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Trends and Outlook: Agricultural Water Management in Southern Africa

SYNTHESIS REPORT

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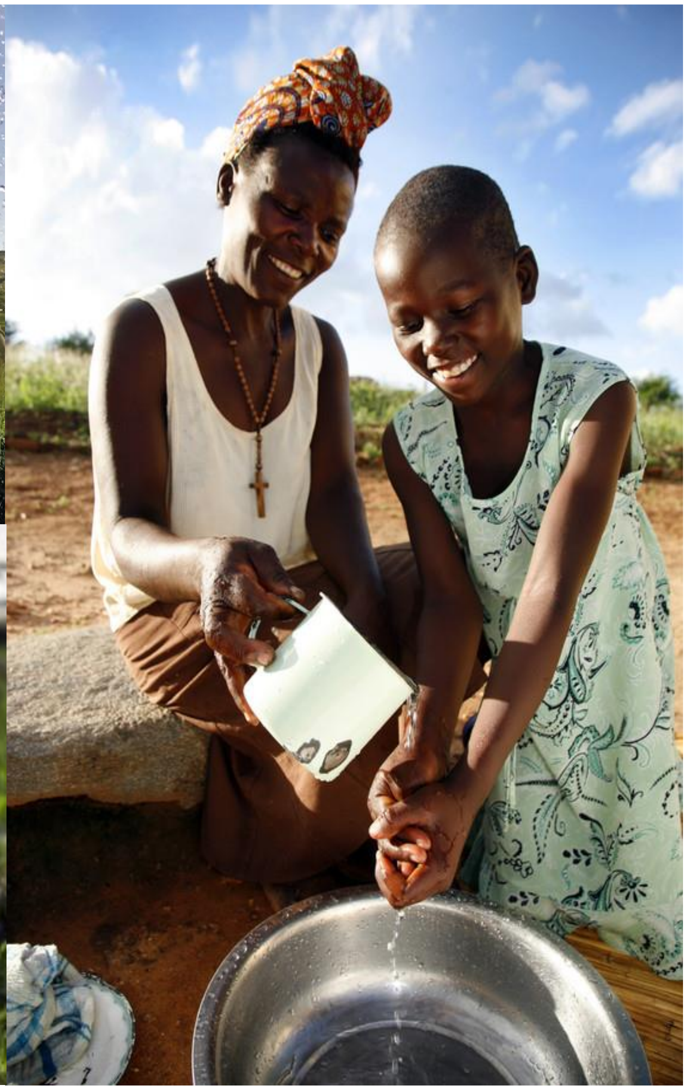

Executive Summary

In spite of the strong policy commitments of the Southern African Development Community (SADC) to water development and to agricultural development for poverty alleviation, food security and broad based agricultural and economic growth, agricultural water management and irrigation was the orphan in both the agricultural and water sectors. With support from the United States Agency for International Development's (USAID's) Feed the Future Program implemented through the Southern Africa Regional Mission, the present study aimed to fill this gap. The research consisted of local case studies and national policy and investment analysis, in particular in Malawi, South Africa, Zambia and Zimbabwe (see www.iwmi.org for the reports of these country studies). Their findings informed the present regional SADC-wide synthesis study, for which further analysis was conducted as well.

The questions focused on

(1) The hydrology of the region under climate change, the nature of water scarcity, and the status of water withdrawals for agriculture; and

(2) Lessons from past investments in agwater management by, respectively, government and partners, smallholders, and agri-business that point at evidence-based solutions to unleash the untapped potentials of agwater management.

The main findings were the following

(1) Hydrology and climate change

Climate change is predicted to exacerbate the already considerable variability and unpredictability of rainfall and temperature in SADC even more than elsewhere in the world. SADC countries will warm up faster; become drier; face more extreme droughts and floods; while sea water levels rise faster as well.

