systems vary in size cross Zimbabwe. The irrigation systems that can be used by smallholder farmers are determined by several factors which include; water source, topography, soils, climate, type of crops to be grown, availability and cost of capital and labour (Mupaso et al. 2014). In addition, the type of irrigation technology available, system design and its associated energy requirements, water use efficiencies as well as socio-economic, health and environmental aspects will also affect the type of irrigation system (FAO, 1999). In most small scale farming areas, the source of irrigation are shallow well and the can or bucket are the most commonly used method of irrigation (Nyamadzawo 2014). However, a few small scale farmers use petrol pumps and for irrigation. Flood and sprinkler irrigation are common in government initiated irrigation schemes (FAO, 2000). The method of irrigation will determine pump size and other distribution equipment needed (www.aces.edu). If the plan is to hand water with a hose, a smaller pump can be used because this will require less pressure (www.aces.edu). Irrigation of larger areas require larger pumps, depending on the sprinkler head and distance and slope the water must traverse, while trickle and drip irrigation are the most efficient systems for high value crop production systems(www.aces.edu) because it is highly efficient.

5. 4 RWHI Supply

Water supply systems are generally divided into four supply chain components which are summarised in the following tables.

Table 6. Pump types available on the market in Zimbabwe and their general characteristics. Source: Nazare 2014

Pump type	Power source	Water source type	Suction Head	Total head	Discharge (pumping rate)	APPLICATIONS OF PUMP
Single stage centrifugal	Electric, electric solar (photo voltaic), electric generator, diesel motor direct, petrol motor direct, paraffin motor direct	Open shallow flowing	<7m flooded suction	medium	low medium high	Applications Pumping clean and unclean water Used for shallow wells <7m suction head) and open water bodies. Flooded suction applications e.g. in tall buildings, surface irrigation, And shifting water between two large water bodies Used as booster pumps (pressurising pumps)
Multi stage centrifugal	Electric, electric solar (photo voltaic), electric generator, diesel motor direct petrol motor direct, paraffin motor direct	Open shallow flowing	<7m flooded suction	medium high		Applications Pumping clean and unclean water Used for shallow wells (<7m suction head) and open water bodies, flooded suction applications e.g. in tall buildings, surface irrigation, Used as booster pumps (pressurising pumps)
Submersible Electric, single and multi-stage	Electric, electric solar (photo voltaic), electric generator	wells boreholes open water bodies	no suction flooded suction	all heads	large range	Clean water applications Applications in deep boreholes and wells Specialised types can be used in a horizontal mode to compete in surface water bodies with centrifugal pumps

Pump type	Power source	Water source type	Suction Head	Total head	Discharge (pumping rate)	Applications of pump and general comments
Mono pumps (screw pumps)	Electricity, electric solar (photo voltaic) electric generator diesel motor direct petrol motor direct paraffin motor direct manual	wells and boreholes	delivery head only	large range of delivery heads	Large range	clean water applications in deep boreholes and wells losing market share to electric submersible pumps structure is cumbersome
Bush pumps	manual wind	boreholes	delivery head only	Medium delivery heads (0-100m)	Low (1l/s)	The standard pump in Zimbabwe's rural areas Deep bore hole or well pumping remote applications, durable
Rope and washer pumps	manual	wells	Delivery head only	low	Low (<3l/s)	Domestic applications and gardens, produced by the informal sector
Prodorite pump	manual	Wells and reservoirs	Delivery only	low	Low (1l/s)	Medium depth wells and boreholes. Domestic applications
Treadle pumps	manual	Open water bodies, wells	Suction and delivery	low	Relatively high compared to other manual pumps (4l/s)	Gardening applications and largely promoted by NGO's

Gravity feed (pipes)	gravity	rivers	Delivery only	Large range	Large range	Agricultural applications
Bucket pumps	manual	wells	Delivery only (lifting)	high	low	Domestic applications

Table 7. Availability of pumps in Zimbabwe (Nazare 2014)

Pump type	Commercial sources	Comments
Single stage centrifugal	Formal Commercial outlets	Pumps readily available in hardware shops in all urban areas. Low cost in electric, petrol and diesel versions. O.5Hp electric pumps sell for as low as US25. The 6Hp petrol pumps sell for US 120.
Multi stage centrifugal	Formal Commercial outlets	Specialised pumps used in high pressure applications. Not readily available in ordinary hardware shops
Submersible electric single and multi-stage	Formal Commercial outlets	Relatively new technology. Light and easy to install. Material costs as low as US150 depending on the brand
Mono pumps (screw pumps)	Formal Commercial outlets	An old technology now largely superseded by electric submersible pumps. Heavy, cumbersome and not user friendly. The pumps require specialist handling equipment for installation and retrieval. High installation and retrieval costs Most entities with mono pumps have shifted to electric submersibles. Costs vary but significantly higher than electric submersible. ($3500 for you average set up)
Bush pumps	Formal Commercial outlets	Government through its parastatals has installed in excess of 80 000bush pumps in the rural areas. A large proportion has broken down as communities lack the expertise to

		repair and capacity to procure spare parts. Material costs for a complete pump are plus or minus US1500
Rope and washer pumps	Informal sector in the major centres (Mbare Magaba)	The full supply chain is controlled by the informal sector including manufacturing, installation and after sales service. Cost is of the order of US$200 including installation
Prodorite pump	Prodorite	The company has stopped supplying these pumps
Treadle pumps	Largely imported from Botswana	The pump was introduced by NGO's who were promoting market gardens as part of their food and Nutrition programmes. Relatively expensive ($450)
Gravity feed	Piping, mostly poly pipe from commercial outlets	A relatively cheap way of conveying water. Works in situations in which the source of water is elevated above the point of application. The method is used in Mutoko by market gardeners who source water from points up stream. Pipe costs are of the order of $1/m
Bucket pumps	Informal sector supplies	The set up consists of a windlass, a rope and a bucket. The windlass is used to lower the bucket at the end of the rope into a well.

