Green Climate Fund: Climate Resilient Irrigation in Southern Zimbabwe - Mzingwane, Runde and Save River Basins

CRIDF Activity Name and Code: Green Climate Fund Proposal, IF02-008

Deliverables #: D03a

Version: Final

2 April 2017

Quality Assurance Checklist

In preparing this document CRIDF can confirm that it has followed CRIDF's internal general procedures, including appropriate CRIDF generic scope of work and that it has undergone appropriate quality assurance (QA) and quality control (QC) procedures as detailed in CRIDF's QA manual. Furthermore, CRIDF can confirm the applicable specific internal process and procedures have been followed including:

- CRIDF's Cost Benefit Assessments (CBAs) guideline have been applied as appropriate;
- CRIDF's Gender Equality and Social Inclusion (GESI) guidelines have been applied as appropriate;
- CRIDF's Climate vulnerability mapping methodology has been applied as appropriate;
- CRIDF's Climate Change Risk Assessment (CCRA) protocol have been applied as appropriate;
- CRIDF's Procurement guidelines have been followed as appropriate;
- CRIDF's Screens as appropriate.

Lead Author(s)	Herbert Nyakutsikwa	CRIDF QA'd:	Leonard Magara	CRIDF QC'd:	Rebecca Ann Brooks	CRIDF Approved:	Charles Reeve
Date:	03/05/2017	Date:	09/05/2017	Date:	11/05/2017	Date:	11/05/2017

Disclaimer

The British Government's Department for International Development (DFID) financed this work as part of the United Kingdom's aid programme. However, the views and recommendations contained in this report are those of the consultant, and DFID is not responsible for, or bound by the recommendations made.

CRIDF

Contents

List of Figures

List of Tables

List of Acronyms

Acronym	Long Form
AER	Agro- Ecological Regions
CBA	Cost Benefit Analysis
CCRA	Climate Change Risk Assessment
CIMMYT	International Maize and Wheat Improvement Centre
CRIDF	Climate Resilient Infrastructure Development Facility
CSA	Climate Smart Agriculture
DFID	Department for International Development
ECRAI	Enhancing the Climate Resilience of Africa's Infrastructure
EU	European Union
FAO	Food and Agricultural Organization
GEF	Global Environmental Facility
GESI	Gender Equality and Social Inclusion
IFAD	International Fund for Agriculture Development
IMC	Irrigation Management Committee
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
LGP	Length of Growing Period
MSD	Meteorological Services Department
PSIP	Public Sector Investment Programme
RUSED	Rural Sustainable Energy Development
SAMP	Seeds and Markets Project
SDC	Swiss Agency for Development Cooperation
SMIDSP	FAO's Smallholder Micro-Irrigation Development Support Programme
ZESA	Zimbabwe Electricity Supply Authority
ZINWA	Zimbabwean National Water Authority
ZMSD	Zimbabwe Meteorological Services Department

Executive Summary

The agriculture sector contributes upto 15 percent of Zimbabwe's GDP. It is the backbone of the country's economy and a pivotal driver for industrial activity. It is the basis of the direct and indirect livelihoods of almost 70 percent of the country's population, making it fundamental to reducing poverty and inequality, especially because of its increasing significance since 2000. Those dependent on agriculture are largely smallholder farmers in rural areas working on communally owned land (often less than a 2ha plot per household). The majority of rural smallholders practice rainfed agriculture, and are thus dependent on the quality of the rainy season to produce crops, in the absence of infrastructure and other services. If the rainy season is not effective or their water sources have depleted (i.e. rivers and boreholes have dried up), smallholders are often forced to practice 'stream-bed cultivation' (planting crops in river-beds), which contributes to increased erosion and siltation in rivers. The majority of the poorest smallholders reside in southern parts of Zimbabwe, in Manicaland, Masvingo and Matabeleland South provinces, which lie in the Mzingwane, Runde and Save river basins. Biophysically speaking, these are the areas least suitable for rainfed agricultural production (AERs IV and V). They receive the least amount and most erratic rainfall patterns, are subject to the highest temperatures in the country (which increase PET), and experience the shortest growing periods.

Climate change has been observed to have negatively impacted on variables relevant to agriculture in Zimbabwe. These include: increasing temperature, decreasing total annual precipitation (and increasing PET), increasing variability in rainfall distribution (with increasing frequency and length of mid-season droughts), increasing frequency and severity of extreme weather events, such as floods and droughts, decreasing river run-off, shifting AERs (showing an increase in areas less suitable for rainfed agriculture) and shrinking growing periods. Projections suggest Zimbabwe will continue to experience adverse changes due to climate change, and impacts will likely increase in intensity overtime. Both observed and predicted trends indicate southern Zimbabwe will be the most affected, where the poorest rural farming communities reside.

In southern Zimbabwe, climate impacts, poverty and exposure collide, resulting in vulnerability. Investment in irrigation for climate resilience, as the cornerstone of an adaptation strategy, presents an opportunity to provide a regular water supply in the face of climate change. Designed in response to climate change, irrigation can supplement rainfall during mid-season droughts (which are predicted to intensify under climate change) by collecting rainfall from short, sharp storms that are normally (and increasingly) experienced in the cropping season, and disbursing the collected water in a controlled manner when needed through irrigation. It provides an opportunity to stop a cycle of food humanitarian assistance, which is estimated to be US$30 million per year. Irrigation also enables annual double cropping, allowing crops which have not previously been grown to be introduced in certain areas (e.g. wheat and beans), thus generating higher annual yields and increasing revenues. It can also provide communities with an off-river water supply, which will reduce the need to practice stream-bed cultivation and give communities the ability to contribute to water resource protection, thus making them part of the solution. Irrigation has the added benefits of improving incomes, employment and general livelihoods for the poor while contributing to environmental conservation.

Numerous donors have implemented irrigation projects in Zimbabwe, as well as projects relating to solar installation to power irrigation schemes. It is significant to note that some are being implemented at the same time, which should allow for synergies, and many of them have other components, for example, market linkages, which compliment irrigation components, or vice versa, and form a crucial part of a climate resilient approach.

From an analysis of existing and previous irrigation efforts, key lessons that have been identified to take forward in designing and implementing irrigation investments include:

- Irrigation design needs to be climate resilient (climate-proofed water abstraction and storage infrastructure) to withstand flood damage and incorporate more efficient and appropriate irrigation technology e.g. alternatives to flood irrigation;
- Even though larger equipment may be more effective, it does not appear that large and complex farm machinery is best suited to the context. Large machinery may also cause problems in terms of shared ownership. Small family held equipment still appears to be the most suitable; this must, however, be complimented by shared bulk water supply infrastructure;
- Market linkages should be an inherent part of any irrigation intervention, focusing on both supply and demand sides of the value chain. Direct involvement of businesses in irrigation schemes is highly recommended e.g. distributors and seed suppliers should be engaged at the earliest stage possible to promote markets and provide an exit strategy for the project. A PPP arrangement is proposed as a model to consider;
- Training and capacity building on all project components e.g. provision of equipment, strengthening IMCs, market analysis etc. should be provided in order to teach farmers/IMCs how best to utilise infrastructure and encourage ownership;
- Financial viability is not just a design consideration, but is also a key sustainability consideration, thus it is necessary to provide time and resources in the project budget for IMCs to develop their capacity to plan appropriately for successful O&M. CRIDF's Bikita Kufandada pilot project provides a useful example of financial structuring to achieve sustainability;
- Institutional strengthening, at the community level and across government and the private sector, is integral to irrigation interventions in order for the investment to be sustained and utilised by the community in the long-term. This is predominantly done through IMCs, and the creation of a constitution and 'maintenance fund'; and

An irrigation system typically comprises of the following infrastructural components: development of a water source, abstraction from a water source, a conveyance system, night/in-field storage, infield distribution (also called 'irrigation technology') and storm and flood storage facilities. Ancillaries include access roads and buildings for administration, storage and sheds. To collect baseline information on the status of irrigation in southern Zimbabwe, a sample of 16 irrigation schemes across the Mzingwane, Runde and Save river basins were visited. While the schemes are in various operational states, they experience viability problems, generally in terms of physical infrastructure and operation. The main problems identified are:

- Poor performance due to poor design, such as pump houses situated below the flood line of rivers, and failure to incorporate storm water management and erosion control measures;
- Failed pumping systems due to breakdowns or power outages, or disconnections due to power debts;
- Failed water conveyance system and broken distribution pipes and canals and associated control structures;

- Irrigation infrastructure damaged by both domestic and wild animals, such as elephants; and
- More recently, failure due to substandard materials and equipment being used and poor design and construction procedures.

A three-step methodology was employed to select irrigation sites for intervention. First, all known irrigation schemes in the target area (Save, Runde and Mzingwane river basins) was collated from the DoI's Irrigation Masterplan and cross-referenced with other sources such as CRIDF and the AfDB funded Shared Watercourse Support Project. This list identified over 500 irrigation sites. Second, eligibility selection criteria were determined in order to narrow down the number of schemes to deserving cases. The criteria selected were validated by findings from desk-based research and site visits, as well as from consultations with relevant key stakeholders. It includes criteria covering size, number of beneficiaries, land availability and soil suitability, water availability, and vulnerability. Thirdly, the selection criteria were applied to the list of 500 plus irrigation sites, to result in the proposed intervention sites. As part of this process, irrigation schemes were screened against those that are already being implemented under various other donor and public initiatives.

While recognising each irrigation scheme requires a site-specific design due to specific biophysical, social and economic circumstances, for the purposes of this study, irrigation schemes with similar characteristics, such as similar water demand and pressure requirements, have been 'banded' to calculate infrastructure requirements, such as conveyance and pump/motor size. Per band, the most appropriate irrigation technology was then considered, and water abstraction and storage infrastructure designed and 'climate proofed'. Each irrigation scheme representative sample from each 'band' was then designed, and individually costed. A representative sample of each band is presented in this report.

Corresponding with infrastructure investments is infrastructure sustainability. This report presents three fundamental requirements as key to achieving long-term sustainability, namely: a competitive service provider and buyer markets, strengthened institutional arrangements and government support.

Table 1 below shows the proposed selected scheme totals per basin and their associated costs.

Table 1: Scheme costs per basin

Basin	Number of schemes	Irrigation Hectares	Number of Beneficiary Households	Irrigation Cost USD	Solar Cost USD	Grid Connection Cost USD	Total USD
Mzingwane	10	502	2331	4611550	1275000	220000	6106550
Runde	21	952	3685	8938000	2925000	440000	12303000
Save	21	1589	6751	14226050	2625000	420000	**18016050**
TOTAL	52	3043	12767	27775600	7,500,000	1,110,000	**36,071,350**

1. Agriculture, climate change and irrigation in southern Zimbabwe

This chapter presents the agricultural context of southern Zimbabwe; agriculture being the most important sector for livelihoods in Manicaland, Matebeleland South and Masvingo provinces. It then briefly outlines the climate change scenario, before presenting the impacts of climate change on agriculture and food security. It predominantly summarises analyses from a World Bank study[1]: *Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector*, which provided major input in relation to water and agriculture in the soon to be released National Climate Policy (herein referred to as the World Bank study). Finally, it presents irrigation as a response to climate change to improve vulnerable agricultural livelihoods in southern Zimbabwe.

1.1 Importance of agriculture

The agriculture sector contributes up to 15 percent of Zimbabwe's GDP[2]. It accounts for 40 percent of total export earnings (the largest contributor)[3], and provides 60 percent of raw materials required by the agro-based industries[4]. It is also the basis of the direct and indirect livelihoods of almost 70 percent of the country's population, making it fundamental to reducing poverty and inequality, especially because of its increasing significance since 2000[5]. Those dependent on agriculture are largely smallholder farmers in rural areas farming on communally owned land (often less than a 2ha plot per household). They predominantly live in conditions of poverty[6], with limited access to agro-inputs, labour, finance, transport links, markets, resources, information, technology etc.

The majority of rural smallholders practice rainfed agriculture, and are thus dependent on the quality of the rainy season to produce crops, in the absence of infrastructure and other services. Livestock production plays an important role as a means of diversification of income[7]. Severe food insecurity and low education, health and sanitation rates and are typical trends in rural areas. Wood is the main source of energy for cooking (compared to electricity in urban provinces)[8]. The subsistence needs of the majority of families are not met by households' food production. Families are therefore often forced to buy food in markets at high rates, particularly in times of drought. Families also must often rely on non-farm income sources (humanitarian assistance, diaspora

[1] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.
[2] The World Bank: http://blogs.worldbank.org/africacan/getting-zimbabwes-agriculture-moving-again-the-beckoning-of-new-era.
[3] Ibid.
[4] Mudimu, G, 2003. Zimbabwe Food Security Issues Paper. Forum for Food Security in Southern Africa. London: Overseas Development Institute (ODI). www.odi.org.uk/ projects/03-food-security-forum/docs/ZimbabweCIPfinal.pdf (Accessed 24 January 2011).
[5] Anseew, A. Kapuya, T., and Saruchera, D. 2012. Zimbabwe's agricultural reconstruction: Present state, ongoing projects and prospects for investment. Development Planning Division Working Paper Series No. 32. Development Bank of Southern Africa, Johannesburg.
[6] UNICEF. 2015. Zimbabwe Poverty Atlas. UNICEF Zimbabwe, The World Bank and Zimbabwe National Statistics Agency.
[7] IFAD. 2016. Smallholder Irrigation Revitalisation Programme: Detailed Design Report. East and Southern African Division. Programme Management Department.
[8] UNICEF. 2015. Zimbabwe Poverty Atlas. UNICEF Zimbabwe.

remittances, casual labour etc.) to manage the gap to the next food season[9]. On the day prior to the assessment, the 2014 ZimVAC assessment reported that about 35 percent of children aged between 6 and 59 months had consumed fewer than three meals[10]. According to the 2016 ZimVAC report, since 2014 there has been an increase in the proportion of households selling household assets, reducing non-food expenditure, withdrawing children from school, selling more animals and resorting to begging to cope with food challenges[11].

If the rainy season is not effective or their water sources have depleted (i.e. rivers and boreholes have dried up), smallholders are often forced to practice ‘stream-bed cultivation’ (planting crops in river-beds), which contributes to increased siltation and erosion in river-beds. As identified by the ZimVAC 2014 report, water shortages continue to be a development priority for communities: 22.4 percent of sampled communities prioritised improvement of water and sanitation, irrigation, dam construction and rehabilitation (the highest proportion of all development priorities identified)[12].

The majority of the poorest, rural smallholders and their families reside in southern parts of Zimbabwe, in Manicaland, Masvingo and Matabeleland South provinces, which lie in the Mzingwane, Runde and Save river basins. Collectively, these provinces (covering 147,197 sq. km), are home to 3,921,681 people, according to the 2012 census[13].

1.1.1 Biophysical context of agriculture

A distinct feature of the country’s climate is a prolonged dry season of 7-8 months (April to October) and a short rainy season of 4 months (mid-November to mid-March)[14][15]. Zimbabwe’s planting season accordingly begins in October/November, and the harvest season starts from around March/April. The heaviest rains usually fall in December, often with short, sharp storms and mid-season droughts experienced in January, and drizzly rain (perfect for crops) in February, before the dry season starts again (April to October; Zimbabwe’s winter and spring). Average annual temperatures range from 23ºC in the southern areas (Lowveld) to 18ºC in the northern (Highveld) parts of the country[16]. Vincent and Thomas (1960) divide Zimbabwe into five agro-ecological regions (AERs) to depict agricultural potential and form a spatial framework for agricultural planning, based on rainfall, temperature and soil patterns (see Figure 1, below)[17]. Table 2, below, describes each region in tabular form.

[9] IFAD. 2016. Smallholder Irrigation Revitalisation Programme: Detailed Design Report. East and Southern African Division. Programme Management Department.
[10] ZimVAC. 2014. Zimbabwe Vulnerability Assessment Committee 2014 Rural Livelihoods Assessment. SIRDC.
[11] ZimVAC. 2016. Zimbabwe Vulnerability Assessment Committee 2016 Rural Livelihoods Assessment. SIRDC.
[12] ZimVAC. 2014. Zimbabwe Vulnerability Assessment Committee 2014 Rural Livelihoods Assessment. SIRDC.
[13] ZimStat. 2012. Zimbabwe Population Census 2012. Population Census Office. Harare.
[14] UNDP. 2014. Scaling Up Adaptation: Project Document. UNDP Environmental Finance Services.
[15] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, pp.39-46.
[16] Ibid.
[17] Vincent, V. and Thomas, R. G. 1960. An agricultural survey of Southern Rhodesia: Part I: agro-ecological survey Government Printer, Salisbury.

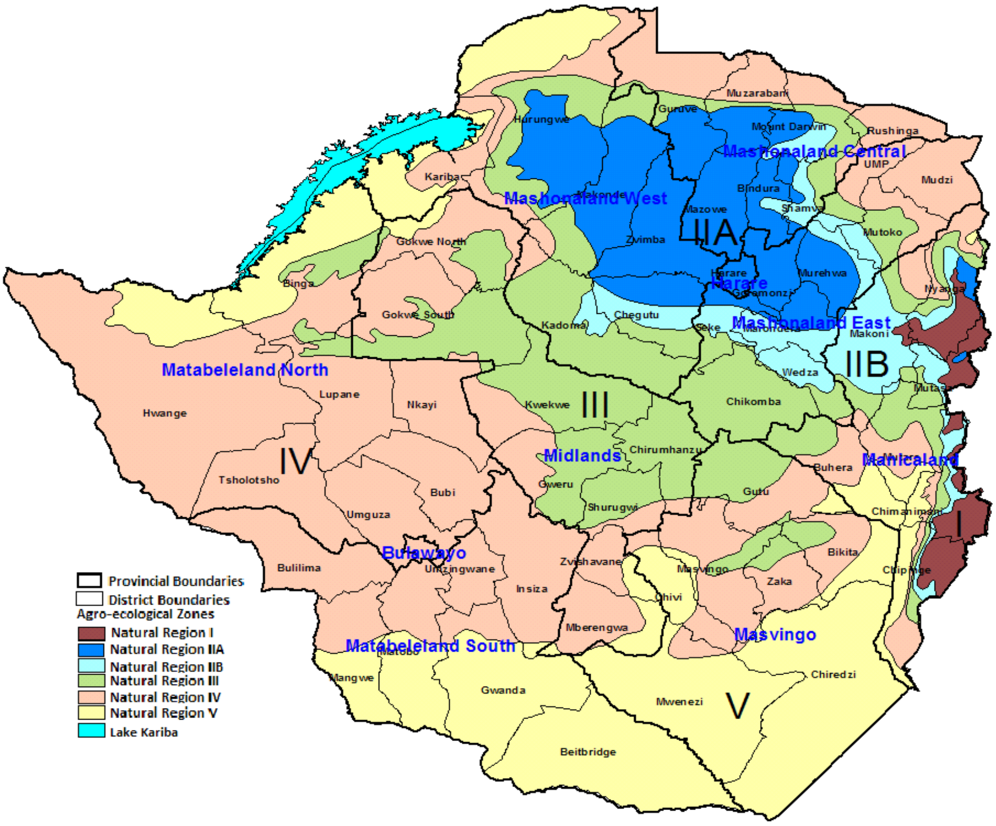


Figure 1: Spatial distribution of AERs based on the 1960 classification

Table 2: Description of Agro- Ecological Regions (AER)

AER	Percent total land mass	Annual rainfall (mm)	Description
I	4.0	>1000	Region I is in the eastern highlands of the country and is suitable for forestry and intensive diversified farming including tea, coffee, deciduous fruit and intensive livestock production.
II	7.6	700-1050	Region II covers the north-eastern high veld and is suitable for intensive cropping and livestock production.
III	16.1	500-800	Region III mainly covers the midlands and is characterised by mid-season dry spells and high temperatures. In this region drought resistant crops are grown; livestock and intensive farming are practised.
IV	39.9	450-650	Region IV occupies the low-lying areas in the northern and southern parts of the country and is characterised by seasonal droughts and severe dry spells during the rainy season (usually in January). It is unsuitable for rainfed agriculture but for livestock production.

AER	Percent total land mass	Annual rainfall (mm)	Description
V	32.5	<450	Region V covers the low-lands and receives below 650 mm of annual rainfall, suitable for extensive livestock production or game ranching.

Source: Adapted from Vincent and Thomas (1960), Mugandani et al (2012); Kuri et al. (2014)

Muir-Leresche (2006) describes the distribution of the AERs as follows: AERs I and II have highest agricultural potential and cover 20 percent (8 million hectares) of the country's total land mass, while AERs IV and V have the lowest potential and account for about 59 percent[18]. In other words, the quality of the land resource declines from AER I through to V. AERs I and II have an average mean annual precipitation of over 1,000 mm, whereas AERs IV and V have less than 450mm[19]. In the most easterly parts of the country (AER I), the Length of the Growing Period (LGP)[20] is significantly higher than in the rest of the country, reaching above 160 days[21] (the LGP is the number of days where agricultural conditions (heat and water) are suitable for growing crops in a season). The south and south-west regions (AERs IV and V) have the lowest LGP at 100-135 days (see Figure X below). In addition to low rainfall, annual rainfall in AER V is highly variable, characterised by erratic and unpredictable rainfall (short, sharp isolated storms), rather than evenly distributed. AER IV and V cover the entirety of Zimbabwe's southern provinces in the Mzingwane, Runde and Save River basins and account for approximately 30 percent of the total country population and 60 percent of its rural population.

[18] Muir, K. 2006. Agriculture in Zimbabwe. In: Rukuni, M., Tawonezvi, P., Eicher, C., Munyuki-Hungwe, M. and Matondi, P. (eds.). Zimbabwe's agricultural revolution revisted. Harare: University of Zimbabwe Publications, 99-116.
[19] Mugandani R, Wuta M, Makarau A, Chipindu B. 2012. Re-classification of agro-ecological regions of Zimbabwe in conformity with climate variability and change. African Crop Science Journal 20:361 – 369.
[20] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, p.37: '*The Length of the Growing Period (LGP) is the period (in days) during a year when actual evapotranspiration (ETa) for a rainfed perennial reference crop is greater than half the potential evapotranspiration (PET). As such, this metric is not crop-specific. Note that the upper bound of ETa is precipitation. Therefore in its simplest form, LGP is the period when rainfall exceeds half PET. The methodology for the analysis for the LGP is based on screening-level approaches designed and implemented by the Food and Agricultural Organization (FAO) and the International Food Policy Research Institute (IFPRI). The average historical length of the LGP in Zimbabwe is defined by the average of 1950-1999 values.*'
[21] Ibid.

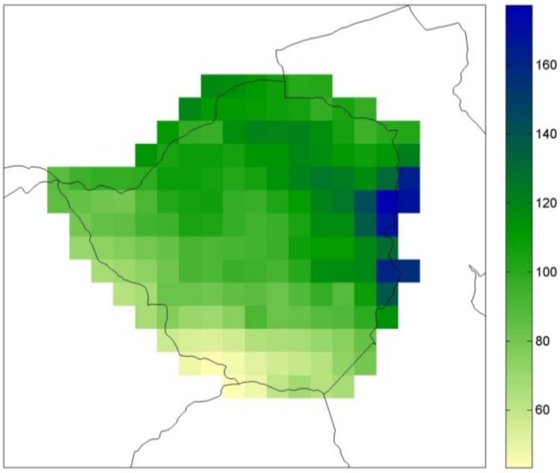


Figure 2: Historical Length of Growing Period (LGP) in days

Table 3, below, from analysis conducted in the World Bank study, presents mean annual precipitation data at basin level, comparing two datasets (data generated by the Princeton Land Surface Hydrology research group and locally observed station data from the Zimbabwe Meteorological Service)[22]. As stated in the study, there is a good fit between the datasets: Princeton data are within 4 percent of observed data in all cases except for Mzingwane and Sanyati, which show a 16 percent and 12 percent variance respectively[23]. The data vary from a low 456 vs. 547 mm for Mzingwane basin (southern Zimbabwe), to a high 824 vs. 841 mm for Mazoe basin (north east Zimbabwe)[24]. Table 4, from the same study, presents the mean annual precipitation, temperature and PET per agro-ecological regions (AERs)[25]. AERs IV and V experience the highest temperatures, lowest mean annual precipitation and highest PET. Comparing the two tables, figures are more homogenous and pronounced across AERs than river basins.

These average figures, however, conceal considerable intra-annual variability in climate. As indicated in Table 2 (above), while a large part of the country experiences inadequate rainfall (in terms of total amount), the country also experiences erratic rainfall (in terms of distribution)[26]. Rainfall effectiveness is further compromised by high PET rates, which in many places requires more than double the annual precipitation because of high temperatures[27]. Additionally, while rainfall shortage is a major problem (droughts are frequent; and mid-season droughts are particularly problematic), in some years, floods, particularly in low lying areas, have major negative impacts on food security and other socio-economic aspects[28]. Such phenomena, particularly rainfall variability, are experienced more dramatically in southern provinces. This indicates that the quality of rainfall, in terms of

---

[22] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.
[23] Ibid, p.35.
[24] Ibid, pp. 35-6.
[25] Ibid.
[26] Ibid.
[27] Ibid, p.1.
[28] Ibid, p.1.

distribution across the year on a day-to-day basis, often hidden in total annual rainfall graphs, is an important factor to consider when planning agricultural production[29].