Average annual freshwater resources per capita are abundant in 11 countries. Three other countries are close to water scarcity, while Seychelles is water scarce per capita. Only 9.2 percent of water resources have been developed. The often cited figure that 'agriculture uses 60-70 percent of water' refers to 60-70 percent of *water withdrawals* of water that *has been developed*. It conveys an achievement: at least some water has been developed for the sector that provides a living for the country's majority.

The pivotal role of infrastructure development to harness these resources and adapt to spatial and temporal variability has been clearest in South Africa, which has developed most of its water resources in the past century. This underpinned its current economic strength

(which, however, is accompanied by high structural unemployment). South Africa also achieved the norm of the Comprehensive African Agricultural Development Programme (CAADP) that at least 7 percent of cultivated area should be irrigated. (However, smallholders only constitute 3 percent of this; most is large-scale irrigation). South Africa is 'physically water scarce' in the sense that options for cost-effective infrastructure development have become increasingly rare. Everywhere else in SADC, economic water scarcity prevails: the means to develop amply available surface and groundwater resources are lacking. Hardly any portion of cultivated land is irrigated as yet. This represents a significant untapped potential.

(2) Governments

Initially, governments played a strong role as investors and managers of top-down smallholder irrigation schemes. However, soon after independence, and forced by the Structural Adjustment Programs, governments, donors and NGOs shifted to participatory approaches with more attention to affordable technologies. Both existing and new publicly financed irrigation schemes need support to strengthen forward and backward linkages. Although investments are costly, these schemes remain justified where economies of scale and bulk input provision and sale, also by agri-business, can be realized.

Governments are also unique authorities as custodians of land and water resources, responsible to reform SADC's colonial legacy of resource tenure. There have been considerable efforts to reform land tenure, although customary rights remain weak *vis-à-vis* the extensive claims by large-scale investors. In contrast, water reform has hardly addressed key issues such as the colonial dispossession of customary water rights' regimes as yet. The resulting excessive regulation of smallholders contradicts agricultural policies that seek to *support* smallholders. On the other hand, large-scale users can swiftly get lawful access to most of the country's water resources.

(3) Smallholders

A significant change in formal policy has been the growing recognition of smallholders' own investments in agricultural water management, through river diversions, groundwater recharge and irrigation, soil conservation, wetland cultivation, flood recession cultivation, etc. This response to climate variability has existed since time immemorial, but has recently accelerated as a result of population growth and increasing land pressure; the emergence of new markets for high-value horticultural crops; availability of affordable technologies; and government support. Indeed, this fully-fledged 'private sector' contributes most to the proportion of smallholder cultivated land that is irrigated. Its major strength is that these investments occur at no cost to the tax payer. Public support can boost these investments by further technology development and dissemination and support to forward and backward linkages.

(4) Agri-business

Outgrower arrangements without land re-allocation could further strengthen the forward and backward linkages mentioned above. However, agri-business's rush to SADC's abundant land and water resources requires land acquisitions that are increasingly contested. Only a few cases for example, sugar estates expansion that created considerable employment, seem to have worked.

(5) Synergies

The study identified a range of untapped synergies between the agricultural and water sectors that would enable both sectors to contribute more effectively to poverty alleviation, food security and broad-based agricultural growth. A low hanging fruit for synergy is to remove over-regulation of smallholders, for example, by full formal recognition of local water law, and by adjusting current permit systems to first target the few high-impact users that should, and that logistically *can*, be regulated.

Perhaps the most important untapped synergy is a cross-country comparison of agwater management investments. As shown by this research, the shared history of SADC's member states, smallholders and regional agri-business has yielded similar approaches and learning processes. Yet, they have hardly been put side-by-side and compared. Comparative research can map the different modalities and combinations of all three types of investments, and assess their respective costs and benefits to smallholders and agri-business. Findings will be vital information for evidence-based answers to SADC's agrarian question that can inform the allocation of both public resources and water resources. In the absence of even a base line for monitoring, the study concludes with proposed 'must-have' indicators.