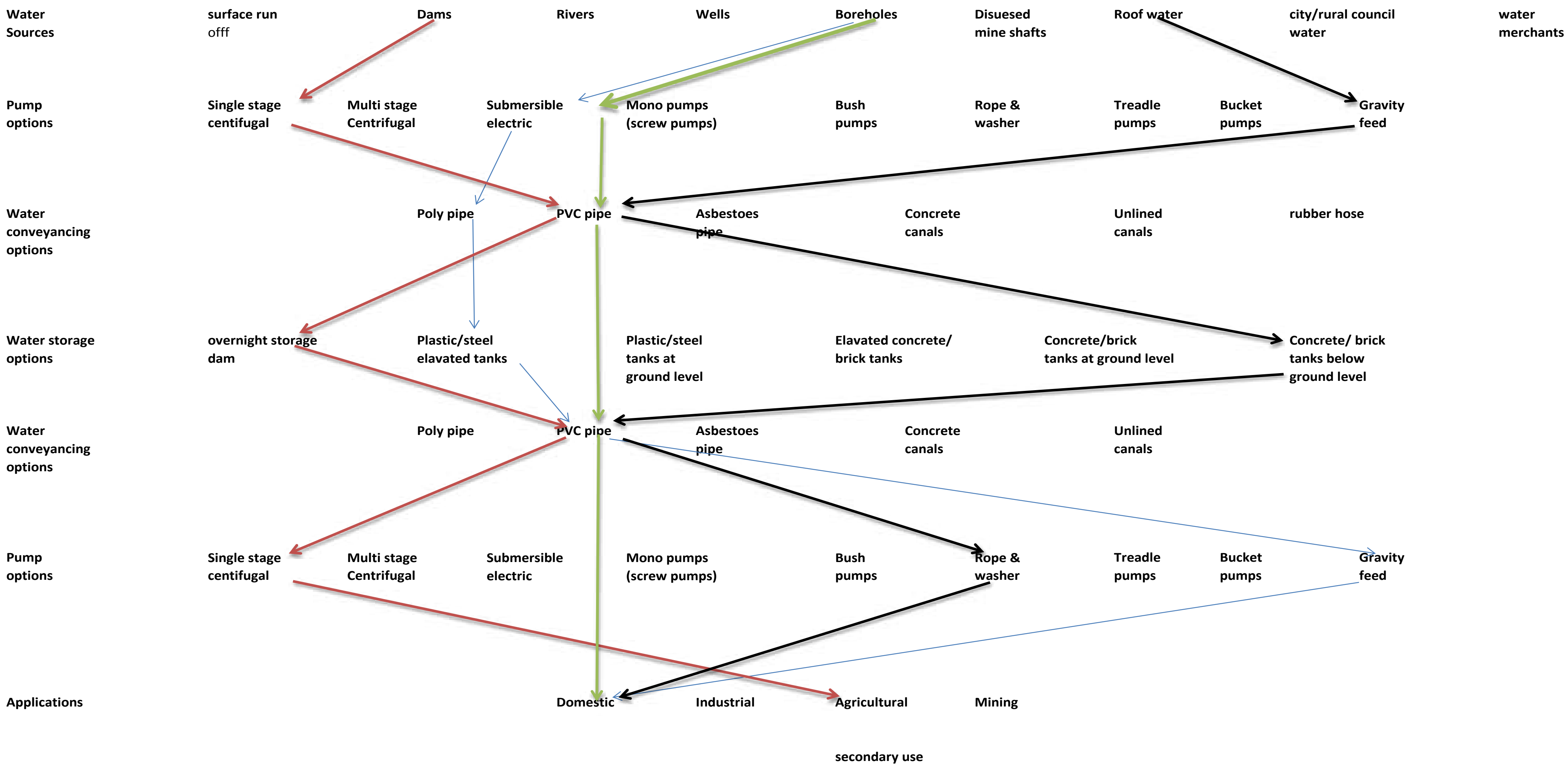
Table 8. Water storage methods used in Zimbabwe

Storage methods	Supply method from water source to the tank and then to the point of use	Comments	Sources
Elevated Plastic/steel tanks	A pump is used to lift water into the tank. Water is gravity fed to the point of	Method has become very popular in urban centres as councils are having difficulty in supplying adequate water to residents. Typical set up costs are US$1000 for a 5000L tank, stand and fittings. Steel tanks are largely being faced out as they have a	**Nazare (2014)**

	application.	relatively short operating life storage capacity is normally less than 10 000L. Standard tank sizes are 10 000L, 5000L, 2000L, and 1000L	
Ground level plastic/steel tanks	A pump is used to load the tank from source. Alternatively water is harvested from an elevated source (roof tops or upstream). Separate Booster pumps are used to elevate or pressurise the water to the point of application.	A popular method for those with unlimited access to electric power supplies as the method requires an electric booster pump (centrifugal pump) to supply water from the storage tank to the point of application.	**Nazare (2014)**
Elevated brick/mortar tanks	A pump is used to lift water into the tank. Alternatively water is harvested from an elevated source (roof tops or upstream) From the tank the water flows by gravity to the point of application. The tanks are normally constructed on elevated ground e.g. hillsides or on brick/stone pillars.	Method is widely used in urban areas, on farms and by large rural communities including schools in cases were power availability for running pumps is not reliable, or pump size is limited and yet application rate is large. The pump is then allowed to run even 24hours per day to keep the tank full. The tank is sited on an elevated piece of ground in relation to the point of application. The tanks have high storage capacity.	**Nazare (2014)**
Ground level	A pump is used to lift water	Method is widely used on farms and large rural communities	**Nazare (2014)**