Table 3: Basin-Level Mean Annual Precipitation (comparison of observed and Princeton data)

Basin	Mean Annual Precipitation (mm)		Mean annual temperatures (ºC) (1950-1999)*
	Observed	Princeton	
Gwayi	599.0	613.8	21.5
Manyame	709.0	734.8	22.0
Mazoe	824.0	840.9	20.6
Mzingwane	547.0	456.1	21.3
Runde	606.0	615.3	20.6
Sanyati	635.0	716.4	21.6
Save	815.0	806.5	20.0

**Source: ECRAI study (2015)[30]*

Table 4: Observed mean annual precipitation, PET and temperature per agro-ecological regions in Zimbabwe (1950-1999)

AER	Precipitation (mm/year)	Temperature (ºC)	PET (mm/year)
I	1,114.4	18.9	1,395.4
IIa	796.0	20.1	1,642.0
IIb	852.5	19.5	1,553.4
III	723.3	20.6	1,665.8
IV	640.7	21.4	1,744.4
V	546.9	22.2	1,843.5

At this point, it is important to make the connection that areas in southern Zimbabwe, which are resident to the majority of the poorest population[31] dependent on rainfed agriculture, are also the areas that are the least suitable for rainfed agricultural production (AERs IV and V). These areas receive the least amount and most

[29] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, pp.39-46.
[30] Raffaello, C et al. 2015. Enhancing the Climate Resilience of Africa's Infrastructure: The Power and Water Sectors. Washington, DC: Wold Bank.
[31] Due to the country's colonial history, the driest and worst quality lands of AERs IV and V are home to about 5 million people, the majority of which live in communal lands.

erratic rainfall patterns, are subject to the highest temperatures in the country (which increase PET), have the poorest soil quality for agricultural production, and experience the shortest growing periods.

1.2 Climate change in southern Zimbabwe

As a country with an economy and a majority rural population heavily dependent on agriculture, the performance of which is heavily reliant on the effectiveness and quality of rainfall, Zimbabwe is highly vulnerable to the impacts of climate change. This section presents observed and projected changes to variables important for agriculture, namely: temperature, precipitation, river run-off, shifting AERs and LGP.

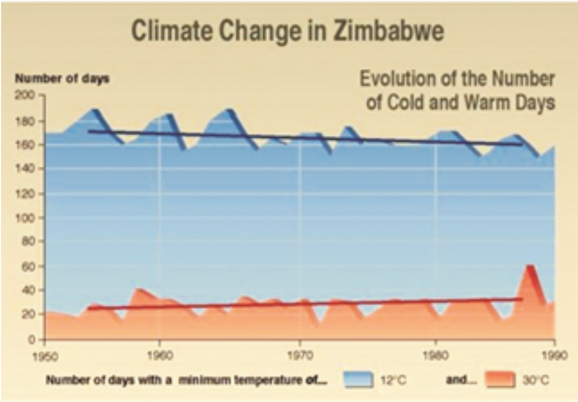
1.2.1 Temperature

Observed temperature trends

Since 1950, Zimbabwe has been experiencing hotter and fewer cold days (Source: Meteorological Services Department

Figure 3, below). The country's annual mean surface temperature has warmed by about 0.4ºC from 1900 to 2000, with the national average maximum temperature increasing by about 1ºC over the same period[32]. The increase in mean temperatures has been experienced especially during the dry season, with minimum temperatures increasing more rapidly than maximum temperatures[33]. Daily minimum and maximum temperatures have risen by approximately 2.6°C and 2°C respectively over the last century[34]. The period from 1980 to date has been the warmest on record.

[32] Davis, R. and Hirji, R. 2014. Climate change and water resources planning, development and management in Zimbabwe: An issues paper. World Bank: Washington DC and Government of Zimbabwe; Harare.
[33] GoZ. 2013. Zimbabwe Climate Change Response Strategy. Ministry of Environment and Natural Resources Management. www.ies.ac.zw/downloads/draftpercent20strategy.pdf
[34] Makarau, A. 1999. Zimbabwe's climate: Past, present and future. In: Manzungu, E., Senzanje, A., and van der Zaag, P. (eds.) Water for agriculture in Zimbabwe: Policy and management options for the smallholder sector. Harare, University of Zimbabwe Publications. 3-16.



Source: Meteorological Services Department

Figure 3: Warm and cold days in Zimbabwe

Projected temperature trends

Projections anticipate warming rates of 0.5–2^{0}C by 2030, 1–3.5^{0}C by 2070, and 3–4^{0}C by 2100 (all across the 1961-1990 baseline), assuming an A2 greenhouse gas emissions pathway[35,36,37]. This is consistent with the World Bank study's future scenarios projection, which predicts an increase in average annual temperature of between 3℃ and 4°C from 2020-2100 relative to actual records for 1900-2000 (Figure 9)[38]. These scenarios suggest a warming rate of just below 0.2^{0}C per decade to over 0.5^{0}C per decade.

---

[35] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptations options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.
[36] Engelbrecht, F and Bopape, M.J. 2009. Projections of Future Climate Change over Southern Africa. CSIR Natural Resources and the Environment Atmospheric Modelling.
[37] KNMI. 2006. Climate Change Scenarios. KNMI. The Netherlands.
[38] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptations options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.

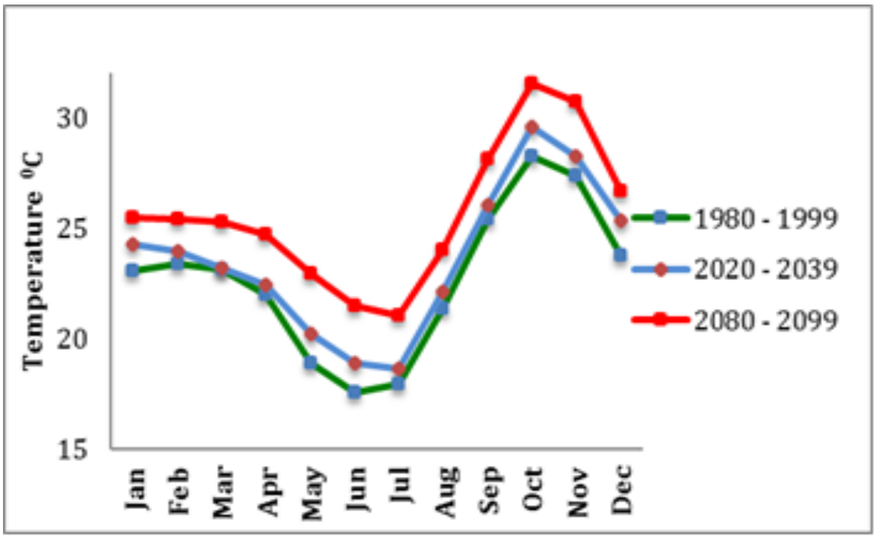


Figure 4: Comparison of actual [1980-1999] and projected [2020-2039 and 2080 - 2099] annual mean temperatures in Zimbabwe

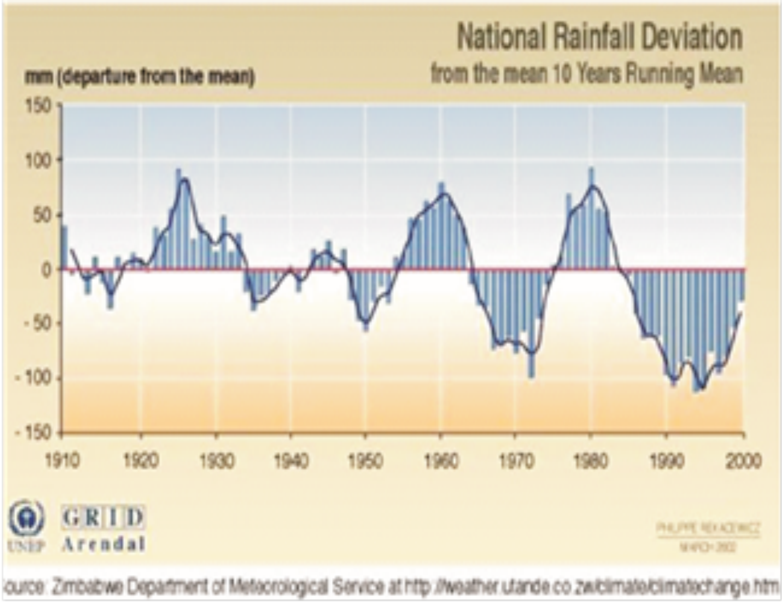
Source: Zimbabwe Department Meteorological Services

1.2.2 Precipitation

Observed precipitation trends

The country experienced an overall **5 percent decline** in the total amount of rainfall over the 20th century (Figure 8)[39]. Over the early part of the 21st century, rainfall has exhibited **considerable spatial and temporal variability**, characterized by late onset of rains, increases in the frequency and intensity of heavy rainfall events (and decreases in low intensity rainfall events), increases in the proportion of low rainfall years, and increases in the frequency and intensity of mid-season dry-spells[40]. **Extreme events in the form of droughts, mid-season dry spells, floods and storms (tropical cyclones) have increased in frequency and intensity.**

[39] Unganai, L.1996. Historic and future climatic change in Zimbabwe, Climate Research, Vol. 6: 137-145.
[40] Eriksen S. 2008. Climate Change in Eastern and Southern Africa: Impacts, Vulnerability and Adaptation. University of Oslo.



Source: Meteorological Services Department

Figure 5: Precipitation deviation in Zimbabwe

Projected precipitation trends

There are various predictions simulated by global climate change models on how precipitation changes for Southern Africa (and Zimbabwe) will occur. According to information presented in the NCCRS, a **decrease in annual rainfall** is predicted to occur in all seasons. This is more conclusive for the early and late rains than for the main rainy season months of December to February. However, other predictions indicate drying is expected by as much as 10–20 percent of the baseline to be a result of increased evaporation caused by high temperatures, rather than a net reduction in mean annual precipitation[41].

Data from the World Bank study indicate rainfall is expected to become **more variable**, as an analysis of basin-level changes in precipitation to 2050 under 121 climate scenarios shows greater changes in the extreme percentiles than the mean annual data[42]. This is also indicated by information from the MSD in an Oxfam (2014) report, as it has been observed that the rainy season occurs later in the year, with heavier bursts over a shorter time period, with elongating mid-season dry spells, pointing to changing seasonality[43].

1.2.3 River runoff

River runoff is an important factor to consider when analysing agricultural potential as impacted by climate change. A decline in river runoff not only decreases ecological habitats, but coupled with increasing temperatures (which contribute to increased erosion), flash floods are more likely to increase in severity with

[41] KNMI. 2006. Climate Change Scenarios. KNMI. The Netherlands.
[42] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, p.40.
[43] Magrath, J. 2015. Transforming Lives in Zimbabwe. OXFAM Case Study. OXFAM.

concomitant damage to infrastructure. The World Bank study uses a rainfall-runoff model[44] (Figure 6, below) to develop estimates of projected changes in river runoff in Zimbabwe's seven river basins across the 121 climate scenarios as generated in the ECRAI study.

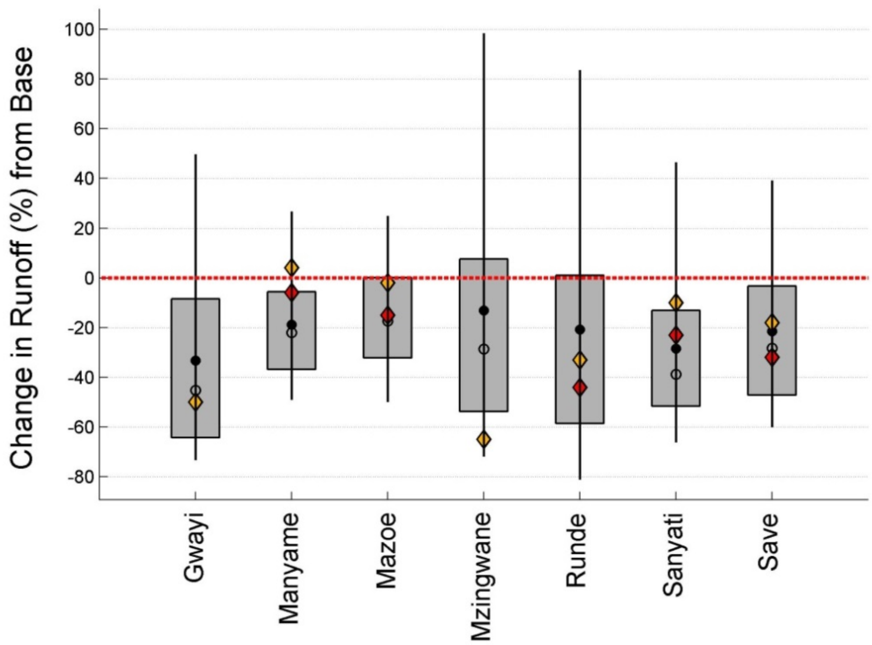


Figure 6: Percent change in river runoff between the 1961-1900 baseline and 2040-2050

Figure 6 shows the percentage change in mean annual river runoff between the 1961-1990 baseline and the 2040-2050 period, where each boxplot shows the span of changes across the 121 scenarios. In five out of seven basins, 75 percent of scenarios show reductions in runoff (i.e., the entire 'box' is below the line). However, some basins show a much greater range of uncertainty across climate scenarios than others. Changes in Mzingwane, for example, range from -70 to +100 percent, whereas changes in Manyame range from only -50 to +30 percent. Generally, drier basins, such as Mzingwane and Runde in southern Zimbabwe, are projected to experience sharp declines in runoff and show larger ranges of uncertainty than those with wetter climates.

---

[44] '*The boxplot shows the span of projected changes across the 121 climate scenarios in each of the seven basins. The box spans the 25th to 75th percentiles, and the whiskers span the 5th to 95th percentiles; the solid circle is the mean and the open circle is the median. The red and orange diamonds show changes to 2050 under the A2a and B2a scenarios of the Issues Paper. Note that A2a projections were not available for the Gwayi or Mzingwane catchments.' In:* Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies. p.42.
[45] Ibid

1.2.4 Shifts in Agro-Ecological Regions

Since the distribution of AERs is mainly driven by temperature and precipitation, it follows that projected changes in these two parameters will significantly change the distribution of AERs.

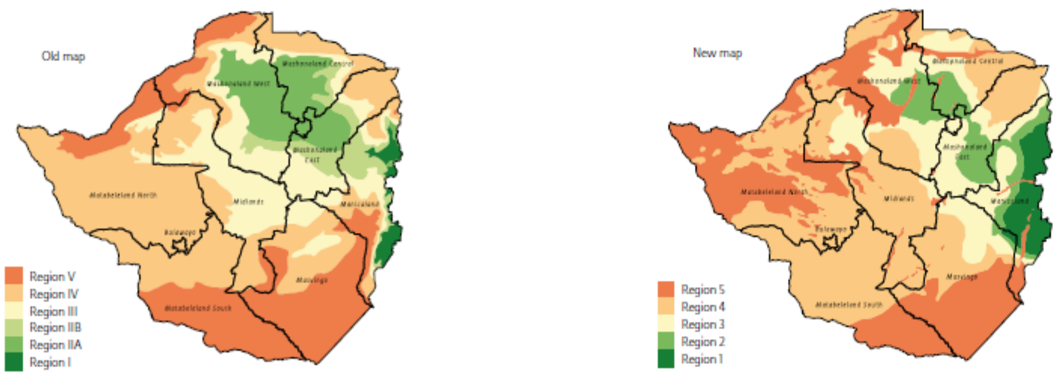
Table 5 and Source: ***Mugandani et al (2012)***

Figure 7 compare the distribution of AERs under current and future climates.

Table 5: Distribution of Zimbabwe's AERs taking into account climate change

Region	Area ('000 ha) at present	Percent of total land area at present	Percent increase/decrease under future climate
I	1,444	4.0	+106
II	2,966	7.6	-49
III	6,283	16.1	-13.9
IV	15,571	39.9	+5.6
V	12,683	32.5	+22.5

Source: Adapted from Vincent and Thomas (1960); Mugandani et al (2012)



Source: Mugandani et al (2012)

Figure 7: Zimbabwe's spatial distribution of AERs as mapped in 1960 (old); and based on future climate projections (new)

As shown in Figure 7, the distribution of AERs has changed since 1960 and is projected to change towards more aridity under increasing climate change[46][47]. Based on measurements of average climatic conditions of

[46] Mugandani R, Wuta M, Makarau A, Chipindu B. 2012. Re-classification of agro-ecological regions of Zimbabwe in conformity with climate variability and change. African Crop Science Journal 20:361 – 369.

[47] Nyabako, T., and E. Manzungu, 2012. An assessment of the adaptability to climate change of commercially available maize varieties in Zimbabwe. Environment Natural Resources, 2: 32-46.

1972-2006 it is estimated that currently AERs II and III, the most suited areas for rain-fed crop and livestock production have decreased significantly, while already poorly suited regions to rain-fed farming systems (AERs IV and V) have expanded by close to a third[48]. This contributes to rain-fed farming systems in AERs IV and V becoming increasingly unsustainable, and even mixed crop-livestock systems in these areas are expected to become more vulnerable, as natural processes in semi-arid areas that sustain soil moisture for rain-fed cropping and fodder production for livestock are negatively affected[49][50][51]

1.2.5 Length of the Growing Period

The World Bank study presents analysis of LGP under climate change, according to the spatial distribution of the mean percent change in LGP across 121 climate scenarios (from the World Bank's 'Enhancing the Climate Resilience of Africa's Infrastructure (ECRAI) Africa-wide study, complemented and calibrated using national data sources (1950s to 2010))[52]. As can be seen in Figure 8, below, presented in the study, the mean percentage change is highest in the south and southwest of the country, and lowest in the north and northeast, indicating a shrinking LGP in southern parts of Zimbabwe.

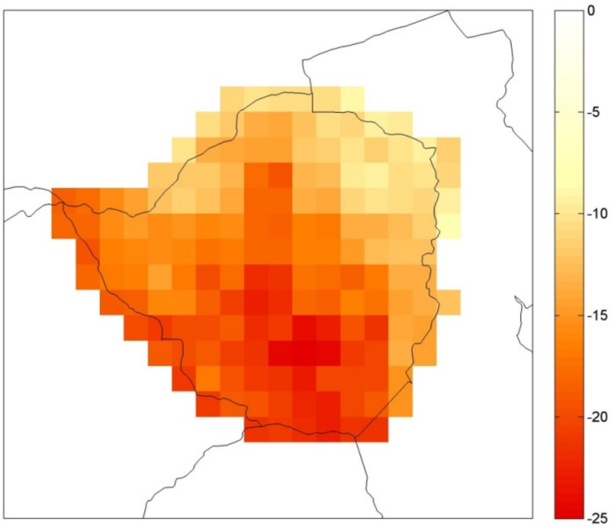


Figure 8: Mean change in Length of the Growing Period (percent) from Base

Overall, climate change has been observed to have impacted on variables relevant to agriculture in Zimbabwe. Projections suggest Zimbabwe will continue to experience changes due to climate change, and such impacts will likely increase in intensity overtime. Both observed and predicted trends indicate southern Zimbabwe will be most affected.

---

[48] Ibid.
[49] Kahinda et al. 2007. Rainwater harvesting to enhance water productivity of rain-fed agriculture in semi-arid Zimbabwe. Physics and Chemistry of the Earth, 32 (2007), pp. 1068-1073.
[50] Wani, et al. 2009. Rain-fed Agriculture: Unlocking the Potential. Wallingford, UK. pp: 124-132.
[51] Tadross. M, P. et al. 2008. Growing-season rainfall and scenarios of future change in southeast Africa: implications for cultivating maize. Climate Research: Integrating analysis of regional climate change and response options. Vol. 40, pp.147-161.
[52] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.

1.3 Climate change impacts on agriculture

It is generally agreed that while there are some benefits to certain crop varieties in specific places, climate change will have negative impacts on agricultural production, especially concerning trends such as: increasing temperature, decreasing total annual precipitation (and correspondingly increasing PET), increasing rainfall distribution (with increasing frequency and length of mid-season dry spells), increasing frequency and severity of extreme weather events, such as floods and droughts, decreasing river run-off, shifting AERs (showing an increase in areas less suitable for rainfed agriculture) and decreasing LGP, as presented above. In particular, increasing rainfall variability, which sees precipitation fall in shorter and sharper bursts and intensifying mid-season dry spells in both frequency and length, poses profound impacts to smallholders' food security and livelihoods, as crops are subject to more heat stress. While rainfall variability is often under-reported relative to more 'dramatic' extreme events such as droughts and floods (which have the potential to destroy a harvest)[53], rainfall patterns make the difference between a harvest and no harvest at all. In southern Zimbabwe, climate impacts, poverty and exposure collide, resulting in vulnerability (see Figure 9, below). While climate change is impacting the country as a whole, the greatest intensity of impacts are experienced in the southern provinces, where the majority of smallholder farmers practicing rainfed agriculture are already vulnerable as a result of poverty and the absence of access to services and resources. This section presents analysis taken directly from the World Bank study[54].

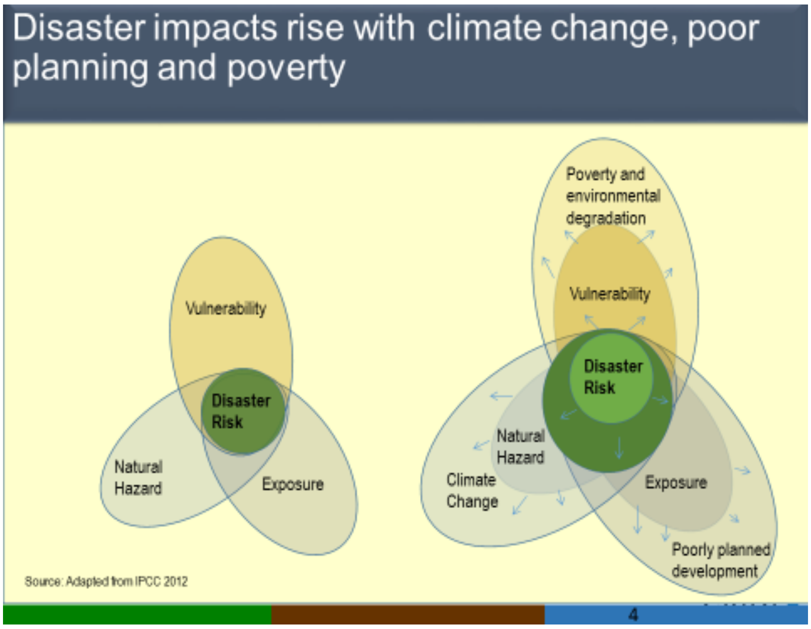


Figure 9: Poverty, vulnerability and climate change

[53] Oxfam. 2009. What happened to the seasons?: Changing seasonality may be one of the major impacts of climate change. Oxfam GB. http://policy-practice.oxfam.org.uk/publications/what-happened-to-theseasons-changing-seasonality-may-be-one-of-the-major-impac-112501 (Accessed 31 January 2017)

[54] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.

1.3.1 Decreasing crop yields

Studies indicate that under predicted climate change, farmers who live in AERs III, IV and V will be unable to grow rainfed maize, the staple food crop, including the current drought tolerant varieties[55]. This has direct consequences on the food and income security of over 3.5 million people (or 700,000 households)[56]. Crop yields of maize grown in AERs I and II are also expected to decrease: a similar number of people located in these regions would lose about 2 percent to 15 percent of the normal maize output[57].

The World Bank study analyses crop yield and spatial distribution of rainfed crops (using the major grain and cash crops: maize, sorghum, millet, groundnuts, cotton and tobacco) under climate change (see Figures 10 and 11)[58]. As shown in Figure 10, historical rainfed yields range from approximately 30 percent to 90 percent of irrigated yields, depending on location within the country, with cotton and maize performing most poorly[59]. All crops show a gradient of increasing rainfed yield from the southwest to the northeast, roughly corresponding to the spatial pattern of mean annual precipitation across the country[60].

The following passages comprise of extracts from the World Bank study's analysis of Figures 10 and 11:

Mean change in rainfed yield fraction relative to irrigated under the majority of the 121 climate scenarios show a negative change, with the largest decreases in southern part of the country (Figure 11). The decrease is particularly extreme for maize because of its comparably high yield sensitivity to water stress. The change of yields of the main cash crops (cotton and tobacco) under the middle 50 percent of projected climate scenarios range between 0 percent and 10 percent, with the drier AERs recording slightly greater yield reductions. Generally average yield reduction increases across AERs from 1 to 5, implying that drier areas will incur higher percentage yield reductions. However, the pattern is less clear compared to the increasing range of results across climate scenarios that occur in drier areas. The areas suitable for growing maize are expected to substantially decrease by the year 2050, while the areas suitable for growing cotton and sorghum will increase. The small difference between sorghum and millet is mainly because the two have the same yield response factor (0.9) and are grown under relatively similar conditions. Both can substitute maize as a source of grain, although Zimbabwean consumers prefer maize.