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Acronyms

10^9 m^3 pa	10 billion cubic meter per annum
AR5	Fifth Annua lAssessment Report
AU	African Union
CAADP	Comprehensive African Agricultrual Development Program
CICOS	Commission Internationale du Bassin Congo-Oubangui-Sangha
CMIP	Coupled Model Intercomparison Project
DOI	Departmentof Irrigation [Malawi]
DRC	Democratic Repubic of Congo
DWA	Department of Water Affairs [South Africa]
ENSO	El Niño Southern Oscillation
FANR	Food, Agricuture and Natural Resources [Division]
FAO	Food and Agricultural Organization of the United Nations
GDP	gross domestic product
GoT	Government of Tanzania
ha	hectare
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
ITCZ	inter-tropical convergence zone
IWMI	International Water Management Institute
JICA	Japan International Development Agency
KASKOL	Kaleya Smallholder Company
KOBWA	Komati Basin Water Authority
LIMCOM	Limpopo Watercourse Commission
m^3/c pa	Cubic meter per annum
MAIWD	Ministry of Agriculture, Irrigation and Water Development [Malawi]
Mm^3	Million m^3
MUS	multiple use water services
NEPAD	New Partnership for Africa's Development
NGO	non-governmental organization
O&M	operation and maintenance
ORASECOM	Orange-Senqu River Commission
PJTC	Permanent Joint technical Committee [in the Kunene Basin]
PPP	public private partnership
RAP	Regional Agricultural Policy
RCP	Representative Concentration Pathway
ReSAKSS – SA	Southern Africa Regional Strategic Analysis, Knowledge and Support Systems
RSAP IV	Regional Strategic Action Plan IV
SACGOT	Southern Agricultural Growth Corridor of Tanzania
SADC	Southern African Development Community

SFG	Strategic Foresight Group
SRES	Special Report on Emissions Scenarios
SST	sea surface temperature
TSB	TSB Sugar Ltd
TTT	tropical temperate trough
USAID	United States Agency for International Development
WMA	water management area
WUA	water user association
ZAMCOM	Zambezi Watercourse Commission
ZNFU	Zambia National Farmers Union

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1 Introduction

1.1 Agricultural water management for poverty alleviation and sustainable growth

About 70 percent of citizens of the Southern African Development Community (SADC) depend on rainfed agriculture for their livelihoods (SADC 2003). Moreover, enhanced and sustainable development of this sector is the engine of improved economic growth, socio-human development, food and nutrition security and alleviation of poverty (SADC 2014a). Broad-based agricultural growth with agriculture-based industrialization can replace the extractive, capital-intensive and often 'jobless growth' path as currently persists in SADC's dual economies. Inclusive agricultural growth not only contributes to national food security at affordable prices, export and foreign currency; it also creates employment for the rapidly growing new generations, narrows the wealth gaps, and stabilizes SADC's young democracies.

However, rainfed agriculture is directly exposed to the hazards of climate. SADC's rainfall patterns are characterised by high and unpredictable variability over the seasons, years, and decades. Moreover, Southern Africa is predicted to warm up faster than the rest of the world (IPCC, 2014). It is one of the few regions in the world that will experience significantly drier conditions, more extreme and unpredictable dry spells, droughts, and floods, while sea levels will rise faster here than elsewhere. These increased temperatures and less predictable, more variable extreme events hold SADC's farmers and economy 'hostage to hydrology'. This is also true where average rainfall is abundant. These predictions of long-term climate-induced changes render the need for 'no regret' measures today even more urgent.

A key 'no regret' measure that turns these climate hazards into opportunities is improved agricultural water management, or 'agwater management'. Agwater management encompasses a broad menu of techniques ranging from improved on-field water harvesting and soil moisture retention to year-round water storage for year-round fully controlled irrigation of crops, trees and livestock feed; improved water supplies for livestock; and the development of fisheries and aquaculture. Agricultural water management was a vital component in Asia's Green Revolution to boost the 'trickle-up' growth path through poverty alleviation (Jazairy, 1992).