brick mortar tanks	into the tank Water is gravity fed to the point of application.	including schools in cases were power availability for running pumps is not reliable, or pump size is limited and yet application rate is large. The pump is then allowed to run even 24hours per day to keep the tank full. The set up however requires a booster pump to lift or pressurise the water to the point of application. The tanks have high storage capacity.	
Below ground brick mortar tanks	Water is gravity fed from the source (e.g. house roofs) into the underground tanks. A pump is used to lift water from the tank to the point of application.	Low cost brick and mortar tanks are built below ground with the surrounding soil offering support to the structure. The arrangement however requires a pump to lift water from below ground to the point of application. This is not a popular method. Below ground tanks are cheaper than above ground versions but are rarely used in Zimbabwe.	**Nazare (2014)**
Overnight storage reservoir	A pump is used to load the overnight storage tank from the water source. A separate booster pump transfers water from the overnight storage dam to the point of application.	Method is popular on farms in which the primary source of water is distant. The farm would install a large pump at the primary source (river or dam) and pump water to a ground reservoir (which at times is lined with plastic to reduce infiltration). The reservoir is sited at some central location within the farm. A second pump is installed next to the reservoir to allow for distribution to the fields.	**Nazare (2014)**
Sand dams Ground water dams	Water stored and used during the dry season in semi arid areas	Reinforced concrete wall built across a seasonal river bed. Water is stored within the sand below ground level.	De Hamer et al (2006) Moyce et al. (2006)

Figure 8: <u>Water source, pumping, conveyancing and storage options on offer in Zimbabwe</u>



Source: Nazare (2014)

Table 9. Water conveyancing (transportation) methods. Source: Nazare 2014

Method of transporting water	Availability	Comments
Polypipe	Readily available in long lengths (100 m) in most hardware shops A large range of diameters and pressure ratings	Relatively low price. Short life if exposed to the sun. Cost ranges from $60-100 per 100m length Life is extended by burying under ground Light and easy to install Largely manufactured from recycled plastic by a good number of companies in the major cities in Zimbabwe
PVC pipe	Readily available in standard 6m lengths in most hardware shops Wide range of diameters to handle different discharge rates Wide range of pressure ratings to handle different operating pressures	Relatively low price. Short life if exposed to the sun. Life is extended by burying underground. Light and easy to install Most pipes manufactured by Pro Plastics and Prodorite in Zimbabwe with the rest being imported
Asbestos pipe	Available from one company called Turnal Asbestos with a wide countrywide distribution network	Relatively expensive. Heavy pipes in standard 4 m lengths Almost always buried underground. High pressure ratings
Aluminium pipe	Traditionally manufactured by one supplier countrywide in the form of Aluminium industries.	Relatively expensive. Available in standard 6 m lengths for the 50 and 73mm diameter pipes and 9 m lengths for the 150mm lines. Largely used by farmers for in field irrigation works as they are light and do not get degraded

	Importation is now an option	by exposure to the sun
Lined canals	Made from bricks and mortar	Applications are in schemes were the discharge rates are high (irrigation works). Need for skilled labour in designing, installation and maintenance
Unlined canals	Limited need for materials as the canals are not lined	Applications are in schemes were the discharge rates are high (irrigation works). Need for skilled labour in designing, installation and maintenance.

5.4.1 Transmission and distribution systems

Transmission and distribution systems are important because they determine the amount of water that reaches the crops. Transmission varies with the available technologies and ranges from the ordinary canals, lined canals, PVC, concrete and asbestos pipes. The method of transmission is usually an economic decision and is determined by the available resources. Transmission can result in water losses along the way (transmission losses) and these can reduce the efficiency of the irrigation system.

In most small-scale irrigation schemes, the method of transmission is low-cost. However, some of the methods used are generally associated with large transmission losses. The high costs associated to PVC piping makes them not suitable to many small-scale farmers. Table 9 summaries the methods of transmission that are available on the Zimbabwe market (Nazare 2014). For possible combinations, follow arrows with similar colours in Figure 8.

5.4.2 RWHI potential in Zimbabwe

There is a huge growth potential in RWH and small-scale irrigation in Zimbabwe (FAO 2010) as only a fraction of the water resources which can potentially be used for irrigation is currently being utilized (FAO 2010; Moyce et al. 2006). In addition, there are large areas of land which can be irrigated that are lying idle, or are only being used for rain-fed crop production, the irrigation potential for the country is estimated at 600.000 ha, (FAO 2000).). Water resources in Zimbabwe can be divided into two categories:

- Ground water resources (boreholes, wells), which have a potential of 3.0 Million ML (use m^3), but the current usage is only +/- 1.0 Million ML/yr (use m^3) (ZINWA 2014)

Surface water resources (rivers, dams, swamps), which have a combined storage of 8.7 Million m^3, but only 10 % yield of 3.7 Million ML is currently being utilised (ZINWA 2014), thus leaving 5 m^3 being under-utilised. Most formal irrigation schemes in the country depend on water stored in small and medium-sized dams e.g. Murara dam at Murara irrigation scheme, (FAO 2010). Other important water sources are boreholes/deep wells, direct river diversion, shallow wells/springs and sand abstraction (FAO 2010). In addition to the use of RWH, there is also a great opportunity for the cultivation of wetlands or dambos. Dambos cover a national area of 1.28 million ha, with~260 000 ha in small-scale farming most of which are located in the semi-arid areas (Institute of Water Sanitation and Development 2006). However, only around 20 000 ha of dambos are cultivated in the small-scale farming areas regardless of the fact that local research has confirmed the safety and advantages of dambo cultivation (Institute of Water Sanitation and Development 2006). In addition, there is still no enabling national legislation and policy to promote the sustainable use of these dambos (FAO 2015).

5.4.3 Conclusions and /or recommendations

In Zimbabwe, the net benefits of small-scale irrigation development and RWH tends to be positive because crop yields and income generation is higher compared to dryland cropping. There are several available practices and technologies. However, the technology selection will mainly depend on available resources, site characteristics, and training availed to farmers. Support by outside organisations such as government departments and NGOs are also important determinants. However, RWHI has not been given priority in funding due to the prevailing economic conditions. It is therefore recommended that more funding is made available in order to develop RWHI for smallholder farming areas of Zimbabwe. It is also recommended that efforts should be made to avail irrigation equipment at affordable costs.

6. Mapping of best practice of integration of rainwater harvesting and small-scale irrigation

6.1. Water harvesting, a case study from Masvingo Province of Zimbabwe

Problem statement

Water shortage was identified as the leading cause of low harvests leading to chronic food shortages. This is especially the case in agro-ecological regions IV and V which is characterized by low and erratic rainfall. Local NGOs promoted the use of various technologies to harvest water and apply it to the field so as to increase crop yields.