---

[55] Nyabako, T. and Manzungu, E. 2012. An assessment of the adaptability to climate change of commercially available maize varieties in Zimbabwe. Environment and Natural Resources Research, 2(1), 32-46.
[56] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies.
[57] Ibid.
[58] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, pp.50-53.
[59] Ibid, p.50.
[60] Ibid, p.50.

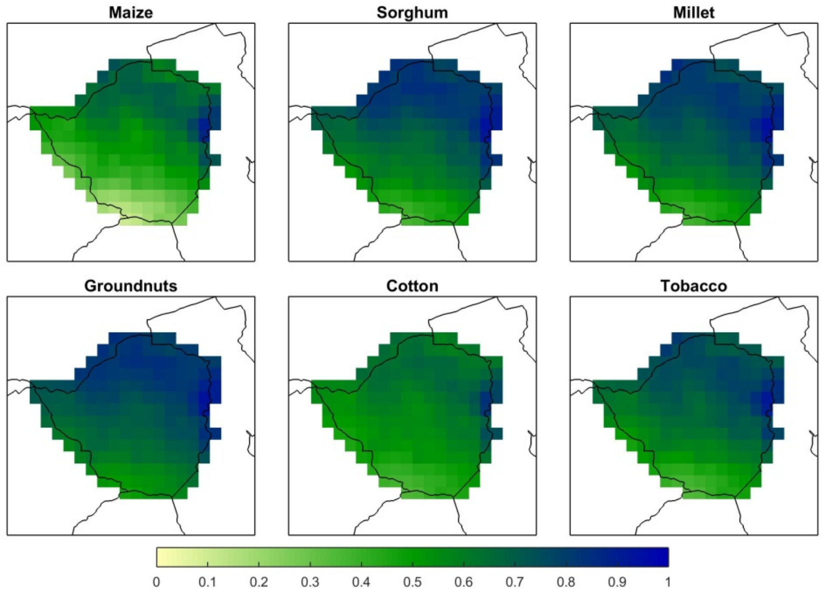


Figure 10: Historical rainfed yield fraction (relative to irrigated)

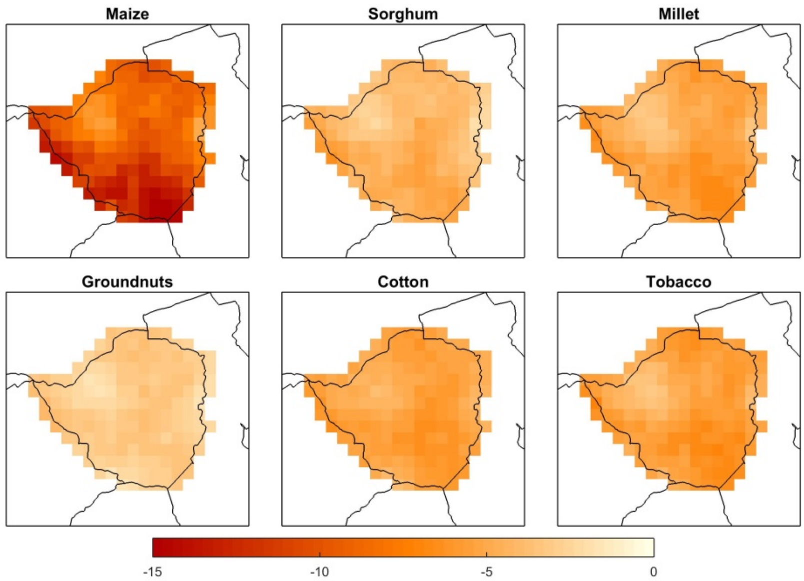


Figure 11: Mean change in rainfed yield fraction (relative to irrigated) in percent from base (map)

The implications of the above findings are that rainfed crop production will have to be differentiated according to the new agro-ecological conditions taking into account the available varieties. While areas suitable for growing maize are expected to substantially decrease by the year 2080, the areas suitable for growing cotton and sorghum, which are drought tolerant, will increase. Thus, in the southwestern parts of the country, maize will become increasingly vulnerable to climate change, while cotton and sorghum will become less vulnerable

(Brown et al. 2012)[61]*. This suggests that there has to be a change in strategy/philosophy when it comes to growing maize in the future.*

It is, however, worth making the observation that there are two primary limitations of this rainfed yield analysis: (i) crop yields are based on monthly, rather than daily, climate; and (ii) changes in rainfed crop yields are driven by precipitation and PET only, and are unaffected by direct temperature effects and do not take into account carbon fertilisation. In actuality, the daily variations of climate have a significant effect on crop yields, and changes in temperature under climate change can either have a positive or negative effect on yields depending on the historical climate pattern. A more accurate assessment would involve a biophysical crop model that builds crop biomass on a daily basis, and accounts for temperature and CO_2 effects on yields directly.

A study by Kuri et al. (2014) analyses the relationship between the number of 'dry dekads' (a ten-day period with a Vegetation Condition Index (VCI) value below 35 percent[62]) in a particular wet season to the corresponding maize yield that was harvested at the end of that season, using linear regression[63]. The VCI compares the current NDVI (normalised difference vegetation index) to the range of values observed in the same period in previous years[64]. Analysis was conducted for four wet seasons: i.e., 2009/10, 2010/11, 2011/12 and 2012/13, the results of which are presented in Figure 12, below.

[61] Balcet, J.C. Manzungu, E, and Moyo, S. 2015. *Options for climate-proofing the Zimbabwe Agriculture Investment Plan (ZAIP) and climate adaptation in the irrigation sector.* A document produced for the World Bank, Harare, Zimbabwe.
[62] Liu, W.T., Kogan, F.N., 1996. Monitoring regional drought using the Vegetation Con-dition Index. Int. J. Remote Sens. 17 (14), 2761–2782. *In: In:* Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, p.44.
[63] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, pp.39-46.
[64] Source: http://land.copernicus.eu/global/products/vci

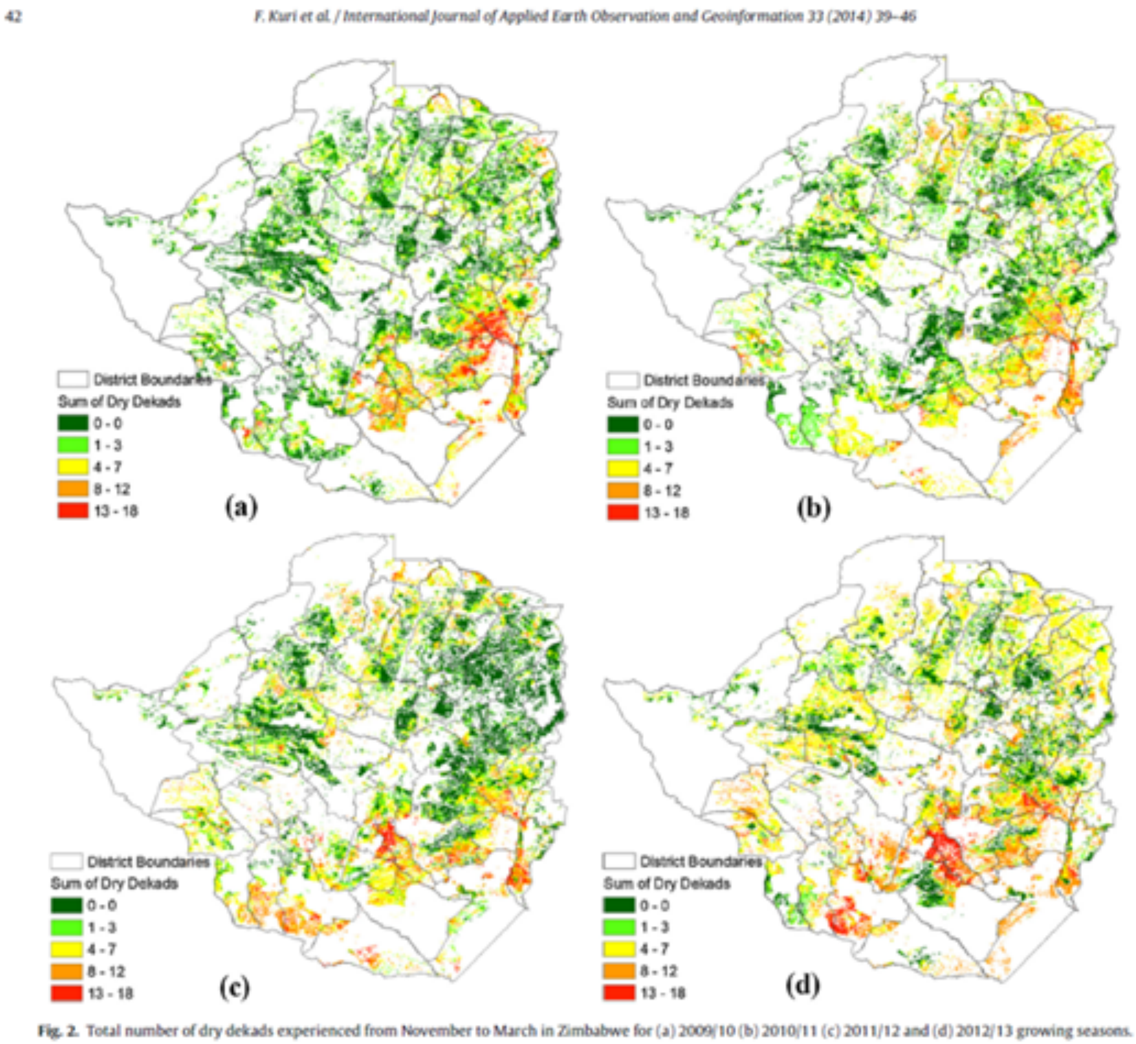


Figure 12: Distribution of Dry Dekads

The number of VCI derived dry dekads range from 0 to 18 in a season, with south eastern parts of the country experiencing the highest number of dry dekads (Figure 12)[65]. The results indicate that there is a consistently significant negative linear relationship[66] between the number of dry dekads and average maize yield for the four consecutive wet seasons considered in this study, i.e. from 2009 to 2013[67]. In other words, the higher the number of dry dekads experienced during the crop growing season, the higher the drought related stress that crop experiences, resulting in poor crop yield[68]. **This proves that dry spells are a major limiting factor on**

[65] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, p.42.

[66] 'The Shapiro–Wilk test for normality showed that the data (average yield for all wards with the same number of dry dekads) is not normally distributed and the Spearman's Rho correlation test indicated that there is high correlation between the average maize yield and number of dry dekads.' *In:* Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, p.42.

[67] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, pp.39-46.

[68] Ibid, p.44.

rainfed agriculture[69]. As Kuri et al. (2016) state, 'the models were developed over the wet season consisting of 18 dekads, meaning a season can only have maximum of 18 dekads of which, if they are all dry, yields are zero'[70].

1.3.2 Crop revenue and food security

Zimbabwe will face significantly reduced household and national level revenues, incomes and employment as a result of yield reductions in crops[71]. Mano and Nhemachena (2007) show that a 2.5° C increase in temperature and precipitation can cause a significant decrease of net farm revenue by US$400 million across the country[72]. The same study indicates that a decrease in precipitation of between 7 and 14 percent would result in a decrease in farm revenue of US$300 million[73].

As stated in the World Bank study, the financial losses incurred from cash crop yield reductions will substantially undermine rural livelihoods, which also represent a 'significant loss of farm jobs, wages, and net farm incomes, which finance various social needs (e.g. health, education etc.)'[74]. Analysis from the same study indicates that 'the loss of revenue from cotton would mainly affect those in the south and north-west parts of the country where it is mostly grown (largely in AERs III, IV and V), while the loss of jobs and farm incomes from soybeans and tobacco would mostly affect rural households in AERs I and II'[75]. Relative yield decrease will be close to 10 percent at a minimum and above 30 percent at the maximum across almost all river basins[76].

Regarding maize production, the World Bank study predicts that 'if current maize varieties are used, there will be an average climate-induced shortfall of between 6 and 12 percent across AERs due to yield reduction'[77]. The study states that the net result will be that the total annual maize requirement and the Strategic Grain Reserve will be compromised, and that 'if no sustainable adaptations are put in place in terms of increasing maize yields and relocating its production to AERs 1 and 2, then the country will have to rely on expensive grain imports'[78]. It also highlights that 'the option of increasing the area will become more and more unviable because

---

[69] Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik, P.C., Sohrabi, Y., 2010. Effectof drought stress on yield, proline and chlorophyll contents in three chickpeacultivars. Aust. J. Crop Sci. 4 (8), 580–585.*In:* Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, pp.39-46.

[70] Kuri, F. et al. 2014. Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index. International Journal of Applied Earth Observation and Geoinformation. 33, p.44.

[71] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, p.53.

[72] Mano R. and Nhemechena C. 2007. Assessment of the Economic Impacts of Climate Change on Agriculture in Zimbabwe: A Ricardian Approach. Policy Research Working Paper 4292 July 2007. The World Bank.

[73] Ibid.

[74] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, p.11.

[75] Ibid, p.11.

[76] Balcet, J.C. Manzungu, E, and Moyo, S. 2015. *Options for climate-proofing the Zimbabwe Agriculture Investment Plan (ZAIP) and climate adaptation in the irrigation sector.* A document produced for the World Bank, Harare, Zimbabwe.

[77] Manzungu, E., Moyo, S., Boehlert, B. and Cervigini, R. (in press). Potential impacts of climate change and adaptation options in Zimbabwe's agricultural sector. Harare: Sam Moyo African Institute for Agrarian Studies, p.53.

[78] Ibid, p.53.

of limited arable land with suitable amounts of water realised from precipitation'[79]. The projected yield reduction pattern agrees with other modelling efforts which have been undertaken in the country[80].

1.4 Irrigation as a response to climate change in southern Zimbabwe

Every year Zimbabwe contributes to providing humanitarian relief to vulnerable populations, predominantly affected by drought. From April 2016 to March 2017, US$215 million of humanitarian support was provided by the United Nations, development and humanitarian partners and the Government to nearly two million vulnerable people affected by drought[81]. Unverified reports indicate that Government annual expenditure on food relief averages at US$30 million over the last decade. This is a significant amount of money, the impacts of which will only contribute to decreasing Zimbabwe's ability to respond to climate change on a national scale (in other words reducing its adaptive capacity). Investments in climate resilient irrigation, as the cornerstone of an adaptation strategy, present an opportunity to stop a cycle of food relief and embed resilience to climate change into interventions.

Additionally, increasing climate impacts are likely to increase the need for rural smallholder farmers practicing rainfed agriculture in southern Zimbabwe to conduct stream-bed cultivation. When the rainy season is inadequate to produce crops, or there are over 8 dry dekends in a cropping season (see Kuri et al. 2014 analysis above), poor people without access to resources often do not have a choice but to inadvertently degrade the very resource they are dependent on, and contribute to increased siltation and erosion of river beds. Providing a sustainable off-river source of water in the face of climate change via irrigation will give communities the ability to contribute to water resource protection, and thus make them part of the solution, rather than blaming them for implications of a problem they did not cause.

When designed in response to climate change, irrigation can provide a sustainable and reliable means of using water for agricultural purposes, and thus contribute to increasing the adaptive capacity of vulnerable smallholders. Given the fact that southern Zimbabwe will continue to experience negative climate impacts on agriculture, particularly in the form of increased rainfall variability on a day-to-day basis with increasing mid-season droughts, irrigation can supplement rainfall during this time, by collecting rainfall from short, sharp storms, which are normally (and increasingly) experienced in the cropping season, and disbursing the collected water in a controlled manner during mid-season droughts (also increasing in frequency). As a result, irrigation can be used to improve yields through more intensive cropping against the water security it provides. Smaller lands will thus be able to be utilised more efficiently to produce significantly more produce.

Irrigation can also potentially enable annual double cropping (growing two crops in the same piece of land during a single growing season), allowing crops which have not previously been grown to be introduced in certain areas (e.g. wheat and beans), thus generating higher annual yields and increasing revenues over time. It is

---

[79] Ibid, p.53.

[80] Nyabako, T. and Manzungu, E. 2012. An assessment of the adaptability to climate change of commercially available maize varieties in Zimbabwe. Environment and Natural Resources Research, 2(1), 32-46.

[81] United Nations Zimbabwe. 2017. Development Partnership Delivers Strong Results in Zim. http://www.zw.one.un.org/newsroom/news/development-partnership-delivers-strong-results-zim (Accessed 31 March 2017)

important to note here that irrigated farming can only become successful when farmers adopt new farming systems that are more intensive, productive and sustainable in the face of climate change impacts, rather than continue with those currently employed for dryland plot cultivation, so that they can effectively transition from subsistence to profitable schemes. Thus, a holistic intervention is needed to result in climate resilient irrigation to improve farmers' income security in southern Zimbabwe. The capture of flood waters via irrigation and providing access to water for irrigation during dry dekads present a significant opportunity to arrest the cycle of poverty, humanitarian food assistance and environmental degradation caused by climate change for rural communities in southern Zimbabwe. This has the added benefits of improving incomes, employment and general livelihoods for the poor.

2. Irrigation efforts and lessons learned

This chapter presents an overview of existing irrigation efforts in Zimbabwe, followed by an analysis of lessons learned, conducted through a desk-based review. It must be noted that a significant limitation to this review is the lack of project design and evaluation documents available, both from previous and existing programmes; as lessons learned are unfortunately not always captured in institutional memory.

2.1 Government schemes

GoZ has prioritised irrigation development in recent years. As stated in Zimbabwe's Agriculture Investment Plan (ZAIP), investments have a budget estimate of USD900 million over a five-year period from 2013-2017[82]. Out of this budget, USD2.5 million is aimed to be spent annually through the Public Sector Investment Programme (PSIP), with efforts focused on poor rainfall areas for the development of smallholder irrigation infrastructure on communal lands (Table 6). Historical efforts by Government and non-governmental organisations have contributed to Zimbabwe becoming one of the most dammed countries in Southern Africa, with 2,200 dams, 1,940 of which are small dams, most of them serving smallholder irrigation schemes. A significant proportion of these, however, lack irrigation infrastructure beneficial to farmers.

2.2 Donor projects

Numerous donors have implemented irrigation projects in Zimbabwe for many years. Only recently (the past one year), have projects installed solar panels to power irrigation schemes, however there are a number of existing efforts on which can be built on. The main past and existing projects are presented in Table 6. It is significant to note that many are being implemented at the same time, which should allow for synergies, and many have other components, for example, market linkages, which compliment irrigation components.

[82] GoZ. 2013. Zimbabwe Agriculture Investment Plan 2013-2017. A Comprehensive Framework for the Development of Zimbabwe's Agriculture Sector. Ministry of Agriculture, Mechanisation and Irrigation Development.

Table 6: Existing Efforts in Smallholder Irrigation in Zimbabwe

Project/Programme details	Description	Results/current status
Name: Public Sector Investment Programme (PSIP) **Funder:** GoZ **Implementation agency:** Dept of Irrigation **Amount:** USD5.5 million over a five-year period (USD2.5 million spent annually) **Duration:** On-going	Rehabilitation and construction of communal irrigation schemes through in-house design and construction	Since 2000 an area covering 3,500ha has been rehabilitated. Both design and construction done in-house by DoI. In service training of engineers and technician, as well as for farmers, has been undertaken.
Name: Smallholder Irrigation Support Project **Funder:** EU, FAO and GoZ **Implementation agency:** FAO **Time period:** 2014-2017 **Amount:** 6 million Euros **Beneficiaries:** 2,000 households	Improving income, food and nutrition security of smallholder communal farmers in Manicaland and Matebeleland South provinces through the rehabilitation of 20 irrigation schemes covering some 1,000ha and involving 2,000 households. The Programme has the following five key result areas: 1) Functional capacity of installed irrigation infrastructure and equipment at targeted schemes increased; 2) Capacity of smallholder irrigation farmers for crop production and scheme management enhanced; 3) Agribusiness development in smallholder irrigation promoted; 4) Management and conservation of irrigation scheme sub-catchments enhance; and 5) Service delivery capacity of institutions supporting irrigation schemes.	-Crop yields increased from 1t/ha to at least 5t/ha -Very strong market linkages developed involving financiers and buyers of agricultural produce -Laid a foundation for a private-sector based extension service management model - However, Programme lacked a focus on climate proofed irrigation designs and some projects in Matabeleland South were washed away by floods in early 2017.

Project/Programme details	Description	Results/current status
Name: Brazil-Zimbabwe cooperation programme under the More Food for Africa Programme **Funder:** Brazil **Implementing agency:** GOZ **Duration:** MoU between Brazil and Zimbabwe signed in 2011. Second phase is expected to start later in 2016. **Amount:** USD270 million (not all the money is earmarked for irrigation. **Beneficiaries:** Approx. 60, 000 households.	A major agricultural mechanisation cooperation programme supplying tractors, tractor-drawn equipment and irrigation equipment under a concessionary loan agreement from Brazil under the More Food Africa programme. It has three components, executed simultaneously: 1) Exchange of family-farming-focused public policy experiences; 2) Technical assistance focused on strengthening extension systems; and 3) Concessional loan for the acquisition of farm machinery and equipment.	-Delivery of the first of three tranches of tractors, mechanisation and irrigation equipment amounting to USD38 million was done between October 2014 and January 2015. -Practically every smallholder irrigation scheme in the country has been availed a tractor and equipment under a loan arrangement. -Some irrigation schemes have been equipped with modern more efficient irrigation systems such as centre pivots.
Name: Rehabilitation of Small Irrigation Schemes in Zimbabwe **Funder:** SDC (Swiss Agency for Development Cooperation) **Implementing agency:** International Water Management Institute (IWMI)	Ensuring that rural communities in the dry areas of Masvingo province enjoy food security, enhanced livelihoods, income and nutrition through rehabilitation of irrigation infrastructure and promoting commercial irrigation in Fuve-Panganai and Rupike schemes.	-Studies on constraints facing smallholder irrigation were completed with marketing challenges being the most outstanding. -Irrigation infrastructure rehabilitated but costs of rehabilitation too high because of use of huge fees charged by IWM underlining the

Project/Programme details	Description	Results/current status
Partners: GoZ (Dept of Irrigation), CIMMYT, GRM, FAO **Budget:** 8,700,000 Swiss Francs (rehabilitation of 2 schemes in Masvingo province **Duration:** 2 years (Jul 2011 – June 2013) **Beneficiaries:** 2,000 persons		need to use local organisations as implementing agencies. -Farmers trained in all aspects of scheme management.
Name: Rehabilitation of Small Irrigation Schemes **Funder:** SDC **Implementing agency:** FAO and GOZ **Duration:** Dec 2014 – Dec 2018 **Amount:** CHF 6,080,000 **Beneficiaries:** Up to 200 in 8 irrigation schemes covering 700 ha	Improving income, food and nutrition security of smallholder farmers in Masvingo province through the rehabilitation of small-scale irrigation schemes and linking them to viable markets focusing on communal schemes with irrigators having an average plot size of 0.5ha to 1.0 ha with a common water source and conveyance system and an area of 50 – 100 ha. The Programme is emphasizing active engagement of farmers through in cash and in-kind contribution.	-The Programme is underway and is yet to reach its mid-point as far implementation is concerned. -Early indications show that all components of the programme are progressing well.
Name: Nyakomba Irrigation Scheme expansion **Funder:** Japan International Cooperation Agency (JICA)	Rehabilitation and construction of a new block (block A) at Nyakomba irrigation scheme (re-started after blocks B, C and D were completed in 2000). An additional 146 ha are being added under irrigation, ensuring water pumps and other irrigation infrastructure is fully rehabilitated.	Just started. The Programme builds on earlier work and focuses on how sustainability in smallholder irrigation can be achieved, focusing on increasing crop production and productivity.

Project/Programme details	Description	Results/current status
Amount: USD15 million **Duration:** Dec 2016 - March 2019 **Beneficiaries:** 230 farmers added to give a total of 861 smallholder farmers.	.	
Name: Munjanganja Irrigation Scheme **Funder:** JICA and GOz **Amount:** Unavailable **Duration:** Unavailable **Beneficiaries**: 175 plotholders	The Japanese government financed the construction of Munjanganja Dam, a supply canal and a night storage dam while the Zimbabwean government financed construction of infield infrastructure. The irrigation scheme is managed by an irrigation management committee that has a binding constitution, written in the vernacular, and supported by the Dept of Irrigation for the maintenance of canals and watering schedules. AGRITEX provides agronomy training to farmers.	Irrigators confirmed that they rely more on the irrigation enterprise than on rainfed crops because they have high yields all year with a good harvest when water is available. However, the neighbourhood market is about 30 km away and there remains a need to create market linkage for farmers.
Name: Smallholder Irrigation Revitalization Programme **Funder:** International Fund for Agriculture Development (IFAD) Implementing agency: GoZ **Total project cost:** US$ 51.2 million	Revitalization of about 8,000 ha of existing smallholder irrigation schemes, mostly in communal and old resettlement areas in the natural regions III, IV and V in the provinces of Manicaland, Masvingo, Matabeleland South, and Midlands provinces benefitting more than 20,000 households through 1) rehabilitation and development of irrigation infrastructure, 2) extension of agricultural credit, 3) institutional strengthening, 4) improving market access and business development and 5) ensuring adequate catchment management. Government is expected to establish a unit to co-ordinate the implementation of the programme.	Due to start in April 2017. The Programme will disburse some of the money through the Department of Irrigation. To this end the Department has been audited by Deloitte and Touche, a leading accountancy firm.