The CAADP of the African Union's (AU's) New Partnership for Africa's Development (NEPAD) recognized this unlocked potential throughout Africa by prioritizing the first of its four pillars, that of 'Sustainable Land and Water Management'. In pillar one, African states committed to the doubling of irrigated area from the 3.5 percent at the time to 7 percent by 2015 (CAADP 2009).

SADC's Regional Indicative Strategic Development Plan (2003, revised in 2007 and 2015) re-affirms CAADP goals, including pillar one. SADC operationalizes this through both its Water Division and the Food, Agriculture and Natural Resources (FANR) Division. The SADC Regional Agricultural Policy (RAP) (SADC 2014a) envisages the improvement of the management of water resources for agriculture (SADC 2014a, section 10.5). In the results framework, outcome 1.4 foresees that water infrastructure for agriculture is expanded and upgraded. The RAP commits to assess the effective utilisation of existing irrigation infrastructure and to promote new infrastructure development (SADC 2014a, section 16.1 (75)). In terms of monitoring, the RAP results framework signals the need to provide baseline data on the number of dams, irrigated area and irrigation management practiced in the SADC region (SADC 2014b).

The Regional Strategic Action Plan IV (RSAP IV) (SADC 2015), which is based on the SADC Water Policy (2005) and Strategy (2006) aims at 'An equitable and sustainable utilization of water for social and environmental justice, regional integration and economic benefit for present and future generations'. Noting that there is about 50 million hectares (ha) of irrigable land available within the SADC Region of which only 3.4 million ha (7 percent) is currently irrigated, the RSAP IV emphasizes the importance of infrastructure development and water resource management for food security in the water-food nexus, and the stronger urgency to take action in the view of climate variability and change. RSAP IV also highlights the benefits of multipurpose dams for both energy and irrigation. At local level, SADC Water commits to conduct action-research to develop and sustainably implement resilient water-related infrastructure; and to innovate affordable and appropriate technologies and innovative approaches and practices. Priority interventions are the demonstration and upscaling of community-based water for livelihoods projects (SADC 2015).

1.2 Trends in irrigated area

In spite of the major unlocked potentials and strong policy commitments, the average percentage of arable land in SADC has only slightly increased from 7.6 percent in 1990 to 8.4 percent in 2012 according to the Food and Agricultural Organization of the United Nations (FAO's) AQUASTAT (FAO, 2013) (see Figure 1). A peak was reached a decade earlier. Moreover, the high average percentage of irrigated land is largely the result of irrigation by large-scale agribusiness in only four countries (Madagascar, Mauritius, South Africa and Swaziland). Moreover, both smallholder irrigation in South Africa and irrigated land area in Madagascar declined.