Technical solution

Various technologies were put in place in order to increase food security of vulnerable households (Table 1). Low cost irrigation technologies have been promoted by different NGOs across the country. In this case study we will evaluate the irrigation technologies used by farmers that are promoted by the NGO in Masvingo province in particular the drip kit system. It is important to note that over 70 000 low cost drip kit systems have been distributed by various NGOs since 2000.

Water harvesting

Farmers mainly use harvested water in perennial dams e.g., Magudu and Muremba dams) and seasonal dams e.g Nyamande dams. Farmers also have underground water sources such as boreholes and individual wells. In some cases, well organized farmers built weirs and pits in order to capture water. In this area, there are also a large number of farmers who have adopted the bare rock water harvesting method replicated from local farmers Mr Maseko Phiri (Figure 8) and Mr Chiwara.

Water conveyancing

Farmers mainly used buckets and tins to transfer water from the source. Farmers constructed their own system of pipes 50m from dam to take water to their gardens via siphon mechanism. There were drip kits available in some areas but there were not being used because of the labor required to ferry water from dam and putting it into drums. In well organized systems diesel and electric pumps are used though farmers had to contribute to the cost of power and maintenance. Gravity is also used to transfer water from the source to the storage reservoir or directly to the field.

Application

Farmers mainly used the bucket system. There were drip kits available in some areas but there were not being used because of the labour required to ferry water from dam and putting it into drums. Drip kits were allocated by the NGO but most of these are no longer in operation. Overhead and semi-portable sprinkler systems that had diesel and electric pumps are occasionally used by some small holder farmers.

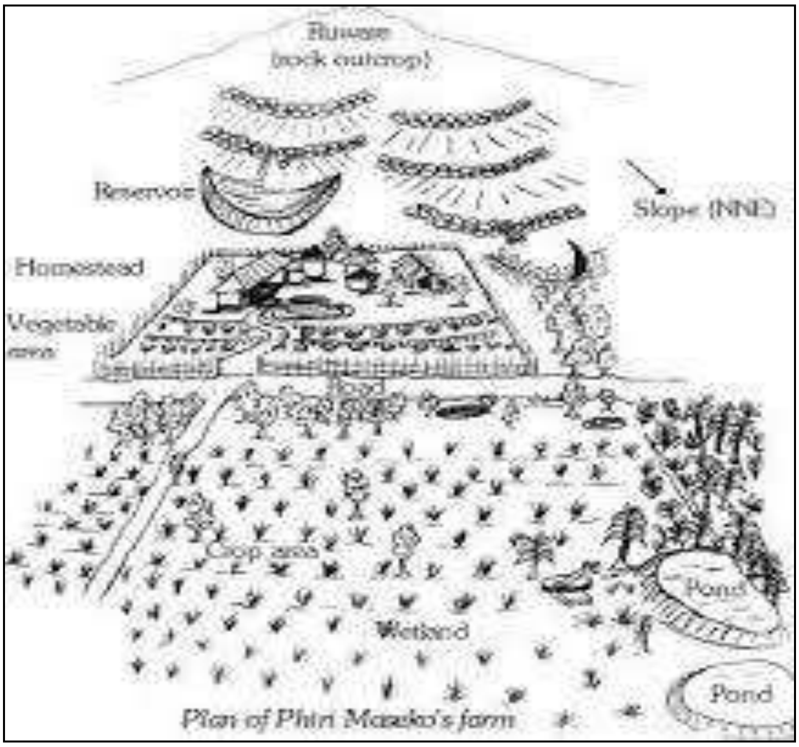


Figure 8: A schematic drawing of a water harvesting system in Zvishavane District.

Table 1: Rainwater harvesting and irrigation methods in Masvingo Province, Zimbabwe

District	METHODS USED			Challenges faced
	Harvesting	**Transmission**	**Application**	
Masvingo	-perennial dam -seasonal dam -borehole -individual wells -weir	-PVC pipes -buckets -cans/tins	-buckets -drip kits	-lack of training to utilize drip kits -labor intensive to put water in tank
Gutu	-bush pumps -small pool -individual wells -vlei	-buckets -tins/cans	-drip kit -buckets	-need for a reliable conveyance system to put in tank
Churumhanzi	-dams -wells -storage tank -borehole -sand dams	-lined canals -unlined canals -poly pipes -diesel pumps -electric pumps -elephant pumps	-buckets -drip kits -surface irrigation	-water is limited -siltation of dams -pumps broke down and no spare parts could be bought -some dams are leaking -poor design of scheme
Zvishavane	-seasonal stream -borehole -dams -core trench with weir -reseivor -rock outcrop	-gravity -engine and pump -pipes -electric pump -lined canals -gravity	-drip kits -buckets -overhead sprinkler -semi-portable sprinkler	-poor design of some schemes making it difficult to operate at full capacity -breakdown of pumps

Sources: FAO (2000); AGRITEX estimates; IWSD, (2006).

6.1.1 Financial profile (funding, investments, costs, social evaluation (if available)

The rain water Harvesting at Mr Phiri's homestead is an example of a farmer innovation where the farmer funded the whole programme with his own resources. However, information on the total cost of this innovation is not available. Farmers do not pay for the harvested water as raw water prices gazetted by the ZINWA give fee payment waiver for the development of small dams or weirs that harness less than 5 ML. These small dams do not require a permit but just registration.

6.1.2 Policy and regulation followed

The case study at Mr Phiri's homestead follows the general policies of the government of RWH for small-scale irrigation. Irrigation development is one of the major priorities for agricultural development in Zimbabwe. The current national Development strategy (ZIM ASSET) emphasizes the role of promoting RWH and small-scale irrigation for rural development. Irrigation development has been considered of high importance to the country by the governments in Zimbabwe (FAO, 2015) and as such the government focused irrigation development to the small-scale farming sector, through the promotion of farmer-managed smallholder schemes and the promotion of RWH.