Project/Programme details	Description	Results/current status
DSF grant: US$ 25.5 million (channelled through Ministry of Finance)[83] **Approval date:** 2016-09-22. **Number of beneficiaries**: 20, 000 households		
Name: Shashe Irrigation scheme **Donor:** EU, UNDP/GEF **Implementing partners:** CESVI and Safire **Amount:** Unavailable **Safire grant:** 1.5 million **Duration:** 2011-2015	Creation of a sustainable system of management through a major paradigm shift involving three interlinked principal ingredients: 1) market viability, 2) strategic partnerships and 3) maximum devolved jurisdiction to local level as well as introduction of citrus and on a scale both in terms of hectares and lead-time (5 years for its commercial viability).	-Food security has already been enhanced and the general livelihoods of all the people have been improved. -Farmers were assisted to managed state of art irrigation technology: 1) submersible pumps replaced well points supported by prime movers mounted on the riverbanks, 2) polyethylene pipes replaced asbestos cement delivery pipes, canals and furrows, 3) booster pumps and generators (to overcome power outages and insure water delivery), 4) centre pivots installed to provide water to citrus and

[83] The feasibility report is being finalised. The objectives are the same as for SIP save for inventory of schemes.

Project/Programme details	Description	Results/current status
		inter-row crops with maximum accuracy, efficiency and reliability.
Irrigation projects that factor climate impacts		
Name: Climate Resilient Infrastructure Development Facility (CRIDF) pilot projects: Kufandada and Bindangombe **Funder:** DFID **Duration:** 2013-2016 **Amount:** £24 million	Construction of (new) climate resilient infrastructure through a river basin approach, underpinned by a 100kW renewable energy power source (solar). Based on a financial and sustainability analysis. Facilitated IMC formation and constitution drafting, introduced a 'maintenance fund'; introduced offtake purchase agreements and outgrower market linkage; integrated AGRITEX into the running of the scheme; facilitated soil fertility restoration on degraded lands	Solar power to hospital Functioning Irrigation Management Committee with Maintenance Fund Communally owned and managed bulk irrigation infrastructure
Solar interventions on irrigation schemes		
Name: Mashaba Solar Mini Grid Funders: European Union (EU-ACP), OPEC Fund for International Development (OFID), the Global Environmental Facility (GEF) **Implementing agencies:** SNV, Practical Action, and Dabane Trust with the support of Government Ministries and Departments.	Providing in excess of 160KW solar energy to power three irrigation schemes, five business centres, a clinic, a school and a study centre. The project demonstrates a business and financial model of providing decentralised renewable energy through a partnership of public and private sectors and donors. The major aim of the project is to promote universal access to modern energy services for 10,000 rural men and women in 2,800 households in Gwanda South, contributing to better economic and social well-being.	Achievements are listed as: -A 99KW decentralised mini-grid, 2 energy centres and 2 stand-alone power units that will sell power to 3 irrigation schemes, 5 business centres, a clinic, a school and a study centre. -An energy centre that supports economic activities such as cold rooms, agro processing, welding and similar activities that require substantial energy.

Project/Programme details	Description	Results/current status
Duration: 2015-2019 **Amount:** £4.6 million Beneficiries:10, 000 persons		-A resource/study centre which will house facilities that include ICT provision, e-learning, internet, TV, after hours study and community information. -Energy kiosks for household energy requirements such as lighting, communication/mobile phone charging, entertainment (televisions and radios), battery charging among other low energy uses.
Name: OXFAM Rural Sustainable Energy Development (RUSED) **Funders:** cofounded by the European Union through the ACP-Energy facility and Oxfam **Implementing agencies:** jointly implemented by Oxfam and Practical Action. **Amount:** EURO 2 million **Duration:** 4 years (August 2011 – July 2015)	Project objective: to enhance sustainable livelihoods for the poor rural population by increasing access to modern, affordable, and sustainable renewable energy services in Zimbabwe by 2015. The project was implemented in the Gutu district in wards 12, 13, 14 and 15 and in the Mutare district in ward 22. In Gutu the project promoted community's increased uptake and access to solar powered renewable energy products, while in Mutare the project promoted enterprise development and improved livelihoods options from electricity supplied through a Micro Hydro power plant. In Gutu the project expanded the previous project in the district, the Ruti irrigation scheme and food security and livelihoods projects. In Himalaya in Mutare, the project built on the Chipendeke Micro Hydro power scheme established in the same area by Practical Action.	The Ruti irrigation project has been a great success – it is currently seeing farmers produce an average of 4 to 5 tons of maize per hectare, whereas on their dryland plots they have harvested almost nothing this year (2015) due to serious drought. Creation of a solar market Power to four clinics and two schools – increasing safety and quality of hospital services – considerable impacts on health and education Project results:

Project/Programme details	Description	Results/current status
Target groups: 300 irrigation farming households, 2 clinics, 1 school, 20 local entrepreneurs and 1 agribusiness centre		Himalaya irrigation community has access to micro-hydro energy system. Ruti irrigation community has access to solar energy systems for socio-economic activities Market linkage system developed for solar lanterns and solar technical support to serve up to 500 households around the Ruti irrigation scheme in Gutu. Final beneficiaries: 19,200 men, women and children

Source: Various

2.3 Lessons learned

2.3.1 Climate resilient design

Irrigation interventions in Zimbabwe have largely implemented a ‘rehabilitation approach’ (sometimes called a ‘modernisation approach’), that predominantly follows a ‘business as usual’ approach. This consists of re-engineering deficient infrastructure to its original design, or constructing new schemes based on original designs. This approach does not consider that the design *itself* may be inadequate to take into account changes in land and water resources as a result of climate change. For example, it does not consider that an increase in the frequency and severity of floods and droughts may necessitate a change in infrastructure, in both a design sense in terms of engineering specifications, to account for more variable flows, and the increasing occurrence of more intense floods; as well as in implementation and management, such as incorporating climate risk management into institutional arrangements and O&M plans (see below). The Shashe irrigation project implemented by Safire and funded by UNDP/GEF has made great progress in terms of providing irrigation for 450ha in Manicaland province (AER IV and V). A weir has been built and support for the upkeep of irrigation infrastructure and agronomic practices is provided by AGRITEX and DoI. However, every year, even with one storm, the whole of the distribution canal, which conveys water from the water source to farmers’ fields, is completely silted. Flooding in the region has been seen to be increasing, as well as the occurrence extreme flooding events, such as the severe flash flood which hit the Shashe irrigation scheme on the night of 26th December 2014. The rainfall received amounted to 70mm, which is considered extreme relative to the area (the previous recorded highest rainfall was 50mm in 2013)[84]. Contributing factors were reported to be the high levels of siltation caused by continued poor land use practices like overgrazing and stream bank cultivation in the upstream catchment areas. Each time, the 8km distribution canal is desilted by renting government owned mechanical equipment for $200 per hour.

A lack of consideration of climate change impacts in irrigation design often results in damage to investments in infrastructure from floods, as well as inefficient operation of pumping plants due to highly variable water levels. This makes the entire irrigation system and farmers’ livelihoods more vulnerable to climate change impacts, as during a mid-season drought, a few hours of irrigation to farmer’s crops can prevent heat stress, thus avoiding the crops to be destroyed. Typically, a ‘rehabilitation’ approach also pays limited attention to institutional arrangements which incorporate climate risk management into planning and O&M (Operations & Maintenance) (see below)[85]. Additionally, many irrigation designs incorporate irrigation technology that is inefficient; particularly concerning water wasting irrigation systems e.g. flood irrigation. In response to climate change, especially in areas that are likely to experience an increase in rainfall variability, it is imperative to increase efficiency and appropriateness of irrigation infrastructure.

[84] Safire. 2015. Shashe Irrigation Scheme Post Flooding Disaster Assessment Report. Safre.
[85] Renault, D. Modernization of irrigation systems: a continuing process. FAO Corporate Documentary Centre. http://www.fao.org/docrep/003/X6626E/x6626e04.htm.

The UK's Department of International Development (DFID) funded Climate Resilient Infrastructure Development Facility (CRIDF) has implemented demonstration climate resilient projects in Bikita, Chivi and Gwanda districts (see Table 2, above). One such project is the 28ha Kufandada Irrigation and River Protection scheme, located in a communal area in Bikita District, forming part of the Save River basin, Masvingo Province, 95 km east of Masvingo town. CRIDF's approach factors climate considerations into irrigation design, by including the results of local-level climate vulnerability and risk assessments and hydrological modelling (for variable flows and climate-related extreme events) to 'climate proof' infrastructure, so that the intervention is able to adequately withstand current and future climate impacts. The Kufandada scheme design includes a 100kW solar power supply, a weir, 1 million litre night storage tank and several kilometres of pipe network for irrigation. The solar power supply is set up to directly benefit a rural hospital, with a total service population of approximately 40,000, including pregnant women, HIV patients and young children, including orphans. Collectively, climate proofed water abstraction and storage infrastructure, the use of solar power, coupled with climate risk-informed institutional arrangements, extension services and market linkages (see below sections) have created an empowered and enthusiastic beneficiary rural community. This has enhanced the climate resilience and sustainability of investments, and indicates that 'climate resilient' design is inherent to successful interventions in the area, given the climate change context in southern Zimbabwe (see Chapter 1).

2.3.2 Appropriateness of concepts, irrigation technology and equipment

The Brazilian-Zimbabwe Cooperative Programme under the More Food for Africa programme provides Zimbabwe with tractors, tractor drawn machinery and irrigation equipment in a concessionary loan agreement (see Table 6). To complement the equipment and machinery, the programme promotes the concept of family farming, which is credited for most of Brazil's improvements in agriculture development since Lula da Silva's presidency[86]. However, this concept does not assume the same meaning in Zimbabwe. In the Zimbabwean context, family farming is synonymous with subsistence farming, where households manage plots of land often no more than 2ha in size, with limited tools and inputs. As presented in Chapter 1, at best, households produce just enough to meet family consumption needs. In Brazil, a typical family farm is larger than even a large scale commercial farm in Zimbabwe, and has access to a greater amount and quality of agro-inputs and resources, relatively speaking. In terms of implementation, unlike the Brazilian case, Zimbabwe does not have a plethora of active civil society structures the government can readily partner with to promote the family farming concept, and for full utilisation among the target group of beneficiaries (smallholder farmers), some sharing of the machinery and equipment may be necessary. While this has been relatively successful in Brazil, from past experiences in Zimbabwe, the use and management of communally owned farm machinery presents problems[87]. Thus, due to the Zimbabwean scale and setting, complex technologies and large-scale equipment may not be the most suitable. Ox-drawn equipment may offer better chances for success on individual small-scale plots. On the CRIDF projects famers have resorted to ox-drawn land preparation instead of tractor drawn

[86] Mukwereza, L. 2015. Zimbabwe-Brazil cooperation through the More Food Africa Programme. FAC Working Paper.
[87] Mukwereza 2013; Rusike 1988 in Mukwereza, L. 2015. Zimbabwe-Brazil cooperation through the More Food Africa Programme. FAC Working Paper.

implements. It is also important to note that equipment belongs to and is run by DoI, GoZ, which in itself, while guaranteeing technical services, introduces some bureaucracy.

Communally owned bulk water supply infrastructure has been found viable where communities realise economic benefits through their individual plots within the scheme. Maintenance of this common infrastructure has been accepted in such instances.

2.3.3 Market linkages

The FAO has been one of the most active implementing agencies in Zimbabwe over the past 10 years, working in collaboration with GoZ and various donors including the EU and Dutch. It is the lead agency of the Agriculture Cluster, coordinating and monitoring humanitarian interventions in the agricultural sector and chairing monthly agriculture meetings, bringing together the key actors in the sector[88]. It has implemented a number of programmes focusing on food security, with irrigation and market linkages components. In an evaluation report of the Market and Agri-services linkage component of the FAO's Smallholder Micro-Irrigation Development Support Programme (SMIDSP) (see Table 5), a sustainable irrigation scheme is characterised by 'viable production, which in turn will be guaranteed by linkage and access to a viable sustainable market'[89]. The report concludes that such arrangements have scope for contributing to overall programme sustainability, as they offer assured markets; provided the farmers are able to maximise viable production. This will be enhanced by the farmers receiving quality technical assistance on production, marketing, and financial management as well as having sustainable organizational arrangements that minimize transaction costs (for both the farmers and the buyers) and offer opportunity to benefit from economies of scale.

The Swiss Agency for Development and Cooperation (SDC) has also been very active in promoting value chains through its projects in Zimbabwe, principally seed value chains. For example, the Seeds and Markets Project (SAMP) adopts a systems approach across the entire seed value chain. Working with GoZ, the project aims to strengthen the link between small-scale seed producers and crop breeders in the public sector, in order to promote farmers' access to appropriate seed varieties[90]. Correspondingly, the project focuses on demand aspects, as seed production was carefully planned jointly with distributors who provided a market for seed. One target area of the project was in the Zaka district of Masvingo. SDC is also supporting international partners such as the International Maize and Wheat Improvement Centre (CIMMYT) located near Harare to promote greater production of quality seeds of improved varieties[91]. From this experience, focusing on both supply and demand seems a crucial element of a value chain 'systems' approach, as well as focusing specifically on

---

[88] IFAD. 2016. Smallholder Irrigation Revitalisation Programme: Detailed Design Report. East and Southern African Division. Programme Management Department.

[89] Mudimu, G. D. Mid-term evaluation of the smallholder micro-irrigation development support programme (SMIDSP) report on the Market and agri-services linkage component. FAO.

[90] Kinloch, D. V. 2015. Final Report: Preparation of Project Design Document for Seeds and Access to Markets Project (SAMP) Phase 3. SDC.

[91] OECD. 2012. Effective support for agricultural development. China-DAC Study Group.

engaging private companies such as seed producers in interventions, which would contribute to irrigation sustainability and provide an exit strategy.

Additionally, lesson learning from an intervention by the Japan International Cooperation Agency (JICA) indicates that the absence of market linkages may be a limiting factor to the success of the programme. In 1997, the Japanese government financed the construction of Munjanganja Dam, a water transfer canal and a night storage dam, while GoZ financed construction of infield infrastructure (see Table 5, above). JICA supported the irrigation scheme next to the dam, which is managed by an Irrigation Management Committee (IMC) that has a binding constitution, written in the vernacular, and supported by DoI for the maintenance of canals and watering schedules. AGRITEX provides agronomy training to the farmers. As a result of the intervention, irrigators have confirmed that they rely more on the irrigation enterprise than on rainfed crops because they have high yields all year with a good harvest, if water is available. Despite JICA's conclusive findings on the importance of market linkages, the neighbourhood market is about 30 km away and there remains a need to create market linkage for farmers to improve their income security[92].

2.3.4 Training and capacity building

Several interventions have provided training for communities and extension workers to utilise infrastructure, technologies and equipment provided, to help increase agricultural production, with mixed success. The demand for training is apparent: a study on Save irrigation schemes indicated that only 21 percent of the farmers were trained in basic pump repair and maintenance, despite such training being critical to the sustainability of the schemes. Training in market analysis is a strong component of FAO interventions. In the evaluation of the FAO's Market and Agri-Services Linkages Component of the SMIDSP, discussions with farmers at all schemes visited indicated that farmers have good knowledge and understanding of the need to link production to market demand and secure markets prior to production. However, evidence suggests that in each season, farmers continued to produce crops they had been accustomed to producing and target markets they were used to, instead of identifying markets to guide production. Market assessments would also not be conducted prior to production. Interestingly, the evaluation noted that at all schemes farmers wanted more training on marketing, and that the early impacts of market training provided by the intervention indicated positive steps to changing the behaviour of farmers' to improve their income security over the long-term. The below passage is taken directly from the evaluation report.

From qualitative assessment conducted in the evaluation, the farmers in the SMIDSP programme showed signs of undergoing fundamental changes in their approach to farming and marketing as a result of training on market analysis. From discussions with the farmers, there were indications that their behaviour and attitude to farming as a business is changing as a result of the training they received from the project. They were seen to be aggressively applying some of the knowledge and information acquired from the Training for Transformation and Farm Business Management and Contract Farming. On the programme, two firms that entered into

92 Ibid.

marketing arrangements indicated that they are impressed by the farmers' knowledge and understanding of the business of horticultural production and marketing at Chitora and at Insukamini, in particular. These programme effects are likely continue beyond SMIDSP lifetime thereby contributing to sustainability.

This suggests that it is particularly pertinent to provide training on how to read and interpret markets and, significantly, how to turn market opportunities into action to increase smallholders' profitability, while recognising that this is often one of the hardest aspects of interventions, as it necessitates behaviour change on the part of smallholder farmers and service providers/intermediaries, across government and the private sector. This thus requires a holistic, whole system-level, coordinated approach. Particularly, the FAO experience implies training must engage agribusinesses and distributors in certain aspects. It is important to note that in order for such training to happen, access to high quality and user-friendly information is a prerequisite. It is also important to note that an assessment of climate risks in value chains is a significant gap in market analysis training across all interventions. It is therefore perhaps necessary to work with agribusiness to include climate risk management into their business models by embedding climate resilience into their supply chains.

Zimbabwe has long been a regional leader in agricultural research and development. Currently Zimbabwe receives significant investment in research and development from China. The Chinese government is a major part in Zimbabwe's development, providing technical co-operation as well as a range of grants and soft loans to the country. The USD 30 million Chinese Agricultural Technology Demonstration Centre, which operates as a joint venture with the Zimbabwean government, has been commissioned at Gwebi Agricultural College, about 40km north-west of Harare. It takes applied agricultural research and reform from the Chinese experience since the 1990s. Developing public and mixed-market mechanisms for agricultural research and extension services was a key component of China's agricultural reform. This project consequently applies the same model.

Across all interventions, there is an evident gap in the provision of capacity building training in climate risk management regarding the selection of irrigation technologies, management and maintenance, agricultural production and market linkages, as well as institutional management arrangements.

2.3.5 Financial viability

The evaluation report of the FAO's Market and Agri-Services Linkages Component of the SMIDP states that: 'financial sustainability will be ensured if there is viable production and marketing of produce which will enable the famers to contribute a certain percentage of their crop revenue towards operation and maintenance costs of the scheme, provision of scheme levels services such as technical advice, market assessments, post-harvest facilities, marketing of produce.'[93] While this is theoretically sustainable as a concept, other experiences indicate that this is not enough to achieve financial sustainability. Financial viability in the approach to irrigation scheme design itself is a crucial component to support achievement of financial sustainability, rather than simply relying on increased income supposedly generated by farmers' increased yields. For instance, the CRIDF experience has found that O&M costs need to be factored into the budget line of the project intervention at the start of the

[93] FAO. 2010. Mid-term Evaluation of the Smallholder Micro-Irrigation Development Support Programme (SMIDSP) Report on the Market and Agri-Services Linkage Component. FAO.

project, to allow time for capacity building IMCs to be able to put appropriate measures in place to eventually fulfil their upkeep responsibilities (see case study, below). Additionally, most irrigation schemes have not put in place adequate funding arrangements for O&M due to climate-induced perennial water shortages which have led to depressed production and incomes, compromising their ability to set aside a fund for such purpose. Providing O&M costs for the first two years of operation will allow time to also account for climate risk management into planning. This highlights the importance of a climate resilient irrigation design approach in terms of financial viability, as well as a response to water security per se.

The other critical success factor to financial sustainability as defined by the FAO intervention is productivity, especially with respect to soil fertility. Yields are a direct result of nutrient availability to the crop, all other factors being equal. Most small-scale farmlands in rural Zimbabwe are degraded due to 'mining' of nutrients. In the 1950s, with less population density, nomadic farming used to be practiced to allow rotation of lands to restore fertility. High population densities and poverty have resulted in the same lands being cropped barren of any fertility. CRIDF's Kufandada and Bindangombe schemes have identified that agricultural support to farmers to help them to increase yields is key to both financial and overall sustainability.

Case study: CRIDF’s financial viability assessment

The budget for CRIDF’s pilot project in Kufandada is structured based on a Cost Benefit Analysis (CBA), to assess the financial and economic viability of the project intervention. CRIDF’s CBA results for the Kufandada scheme necessitate a budget consisting of capex grant financing, both upfront and for two years after implementation in O&M, to support the initial start-up of revenue funded O&M by the community. The main premise of the design is that O&M costs are covered in the first two years by the project budget (this is factored into project design as a specific budget line); in order to allow Irrigation Management Committees (IMCs) time to build resources into their budgets for adequate O&M. The capacity building component of the project supports the IMC to incorporate appropriate planning measures. Following this time period, O&M costs are covered by funds collected in a ‘Maintenance Fund’, which all members of the community who benefit from the scheme contribute to on a monthly basis from the start of the project or deducted from revenues (as stated in the constitution). Over time, this should provide enough funds to pay for equipment repairs and for technicians to be hired by schemes to repair the infrastructure. Profits generated from surplus production from the first season would also be included in the ‘Maintenance Fund’ as an initial buffer, to encourage the concept of investing back into the next season, through buying inputs, technology and fertilisers etc., rather than spending profits elsewhere.

2.3.6 Management of irrigation schemes: institutional support component

A crucial element of sustainability in many existing programmes, such as the FAO’s SMDIP, JICA’s Nyakomba Irrigation Scheme Expansion and CRIDF’s Kufandada demonstration scheme, appears to be achieved through providing an institutional support component to communities, to support them to establish self-management and self-governance arrangements (and ultimately self-sustainability), primarily for the upkeep (O&M) of the infrastructure and collective activity organisation regarding cropping patterns. This has predominantly been done through strengthening IMCs. For example, the FAO's SMDIP supported IMCs, and also Marketing Committees, which, with technical support from AGRITEX, organised farmers to exploit economies of scale and negotiate and secure sustainable marketing arrangements. In the evaluation report, two firms involved in the programme, Muchero Africa and Chishawasha Natural Greens, stated that they viewed the level of organization as providing an opportunity for the firms to reduce costs and risk in dealing with individual farmers. The activities of IMCs include ensuring the protection of pumps and motors from extreme floods, maximising benefits from dwindling water resources (through water demand management and conservation) and fixing pipes quickly to ensure minimum leakages and effective water application and reduction of wastage of power.

In CRIDF's Kufandada and Bindangombe pilot schemes, community constitution formulation and drafting was a key element of institutional support. This 'set of rules', allowed the IMC to encourage individual participation to the maintenance of communally used irrigation infrastructure. Related to the above section, a key part of the constitution is contribution by all members of the community who benefit from the irrigation scheme to a fund to pay for communal infrastructure and equipment which may need replacing over time, or for its upkeep. CRIDF's approach also considers the introduction of offtake purchase agreements and outgrower market linkage and facilitating soil fertility restoration on degraded lands to be integral to institutional support, and to scheme sustainability.

The EU-funded CESVI project in Shashe, working with the Beitbridge Rural District Council, located in AER V, Maramani Communal Land, is introducing highly valuable long-term (citrus) and seasonal (grain and vegetables) crops through irrigation, where management arrangements are integral to the project's approach (see case study below). In a lessons learning report[94], the following management arrangements were recommended:

- A management arrangement paradigm must be developed as part of the community's own vision and mission and fit with its worldviews and perception of how to best improve its livelihood strategies
- It must develop in circumstances which allow a conservative and cautious community to adapt to the changes brought about by technology, the demands of a market driven economy and reliance on outside agencies for support and expertise
- Perhaps most importantly, the imperative of ownership of the scheme must be firmly in the hands of the community

In the Shashe irrigation scheme, Institutional models were moved away from a 'technocratic' model, which was originally implemented on the basis that technocrats would manage the scheme at a high level. However, technocrats did not have the capacity to manage down to a field level, and reduced government support lead to infrastructure deterioration and collapse. Local level management did not have the capacity to manage the

[94] Latham, C. J. K. et al. 2015. From subsistence agriculture to commercial enterprise: community management of green technologies for resilient food production. Future of Food: Journal on Food, Agriculture and Society 3(2), pp.8-17.

financial, institutional and marketing requirements for sustainability. However, a 'local' model, which places a greater responsibility on local communities, also fails because technical knowledge is lacking, crops are grown largely for self-subsistence and local institutions fail to manage adequately as they lack capacity. Therefore, the model sought to facilitate institutional arrangements with the aim of creating a major paradigm shift involving three interlinked principle ingredients: (i) market viability, (ii) strategic partnerships and (iii) maximum devolved jurisdiction to local level[95].