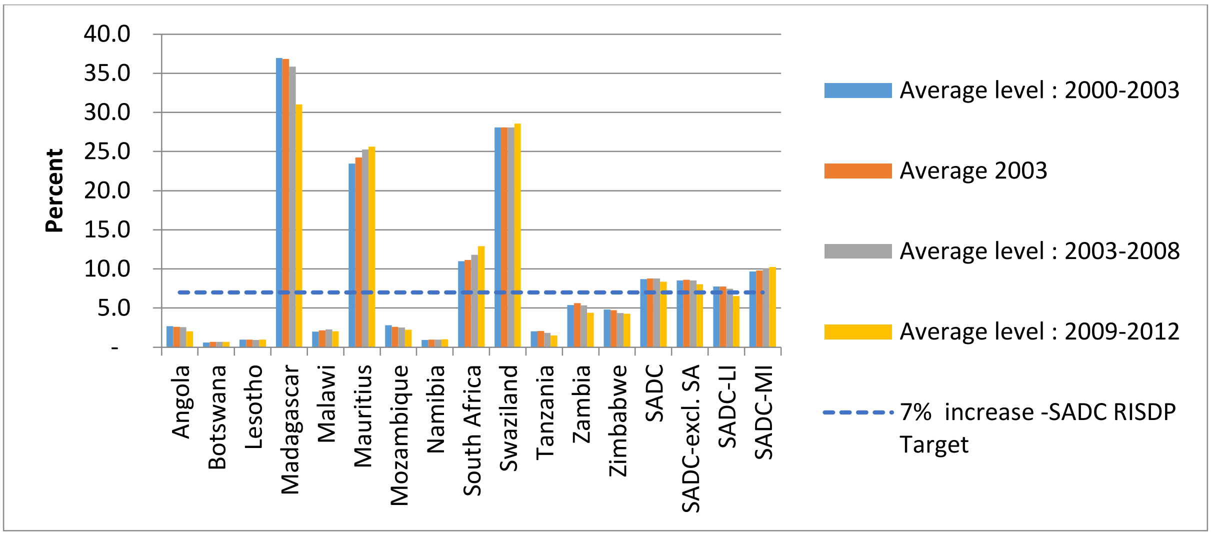


Figure 1: Irrigated area as proportion of cultivated area

Source: FAO AQUASTAT (2013)

This raises a pertinent question: why is irrigation expansion stagnating, and how can this be turned around? Unfortunately, there is no systematic regional body of knowledge to analyze these trends and provide answers. As the Regional Agricultural Policy observes, there is not even a base line on irrigation management practiced in the region, neither for the upgrading of existing infrastructure nor for new investments.

Moreover, in spite of the clearly related common goals of the Water and FANR divisions in SADC and in national states, forums to bring these sectors and other relevant stakeholders together are rare. Potential synergies between sectors that would allow each sector to better achieve its goals remain untapped.

The present study on 'Trends and Outlook: Agricultural Water Management in Southern Africa' seeks to fill these gaps. The project is part of the Regional Strategic Analysis and Knowledge Support System – Southern Africa project, implemented by the Southern Africa Regional Program of the IWMI. It is supported by USAID's Feed the Future Program through USAID's Southern Africa Regional Program. At the interface of both water and agriculture, the IWMI is well placed to enable such dialogue and provide a robust knowledge base on inclusive agricultural growth in general, and agwater management in particular.

1.3 Study aim and method

In order to explain the current stagnation and find ways to overcome this, the following questions will be answered:

- What are the precise hydrological hazards of climate variability and change, and what is the meaning of 'water scarcity' for agriculture in SADC?

- What lessons can be learnt from past and current investments in agwater management in SADC, in particular from their strengths and weaknesses in sustainably contributing to poverty alleviation, food security and agricultural and economic growth?
- How can SADC and national government, non-governmental organizations (NGOs) and donors build on these strengths and overcome weaknesses?
- What are the untapped synergies between the public sector agencies with mandates in agriculture and those with mandates in water management, so that both sectors can achieve their goals more effectively?
- What are minimum 'must-have' indicators?

The method to answer these questions consisted of both an extensive literature review and analysis of past performance (Mutiro and Lautze 2015), as well as interviews with key stakeholders at SADC and national levels. Further national studies with illustrative in-depth case studies were conducted in four selected countries: Malawi, South Africa, Zambia and Zimbabwe. This report is the Synthesis Report.

The Synthesis Report and the four country reports of the Trends and Outlook: Agricultural Water Management in Southern Africa Project are available at www.iwmi.org - Southern Africa Regional Program.

1.4 Definitions and research approach

Agwater management encompasses a wide range of interrelated hard- and software measures to ensure that the right quantities of water of the right quality reaches the right sites of agricultural (and other) uses at the right time. Improved water control enables crop diversification, stabilizes and increases crop yields, and enables more cropping seasons, including the slack and hunger seasons. Storage in dams or in 'green infrastructure' (such as recharged aquifers or managed wetlands) attenuates floods. Hardware typically includes (combinations of) infrastructure to harvest and store precipitation and run-off water by recharging aquifers, to convey and apply water, and to drain excess water. This study focuses primarily on water supply to crops through infrastructure that extends beyond in-field soil and water conservation alone.