6.1.3 Lessons learned (obtained results: stakeholder's acceptance, replicability, overcoming barriers, operational results).

- Small-scale farmers can sustain themselves through utilizing RWH for small-scale irrigation.
- The farming community, researchers and extension officers can learn a lot from farmer innovation, hence there is need to foster close linkage among these institutions.
- Training of beneficiaries and extension agents on principles and practices of improved technologies was needed. There was generally very low uptake of improved technologies by farmers because no training was conducted prior to the implementation of the technologies.
- Installation of demonstration pilot plot needed so that farmers can learn and appreciate systems with good potential.

- Maximum effectiveness the technology should suit the farmer and not the other way round. Participatory irrigation design should be implemented. Provision of water harvesting methods to poor households should be based on assessments of local demand and potential sources of water.
- To serve vulnerable farmers from ferrying water for long distances there is need for improved RWH e.g., through constructing reservoirs around strategic points. Water conveyance mechanisms have to be installed for some gardens.
- Education and awareness campaigns are essential. There is need to completely revolutionise the way implementation was done in the previous phases. A methodology has to be developed on a step by step procedure to be followed in implementing community projects especially technical projects such as drip irrigation.

6.2 Case study 2

6.2.1 Dambo water harvesting for small-scale irrigation in Chiota small-scale farming area, Zimbabwe

Dambos are seasonally saturated, grasslands which are a valuable resource for agricultural purposes due to availability of water and high fertility (McCartney *et al.* 2005). In the smallholder farming area, dambos are important resources that is used for growing a variety of crops, among them vegetables and cereals. The recent climate-change and variability associated global phenomena, mid-season dry spells and frequent droughts (Figure 9) have resulted in poor yields under rain-fed cropping systems in most small-scale farming areas and this has forced farmers to resort to use of dambos. In Chiota smallholder farming area, many farmers have abandoned cultivating upland fields, for dambos as a coping and adaptation strategy. The cultivation of dambos amongst smallholder communities has also been reported in several African countries including Malawi (Mloza-Banda 2005; Rwanda (SADC 2001), and Zambia (Shimada 1994; Kuntashula *et al.* 2006).

Figure 9. Wilting and poor maize crops from upland fields in Chiota small-scale farming area

In many arid and semi-arid regions, the capacity of dambo to retain moisture for long periods and sometimes throughout the year and high fertility associated with these wetlands have resulted in their widespread use for cultivation. Dambos are strategic resources worth exploiting for food production to cope with hunger that is manifested particularly during drought years. Dambos provide a good regular supply of crops, among them being vegetables, rice, and maize which are easily irrigated using water which is harvest in the dambos (Figure 10). For poor rural households that are short of food, dambos can provide a life-saving safety net and they represent a development opportunity.

Figure 10. Healthy crops growing in dambo gardens

6.2.2 Financial profile

Funding dambo farming is done by the individual farmers. Dambo gardens are individually owned and operated. Costs associated with dambo cultivation included fencing, digging of small dams and wells, money for inputs (seed, fertilizers), herbicides.

In Chiota dambos are intensively cultivated and the majority of the famers in Chiota depended on growing crops in dambo gardens for a livelihood. The Dambo Research Unit (1987) reported that over 30 different crops are grown in dambos in Zimbabwe. The crop acreage is determined by several factors, among them cost of seed, fertilisers and market price (Shimada 1994). In Chiota, dambo gardens provided the single largest source (80%) of income to meet household needs such as paying for school fees, buying fertilizers, agrochemicals, and fencing (Dambo Research Unit 1987; Shimada 1994; Mabeza and Mawere 2012). Mabeza and Mawere (2012) reported that 85.4% of the households in Seke survived on market gardening and besides providing for the basics, farmers could also afford to purchase luxuries, e.g., satellite TV and mobile phones. Theoretically farmers get significant income from the sale of their vegetables. However, because of challenges associated with marketing of their produce, for example lack of transport, poor market prices, middlemen, deterioration of produce before it gets to the market to name a few of the challenges, the earnings of most of the farmers low. It is therefore recommended that farmers should get assistance in forming market linkages.

6.2.3 Involved policy and regulation

The land capability classification system of Zimbabwe places dambos in Class V, which denotes that the soils are not suitable for cultivation (Ivy 1981). In addition, dambo cultivation was prohibited during the colonial times due to environmental hazards associated with their utilization, i.e. soil erosion (Rattray et al. 1953). The utilization of dambos was governed by the Natural Resources Board (NRB) which has been replaced by the Environmental Management Act of 2007. Though the farming potential of these seasonal wetlands is high, use was restricted through various prohibitive measures enshrined in the legislation. Nonetheless, these legislations were largely ignored country-wide. After independence in 1980, the cultivation of dambos increased largely due to frequent crop failures in upland fields and relaxed policing of legislation. Climate change and variability has resulted in increased frequency of crop failure in upland fields and, consequently, increased food insecurity among the smallholder community in Zimbabwe and in response smallholder farmers have resorted to the cultivation of dambos where there is available water.

6.2.4 Lessons learnt

Cultivating dambos has resulted in significant improvement of household food security as households who cultivated dambos harvested enough maize for their household needs (Dambo Research Unit 1987, Orr and Ritchie 2004). As such the government has started offering support service to farmers who practice small-scale irrigation in dambos. Dambo gardens also provided additional foods such as sweet potatoes and Irish potatoes for household consumption which ensure household food security and a diversity of foods. The Dambo Research Unit (1987) reported that during the drought year of 1969/1970, 84% of the households who cultivated dambos had enough food, while only 21% of those who cultivated uplands had enough food.

The results from Chiota can possibly be replicated to other regions in the country. In Zimbabwe dambos occupy 1.28 million ha, and they provide a readily available source for water for small-scale irrigation. Potential barriers the utilisation of dambos for irrigation in the small-scale farming sector include and challenges of land degradation and erosion and the potential drying up of streams and rivers as dambos form the headwater of most rivers in Zimbabwe. However, there is need for more research to evaluate the environmental sustainability of dambo utilization.