A Safire implemented project, funded by GEF/UNDP in Betebridge, has encouraged institutional arrangements in schemes to be considered as essential to success by communities by taking community members in an intervention area to other successful sites. This allows experience sharing to take place, and the incomes of farmers who are members of an IMC run scheme can be compared. The rationale behind such an approach was to try to facilitate behaviour change of farmers: the most crucial aspect of a programme but often the hardest.

IMCs and their membership need access and training in effective use of climate information. Prior to a growing season, appropriate information on rainfall forecasts would inform rainfed and irrigated cropping investment proportions. During the rainy/growing season, bi-weekly forecasts of dry dekads are essential in irrigation cycle planning and management. It is important to note that a gap in support to IMCs is the lack climate risk management in their institutional set up and daily activities.

[95] Ibid.

Case study: Shashe Irrigation scheme (EU-funded CESVI project)

The Shashe Irrigation scheme is located in agro-ecological Zone V in Maramani Communal Land. Here, rainfall is usually well below 650mm and is characterised by erratic and varied distribution. Climate induced droughts and storms are endemic. Storms are often violent and highly concentrated, causing devastating flash floods. Recurrent damage to canals and barrages on irrigation schemes is common. Siltation is a significant problem, caused in part by overgrazing due to non-existent grazing management and massive overstocking in the entire area. Rain-fed agriculture has never been successful in this area. Irrigation has been historically promoted. Although heavily subsidised, irrigation agriculture has been only marginally successful due lack of climate risks consideration in the design of irrigation infrastructure, poor management, lack of markets and unsuitable crops selection.

The approach introduced by the EU-funded CESVI project and the LED funded SAFIRE components focused on various climate sensitive interventions. Firstly, after years of perennial climate disasters destroying crops, in which flooding in the irrigation scheme resulted from the river bursting its banks annually, the SAFIRE project introduced the construction of flood barrages that safeguard the irrigation scheme's perennial losses due to flooding. CESVI also introduced sustainable modern irrigation technology to replace the flood irrigation system. The new system is capable of optimising crop production by reducing the consumption of water. Thirdly, crop diversification was introduced to address climate risks of mono or narrow cropping. The project introduced highly valuable long-term (citrus) and seasonal (grains and vegetables) crops.

The replacement of flood irrigation technologies with a modern and water efficient irrigation system and the introduction of cash crops and contract farming have allowed the community to transform from drought prone subsistence agriculture to climate proofed commercial irrigation. The introduction of centre pivots, while reducing the overall need for water, ensures homogeneous irrigation allowing excellent yields of crops previously unimaginable in hot and dry climates. The introduction of citrus as an additional horticulture crop has proved to be profitable crop for the vulnerable smallholder farmers and has stimulated the establishment and growth of different private company out-grower schemes and investors in the area, like Beit Bridge Juicing and the Schweppes juice processing facility.

2.3.7 Conclusion and gaps

From an analysis of existing and previous irrigation efforts, key lessons identified to take forward in designing and implementing irrigation interventions are:

- Irrigation design that is climate resilient in terms of the design itself (climate proofed water abstraction and storage infrastructure) and incorporates more efficient and appropriate irrigation technology e.g. not flood irrigation

- Appropriate technology and equipment – even though larger equipment may be more effective, it does not appear that large and complex farm machinery is best suited to the context. They may also cause problems in terms of shared ownership. Small family held equipment still appears to be the most suitable
- Market linkages should be an inherent part of any irrigation intervention, focusing on both supply and demand sides of the value chain. Direct involvement of businesses in the project e.g. distributors and seed suppliers should be aimed for at the earliest stage possible, to promote markets and provide an exit strategy for the project
- Training and capacity building on all project components e.g. provision of equipment, strengthening IMCs, market analysis etc. should be provided, to teach farmers/beneficiaries/IMCs how best to utilise infrastructure
- Financial viability is not just a design consideration, but is also a key sustainability consideration, meaning that it is necessary to provide time for IMCs to develop their capacity to plan appropriately for successful O&M in the project budget. CRIDF's Kufandada pilot project provides a useful example of financial structuring to achieve sustainability.
- Institutional strengthening, at the community level and across government and the private sector is integral to irrigation interventions for the investment to be sustained and utilised in the long-term by the community. This is predominantly done through IMCs, and the creation of a constitution and 'maintenance fund'.

2.4 Case study: CRIDF in the Save river basin

Kufandada and Bindangombe irrigation schemes

The Chivi and Bikita Districts lie within the Save River Basin, a water catchment area consisting of tributary flows from the Runde and Save Rivers. The basin, already experiencing lower than average rainfall, is in an area that's particularly vulnerable to climate change. Historically, communities have practiced rain fed agriculture, which posed a viable livelihood strategy without any serious challenges. Recent years, however, have seen increasing climate impacts such as lengthening dry season and longer in-season dry spells. Unsustainable local land use, including stream bed cultivation in search of water, has led to soil erosion and silt build-up in the river and its associated infrastructure, damaging the river ecosystem. Unemployment also tops 90 percent and there's a high dependence on subsistence farming, which means the population is extremely vulnerable to drought, hunger and malnutrition, while relying on potentially diminishing and contaminated water sources.

CRIDF has recently completed the Kufandada irrigation scheme, which focuses on directly addressing the growing climate vulnerability of the local community and Bikita Rural Hospital, by ensuring the availability of safe, clean water for domestic usage, as well as enabling farmers to boost their incomes by engaging in effective, small-scale, commercial farming. The Hospital has been assisted to revive its in-patient nutrition garden scheme. Water is now channelled via solar power pumps to irrigate 28 hectares of land via sprinkler systems from a newly constructed weir to provide a pick-up water storage facility. To ensure the sustainability of the installed system, farmers have been encouraged to no longer cultivate riverbanks and instead protect them with gabion mats and tree plantations preventing soil erosion and consequential siltation of the downstream weir. CRIDF has also repaired existing hand pumps and constructed three new boreholes locally to improve household water access. Five multi compartment ventilated improved pit latrines have also been built to help improve sanitation standards.

A second, similar, water infrastructure scheme has been implemented at Bindangombe. This facilitates the irrigation of 34 hectares of farmland, enabling farmers to diversify their crops and grow year-round. Together with the provision of five new boreholes for village water collection, the scheme is set to improve the food security and nutritional status of 300 households with a further total of 1,200 households benefiting through employment opportunities.

Both projects are part of a holistic intervention which combined the provision of climate resilient irrigation infrastructure with sustainable land use practices, CSA extension services and market linkages, including improving farmers' access to seed suppliers and links to agribusinesses for contract farming opportunities, to ensure the projects' value is maximized and lasting climate resilience is built for the surrounding communities.

Technical assistance for national water authorities

Building on CRIDF's provision of infrastructure and better land management, CRIDF has started working with the Mozambique and Zimbabwean Water authorities to build their capacity to promote better land management, scale up infrastructure for communities, as well as operate existing large-scale infrastructure more efficiently. CRIDF's 12 workshops (to date) on local water management for transboundary benefits, climate change mitigation and adaptation and integrated water resource management have been well received by ARA-Centro in Mozambique and its counterpart in Zimbabwe, the Zimbabwean National Water Authority, ZINWA.

The training sessions, delivered to technical staff at the Save and Runde Catchment Offices, as well as other relevant stakeholders from the water authorities, have been successful in building institutional capacity in water management; as well as encouraged a stronger sense of waterway ownership, driving the sustainability of the project. CRIDF's technical assistance has also involved the establishment of a Save Basin Stakeholder Committee in Mozambique, to formalise stakeholder involvement in integrated water resource management and the transboundary joint management of the river basin. This has contributed to formalising partnerships and facilitating communication.

Promoting regional dialogue and cooperation

The Save Basin is one of three river basins that traverse the border between Mozambique and Zimbabwe. This cross-boundary location has presented challenges for water resource management and development. Yet CRIDF's intervention in the Save Basin has created a space for dialogue and cooperation. Hosting study tours has facilitated the exchange of information between ZINWA and ARA-Centro, helping to forge better mutual understanding of their respective roles. Both have now implemented and been trained in the utilisation of the same water resource planning and management computer modelling software, viz WRYM & P - Water Resources Yield Model and Planning software. The system enables a more efficient monitoring of water movement by predicting the impact of precipitation changes. Both parties have also agreed to adhere to the Save Joint Water Commission's Save Dam Operation Rules Framework, which mitigates water allocation issues by providing guidance on the optimal operation of large river infrastructure for managing water resources and promoting climate change resilience. The framework has also helped to significantly improve data collection and water resource assessments. For example, the data series for rainfall and information on water resource assessments have been extended by 58 years (now covering 1921 to 2015) as a result. Gathering accurate data has boosted confidence in forecasting and led to better-informed resource allocation.

The CRIDF-facilitated cooperation in the Save has led to three agreements between Mozambique and Zimbabwe including:

- The computer modelling package to support water resource assessment planning, development and management in the basin.
- The pilot dam operating rules which have resulted in the regular sharing of information on the status of water resources between the two countries.
- The joint planning, management and development of the shared Save, Buzi and Pungwe Basins by the Joint Water Commission. This includes joint prioritisation and possible joint implementation of the US$ 1.5 billion dam investment program

CRIDF's initiatives in the Save Basin are resulting in transboundary cooperation and promoting an Integrated Water Resource Management (IWRM) approach. By constructing innovative infrastructure on the ground, CRIDF has succeeded in engaging both ARA-Centro and ZINWA on strategic policy issues that affect the whole basin, and reinforced communication channels between them. CRIDF's approach to trans-boundary water management has positively influenced both countries' attitudes to water governance. Strengthening the relationship between Mozambican and Zimbabwean counterparts is a significant step towards further developing the basin for the benefit of its poorer inhabitants and creating climate change resilience.

Table 7: Performance indicators of CRIDF projects in southern Zimbabwe

	Bindangombe	Kufandada
Climate	Annual rainfall of 450-650 mm, severe dry spells during the rainy season, and frequent seasonal droughts. Considered unsuitable for dryland cropping. Smallholders grow drought-tolerant varieties of maize, sorghum, millet. Ideally suitable for cattle production under extensive production systems.	Annual rainfall of 500-750 mm, mid-season dry spells and high temperatures. Production systems are based on drought-tolerant crops and semi-intensive livestock farming based on fodder crops.

<table>
<tr><th></th><th>Bindangombe</th><th>Kufandada</th></tr>
<tr><td rowspan="2">Irrigation Development</td><td>300 households are beneficiaries to the scheme.
Most beneficiaries are vulnerable to famine due to climatic conditions.</td><td>120 households are beneficiaries including Bikita Hospital, which plants nutrition gardens with patients.
Bikita Hospital serves 15,000 people per year</td></tr>
<tr><td colspan="2">Beneficiaries elected an Irrigation Management Committee to steer development of the scheme.
Beneficiaries adopted a constitution and rules and regulations for running the scheme.
Beneficiaries have established a fund to finance operation and maintenance.
Training on operations and maintenance carried for beneficiaries.
Market linkages and production training.</td></tr>
<tr><td>Installed infrastructure</td><td>3.9 km of power line
2ML night storage reservoir to carter for power failures
34 Ha sprinkler irrigation system comprising of 300 plots of 0.1 Hectares each comprising of pumping plant and drag-hose sprinklers. System convertible to drip irrigation to cater for extreme events
Five hand pump boreholes
Environmental works to arrest land degradation and protect the fields</td><td>100kW Solar power plant to provide a source of green energy and capable of powering the installation
A weir on the Rozva river designed to withstand a 1 in 100-year flood
28 Ha sprinkler irrigation system comprising of 120 plots of 0.2 hectares each, pumping plant, balancing 1ML reservoir and drag-hose sprinklers. System convertible to drip irrigation to cater for extreme events
Three hand pump boreholes
Environmental / erosion protection works to protect the works and weir from siltation</td></tr>
</table>

3. Irrigation baseline, site selection and infrastructure design

This chapter presents baseline information on irrigation schemes in southern Zimbabwe to determine the status quo and characteristics of typical irrigation schemes, with a view to informing the infrastructure design and technology selection process. The chapter then details the methodology used to select proposed sites, before presenting the 'climate-proofed' infrastructure design and technology selection approach.

3.1 Irrigation baseline: site characteristics

Through a combination desk-based research, engagement with local communities and authorities, and site visit observations from 16 irrigation schemes across the Save, Runde and Mzingwane river basins, baseline information is presented below.

3.1.1 General characteristics

Location: Irrigation schemes across the Runde, Save and Mzingwane river basins lie predominantly in the Low-Middle-veld of Zimbabwe in AERs IV and V, with parts in AER III. These areas are characterised by relatively low altitude, high temperatures and low and erratic rainfall, with mid-season droughts (see Chapter 1).

Topography: The general topography of the majority of schemes is flat lands with elevations ranging between 450m to 900m above sea level – typical of elevations of the Lowveld area in particular.

Soil quality: Soils are mainly sand to silty loams that drain well. The root zone is deep in most places (up to 1m depth), but a few schemes are located in areas with clay silty loams, with a shallower root zone.

No. of beneficiaries per scheme: Both existing schemes and those planned for development by GoZ generally have upward of 40 beneficiary households per scheme (with each family having between 0.2 and 0.5ha plots). Site visits and consultations indicated that there is no shortage of plot users; rather schemes are oversubscribed with neighbouring households wanting to become members of schemes.

3.1.2 Infrastructure findings

An irrigation system typically comprises of the following infrastructural components: development of a water source, abstraction from a water source, a conveyance system, night/in-field storage, infield distribution (also called 'irrigation technology') and storm and flood storage facilities. Ancillaries are access roads and buildings for administration, storage and sheds. The findings from site visits are presented below, detailing each of these components.

Water source

There are five types of water supply options for irrigation, as follows: river flow, river-bed sand abstraction, dammed water, drilled boreholes and disused mine pits. Irrigation schemes in the target area have a combination of such water sources, with the majority being supplied from river and dammed water.

Abstraction

Water is abstracted and diverted from water sources by either gravity, pumping or a combination of both. The abstraction systems which were identified across irrigation schemes during site visits are presented in Table 7, below.

Table 8: Water abstraction type in southern Zimbabwe

Abstraction Type	Illustration
Direct river pumping abstraction on fixed position and elevation platforms on the river, or dam banks or outlets at dam wall. E.g. Muzhwe, Nyika irrigation, in Runde and Save River Basin	
Direct off-river pumping abstraction on movable trolley (which can change position). E.g. Dinhe Irrigation, Runde River Basin	

Abstraction Type	Illustration
Dam water abstraction sunk intake tower. E.g. Mpudzi Dam, Save River Basin	
Dam wall abstraction e.g. Bindangombe Dam in Runde River Basin	

Abstraction Type	Illustration
Boreholes drilled in riverbed sand. E.g. Tuli River, Mzingwane River Basin	
Boreholes drilled off riverbed on banks and on land e.g. Lower Save River Basin	

Figure 13 Open lined disused canal

Water Conveyance System

Water conveyance systems in the target area are either **rising pipe**, **open lined canal**, or both. In most cases it was observed that there is no flow or pressure measurement facilities. Conveyance **canals** are often left to accumulate silt and sand, which reduces the carrying capacity of the structures (see Figure 13). In canals, abrasion is increased and they often wear more quickly.

Figure 14: Broken canals

Figure 15: Open lined active canal

Where water is supplied and distributed in **pipes**, it was generally noted that at a number of the schemes there were constant breakages on the pipelines, and substantial time is being wasted repairing the pipelines (coupled with the availability of only meagre resources to fix the infrastructure). This results in repeated breakages. The damage to these pipelines is often due to the fact that pipelines were installed at too shallow depths with improper bedding, against the standard guidelines and principles of pipeline installation. This damage is likely to be further exacerbated and/or accelerated due the consequences of climate change, such as erosion.

Figure 16: Broken pipes

Figure 17: Silted open canal

Storm water & soil conservation challenges

It appeared that not many schemes had storm/flood water and soil conservation facilities. Failure to incorporate these into irrigation design has resulted in silted conveyance structures; rendering them non-functional (see Figure 9). In such instances, the concerned sections of the scheme are cut-off from the water and no irrigation takes place.

Night / In-field Water Storage

In almost all schemes, there is either an earth night storage dam, or in-field storage in a constructed brick reservoir. Leakage in reservoirs was a common issue, as was siltation in night storage dams.

Figure 18: Brick reservoirs

Figure 19: Night storage

In-field distribution

Almost invariably, all in-field application systems employ surface methods of furrow, flood, border or sprinkler irrigation, with the majority being flood, drawing water from canals by siphons. Water is usually brought to the field by canals and distributed to the fields by smaller canals. Water is then applied to the field by siphon pipes. Irrigation only takes place when water is being delivered to the fields as per an agreed schedule.

At the Mzingwane scheme, an out of service sprinkler system prevents water from being distributed (see Figure 5, below).

Figure 20: Out of service sprinkler system at Mzingwane scheme

Figure 21: Flood irrigation

Scheme Access Roads

With very few exceptions, access to most of the schemes is only possible by off road vehicles, because the road surfaces are too rough with numerous corrugations, streams, rivulets and rivers that have no culverts and bridges (or these have been washed away in previous floods and have not been repaired or replaced) – meaning communities have poor access to markets, inputs, information, technology, resources etc. In addition, those servicing the irrigation facilities may have problems accessing the schemes. Some roads have been constructed haphazardly without regard for set national standards.

Figure 22: Obstructed Road Access

Storage Facilities and Sheds

The need for buildings for office and storage space at schemes was most notable in Save at Zuvarabuda site, where a pump and motor taken for repairs suffered irreparable damage from weather and other conditions due to lack of storage facilities. The cost of replacing such equipment and the cost of the inconvenience is higher than that of providing these facilities.

Summary of findings

Overall, in all cases, existing schemes had the following components:

- A water source which in some instances needs development e.g. drilling and development of borehole, construction of storage or pickup weir, water intake structure, well points in river bed etc.
- Abstraction system generally consisting of a pumping system or headworks for a gravity system with discharge control mechanisms
- Water conveyance system of either rising pipelines, gravity pipelines, canals and siphons for crossing water courses
- Infield water storage reservoirs
- Land preparation to level and attain requisite grades
- Distribution pipe or canal system complete with control units to distribute the water into the fields
- Drainage system to collect excess irrigation water and its disposal
- Rudimentary storm water drainage system for the management of rainfall runoff
- Access roads

Infrastructure challenges

While the schemes are in various operational states, they continue to experience viability problems, generally in terms of physical infrastructure and operation. The main problems identified are:

- Poor performance due to poor design
- Failed pumping systems due to breakdowns or power outages, or disconnections due to power debts
- Failed irrigation water conveyance and distribution pipes and canals and associated control structures
- Poorly constructed structures failing to function as expected, resulting in failure to get water to the fields
- Irrigation infrastructure vandalised by wild animals, such as elephants
- More recently, failure due to substandard inferior materials and equipment being used

3.1.3 Institutional and management findings

In addition to infrastructure components, irrigation schemes require various institutional and management arrangements for the design, construction and operation phases. Findings from site visits are presented below.

Operation and maintenance

It was clear during discussions with stakeholders that institutional and organisational decline has had a profound impact on routine maintenance of water distribution systems, which includes cleaning and minor repairs. Inadequate routine maintenance reduces water delivery and shortens the life-span of the water distribution system, posing a threat to irrigation farming.

Institutions and support services

Increasing the ability and capacity of smallholder irrigators to respond to climate change through their farming practices is a pre-condition for turning a downward collapse of schemes into upward recovery. Institutions and support services are essential to helping achieve this, as irrigation in response to climate change can only be successful if farmers have holistic packages of support provided by various institutions, and work together.

Farmers involved in irrigation schemes are dependent on each other, because they share the water distribution systems and related infrastructure. This interdependence requires a willingness on the side of farmers to organise themselves and work collectively, in order to achieve their individual objectives. Farmers must collaborate on routine maintenance efforts for the shared water supply and distribution systems, payment for energy where pumping is involved, and payment for water where this has been instituted. Farmers must therefore coordinate their activities, made possible through efficient and functioning institutional and organisational arrangements in Irrigation Management Committees. On many schemes, particularly canal schemes, collaborative arrangements governing the distribution of water to the various hydraulic units and individual plots are essential to ensure that all farmers receive their equal share.

Rules to govern collaboration (institutions) and structures to enforce these rules (organisations) are necessary for effective and sustainable functioning of collective action. Evidence suggests that on their own, irrigator communities and their volunteer leadership structures, usually in the form of elected Irrigation Management Committees, find it difficult to develop enforceable rules. Farmers pursuing individual goals instead of collective goals challenge institutions and erode organisational effectiveness of irrigators.

Weak support services were noted during the assessments in most smallholder irrigation schemes. Support services include extension staff and managers from the Ministry of Agriculture and from service providers of irrigation infrastructure (e.g. pump companies). Others actors (such as those responsible for innovation in smallholder irrigation, and public extension workers who are responsible for guiding and supporting farmer development) have all fallen short of fulfilling their mandates. A lack of effective support services was one of the most resounding findings across almost all schemes. Additionally, support services in farming practices which support farmers to determine soil fertility/plant nutrition, cultivar choice, plant population and plant protection are all necessary for successful farming; otherwise the approach will never be sustainable nor result in transformational change. However, these services are not yet readily available in schemes. It was established that on most smallholder irrigation schemes, farmers have not reached the necessary level of competency and confidence to optimally exploit their farms.

Management

Communal smallholder irrigation schemes are normally managed by the community itself, in Irrigation Management Committees (IMC), and advised and supported by government extension services. Such services provided by IMCs involve management of water distribution, system maintenance, input supplies, marketing, finance, personnel, planning and monitoring etc. The extent of support with regard to these services differed from site to site, but the presence of such services is noted as key to the long-term sustainability of the schemes. Strengthening of such management support is crucial.

Cropping Arrangements

The most common crop with consulted beneficiary farmers was maize for consumption (both as green mealies and dry for maize meal preparation). Beans was the other crop under intermittent cultivation, but some schemes reported that they also practise horticulture with crops like tomatoes. Farmers indicated that they have the capacity and willingness to provide their labour to participate in farming activities throughout the year.

Security

Irrigations schemes need to have security against physical damage by humans and domestic and wild animals to safeguard investments made in infrastructure. On most schemes, the necessity for this was clearly visible; most communities have resorted to using traditional protection measures i.e. use of thorny bushes branches, as existing fences have collapsed and are no longer effective in keeping animals out. There is no money readily available to invest in better protective measures.

3.2 Site selection

A five-step methodology was used to select proposed sites for intervention.

Identification of vulnerable areas

As a result of analysis conducted by the ZRBF[96], vulnerability assessments have been carried out to identify areas most at risk to climate change impacts. These assessments have produced tools (maps) that have pointed to AERs IV and V – which lie in the Mzingwane, Save and Runde river basins and Matabeleland South, Mazvingo and Manicaland provinces – as being the most vulnerable. This study used these findings as the starting point for irrigation scheme site selection. This is because this area, home to approximately 3.5 million people, suffers from the greatest occurrence of multi-hazards (including droughts, mid-season droughts and flooding) (see Figure 22). It is also the area where majority of the population has the least adaptive capacity to cope with climate risks. It is predominantly made up of communal lands, with limited access to resources and services, and people largely suffer from extreme food and income insecurity (see Chapter 1).

96 ZRBF. 2016. Mapping of selected hazards affecting rural livelihoods in Zimbabwe: A district and ward analysis. UNDP Harare.

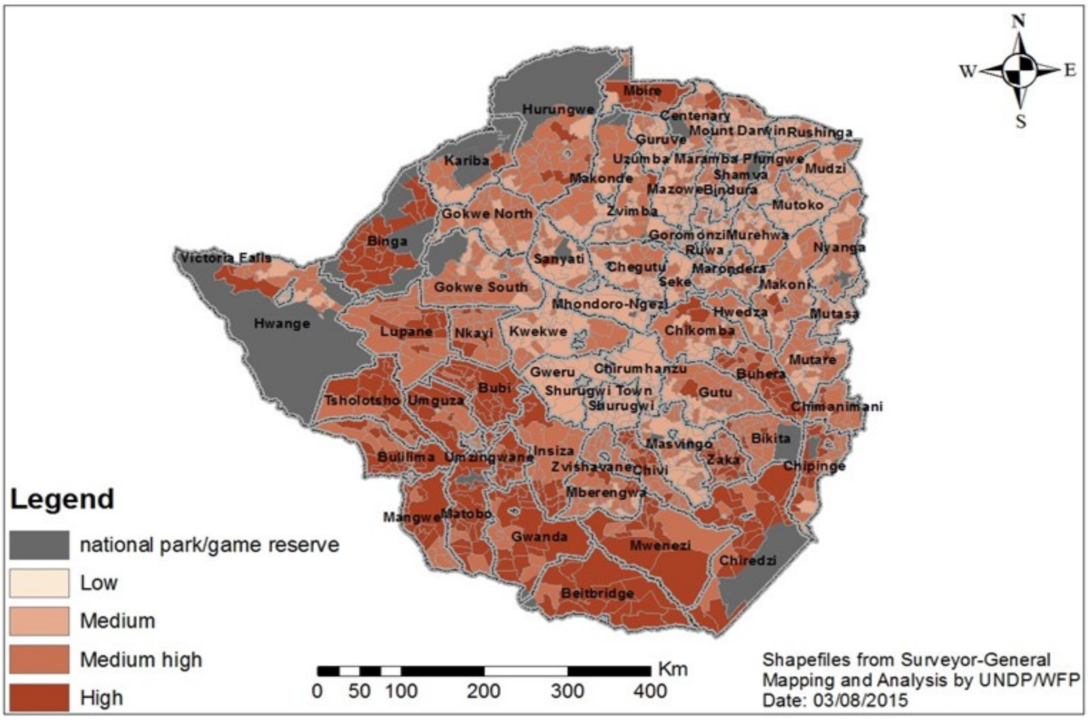


Figure 23: ZRBF mapping of multi-hazards (including droughts, mid-season dry spells and floods)

Collation of all known schemes in the vulnerable areas

DoI is the national authority responsible for all publically managed irrigation infrastructure, both in terms of identification and development. As such it has a full list of all known public irrigation schemes across the country under its Irrigation Masterplan. This list comprises of 500 plus irrigation schemes. As a second step, DoI's list was used to identify all known schemes across Mzingwane, Runde and Save catchments (see Annex 1). The irrigation schemes identified were then cross-referenced and supplemented where necessary by other sources, such as CRIDF and the AfDB funded Shared Watercourse Support Project known irrigation schemes.

Selection criteria developed

A selection criteria was developed to narrow down the 500 plus existing schemes to a viable number for the proposed programme to target. The criterion selected was validated by findings from desk-based research and site visits, as well as from consultations with relevant key stakeholders. Table 2 below presents the five criteria employed and their justification. It is important to note that the justification of one criterion overlaps with others, reflecting the holistic nature of the exercise and approach.

Table 9: Selection Criteria

Criterion	Justification

1. Size of irrigation scheme: between 20-150ha (weighted 5 percent)	A size limitation of no less than 20ha and no more than 150ha has been selected, except in exceptional circumstances[97]. This is because for the investment needed per scheme, less than 20ha would yield an impact that would not be on the scale required to achieve transformational change: the beneficiary size would most likely be below 40 households (see below) and indirect beneficiaries would be limited. Any larger than 150ha would require a disproportionate amount of the budget, which would limit the ability of the overall project to intervene in areas across the three river basins in the southern provinces that are resident to those most vulnerable. Somewhere between 50-100ha would be the most ideal, to ensure investment is maximised according to size, but with a distribution which allows areas across the three provinces to be targeted. This would result in between 50 and 100 schemes in total, to give an intervention area of 2 - 5,000ha across the three provinces.
2. No. of beneficiaries: no less than 40 households (weighted 10 percent)	A household tally of no less than 40 per scheme has been selected, to enable resources to be targeted in a way in which collectively results in the greatest impact across the southern provinces. Any fewer households would mean that for the investment needed in the target site, resources would be less easily available to be disbursed throughout the three provinces. However, it is important to note that there is an exception to this is if there are fewer households with severe vulnerability (see below). Ideally, targeted sites are those that result in the maximum number of beneficiaries possible.
3. Land availability (only in communal areas) and soil suitability (weighted 15 percent)	A public irrigation investment can only be implemented if a) land is available (hence land must be communally owned) and b) soil quality is sufficient for agriculture both now and under projected climate change, given the impact of irrigation. No irrigation schemes are proposed for privately owned or managed lands.
4. Water availability (weighted 40 percent)	Fundamentally, an irrigation scheme cannot be introduced in an area without available water, both now and under projected climate change, which creates the demand for irrigation. This criterion therefore receives the highest weighting at 40 percent.
5. Vulnerability (weighted 20 percent)	The vulnerability of communities to climate change, or their lack of adaptive capacity, is one of the most important selection criteria, as in certain places

[97] Please note: opportunities to expand beyond 150ha exist and were not discounted

	over others, climate change impacts and poverty collide to produce vulnerability. The purpose of introducing irrigation schemes as a response to climate change is to reduce this vulnerability by increasing resilience, and therefore communities in the most 'need' should be targeted, to the greatest extent possible. Vulnerability is defined as the degree to which a population group is unable to anticipate, cope with, resist and recover from the impacts of disasters[98].

Screening out projects already being implemented

Irrigation schemes were screened against those that are already being implemented under various other donor and public initiatives. This was done to prevent any duplication of effort.

Application of criteria

The above criteria were applied to the DoI's list of schemes to select between 50-100 schemes. Tables 9, 10 and 11 present the selected irrigation schemes per river basin, with a corresponding map (Figure 22) which pinpoints the location of all schemes across the three river basins.

[98] As defined by the International Federation of Red Cross and Red Crescent Societies

Table 10: Mzingwane selected schemes

Mzingwane River Basin											
Entry no.	**Name**	**Location coordinates**		**Province**	**District**	**Irrigation System**	**Water Source**	**Irrigable area (ha)**	**Direct Beneficiary**	**Status**	**Remarks**
M1	Masholomoshe	20°52'24.88"S	29° 6'24.91"E	Matabeleland	Gwanda	Surface/ sprinkler drip	Masholomoshe Dam	39	131	exist	revitalise
M2	Sukwe	21°28'37.78"S	29°18'1.09"E	Matabeleland	Gwanda	Surface/ sprinkler drip	Sukwe Dam. Boreholes	28	44	new	Develop from borehole source
M3	Guyu-Chelesa	21°22'37.05"S	28°58'59.89"E	Matabeleland	Gwanda	Sprinkler	Tuli River	85	160	exist	revitalise
M4	Mankonkoni	21°46'15.11"S	29° 4'54.83"E	Matabeleland South	Beit Bridge	sprinker	Tuli River	40	100	exist	revitalise
M5	Bambanani	21° 1'56.35"S	27°55'35.29"E	Matabeleland South	Gwanda	Surface/sprinkler	Bambanani Dam	8	79	exist	revitalise
M6	Zamangoni / Masiyapambili	21° 4'32.23"S	28°30'11.12"E	Matabeleland South	Matobo	sprinkler	Dam	20	40	new	proposed
M7	Tuli Makwe	20°57'40.74"S	28°46'53.76"E	Matabeleland South	Gwanda	Surface	Tuli Makwe Dam	202	491	exist	revitalise
M8	Mambale	21°31'24.00"S	28°15'39.64"E	Matabeleland South	Matobo	sprinkler	Shashe River	28	56	exist	revitalise
M9	Mabindisa Dam	20°12'35.76"	28°46'14.58"	Matabeleland South	Umzingwane	Sprinkler / drip	Dam	30	630	Partially operational	Dam and infield infrastructure rehabilitation
M10	Gwalabana Dam (Mihlo)	20°58'22.54"	28°24'35.92"	Matabeleland South	Matobo	Sprinkler / drip	Dam	22	600	Partially operational	Dam rehab, Consolidation, irrigation infrastructure for small garden
	TOTAL							**502**	**2331**		

Table 11: Runde selected schemes

Runde River Basin											
Entry no.	Name	Location coordinates		Province	District	Existing/ Proposed Irrigation System	Water Source	Irrigable area (ha)	Direct Beneficiary Households	Status	Remarks
R1	Machena	20°35'4.07"S	31°37'59.44"E	Masvingo	Zaka	Sprinkler	Manjirenji and Siya Dams	150	110	exist/ new	revitalise using boreholes (Abundant and shallow groundwater)
R2	Zvinyarikwe Muzhwe	19°56'8.86"S	19°56'8.86"S	Masvingo	Chivi	Sprinkler	Muzhwe Dam	150	300	new	Muzhwe dam tail end abstraction
R3	Musaverema A	20°46'29.98"S	30°32'5.83"E	Masvingo	Mwenezi	Flood/sprinkler	Musawerema Dam by Japan JICA	35	142	exist	revitalise
R4	Nyika Muzhwe	20°11'0.32"S	30°28'37.55"E	Masvingo	Masvingo	sprinkler	Tokwe River from Muzhwe Dam	40	100	new	new
R5	Bwanya	20° 1'20.02"S	30°25'16.62"E	Masvingo	Masvingo	sprinkler	Shashe River	150	300	exist/new	revitalise/ expand
R6	Dinhe	21°11'53.30"S	30°31'47.21"E	Masvingo	Masvingo	sprinkler	Mwenezi River from Manyuchi Dam	35	142	exist/new	revitalise/ expand
R7	Pikinini Jawanda	21° 1'24.35"S	30°25'19.40"E	Masvingo	Mwenezi	sprinkler	Manyuchi Dam	200	300	new	New. ZESA source 14km away. Solar suggested
R8	Nyahombe	20°49'49.93"S	30°59'30.28"E	Masvingo	Chivi	sprinkler		200	300	new	To benefit from Tokwe Mukorsi
R9	Budirirai	20° 4'41.66"S	30°26'16.37"E	Masvingo	Masvingo	Sprinkler	Tokwe River from Muzhwe Dam	20	40	exist/new	revitalise/ expand
R10	Chizumba	21°10'5.94"S	30°32'58.93"E	Masvingo	Chivi	Sprinkler	Mwenezi river from Manyuchi dam	65	250	exist	Revitalise
R11	Diso	20° 2'17.35"S	30°29'46.38"E	Masvingo	Masvingo	sprinkler/drip	Mashava Disused Mine Quarry	40	80	new	New. Water from disused mine pits
R12	Malikango	21°42'5.79"S	31°13'13.75"E	Masvingo	Chiredzi	sprinkler/drip	River	50	200	new	Grid electricity 9km away. Suggest solar
R13	Banga	20°50'16.96"S	30°48'59.48"E	Masvingo	Chivi	sprinkler	Banga Dam	51	425	exist	revitalise Fence need rehab
R14	Matezva	19°54'59.14"S	31°25'29.54"E	Masvingo	Masvingo	sprinkler/drip	Matezva Dam	20	100	exist	revitalise
R15	Gororo	20°45'7.09"S	30°54'0.49"E	Masvingo	Chivi	sprinkler	Tokwe Mukosi	120	240	new	New. To benefit from Tokwe Mukosi
R16a	Bindangombe	20°25'9.62"S	30°37'22.69"E	Masvingo	Chivi	Sprinkler	Bindangombe Dam	34	150	exist	Convert existing power source to solar
R16b	Bindangombe	20°25'9.62"S	30°37'22.69"E	Masvingo	Chivi	Sprinkler	Bindangombe Dam	34	150	exist	Convert existing power source to solar
R16c	Bindangombe	20°25'9.62"S	30°37'22.69"E	Masvingo	Chivi	Sprinkler	Bindangombe Dam	34	150	exist	Convert existing power source to solar
R17	Gondo	20° 6'14.16"S	30°27'10.69"E	Masvingo	Chivi	Flood/sprinkler	River	20	60	exist	Revitalise. Extension of scheme.
R18	Mufusirwa	20°41'57.04"S	32°13'8.20"E	Masvingo	Chiredzi	Centre pivot	Save river/ Osborne dam	50	100	new	Electricity 2km away. Solar suggested
R19	Zvavahera	19°34'2.20"S	31°20'9.35"E	Masvingo	Gutu	Sprinkler	Dam	46	46	exist	Revitalise. Needs fencing
	TOTAL							**1544**	**3685**		

Table 12: Save selected schemes

Save River Basin											
	Name	Location coordinates		Province	District	Existing/ Proposed Irrigation System	Water Source	Irrigable area (ha)	Direct Beneficiary Households	Status	Remarks
S1	Zuvarabuda	21° 4'57.38"S	32°16'7.81"E	Manicaland	Chipinge	Surface/sprinkler	Save River	20	270	exist	revitalise
S2	Farai	21° 4'36.96"S	32°16'4.50"E	Manicaland	Chipinge	Surface/sprinkler	Save River	30	75	exist	revitalise
S3	Charuma	20°01'21.86"	32°20'58.477"	Manicaland	Chipinge	sprinkler & drip	Save Boreholes	64	45	new	develop
S4	Nyachitimbi	20° 6'11.19"S	32°41'51.81"E	Manicaland	Chipinge	sprinkler & drip	Nyamachitimbi River	18	60	exist	Water supply from Nyachitimbi river.
S5	Rimbi	20°33'35.73"S	32°21'49.29"E	Manicaland	Chipinge	Surface/ sprinkler	Save River, 15km pipeline	500	1600	exist	Save, 15km long pipeline
S6	Veneka	20°58'37.70"S	32° 9'40.39"E	Manicaland	Chipinge	Surface/ sprinkler	Save river sand abstraction	30	60	exist	Save River Sand Abstraction
S7	Vimbanai/Mutandahwe	21° 1'45.58"S	32°11'57.26"E	Manicaland	Chipinge	Surface/ sprinkler	Save River	27	68	exist	revitalise
S8	Musirizwi	20°26'42.97"S	32°35'23.00"E	Manicaland	Chipinge	sprinkler	Gambadziya River	60	200	exist	revitalise
S9	Mudzimwa	20° 7'37.61"S	32°23'33.88"E	Manicaland	Chipinge	sprinkler & drip	Tanganda Boreholes	20	60	exist	revitalise
S10	Mpudzi	19°16'54.07"S	32°35'38.63"E	Manicaland	Mutare	Sprinkler & drip	Mpudzi dam	80	800	new	Proposed
S11	Mumhendwe	20° 8'48.89"S	32°21'8.58"E	Manicaland	Chipinge	sprinkler & drip	Boreholes	200	600	new	Proposed
S12	Chisavanye	20°39'25.20"S	32°15'41.32"E	Manicaland	Chipinge	Surface/ sprinkler	Solar Drip. World Vision system completely down. Water from local Boreholes	21	42	exist	Rehabilitate. Solar Drip. World Vision did but system completely down
S13	Taona	20° 6'53.47"S	32°20'55.28"E	Manicaland	Chipinge	Surface/ sprinkler	Save river	262	655	exist	Revitalise
S14	Chakohwa	19°32'39.18"S	32°30'33.66"E	Manicaland	Chimanimani	Surface/ sprinkler	Umvumvumvu River	87	140	exist	Weir needs desilting and revitalise
S15	Mandimwa	19°32'25.42"S	32°45'16.72"E	Manicaland	Chimanimani	Surface/ sprinkler	Boreholes	185	140	exist	revitalise
S16	Nenhowe	19°44'5.01"S	32°25'3.17"E	Manicaland	Chimanimani	Surface /sprinkler	Odzi and Nyanyadzi Rivers	100	100	exist	Pumps require rehabilitation and revitalise
S17	Mhakwe	19°48'3.41"S	32°38'16.44"E	Manicaland	Chimanimani	sprinkler	Munyanyadzi River	20	50	exist	Need training

S18	Murambinda	19°32'25.42"S	32°45'16.72"E	Manicaland	Buhera	Surface/ sprinkler	Abstract Mwerahari river. Await Marowanyati Dam construction	38	76	exist	revitalise
S19	Nerutanga	19°17'38.36"S	31°23'54.37"E	Manicaland	Buhera	Surface/ sprinkler	Nerutanga Dam	40	100	new	Nerutanga dam
S20	Ruti	19°35'30.03"S	31°44'43.74"E	Manicaland	Buhera	sprinkler & drip	Ruti Dam	500	1400	new	new
S21	Mwerihari	19° 6'18.57"S	31°26'58.93"E	Masvingo	Buhera	sprinkler	river	21	210	new	Construct weir and infield irrigation
	TOTAL							**2323**	**6751**		

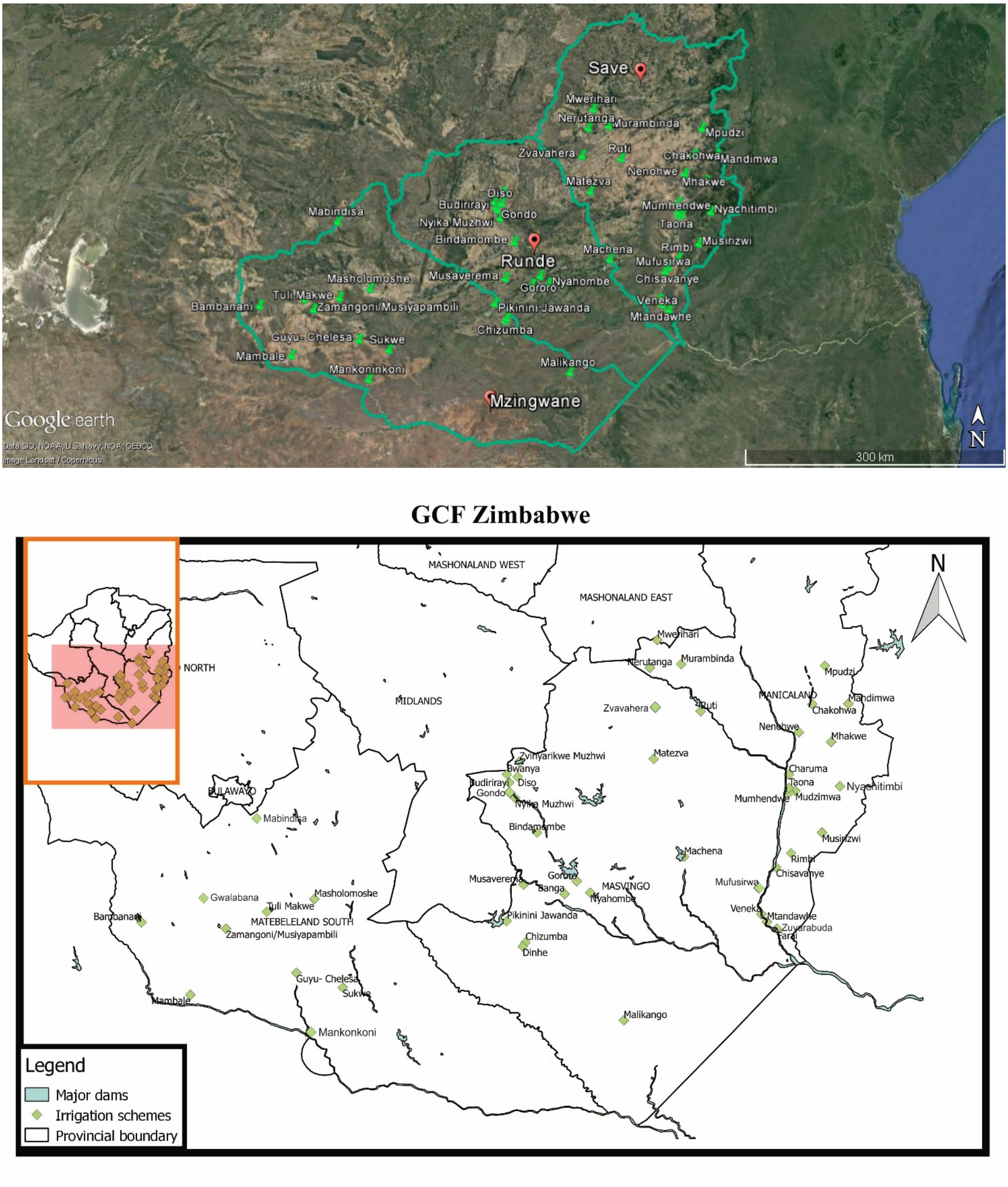


Figure 24: Map of selected schemes

3.3 Infrastructure design

Section 3.1 provided an overview of the baseline site information that should be considered when designing both new and rehabilitated irrigation schemes in southern Zimbabwe, and has been used as a basis for recommending designs and upgrades at each site, as presented in this section. It should be noted that the historical performances and lessons learned of existing irrigation schemes have also been considered to ensure that the shortcomings that led to unsatisfactory scheme performance are adequately addressed (see Chapter 2).

Irrigation schemes are highly case-specific; they are complex and dynamic entities due to a range of factors that influence their effectiveness – including the type of natural resource base (water and soils), technology, scheme and plot size, farmer profile, location and access to markets and services. Diversity among schemes calls for different kinds of interventions to respond to varying farmers' needs and agricultural contexts. For example, revitalisation of existing schemes may see the conversion of canal schemes to pumped overhead sprinkler or drip systems. These revitalisation efforts must be economically and financially viable; it is critical that they achieve reasonable returns otherwise the outcomes will be unsatisfactory relative to investment and efforts. A key primary success factor is the infrastructure design.

However, after analysing the various schemes, a number of similarities were noted in terms of existing and proposed design options:

- The design for infield infrastructure follows standard methodologies – mainly sprinkler or drip.
- Flood irrigation is not recommended in the targeted, water scarce environments.
- The water supply pipelines are computed from the design volume/pressure for water required, resulting in a small range of pipe sizes being required due to the field size limitation.
- The total costs for infield irrigation and supply pipework is determined from unit costs for the conveyance infrastructure.

The highest common cost driver for irrigation is the pumping gear. The pumping gear requirements are determined from the volume and pumping pressure that gives the pump duty point. While this varies from site to site, it can be banded on the basis of type of motor and pump sets to supply the required water volume to the required pressure.

To be able to determine preliminary designs and costings, the schemes were categorised, or 'banded', based on the required pumping infrastructure (see Table 12 below). Schemes that have similar irrigation pump specifications and performance requirements (pump duty point) are grouped into the same band. The pump/motor-based bands also determine the power requirements. The banding thus allows for computation of budget costings, as well as design of power supply requirements.

Table 12 documents the banding of irrigation scheme sites according to head and flow requirements, and Tables 13, 14, and 15 present the banding accorded to each site, per river basin.

Table 13: Banding as per head and flow requirements computed per site

Band	Flow	Head
Band 1	200m3/hr to 540m3/h	Up to 60m
Band 1b	200m3/hr to 540m3/h	Above 60m
Band 2	540m3/hr to 1080m3/hr	Less than 60m
Band 2b	540m3/hr to 1080m3/hr	Above 60m
Band 3	1080m3/hr to 1620m3/hr	Less than 60m
Band 3b	1080m3/hr to 1620m3/hr	Above 60m
Band 4	Higher than 1620m3/hr	Up to 60m
Band 4b	Higher than 1620m3/hr	Greater than 60m

Tables 14, 15 and 16, below, detail the analysed design specifications and band groupings (according to Table 12, above).

Table 14: Mzingwane selected sites per band

	Name	Irrigation System	Est Flow m3/hr	Head (m)	Band
M1	Masholomoshe	Surface/ sprinkler drip	421.2	43	1
M2	Sukwe	Surface/ sprinkler drip	302.4	40	1
M3	Guyu-Chelesa	Sprinkler	918	49	2
M4	Mankonkoni	Sprinkler	432	48	1
M5	Bambanani	Surface/sprinkler	86.4	44	1
M6	Zamangoni / Masiyapambili	Sprinkler	216	58	1
M7	Tuli Makwe	Surface	2181.6	65	4b
M8	Mambale	Sprinkler	302.4	55	1
M9	Mabindisa Dam	Sprinkler / drip	324	44	1
M10	Gwalabana Dam (Mihlo)	Sprinkler / drip	237.6	49	1

Table 15: Runde selected sites per band

	Name	Irrigation System	Est Flow (m3/hr)	Head (m)	Band
R1	Machena	Sprinkler	1620	56	3
R2	Zvinyarikwe Muzhwe	Sprinkler	1620	58	3
R3	Musaverema A	Flood/sprinkler	378	33	1
R4	Nyika Muzhwe	Sprinkler	432	39	1
R5	Bwanya	Sprinkler	1620	49	3
R6	Dinhe	Sprinkler	378	63	1b
R7	Pikinini Jawanda	Sprinkler	2160	76	4b
R8	Nyahombe	Sprinkler	2160	56	4
R9	Budirirai	Sprinkler	216	45	1
R10	Chizumba	Sprinkler	702	70	2b
R11	Diso	Sprinkler/drip	432	69	1b
R12	Malikango	Sprinkler/drip	540	45	1
R13	Banga	Sprinkler	551	49	1
R14	Matezva	Sprinkler/drip	216	58	1
R15	Gororo	Sprinkler	1296	56	3
R16a	Bindangombe	Sprinkler	367		1
R16b	Bindangombe	Sprinkler	367		1
R16c	Bindangombe	Sprinkler	367		1

R17	Gondo	Sprinkler	216	45	1
R18	Mufusirwa	Centre pivot	540	40	1
R19	Zvavahera	Sprinkler	497	80	1b

Table 16: Save selected sites per band

	Name	Existing/ Proposed Irrigation System	Est Flow m3/hr	Head (m)	Band
S1	Zuvarabuda	Surface/sprinkler	216	58	1
S2	Farai	Surface/sprinkler	324	59	1
S3	Charuma	Sprinkler & drip	691	55	2
S4	Nyachitimbi	Sprinkler & drip	194	61	1b
S5	Rimbi	Surface/ sprinkler	5400	70	4b
S6	Veneka	Surface/ sprinkler	324	54	1
S7	Vimbanai/Mutandahwe	Surface/ sprinkler	292	60	1b
S8	Musirizwi	Sprinkler	648	55	2
S9	Mudzimwa	Sprinkler & drip	216	35	1
S10	Mpudzi	Sprinkler & drip	324	67	1b
S11	Mumhendwe	Sprinkler & drip	2160	36	4
S12	Chisavanye	Surface/ sprinkler	227	35	1
S13	Taona	Surface/ sprinkler	2830	50	4
S14	Chakohwa	Surface/ sprinkler	940	61	2b
S15	Mandimwa	Surface/ sprinkler	1998	35	3
S16	Nenhowe	Surface /sprinkler	1080	60	2b
S17	Mhakwe	Sprinkler	216	54	1
S18	Murambinda	Surface/ sprinkler	410	57	1
S19	Nerutanga	Surface/ sprinkler	432	60	1b
S20	Ruti	Sprinkler & drip	5400	63	4b
S21	Mwerihari	Sprinkler	227		1

3.4 Irrigation technology options analysis

Per site, it is important to consider the most appropriate irrigation technology to be used under current and projected climate change and social and economic circumstances. In order to assess this, the following criteria can be usefully considered, and is elaborated on in more detail below:

- Field size and shape;
- Topography;
- Soil suitability
- Irrigation efficiency;
- Cost;
- Labour/capacity;
- Management;
- Maintenance;
- Cropping type & schedules;
- Pressure requirements; and
- Water quality.