6.3 Analysis of best practice case studies

The use of RWH and small-scale irrigation has a great potential to improve crop production in semi-arid small-scale farming sector in Zimbabwe. RWH and irrigation using small wells and dams from dambos is an untapped resource which can change the livelihoods of most smallholder farmers. Moa-Banda (2005) suggested that the significance of dambos for the livelihoods of the populations having access to them is disproportionately greater than that suggested by their area. This suggests that utilising dambos can potentially benefit more people than those cultivating them. It is therefore proposed that we should put in place policies that promote RWH and irrigation development for small-scale areas especially where dambos are available.

6.4 Conclusions and/or recommendations

The promotion of RWH and small-scale irrigation development has the potential to change livelihoods in the scale farming areas. Therefore these practices should be developed and promoted to benefit the smallholder farmer.

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APPENDICES

Appendix 1. Questionaires

Appendix 1a

PRIVATE COMPANIES QUESTIONNAIRE No.

My name is ....I am conducting a study on behalf of the University of Zimbabwe AFRHINET project. AFRHINET is an ACP-EU technology transfer network on rainwater harvesting and irrigation management for sustainable dry land agriculture, food security and poverty alleviation in sub-Saharan Africa. All responses will be kept confidential and will be used for purposes of this study only.

SECTION 1

Name of organisation

Name of respondent

Respondent position in company

Location of company (city)

Period involved with irrigation technologies

Questionnaire ID:

Interviewer name
(surname first):

Interviewer ID :

Date of interview:

A. GENERAL INFORMATION

1. How long have you been in the irrigation industry?

....

....

2. Do you provide service to farmers in the area of RWHI?

....

....

3. What are the products and services that you provide to the smallholder farmers?

....

....

....

....

....

....

4. Do you manufacture and/or retail irrigation products?

....

....

5. What is your source of raw materials for irrigation equipment? Do you recycle or import?

....

....

....

....

6. What is your source of financing?

....

....

....

7. What type of equipment do you deal with? (*tick all that apply*)

☐ overhead ☐ underground ☐ centre pivots ☐ drip ☐ solar others

specify...
....

8. Why do you prefer the above types of equipment and not the other?

....
....
....
....

....
....

B. MARKETING

9. What are the main types of products bought by

a) large commercial farmers

....
....
....

b) commercial A2

....
....
....

b) small scale farmers A2

....
....
....

c) communal farmers

....
....
....

10. Which time of the year are sales of irrigation equipment high?

....
....

11a. How have your sales volumes changed over the past the past five years?

....
....

b. What factors do you attribute the changes to?

....
....
....
....

12. How do you market your products?

☐ field days ☐ agricultural shows ☐ trade fairs ☐ media ☐ extension

others specify..
.

13. Why do you prefer the above types of marketing method?

....
....
....
....
....

C. IRRIGATION DEVELOPMENT

14. Do you offer credit facilities to smallholder farmers?

yes ☐ no ☐

15. If yes, what are the guarantees and/or collateral required?

....
....
....
....
....

16. Do you think credit facilities will increase sales?

....
....

17. What recommendations do you have to improve access to credit?

....
....
....

18.What challenges/problems are associated with credit?

....
....
....
....

19. In your opinion, how can you improve uptake of irrigation technologies by the smallholder farmers?

....
....
....
....
....

20. What are the needs of farmers as far as irrigation equipment and technologies in areas of;

a) harvesting irrigation water

....
....
....
.... b) transmission of irrigation water to the field?

....
....
....
....
....
....

c) application to the field

....
....
....
....
....

21. What are you doing to meet the needs of the farmers (A2 and communal)?

....
....
....
....

22. What is the role of research in

a) Identifying the needs of farmers?

....
....
....

b) Determining appropriate technology required by local smallholder farmers?

....
....
....
....

....
....

....
....
....

D. INTERACTIONS WITH STAKEHOLDERS

23. Do you collaborate with other stakeholders to improve uptake of your products?

....
....
....
....

24. Do you collaborate with local research institutions? If yes which areas?

....
....
....
....

Do you collaborate with local research institutions? If yes which areas?

....
....
....
....

25. How much input do farmers and other users put into determining the products you import?

....
....
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26. What drives your decision to import certain irrigation products?

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D. CHALLENGES

27. What are the challenges faced by farmers in RWH and irrigation from your perspective?

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28. Do you have any possible solutions to the challenges faced by farmers?

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29. What would you recommend to research and government organisations with regards to smallholder farmer water harvesting and irrigation management in Zimbabwe?

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Appendix 1b

NGO KEY INFORMANT **QUESTIONNAIRE No.** [ ]

My name is ....I am conducting a study on behalf of the University of Zimbabwe AFRHINET project. AFRHINET is an ACP-EU technology transfer network on rainwater harvesting (RWH) and irrigation management for sustainable dry land agriculture, food security and poverty alleviation in sub-Saharan Africa. All responses will be kept confidential and will be used for purposes of this study only.

SECTION 1

Name of organisation; Action Contre la Faim

Name of respondent: Karl Riber

Position of respondent in organisation: Country Director

Location of company (city): Harare

Period involved with irrigation programmes: 2010-2012

Questionnaire ID: [ ]

Interviewer name (surname first): [ ]

Interviewer ID : [ ]

Date of interview: [ ]

SECTION 2: BACKGROUND

1. Which provinces does your NGO cover? (Give districts and wards if available)

Masvingo, Mash East, Mash Central

....

2. What types of programmes are offered by your NGO?

Nutrition, and also Water and Sanitation . We used to do Food Security and Livelihoods, but not anymore.

3. Do you offer RWH and irrigation programmes?

yes ☐ no ☐

4a. Do you offer any training or extension services for irrigation programmes?

yes ☐ no ☐

b) If yes, what kind of training do you offer?

....

5. How many water harvesting and/or irrigation projects have you implemented in the last 10 to 15 years?

The only irrigation we have done has been very small scale, in nutrition gardens, and we stopped such projects in 2012.

....