Field Size and Topography

The field size and configuration often dictates what type of system is suitable for that location. Centre pivot systems require large symmetrical parcels of land to operate effectively, and to provide optimum value for money. Centre-pivot applications, however, offer limited flexibility for individual farmer operations. Wheel lines operate best on rectangular-shaped properties that are at least 8 hectares. Travelling guns and drag-hose are more flexible and can adjust to different field sizes and shapes. For the selected sites, all with the exception of Diso in the Runde River Basin, which is an elongated curved field, are suitable for use of sprinkler systems ranging from centre pivots, guns / drag-hose and trickle drip systems.

Irrigation System Application Efficiency

Application efficiency is an indication of the percentage of water applied by the irrigation system that actually ends up in the soil. Lower efficiencies mean more water is lost during the application process due to evaporation, wind drift or runoff, and is therefore not available to the crop. All of these issues will undoubtedly be further exacerbated by the changing climatic conditions. Efficiencies of irrigation systems can vary due to wind, operating pressure, sprinkler trajectory, soil type, time of day and hot or cool weather. Efficiency can also be affected by the design, operation and maintenance of the irrigation system. In order to conserve water, it is therefore best to use a system with higher efficiency such as the pivots and trickle systems, all other issues considered.

Labour

Automated systems such as trickle/drip, centre pivots and solid set sprinklers have low labour requirements compared to other systems, which may not be appropriate in rural areas with high unemployment rates. These systems do not have to be manually moved and irrigation scheduling changes can be done by adjusting the system control. Irrigation systems, such as wheel moves, hand moves and guns require daily labour to move the system from one set to the next. The labour cost may also increase if travel distance to the field is significant. For all selected sites of the River Basins under study, no major labour issues were observed – as local labour is abundant and there are high levels of willingness amongst the communities to contribute with their labour. During construction, local labour will be sourced from the beneficiary community by the contractor, but at special non-commercial rates; the contractor will retain the overall responsibility of the scheme's quality and functionality.

Cost

The capital cost of an irrigation system is often a major consideration when deciding what type of system to purchase. Careful consideration of annual maintenance, operating costs labour, improved system management and water savings may make the more expensive systems more attractive in the long run, because the total lifecycle costs with be lowest. However, the final choice is generally heavily skewed by user-appropriateness.

Management and Maintenance

System management and maintenance vary according to system types, field topography, operating pressures, type of material (PVC, steel etc.) and installation. All systems require regular maintenance, but automated systems, while they may be easier to manage, may not be appropriate for the level of maintenance skills available in a rural setting. The communities visited, and the Agritex officers who advise them, have a reasonably good understanding of the technologies and can be trained-up to ensure adequate operation and maintenance of any of the systems.

To ensure an irrigation system performs as designed, it must be maintained properly. Common faults include leaking seals, breaks in supply mains or lateral lines and valves that do not shutoff properly. The equipment must be checked for proper working order, defective sprinkler and pump bearings, worn impellors cause reduced pressure and flow. Sprinkler nozzles and emitters must be checked seasonally for wear and tear and for signs of clogging. Worn out or oversized nozzles may apply excess water to the crop and cause uneven water distribution. These checks should be more frequent in areas where irrigation supply water contains sediment.

Operation

When operating irrigation systems, the following practices must be observed.

- The sprinkler irrigation system must be operated at the recommended operating pressure at which the system is most efficient.
- Excessive pressure may result in water loss due to bursts, leakages and wind drift. Excessive irrigation may cause excess wastage in return flows.
- Excessive irrigation may also cause leachate movement.
- Whilst irrigating, target the crop only; avoid applying water to non-productive areas, such as roads.
- During non-peak conditions irrigation can be done during late night or early morning hours when evaporation and wind losses are generally lower.

Crop Type

Crop type will often dictate what type of system will work best in a given situation. For example, a solid set system in a maize field is impractical for harvesting or cultivation. Also, a system that is low to the ground will not be able to spread water very far when the crop is taller than the irrigation nozzles. Trickle systems are best suited for horticultural and other row crops, where water can be applied to a localized root zone. Crops indicated for cultivation include maize, sugar beans, ground nuts, sugar beans, millet and possibly soya beans.

Pressure Requirement

The big gun sprinklers have a high-pressure requirement to obtain proper stream dispersal, while centre pivot and trickle systems can operate with relatively low pressure. The pressure requirement is also determined by elevation and pipe friction losses due to system flow rates. High pressure requirements results in higher power demand and costs.

Where the proper pressure requirement for a system could not be delivered or resulted in high pumping costs, a different system has been considered or adjustments to the design have been made.

Water Quality

Water of poor quality can sometimes cause staining on crops. This is undesirable for crops that are sold for fresh market or graded on appearance. Irrigation systems that do not spread water on fruit, such as a trickle system, would be desirable in these cases. Water quality also affects the type of screening or filtration equipment that may be required. Water with high sediment content will wear nozzles, pipes, pump impellors and impellor shafts more quickly increasing maintenance costs dramatically. This was a case observed at Taona Irrigation scheme and is being corrected in the current proposed designs.

Given the above criteria, the following table outlines the key advantages and disadvantages associated with the irrigation technology options, which should be considered for the proposed new and rehabilitated sites.

Table 17: Irrigation technology analysis

Technology	Advantages	Disadvantages
Centre Pivot	• These systems have higher performance efficiencies (75 to 90 percent) of conventional sprinkler systems if low volume spray heads are used • The system travels around the field which makes it easier to match the water application to the crop and soil conditions. • These systems can be automated which reduces the labour component and adds flexibility in management. • System is suited to all soils • Can be used for fertigation and chemigation	• Field geometry is key so as to allow circular movement. Unsuited for fields with high length to width ratios as one needs more smaller units(uneconomic) • Cropping pattern and timing has to be the same for every farmer, which is problematic for small holders • Technology complicated for rural unskilled farmers • Back-up service available in Harare only
Flood	• Flood irrigation is an ancient method of irrigating crops and one of the most commonly used methods of irrigation used today as was witnessed during the visits • Water is delivered to the field by canal and simply flows over the ground through the crop thus low energy requirement • Requires relatively low maintenance since its mainly gravity	• It is not efficient compared with other methods, 30 to 50 percent only of the water applied actually ends up irrigating the crop with the other half being lost to evaporation, runoff, infiltration of uncultivated areas • Uneven application of water • Intensive land preparation needed so that water can freely flow by gravity • Not suitable for light soils • Difficult to use farm machinery due to the borders and ditches • Drainage problems due to over irrigation or seepage • Not suitable for applying liquid fertilisers

Portable Overhead Sprinkler	• Can irrigate land with irregular topography with minimum land levelling and top soil disturbance • Irrigation without excessive losses from deep percolation or surface runoff • Capable of applying light uniform application; good for soils of low water holding capacity, shallow depth or shallow rooted crops • Sprinkler systems can be efficient, provided that the systems are designed with good uniformity in mind. 60 to 75 percent • Overhead solid set systems can have a variety of sprinkler spacing's as the sprinkler layout must match the crop spacing's and field shapes • Supply lines are usually buried PVC or polyethylene pipe with hydrants to which the laterals with sprinklers are connected • These are systems that are similar to the above but tend to be more efficient than sprinkler systems as the sprinkler heads operate at lower pressure, reducing misting and are spaced much closer together which improves uniformity. System efficiency is around 70 to 85 percent • Relatively cheap capital cost and low-tech maintenance requirements • Appropriate land preparation only required • Can apply liquid fertiliser • Small continuous irrigation water supplies can be effectively applied • Suitable for small plot holdings	• Frequent movement of equipment causes accelerated damage • Labour intensive in terms of having to move system around fields • Prone to theft • If system is not changed at prescribed time interval, over irrigation occurs • Pumping costs usually high • Greatly affected by constant/high velocity winds • Good quality water needed

	• Relatively labour intensive, which is suitable for rural people	
Guns systems (Large Volume Sprinkler)	• Gun sprinkler have a very high application rate good for irrigation of large areas • cover larger areas at a time with minimum shifting • Travelling guns overcome the problem of the short set time for stationary guns by moving the gun over a large area during one set	• Gun systems operate at much higher flows and pressures than regular sprinkler, thus higher O&M costs • Poor operation can easily result in deep percolation or runoff • Increased wind drift affects wetting pattern giving non-uniform water distribution • Wind results in higher evaporation losses and lower operating efficiencies than the smaller sprinkler systems hence require higher energy to overcome this • The set irrigation times are short making the system very difficult to manage properly by average farmers. • System efficiency is around 50 to 70 percent

3.5 Climate proofing irrigation infrastructure designs

Irrigation infrastructure should be designed to withstand both the current local climate as well as anticipated changes in rainfall and temperature, so as to provide a service for at least fifty years. As indicated in Chapter 2, a 'business-as-usual' design approach (or a 'rehabilitation approach' or 'modernisation approach'), that only meets current regulatory requirements is no longer sufficient, given the projected medium and long-term impacts of climate change. Therefore, while it is clear that irrigation schemes can be extremely effective adaptation techniques for the target communities practicing subsistence agriculture in AER IV and V, it is critical that *innovative and appropriate* climate resilient designs are proposed, to ensure the long-term viability of the schemes.

In developing these designs, various aspects of the scheme must be considered with a view to optimising the resilience of the system. These include: the engineering design, the types of materials and technologies used, institutional arrangements, local capacity, access to markets, and financial and economic requirements (i.e. trade-offs between security of supply and cost).

Decisions on how to build '*climate proofed*' infrastructure must also acknowledge the level of uncertainty that lies in the current climate projections (as discussed in Chapter 1) and allow for some level of flexibility in design. Some uncertainty cannot be avoided, but it can be dealt with by considering a range of futures and risk thresholds, and by identifying system sensitivities and working to build resilience to climate shocks (i.e. a proactive, rather than reactive, design approach).

It is also critical that lifespan, lifecycle maintenance costs and return on investment are taken into account. The opportunity to build fit-for-purpose infrastructure only occurs at the start of the life of a new or replacement asset. A changing climate may mean that the ongoing functionality of existing infrastructure is compromised, forcing earlier investment and lower returns for existing investment.

Retrofitting to manage climate change impacts is generally costly and to be avoided if possible. For example - the cost of flood-proofing varies greatly and depends on the type and size of structure, local flood characteristics, and the necessary elevation to which the structure must be flood proofed. In general, it is less expensive to flood proof a new structure than an existing structure, and larger schemes have lower unit costs than smaller ones.

Ultimately, it is imperative to understand the social, economic and environmental trade-offs of various technology options, and to reach a broadly-agreed position in the design of the protective facilities. Key questions that have to be asked include:

- What must be protected at all costs?
- What can be sacrificed?
- What can be engineered to build resilience and what are the cost, specification, timing and availability challenges?

As described in section 3.1 above, at many of the target sites visited it was evident that much of the infrastructure damage and deterioration was due to flooding, while siltation was prevalent in reducing dam storages. While it is not possible to mitigate the frequency or duration of this risk, adaptive design techniques that essentially protect the irrigation and related infrastructure should be employed.

Methods of climate proofing infrastructure against floods include:

- **River or watercourse bank reinforcement** which involves adding material to the bank face to increase the bank stability and protection from river scour and erosion. These designs should withstand hydrostatic forces as well as train/direct floods.
- **Bioengineering** which refers to the use of plants or planting to stabilize the bank and increase the ability to resist scour by river and flood flows.
- **Gabions** which are wire-mesh baskets filled with locally available stones in block or mattress (flat) form. They can be stacked to form a stepped wall or can be laid on gentler slopes to form a surface covering for scour protection. The blocks are interlaced to form a flexible surface that resists erosive flood forces.
- **Riprap/Geotextile** which is an exposed layer of well graded stone or rock placed on a sloping bank face to resist erosive flood waters. A synthetic geotextile is usually placed between the riprap and

underlying soil to act as a filter, thereby preventing the piping of soil through the rock and relieving hydrostatic pressure used to provide long term protection.

- **Structure Anchoring** where the structure is pinned and tied to a sound foundation to resist collapse and movement from hydro forces and scour.
- Installation of **watertight closures** which stops migration of water from one site to the other.
- **Usage of sealants** to reduces seepage through walls.
- **Installation of check valves** to prevent the backflow entrance of floodwater flows into utilities in a structure like a pump hose or power station.
- **Above Flood Level Location** of electrical, mechanical, and other equipment and contents will stop the equipment from being flooded.
- **Diversions and rerouting** of existing water course channel to divert excess storm water flow reduces flood risk and protects structures.

The design for flood protection for the proposed scheme has employed two methodologies, predominantly – **above flood level location** and **structure anchoring** with watertight structures where necessary. An allowance for appropriate erosion protection has been made in the design and costings.

3.6 Irrigation project cost estimates by band

This section of the report evaluates the cost of revitalizing and constructing (new) irrigation systems, based on the site conditions of visited sample schemes. The costing includes initial capex as well as recurrent annual costs for the schemes. The capex cost per hectare has been computed to include the preparatory planning, design, procurement and installation of the representative samples of each band of the irrigation schemes. The recurrent annual O&M costs are indicated as a percentage of the full capex value of each scheme.

Capital costs

Capital costs are the costs of designing and constructing the irrigation scheme to the point where it is ready for use. They include the cost of the water source intake/pick up works development, climate proofed abstraction works, transmission system and its controls, in field storage and field application.

The capital costs included the following broad items:

- Design fee
- Purchase price
- Delivery cost
- Installation cost

Indirect costs involved with the purchase of an irrigation system include the following:

- Fencing of the irrigated land
- Access Roads
- Storage Rooms, sheds and basic offices
- Other infrastructure to handle the expected increased yields
- Supply on of electricity to the pump-station

Based on an analysis incorporating both observed and collected information and experiences, as well as the design proposals in the proposed selected sites, average development cost is estimated to be in the range of $7,000 to $12,000 per hectare. The former represents a revitalisation upgrade involving use of sprinkler or pivot system and rehabilitation of the existing infrastructure. The later represents a new scheme with new components from water abstraction to field application. The complexity of the water abstractions system increases the cost of development. The total development cost for approximately 4,600ha, targeting roughly 15,000 direct beneficiary households, is estimated to cost around $42 million dollars.

Operating costs

These O&M costs represent the costs required to keep the irrigation infrastructure in a serviceable condition throughout its planned design horizon. They exclude utility bills and production input costs.

There are two infrastructure main operating cost categories:

- Energy/power (covered in a separate report)
- Repairs and maintenance

Repairs and maintenance costs vary greatly depending on the type of the irrigation scheme and plant installed. While farmers and their families are expected to do simple tasks between the irrigation seasons, they will need to outsource the complex works to professional service providers. The maintenance of pumping equipment and sprinkler or drip irrigation equipment needs outside specialist help and spare parts (if it breaks), so resources must be reserved for this. Standard maintenance and repair costs which must be included in O&M budgets are shown in Table 17, below, as a percentage of capital costs.

Table 18: Indicative maintenance/repair costs

Item	Percentage of capital cost
Electrically driven pump	1
Pipelines	2
Sprinkler equipment	2
Drip equipment	2
Lined channels	5
Unlined channels	10

Source: FAO. 1996. Irrigation Water management training manual: Small-scale pumped irrigation: energy and cost.

Table 19, below, costs the design of a representative scheme per band, to calculate an average cost per band. Tables 20, 21 and 22 present the total budget per scheme. These values have been determined by categorising schemes as per the banding system described under section 3.3, and applying the corresponding costings contained in Table 19.

Table 19: Band design and costing

Scheme Name	District	Scheme size (ha)	Max land available (ha)	No. of irrigators	Development Proposal	Design Flow (M3/hr)	Abstraction Works Including Climate Proofing	Conveyance System	Night storage / Balancing reservoir	In Field Application (irrigation technology)	Other: Land preparation, erosion control, etc.	Access Road	Scheme Buildings for offices storage and sheds	Scheme security and animal control	Total Capital Cost (US$)	Services: Project preparation & Sustainability Capacity Building	*Comments*
BAND 1: Complete Renewal of system equivalent to new (Insert Q,H data for each)																	
Sebasa [99]	Gwanda	45	65	130	Existing system is not currently functioning. A new system with river bed abstraction through boreholes equipped with electrical driven submersible pumps pumping into night storage dam is proposed. Water to be applied to the field through sprinkler systems.	162	Drill Wide BHs/Wells in Tuli River bed Equip submersible pumps Support and headwork structures; provide anchorage	Rising PVC 315mm DN 3km Pipeline with fittings	Brick Tanks of 4000m3 volume	1x400m span (50) Ha centre pivot or overhead sprinkler system	@$150/Ha	Road grading, minor drainage structures and bush clearing	100m2 building	$5/m equiv $800/Ha		Hydrogeological study of the proposed boreholes is required to verify adequacy of supply	*$9,25/Ha*
							For Sand abstraction systems maximum extraction 60m3/h to head of 50m requires - 11kW & this is adequate for 8ha @ $30000 ea including borehole. For 65Ha need (65/8)=8 units $240,000	3000m @ $55/m $165,000	$80,000	$75,000.00	$10,000	Sum $30,000	@$250/m $25,000	$40,000	$665,000	15 percent	
BAND 2: Revitalisation of system																	

[99] The costings have been done for Sebasa, because information is available that provides confidence in costings (even though it is not one of the selected schemes). Sebasa is very similar to a lot of the schemes being proposed and designed.

Guyu-Chelesa	32	112 Need total of 80Ha (32Ha exist 48 to be new expansion)	160	The pumps by the river need replacement. Storage tanks need sealing of a number of cracks causing leakage. The duty pump at the booster pump station needs upgrading. The field supply main pipeline requires rehabilitation as it has been poorly installed in some sections. On the undeveloped section of the fields, two fixed 20Ha centre pivots or overhead sprinkler system can be accommodated	173	Drill Wide BHs/Wells in Tuli River bed Equip submersible pumps Support and headwork structures, provide anchorage	Existing 250mm rising main needs rehabilitation and new main for the new 48Ha proposed needing a 315mm DN	Brick Tanks of 4000m3 volume	1x400m span (50) Ha centre pivot or overhead sprinkler system		Road grading, minor drainage structures and bush clearing	100m2 building	$5/m			*US$8,200/ha*
						Sum $120,000	3000m @ $55/m $165,000	$100,000	$85,000.00	$7,500	Sum $30,000	@$100/m $20,000	$80,000	$607,500		
BAND 3: New System																

Bwanya	Masivingo	150	150	300	The scheme site exists but due budgetary constraints development was abandoned after pipe and pumping materials were delivered to site. Due to subsequent degeneration over time materials cannot be used. The scheme therefore has to be developed from scratch, and it is necessary to develop the abstraction point and pumping system. The water has to be conveyed to an infield storage tank from which the water will have to be applied to the field	1296	Water drawn directly from the weir across Shashe River. Flood protection and anchorage included	Rising main Pipeline 1 km of 425mm diameter to be installed and 5km infield pipelines of 150mm to 225 dia sizes.	New In field night storage dams to be constructed size 8 Ml. A new pump station with two duty pumps and 1 stand by is required by the night storage dams to supply the infield irrigation system at a rate of 180cu.m/hr against a head of 50m	Combination of Sprinkler system and 400m span (50 Ha each) Ha centre pivot (s). Typical lateral inflow rates are 45 - 65lps operating pressure of 20 to 70 psi (14 to 50m)		Road grading, minor drainage structures and bush clearing		$5/m		The weir across Shashe is sound and adequate. Full project survey, designs for conveyance and in-field	*Irrigation development costs are $9,800/Ha.*
							Intake Works $75,000. Pumping gear complete $93,000 per unit by 2 $186,000	Sum $180,000 for main pipeline and $300,000 infield pipelines	Sum $200,000 $25,000 per unit x 2 $50,000.00	$80,000.00 each unit $240,000.00		Sum $30,000	$60,000	$5/m 30,000	$1,311,000	12 percent	
BAND 4: New System																	

Pikinini Jawanda	Mwenezi District	200	300	400	This scheme is non-existent but has been in the planning phase since the completion of the construction of the Manyuchi dam in 1988. Scheme is fully subscribed and will consist of abstracting water from the banks of the Manyuchi Dam at a location with maximum abstraction benefits. Water will be conveyed to the scheme by a rising main equipped with electrically driven pumps pumping into night storage dam. Water to be applied to the field through sprinkler systems.	1728	Intake works by Manyuchi Dam left bank suitably located	Rising GRP pipeline 3km 800mm DN Pipeline with fittings and 5km infield pipelines of 400mm to 150mm dia size.	Brick Tanks of 10000m3 volume	4x400m span (50) Ha centre pivot	A new pump station with two duty pumps and 2 stand by is required by the night storage dams to supply the centre pivots at a rate of 50lps against a head of 50m	Need Small Road Maintenance plant	100m2 building	$5/m			*$9400/Ha*
							Inlet Works $ 75,000 2 pumping sets @$110,00 each $220,000	3000m @ $160/m $480,000 and 5000m @$70 $350,000	$300,000	4x $80,000.00 $320,000	$25,000 per unit x 2 $50,000.00	Sum $30,000	@$200/m $20,000	$35,000	$1,880,000.00		

Table 20: Mzingwane scheme costs

Mzingwane River Basin											
	Name	Province	District	Irrigation System	Irrigable area (ha)	Band	Direct Beneficiary Households	Status	Rate $US	Scheme Cost $US	Remarks
M1	Masholomoshe	Matabeleland	Gwanda	Surface/ sprinkler drip	39	1	131	exist	9250	360750	revitalize
M2	Sukwe	Matabeleland	Gwanda	Surface/ sprinkler drip	28	1	44	new	9250	259000	Develop from borehole source
M3	Guyu-Chelesa	Matabeleland	Gwanda	Sprinkler	85	2	160	exist	8200	697000	revitalize
M4	Mankonkoni	Matabeleland South	Beit Bridge	sprinkler	40	1	100	exist	9250	370000	revitalize
M5	Bambanani	Matabeleland South	Gwanda	Surface/sprinkler	8	1	79	exist	9250	74000	revitalize
M6	Zamangoni / Masiyapambili	Matabeleland South	Matobo	sprinkler	20	1	40	new	9250	185000	proposed
M7	Tuli Makwe	Matabeleland South	Gwanda	Surface	202	4b	491	exist	9400	1898800	revitalize
M8	Mambale	Matabeleland South	Matobo	sprinkler	28	1	56	exist	9250	259000	revitalize
M9	Mabindisa Dam	Matabeleland South	Umzingwane	Sprinkler / drip	30	1	630	Partially operational	9250	277500	Dam and infield infrastructure rehabilitation

M10	Gwalabana Dam (Mihlo)	Matabeleland South	Matobo	Sprinkler / drip	22	1	600	Partially operational	9250	203500	Dam rehab, Consolidation, irrigation infrastructure for small garden
					502		**2331**			4,584,550	

Table 21: Runde scheme costs

Runde River Basin											
Entry no.	**Name**	**Province**	**District**	**Existing/ Proposed Irrigation System**	**Irrigable area (ha)**	**Band**	**Direct Beneficiary Households**	**Status**	**Rate $US**	**Scheme Cost $US**	**Remarks**
R1	Machena	Masvingo	Zaka	Sprinkler	150	3	110	exist/ new	9000	1350000	revitalise using boreholes (Abundant and shallow groundwater)
R2	Zvinyarikwe Muzhwe	Masvingo	Chivi	Sprinkler	150	3	300	new	9000	1350000	Muzhwe dam tail end abstraction
R3	Musaverema A	Masvingo	Mwenezi	Flood/sprinkler	35	1	142	exist	9250	323750	revitalise
R4	Nyika Muzhwe	Masvingo	Masvingo	sprinkler	40	1	100	new	9250	370000	new
R5	Bwanya	Masvingo	Masvingo	sprinkler	150	3	300	exist/new	9000	1350000	revitalise/ expand
R6	Dinhe	Masvingo	Masvingo	sprinkler	35	1b	142	exist/new	9250	323750	revitalise/ expand
R7	Pikinini Jawanda	Masvingo	Mwenezi	sprinkler	200	4b	300	new	9400	1880000	New. ZESA source 14km away. Solar suggested
R8	Nyahombe	Masvingo	Chivi	sprinkler	200	4	300	new	9400	1880000	To benefit from Tokwe Mukorsi

R9	Budirirai	Masvingo	Masvingo	Sprinkler	20	1	40	exist/new	9250	185000	revitalise/ expand
R10	Chizumba	Masvingo	Chivi	Sprinkler	65	2b	250	exist	8200	533000	Revitalise
R11	Diso	Masvingo	Masvingo	sprinkler/drip	40	1b	80	new	9250	370000	New. Water from disused mine pits
R12	Malikango	Masvingo	Chiredzi	sprinkler/drip	50	1	200	new	9250	462500	Grid electricity 9km away. Suggest solar
R13	Banga	Masvingo	Chivi	sprinkler	51	1	425	exist	9250	471750	revitalise Fence need rehab
R14	Matezva	Masvingo	Masvingo	sprinkler/drip	20	1	100	exist	9250	185000	revitalise
R15	Gororo	Masvingo	Chivi	sprinkler	120	3	240	new	8200	984000	New. To benefit from Tokwe Mukosi
R16a	Bindamombe	Masvingo	Chivi	Sprinkler	34	1	150	exist	9250	314500	Convert existing power source to solar
R16b	Bindamombe	Masvingo	Chivi	Sprinkler	34	1	150	exist	9250	314500	Convert existing power source to solar
R16c	Bindamombe	Masvingo	Chivi	Sprinkler	34	1	150	Exist	9250	314500	Convert existing power source to solar

R17	Gondo	Masving o	Chivi	Flood/sprinkle r	20	1	60	Exist	9250	185000	Revitalise. Extension of scheme
R18	Mufusirwa	Masving o	Chiredzi	Centre pivot	50	1	100	New	9250	462500	Electricity 2km away. Solar suggested
R19	Zvavahera	Masving o	Gutu	Sprinkler	46	1b	46	Exist	9250	425500	Revitalise. Needs fencing
					1544		**3685**			**14,035,250**	

Table 22: Save scheme costs

Save River Basin											
Entry no.	**Name**	**Province**	**District**	**Existing/ Proposed Irrigation System**	**Irrigable area (ha)**	**Band**	**Direct Beneficiary Households**	**Status**	**Rate $US**	**Scheme Cost $US**	**Remarks**
1	Zuvarabuda	Manicaland	Chipinge	Surface/sprinkler	20	1	270	exist	9250	185000	revitalize
2	Farai	Manicaland	Chipinge	Surface/sprinkler	30	1	75	exist	9250	277500	revitalize
3	Charuma	Manicaland	Chipinge	sprinkler & drip	64	2	45	new	8200	524800	develop
4	Nyachitimbi		Chipinge	sprinkler & drip	18	1b	60	exist	9250	166500	Water supply from Nyachitimbi river.
5	Rimbi	Manicaland	Chipinge	Surface/ sprinkler	500	4b	1600	exist	9400	4700000	Save, 15km long pipeline
6	Veneka	Manicaland	Chipinge	Surface/ sprinkler	30	1	60	exist	9250	277500	Save River Sand Abstractions
7	Vimbanai/Mutandahwe	Manicaland	Chipinge	Surface/ sprinkler	27	1b	68	exist	9250	249750	revitalize
8	Musirizwi		Chipinge	sprinkler	60	2	200	exist	9250	555000	revitalize
9	Mudzimwa		Chipinge	sprinkler & drip	20	1	60	exist	9250	185000	revitalize
10	Mpudzi	Manicaland	Mutare	Sprinkler & drip	80	2	800	new	8200	656000	Proposed
11	Mumhendwe		Chipinge	sprinkler & drip	200	4	600	new	9400	1880000	Proposed
12	Chisavanye	Manicaland	Chipinge	Surface/ sprinkler	21	1	42	exist	9250	194250	Rehabilitate. Solar Drip. World Vision did but system

											completely down
13	Taona	Manicaland	Chipinge	Surface/ sprinkler	262	4	655	exist	9400	2462800	Revitalize
14	Chakohwa	Manicaland	Chimanimani	Surface/ sprinkler	87	2b	140	exist	8200	713400	Weir needs desilting and revitalize
15	Mandimwa	Manicaland	Chimanimani	Surface/ sprinkler	185	3	140	exist	9000	1665000	revitalize
16	Nenhowe	Manicaland	Chimanimani	Surface /sprinkler	100	2b	100	exist	8200	820000	Pumps require rehabilitation and revitalize
17	Mhakwe	Manicaland	Chimanimani	sprinkler	20	1	50	exist	9250	185000	Need training
18	Murambinda	Manicaland	Buhera	Surface/ sprinkler	38	1	76	exist	9250	351500	revitalize
19	Nerutanga	Manicaland	Buhera	Surface/ sprinkler	40	1b	100	new	9250	370000	Nerutanga dam
20	Ruti	Manicaland	Buhera	sprinkler & drip	500	4b	1400	new	9400	4700000	new
21	Mwerihari	Masvingo	Buhera	sprinkler	21	1	210	new	9250	194250	Construct weir and infield irrigation
					2323		**6751**			**21,313,250**	

Table 23: Summary of Costing

Band	Sum of Direct Beneficiary Households	Sum of Irrigable area (ha)	Sum of Scheme Cost $US	Number of Schemes
1	4368	888	$8,214,000.00	30
1b	268	121	$1,119,250.00	3
2	1445	476	$3,966,200.00	6
2b	250	65	$533,000.00	1
3	1090	755	$6,699,000.00	5
3b	0	0	$-	0
4	4555	1662	$15,622,800.00	5
4b	791	402	$3,778,800.00	2
Grand Total	**12767**	**4369**	**$39,933,050.00**	**52**

4. Sustainability considerations for irrigation infrastructure

Investments in irrigation infrastructure in southern Africa are by nature very costly. Their design, construction and the equipment required (most often imported from overseas) should be able to withstand predicted changes in climate and have an estimated lifespan of fifty years. For this proposed programme, investment lies in the region of US$43 million (see Section 3.6 above). When investing in irrigation infrastructure, an approach to ensuring the long-term sustainability of the schemes must be employed, in order to contribute to safeguarding investments made. While this can be comprised of many aspects, this report recommends that at a minimum the following three key sustainability aspects are considered: 1.) Ensuring service providers are available in the local market to supply back-up services to fix inevitable breakages and repairs (including having access to spare parts); 2.) Supporting community institutional arrangements through IMCs, including private sector involvement; and 3.) Integrating government support from AGRITEX and DoI, the two primary GoZ actors in irrigation, into irrigation schemes to provide technical expertise and guidance to farmers.

4.1 Service provider analysis

While irrigation schemes are designed in such a way as to respond best to the context in which they are implemented (the better adapted to the context, the better the design), they will inevitably encounter breakages and will need to be repaired over time. Increasing the capacity of communities to fix minor repairs is a crucial component of support (as identified in Chapter 2), however, communities will by no means be able, or are expected, to resolve all repairs and problems (especially complicated ones) themselves, and will therefore need to find and contract professionals to service the equipment. This is a crucial element of sustainability, as not only does it enable continuity of irrigation, and thus prevent a decrease in yields, but repairing a problem in good time naturally keeps the scheme in good functioning condition.

Irrigation support services are well established in Zimbabwe. The range of services offered by companies include but are not limited, to:

- Topographical survey services
- Soil survey services
- Irrigation and water engineering design specialists services
- Water abstraction equipment – pumps, valves, fittings and specials
- Water conveyance system materials - pipes, valves, fittings and specials
- In field application equipment and materials such as centre pivots, sprinklers, drip etc.
- Construction and installation services
- Borehole and well point drilling services
- Electro mechanical systems services
- Irrigation system maintenance services

Some companies producing materials and equipment, such as plastic and aluminium pipes, sprinklers, special pipe fittings etc., manufacture locally. However, the majority of companies import products from European countries, Israel, USA, India, China and Brazil, especially centre pivots. The majority of irrigation companies are located in Harare, but a number are spread throughout the country. The sector has a representative body called the Irrigation Association of Zimbabwe, of which a substantial number of the service providers are individual and corporate members – an indication of how well developed the sector is. However, the association has not been very active of late due to the prevailing economic situation. A listing of the companies in the sector is outlined in Annex 4.

4.2 Community institutional arrangements

A fundamental aspect of sustainability is increasing the capacity of communities to operate and maintain irrigation infrastructure themselves for the future. Crucial to achieving this is for communities to feel a sense of ownership and empowerment over the infrastructure and to be able to influence decision-making (which naturally encourages self-investment) of the scheme. Institutional arrangements should therefore be determined in accordance with communities' own worldviews and perceptions of how best to improve their own livelihood strategies[100], aligned with culturally-specific values and norms, rather than be transplanted from another culture into the local context.

Irrigation Management Committees (IMCs)

As highlighted in Chapter 2, institutional arrangements have been predominantly encouraged through supporting and strengthening institutions called Irrigation Management Committees (IMCs). Such institutions have been in existence in Zimbabwe for over fifty years, in some cases, especially on communal lands. IMCs are locally elected community structures which usually comprise of between 3-7 community members (depending on the size of the irrigation scheme). They will often meet regularly (sometimes at least once a week) to discuss key decisions relating to the scheme. They are responsible for day-to-day management, and are therefore crucial for self-organisation and coordination, particularly when concerning cropping cycles and irrigation scheduling, as the elected members make decisions on behalf of the rest of the community. If functioning successfully, IMCs are able to provide a range of different services, depending on the needs and size of community schemes. These may include management of water distribution, system maintenance, input supplies, marketing, finance, personnel, planning and monitoring etc. Project interventions often include a specific budget line for efforts to increase IMCs' capacity.

IMCs are essentially a way of supporting communities to organise and empower themselves. They are seen to be the best practice to date (see Chapter 2), to ensure investments are firmly planted in empowered and capacitated communities who can utilise the benefits of irrigation infrastructure, to ultimately increase their own food and income security overtime. As employed in the Shashe irrigation scheme by CESVI and the EU and the CRIDF DFID-funded demonstration projects (see Chapter 2), it is recommended that the approach to IMCs is a model which seeks to create a major paradigm shift involving maximum devolved jurisdiction to local level and the engagement of private sector companies. To support the set-up and success of such a model, the following three key aspects are recommended.

[100] Latham, C. J. K. et al. 2015. From subsistence agriculture to commercial enterprise: community management of green technologies for resilient food production. Future of Food: Journal on Food, Agriculture and Society 3(2), pp.8-17.

IMC Constitution

An IMC constitution effectively outlines a set of communally agreed rules to which all members of the irrigation scheme are expected to adhere to if they wish to be a member of the scheme and benefit from the communally owned irrigation infrastructure. The constitution establishes a set of expectations regarding norms and behaviour, to result in self-governed and coordinated collective activities. Interventions could usefully help with the drafting and editing of the constitution. The constitution outlines the rights for any community member to be able to join the IMC, as long as they follow the membership rules. It states the fact that the community has use of fractual rights (meaning that while the government owns the infrastructure, the community has the right to use it). Equally, the government cannot supplant the use of fractual rights[101]. While the details of the constitution are subject to each individual community's discretion, some 'rules' to be considered could include having a rotating chair at meetings, having elections every year (or term), when at least half of the IMC retires (in order to ensure IMC membership is as fair and equitable as possible but to keep enough continuity to ensure lessons learning which are gained as the IMC increases its capacity, especially in the first few years of operation, are not lost), having a variety of defined roles within the IMC, for example Secretary, Chairperson, Treasurer etc., and having Annual General Meetings, and Special meetings, whenever necessary.

To signify formal commitment to the scheme, a District Council member could facilitate and oversee the signing of the constitution by all scheme members, (as was the case in CRIDF's demonstration project, Kufandada, in Bikita district, with The Chief Executive Officer of Bikita Rural District Council). See the Kufandada scheme's constitution in Annex X.

Maintenance fund

In order for the IMC to function successfully, they need to have access to funds. A 'maintenance fund' is recommended to be written into the constitution, with each member of the scheme required to contribute a small amount per month. The purpose of this fund is to provide a pool of money for which the IMC can use to pay for repairs, breakages and replacements e.g. a broken pipe, pump bearings etc. The constitution may also want to outline the role of a 'maintenance sub-committee', to which the responsibility of maintaining overall infrastructure maintenance is delegated.

PPP arrangements – exit strategy

The ultimate aim of this investment is for communities to be in a position where they are able to enter a Public Private Partnership (PPP) arrangement in 20 years' time, to own irrigation infrastructure out right. For example, with increased income security overtime, due to surplus potential provided through access to irrigation, good credit ratings as farmers are able to open bank accounts, and an increased sense of business-mindedness, or 'entrepreneurialism', supported in part by a strengthening of IMCs, communities may be able to enter a PPP with a private company, such as agribusiness, seed producers (Zimbabwe Super Seeds) or processors (Schweps, Sidella etc.). This requires not only a substantial increase in income and food security, but a clear

[101] Mechanisms to ensure this is observed beyond the constitution must be put in place.

shift in behavioural change to take place. It is recommended that at a very early stage, IMCs engage with private companies, perhaps through a contract farming arrangement, for them to be able to learn directly the requirements needed to be able to more formally and profitably engage, at the earliest possible opportunity[102].

4.3 Government support

A third, but arguably the most important, aspect of ensuring sustainability is integrating government support into irrigation interventions. Government support predominantly relates to providing technical advice from DoI and AGRITEX.

AGRITEX's role involves supporting IMCs (and beneficiaries) to teach beneficiaries how to operate irrigation infrastructure and in-field irrigation equipment to the best advantage in terms of water application for maximising crop yields. Setting out irrigation cycles and regimes at the various crop growth stages is one of the most important elements of this.

DoI's role is to ensure irrigation infrastructure is maintained through teaching IMC's how to conduct routine maintenance procedures (identifying a problem and knowing where to find service providers who can fix it) and inculcate skills in basic O&M of infrastructure themselves e.g. greasing of pumps, basic sprinkler maintenance to make sure there are no blockages, how to fix simple pipe leakages etc. DoI also keeps a record of qualified professionals who can be called upon and contracted to do the more complicated repairs needed. This is usefully drawn on for DoI to guide IMCs on where they can find such qualified professionals to be able to fix maintenance problems in a timely and cost-efficient manner.

[102] It must be noted that such an arrangement will require support which goes beyond irrigation investments as detailed in this report.

5. Irrigation conclusions and recommendations

Climate change has been observed to have impacted on variables relevant to agriculture in Zimbabwe. Projections suggest Zimbabwe will continue to experience changes due to climate change, and such impacts will likely increase in intensity overtime. While climate change is impacting the country as a whole, the greatest intensity of impacts are experienced in the southern provinces, where the majority of smallholder farmers practicing rainfed agriculture are already vulnerable as a result of poverty and the absence of access to services and infrastructure. The capture of flood waters via irrigation and providing access to water for irrigation during dry dekads present a significant opportunity to arrest the cycle of poverty, humanitarian food assistance and environmental degradation caused by climate change for rural communities in southern Zimbabwe. This has the added benefits of improving incomes, employment and general livelihoods for the poor.

Actors in the sector have for some time been using irrigation to support communities improve their livelihood strategies across the country, especially on communal lands. However, investments are not being fully optimised, as they are not designed in a way which responds to climate change, nor are being implemented in a holistic approach which looks beyond technically sound solutions, such as the importance of considering market linkages and providing appropriate training and incorporating financial viability into design. Lessons learned from analysis of existing efforts include…

Selecting irrigation schemes to intervene in across the target area (southern provinces: Matabeleland South, Masvingo and Manicaland) has followed a five-step methodology. First, areas within southern Zimbabwe in which climate hazards (namely droughts, mid-season dry spells and floods) occur the most are identified, to filter the target area down to the areas which are subject to the most severe (in terms of intensity and occurrence) climate hazards. Second, all known schemes in the southern province were collated from the DoI's Master Irrigation Plan. Third, selection criteria which involved resource (land and water) availability and vulnerability were developed. Using vulnerability is a key priority selection criteria as the interface between climate hazard occurrence and exposure of communities in conditions of poverty produces vulnerability. Fourth, irrigation schemes were screened against those that were already being implemented under other donor and public initiatives to prevent any duplication of effort. Finally, the selection criteria were applied to schemes, to select 50 target sites.

Investment in irrigation schemes should only be made if the necessary structure in place for its long-term sustainability. This report recommends that at least the following three key sustainability aspects are considered: 1.) Ensuring service providers are available in the local market to supply back-up services to fix inevitable breakages and repairs (including having access to spare parts); 2.) Supporting community institutional arrangements through IMCs, including private sector involvement; and 3.) Integrating government support from AGRITEX and DoI, the two primary GoZ actors in irrigation, into irrigation schemes to provide technical expertise and guidance to farmers. The ultimate aim of this investment is for communities to be in a position where they are able to enter a Public Private Partnership (PPP) arrangement in 20 years' time, to own irrigation infrastructure out right.

This requires not only a substantial increase in income and food security, but a clear shift behavioural change to take place.

Based on extensive desk-based research, various stakeholder consultations from national to community-level, and site visits to 16 irrigation schemes, this study recommends the following:

- Construct 60 irrigation schemes in the Save, Runde and Mzingwane river basins through a climate resilient design approach
- Encourage the strengthening of IMCs, particularly through establishing a ‘constitution’ and a maintenance fund, which every member of the irrigation scheme contributes to
- Ensure government support, through DoI and AGRITEX, is integrated into interventions
- Have a budget line in each irrigation scheme for O&M for the first two years of operation

It should be noted that this study recognises the importance of other factors that address services provided in CSA/agriculture, market linkages and climate information, which together present a holistic programme for the success of the investment in irrigation.

6. Irrigation and Power supply Conclusions and recommendations

An irrigation scheme cannot run without power, except in exceptional circumstances when under gravity. In all cases in the above schemes there can be no irrigation at scale without power. To complete the irrigation assessment study, an assessment for power supply was then carried out to analyse power availability options and supply feasibility. Annex 1 to this report provides a detailed analysis of power supply options and whole-life cost effectiveness for viability. This has resulted in the refining of the above irrigation investment proposals, under an iterative process, eventually giving the following conclusions and recommendations:

1. Schemes in remote areas, with no nearby grid power infrastructure have been limited to 30Ha that will be powered by solar
2. Schemes within proximity of 'reliable' grid power would have the first 30Ha under solar and the balance under grid power supply
3. Household plot sizes have been limited to a minimum of 0.1Ha and a maximum of 0.5Ha.

As per the below tables, this analysis reduces the total budget for irrigation and power supply infrastructure from approximately US$42 million to US$38 million, while maintaining the number of schemes at a total 56. Limiting plot size per household makes the scheme reach out to a maximum number of poor, small scale beneficiaries which is the target for grant financing.

Table 24: Mzingwane Basin Scheme Costs

Entry no.	Name	Existing/ Proposed Irrigation System	Direct Beneficiary Households	Hectares under solar	Hectares under grid	Irrigation Scheme Cost $US	Solar Power cost	Grid Connection cost	Total Scheme Cost US$
M1	Masholomoshe	Surface/ Sprinkler	131	30	9	360750	150000	60000	570750
M2	Sukwe	Surface/ Sprinkler Drip	44	28		259000	150000		409000
M3	Guyu-Chelesa	Surface/ Sprinkler Drip	160	30	55	728500	150000	60000	938500
M4	Mankonkoni	Sprinkler	100	30	10	370000	150000	20000	409000
M5	Bambanani	Surface/Sprinkler	79	8		74000	75000		427500
M6	Zamangoni / Masiyapambili	Sprinkler	40	20		185000	75000		278500
M7	Tuli Makwe	Surface	491	30	172	1894300	150000	80000	570750
M8	Mambale	Sprinkler	56	28		259000	150000		409000
M9	Mabindisa Dam	Sprinkler / Drip	630	30		277500	150000		260000
M10	Gwalabana Dam (Mihlo)	Sprinkler / Drip	600	22		203500	75000		2104300
			2331	**256**	**246**	**4,611,550**	**1,275,000**	**220000**	**6106550**

Table 25: Runde Basin Scheme Costs

Entry no.	Name	Existing/ Proposed Irrigation System	Direct Beneficiary Households	Hectares under solar	Hectares under grid	Irrigation Scheme Cost $US	Solar Power Cost	Grid Connection Cost	Total Scheme Cost US$
R1	Machena	Sprinkler	110	30	120	1453500	150000	80000	1683500
R2	Zvinyarikwe Muzhwe	Sprinkler	300	30		277500	150000		427500
R3	Musaverema A	Flood/ Sprinkler	142	30	5	323750	150000	10000	483750
R4	Nyika Muzhwe	Sprinkler	100	30		277500	150000		427500
R5	Bwanya	Sprinkler	300	30	120	1453500	150000	80000	1683500
R6	Dinhe	Sprinkler	142	30	5	323750	150000	10000	483750
R7	Pikinini Jawanda	Sprinkler	300	30		277500	150000		427500
R8	Nyahombe	Sprinkler	300	30		277500	150000		427500
R9	Budirirai	Sprinkler	40	20	0	185000	75000		260000
R10	Chizumba	Sprinkler	250	30	35	601250	150000	60000	811250
R11	Diso	Sprinkler/ Drip	80	30	10	370000	150000	20000	540000
R12	Malikango	Sprinkler/ Drip	200	30		277500	150000		427500
R13	Banga	Sprinkler	425	30	21	471750	150000	60000	681750
R14	Matezva	Sprinkler/ Drip	100	20		185000	75000		260000
R15	Gororo	Sprinkler	240	30		277500	150000		427500
R16a	Bindangombe	Sprinkler	150	30		277500	150000		427500
R16b	Bindangombe	Sprinkler	150	30		277500	150000		427500

R16c	Bindangombe	Sprinkler	150	30		277500	150000		427500
R17	Gondo	Flood/sprinkler	60	20	0	185000	75000		260000
R18	Mufusirwa	Centre pivot	100	30	20	462500	150000	60000	672500
R19	Zvavahera	Sprinkler	46	30	16	425500	150000	60000	635500
			3685	**600**	**352**	**8938000**	**2925000**	**440000**	**12303000**

Table 26: Save Basin Scheme Costs

Entry no.	Name	Existing/ Proposed Irrigation System	Direct Beneficiary Households	Hectares under solar	Hectares under grid	Irrigation Scheme Cost $US	Solar Power Cost	Grid connection cost	Total Scheme Cost US$
S1	Zuvarabuda	Surface/ Sprinkler	270	20		185000	75000		260000
S2	Farai	Surface/ Sprinkler	75	30	0	277500	150000		427500
S3	Charuma	Sprinkler & Drip	45	30		277500	150000		427500
S4	Nyachitimbi	Sprinkler & Drip	60	18	0	166500	75000		241500
S5	Rimbi	Surface/ Sprinkler	1600	30	470	4695500	150000	120000	4965500
S6	Veneka	Surface/ Sprinkler	60	30	0	277500	150000		427500
S7	Vimbanai/ Mutandahwe	Surface/ Sprinkler	68	27	0	249750	750000		324750
S8	Musirizwi	Sprinkler	200	30	30	555000	150000	60000	765000
S9	Mudzimwa	Sprinkler & Drip	60	20	0	185000	75000		260000

S10	Mpudzi	Sprinkler & Drip	800	30		277500	150000		427500
S11	Mumhendwe	Sprinkler & Drip	600	30		277500	150000		427500
S12	Chisavanye	Surface/ Sprinkler	42	21		194250	75000		269250
S13	Taona	Surface/ Sprinkler	655	30	232	2458300	150000	100000	2708300
S14	Chakohwa	Surface/ Sprinkler	140	30	57	277500	150000	60000	487500
S15	Mandimwa	Surface/ Sprinkler	140	30	155	1734500	150000	80000	1964500
S16	Nenhowe	Surface /Sprinkler	100	30	70	851500	150000	60000	1061500
S17	Mhakwe	Sprinkler	50	20	0	185000	75000		260000
S18	Murambinda	Surface/ Sprinkler	76	30	8	351500	150000	10000	561500
S19	Nerutanga	Surface/ Sprinkler	100	30		277500	150000		427500
S20	Ruti	Sprinkler & Drip	1400	30		277500	150000		427500
S21	Mwerihari	Sprinkler	210	21		194250	75000		269250
			6751	**567**	**1022**	**14226050**	**3300000**	**490000**	**18016050**

Annex 1: Site maps

Annex 2: Consultation records

Annex 3: Irrigation Master Plan

Annex 4: Service providers

Annex 5: IMC constitution – Kufandada example

CRIDF