SECTION 3. RAINWATER HHARVESTING AND/OR IRRIGATION PROGRAMMES

6. Project location and title		Period of project	Number of beneficiaries	RWHI used/promoted			Average size of land irrigated
				Harvesting	Transmission	Application	
	e.g Odzi	2010-2014	300	-tanks -rivers -wells -earth dams -dams	-canals -pipes	-drip	3ha
1	Manicaland	2008-2012	1000		Canals in nutrition gardens from the handpump sites		1 ha
2	Masvingo	2008-2012	1000		Canals in nutrition gardens from the handpump sites		1 ha
3							
4							

7. From farmer perspectives, what limitations and/or challenges are there in implementing irrigation technologies for:

a) RWH?

Maintenance. Also it was difficult to get our donors interested in this when we were doing projects where this would have been useful. To be economically feasible, it needs to be done at sites where multiple people can benefit (schools, hospitals) and there were challenges in getting agreements on this and also on ensuring the tanks would be monitored and maintained, so we ended up not doing them.

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b) transmission to the field?

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c) application to the field?

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8. Have the programmes you implemented been sustainable after the projects have ended?

For a while, but we have seen the majority of gardens being underutilized, usually due to pump breakdowns that the garden groups don’t repair.

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9. For irrigation programmes that are still running, do you have an exit strategy. Elaborate on this.
N/A

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10. Explain livelihood and household food security changes that the different irrigation projects have brought about in their different areas.

PROJECT LOCATION	**LIVELIHOOD CHANGES**
e. g Odzi	-HHD income increased from $30 per month to $500 -all children now going to school etc.
	I don't have this data, and our former food security staff has now left the organization.

11. For each irrigation programme, do u think it was successful and why?

Project	**Was it successful? Yes/No**	**Reasons**

12. If u were to run another project on RWH what would you promote in terms of

a) RWH methods

....

....

b) transmission

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c) application

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13. For each irrigation project, what were the main lessons learnt?

PROJECT LOCATION	**MAIN LESSONS LEARNT**
e. g Chiota	-more training is needed in equipment maintenance

14. Did you consider gender stream lining in your projects? If yes, how was it achieved?

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15. Elaborate on any water conflicts that could affect small scale irrigation in your project locations?

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16. What is being done in the specific areas to solve the conflicts?

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17a. Do you have mid and end of project evaluated reports for the RWHI projects that you implemented?

Yes ☐ No ☐

b. Is it possible for us to get copies?

Yes ☐ No ☐

Appendix 1c

HOUSEHOLD QUESTIONNAIRE

QUESTIONNAIRE No. [ ]

My name is ....I am conducting a study on behalf of the University of Zimbabwe AFRHINET project. AFRHINET is an ACP-EU technology transfer network on rainwater harvesting and irrigation management for sustainable dry land agriculture, food security and poverty alleviation in sub-Saharan Africa. All responses will be kept confidential and will be used for purposes of this study only.

SECTION 1a: GENERAL INFORMATION

Household name/ID [ ]

Respondent surname [ ]

Respondent forename (s) [ ]

Respondent gender 1=male [ ] 2=female [ ]

SECTION 1b:

Questionnaire ID: [ ]

Interviewer name (surname first): [ ]

Interviewer ID : [ ]

Date of interview: [ ]

SECTION 2: HOUSEHOLD DEMOGRAPHICS		
2.1	Is respondent household head? *1=yes 0=no*	
2.2	If not, relation to household head *1=spouse 2=child* *3=sibling 4=* *5=daughter in law 6=parent* *7=other (specify--------)*	
2.3	What is the sex of the *1=male 2=female*	
2.4	Age of household head *1=10-19years 2= 20-29years 3=30-39years* *4= 40-49years 5= 50-59years 6 = 60+years*	
2.5	Marital status of household head 1=single 2=married 3=divorced 4=widowed 5=separated 6= other (specify----------------)	
2.6	If married, age of spouse *1=10-19years 2= 20-29years 3=30-39years 4= 40-49years* *5= 50-59years 6 = 60+years 0=none*	
2.7	Highest education level attained by household head *0=none 1=primary 2=ZJC 3=O level 4=A level 5=diploma/vocational* *6=degree 7= other (specify-------------------------------)*	

SECTION 1c: LOCATION ID

Name of village:	
Ward	
District	
Province	
GPS coordinates	

2.8	How many children and adults are currently living in the household?	
2.9	How many are male?	
2.10	How many are female?	
2.11	What are the main sources of the household income? *1=sell of garden crops* *5=formal employment* *2=sell of field crops* *6=remittances from relatives* *2=sell of livestock* *7=others specify* *3=borrowing* *4=craft and art*	1. 2. 3.

SECTION 3: LAND HOLDING								
		Do you have the following land? *1=yes 0=no*	**Total area (ha)**	**Area currently being used (%)** *1=0-10%* *2=11-30%* *3=31-50%* *4=51-80%* *5=81-100%* *99=not applicable*	**Period utilizing area** *1=>5years* *2=5-10years* *3=10-20years* *4=<20years* *99=not applicable*	**How much of the area is under irrigation** *1=0-10%* *2=11-30%* *3=31-50%* *4=51-80%* *5=81-100%* *99=not applicable*	***What type of irrigation is used* the area.**	**Main crop grown**
3.1	Garden							
3.2	Field							
3.3	Pasture							
3.4	Orchard							
3.5	Other (specify)							

SECTION 4: CROP PRODUCTION							
		Did you produce *1=yes 0=no*	Area cultivated (ha)	Was the crop irrigated *1=yes 0=no*	Irrigation method	Total output in last season (tonnes)	Purpose of production *1=household consumption* *2=income* *3=both* *4=other (specify)*
4.4	Maize						
4.5	Sugar bean						
4.6	Tomatoes						
4.7	Green leafy vegetables						
4.8	Onion						
4.9	Other specify						

SECTION 5: IRRIGATION		
5.1	Do you irrigate any of your crops and/or pasture *1=yes 0=no*	
5.2	Who does most of the irrigation *1=male 2=female*	
5.3	What is your main source for irrigation water? *1=dam 2=sand dams 3=stream/rivers 4=open well 5=RWH from roof tops 6=rainwater harvesting from bare rock 7=others (specify)*	
5.4	What is the capacity of you water source (give dimensions)?	
5.5	Is the source 1= perennial or 2= seasonal?	
5.6	What is the method of transmission to field ? *1= canals 2= pipes 3= buckets /cans 4=others specify*..	
5.7	What is the method of application to field ? *1=cans/buckets 2= flood 3= sprinklers 4= drip 5= others specify*	
5.7	How far is the water source form the field?	
5.8	Do you take turns to irrigate? *1=yes 0=no*	
5.9	a. Do you pay for water. *1=yes 0=no* b. if yes, how much is the water levy.($)..	
5.10	What strategies can you use to improve delivery to your field?	

SECTION 6: IRRIGATION DEVELOPMENT

6.1	Where do you get information on RWH and irrigation? 1=yes 0=no Field days/agricultural shows ☐ television ☐ Radio ☐ newspaper ☐ Community gathering ☐ Extension workers ☐ NGOs ☐ others (specify).......................................	
6.2	Other than the irrigation methods you use, what other method are you aware of?	
6.3	Have you seen these technologies being used anywhere?	
6.4	Are you willing to try other methods?	
6.5	In your opinion, what is the best method of irrigation?	

SECTION 7: CHALLENGES

7.1 What are the main challenges/constraint to the current irrigation system that you are using?

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7.2 How much support are they getting from other institutions/stakeholders (research or support)

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7.3 How easily available is the irrigation equipment

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7.4 Training needs (trained in using water pumps...or manuals written in vernacular)

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7.5 a Are backups and spares for irrigation equipment readily available?

0=no ☐ 1=yes ☐ 2=sometimes ☐ 3=not sure/don't ☐
know

7.5 b Can the equipment easily be repaired locally?

0=no ☐ 1=yes ☐ 2=sometimes ☐ 3=not sure/don't ☐
know

7.6 What would you want to see done to improve in the current irrigation system that you use?

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SECTION 8: RESOURCE ENDOWMENT

a. Do you own the following

			Do you own *1=yes* *0=n0*	**Total number owned**
8.1	housing	Asbestos/tiled shelter		
8.2		Thatched shelter		
8.3	transport	car		
8.4		oxcart		
8.5		tractor		
8.6	implements	plough		
8.8		hoe		
8.8		wheelbarrow		
8.9	livestock	cattle		
8.10		goats		
8.11		poultry		
8.12	Communication	radio		
8.13		television		
8.14		Cell phone		

Appendix 1d

NGO KEY INFORMANT **QUESTIONNAIRE No.** [ ]

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SECTION 1

Name of organisation [ ]

Name of respondent [ ]

Position of respondent in organisation [ ]

Location of company (city) [ ]

Period involved with irrigation programmes [ ]

Questionnaire ID: [ ]

Interviewer name (surname first): [ ]

Interviewer ID : [ ]

Date of interview: [ ]

SECTION 2: BACKGROUND

1. Which provinces does your NGO cover? (Give districts and wards if available)

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2. What types of programmes are offered by your NGO?

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3. Do you offer RWH and irrigation programmes?

yes ☐ no ☐

4a. Do you offer any training or extension services for irrigation programmes?

yes ☐ no ☐

b) If yes, what kind of training do you offer?

....

....

....

....

5. How many water harvesting and/or irrigation projects have you implemented in the last 10 to 15 years?

....

SECTION 3. RAINWATER HHARVESTING AND/OR IRRIGATION PROGRAMMES

6. Project location and title		Period of project	Number of beneficiaries	RWHI used/promoted			Average size of land irrigated
				Harvesting	Transmission	Application	
	e.g Odzi	2010-2014	300	-tanks -rivers -wells -earth dams -dams	-canals -pipes	-drip	3ha
1							
2							
3							
4							

7. From farmer perspectives, what limitations and/or challenges are there in implementing irrigation technologies for:

a) RWH?

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b) transmission to the field?

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c) application to the field?

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10. Explain livelihood and household food security changes that the different irrigation projects have brought about in their different areas.

PROJECT LOCATION	LIVELIHOOD CHANGES
e. g Odzi	-HHD income increased from $30 per month to $500 -all children now going to school etc

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13. For each irrigation project, what were the main lessons learnt?

PROJECT LOCATION	**MAIN LESSONS LEARNT**
e. g Chiota	-more training is needed in equipment maintenance

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15. Elaborate on any water conflicts that could affect small scale irrigation in your project locations?

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16. What is being done in the specific areas to solve the conflicts?

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17a. Do you have mid and end of project evaluated reports for the RWHI projects that you implemented?

Yes ☐ No ☐

b. Is it possible for us to get copies?

Yes ☐ No ☐

Appendix 2. Description of Zimbabwe's Natural Regions. Vincent and Thomas, (1960)

Region I:	In the Eastern Highlands, covers less than two percent of Zimbabwe. Annual rainfall is above 1,000 mm. A combination of high rainfall, low temperatures and high altitude makes the region suitable for afforestation and intensive diversified agriculture including the growing of tea, coffee and deciduous fruit, as well as intensive livestock production.
Region II:	Covers the north eastern Highveld and is about 16 percent of the country. Reliable rainfall, 750-1,000 mm, falls between November and March. The area is suitable for intensive cropping and livestock production.
Region III:	Is mainly in the midlands and covers about 18 per cent of the country. Annual rainfall is 500-700 mm which is characterised by mid-season dry spells and high temperatures. The region is suitable for drought resistant crops, livestock and semi-intensive farming.
Region IV:	Is in the low-lying areas in the north and south of the country, and occupies about 37 percent of Zimbabwe. Rainfall is 450-650 mm. The region is characterised by periodic seasonal droughts and severe dry spells during the rainy season. The area is unsuitable for dry land cropping but good for livestock production.
Region V:	These are lowland areas below 900 m, covering 27 percent of the country. The region receives erratic rainfall which is below 650 mm. It is suited to extensive livestock production and game ranching.