There are various classification systems of agwater management – and even more blends: by source (well, surface storage, stream, wetland, groundwater); by technology (which often determines the scale as well); by ownership and/or management either by individuals or communal groups; by plot size and/or scheme size; by goal of investment and type of beneficiaries (household food security; marketing); by formal or informal in terms of formalized, written and state-backed rules; whether privately invested in capital costs and/or operation and maintenance (O&M), and rehabilitation, or by government, NGOs or otherwise; etc.

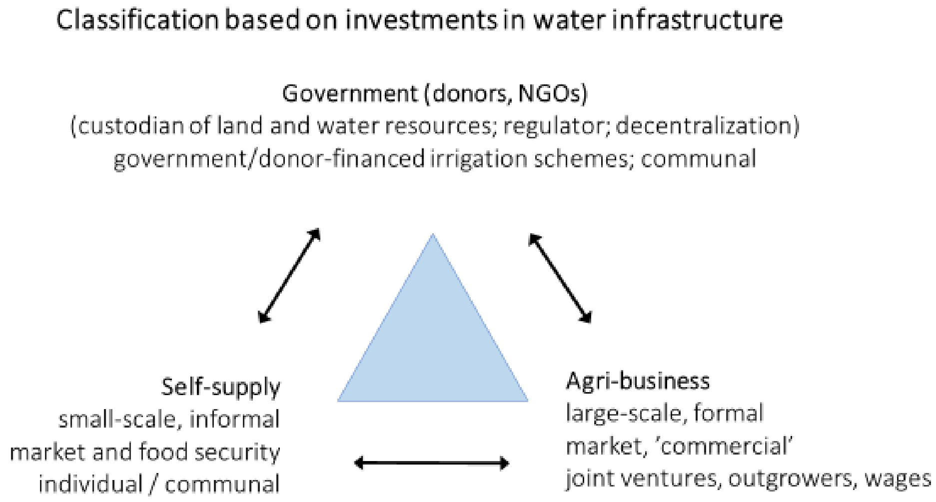


Figure 2: Classification of types of investments in irrigation based on types of investors

For the present purpose of learning lessons for investments, we build on the latter; so the main criterion to distinguish the different types of irrigation is: who is the main investor in the construction and installation of infrastructure? Capital costs are usually the most expensive part of irrigation. Moreover, claims to the water stored and conveyed tend to go together with investments in the infrastructure and subsequent maintenance ('hydraulic property rights creation') (Coward 1986). As we will see, although their performance varies widely, each type is quite specific in terms of the historical and political-economic context in which it emerged and continues to exist, and its strengths and weaknesses in contributing to poverty alleviation and socio-economic growth.

The first type of irrigation investments are by governments, both before and after independence. International donors and financers typically work through governments, while most NGOs also work in close collaboration. Government- or NGO-financed schemes are typically collective schemes. They may be accompanied by resettlement at local or wider scales. The involvement of government can range from very strong (in government-run schemes) to a role that is limited to design and financing of the infrastructure construction and sometimes rehabilitation, leaving all other tasks to communities. In addition to investing in infrastructure, governments also play unique roles as regulator and custodian of the nation's land and water resources in SADC's evolving resource tenure systems. Governments influence the next two types of irrigation in both capacities.

The second type of irrigation investments are by citizens – also known as self-supply – where citizens are the key investors in infrastructure for their own benefits. That is done by individuals or groups, and often is seen as informal. Adaptation to climate variability through these investments has been at the heart of agrarian societies' survival since time immemorial. One strategy for people is move to and from water through their settlement patterns. Both farmers and pastoralists look for the better-watered areas with better rainfall and fertile soils throughout the seasons, also using receding floods and water that accumulates in valley bottoms or entire floodplains for dry season cropping and grazing. People's other age-old strategy is to make water move to them, which requires investments in infrastructure. Household wells provide groundwater for domestic uses, livestock, and small-scale production at and around homesteads. Free gravity energy has long been tapped in mountainous areas in river-diversions, sometimes with night storage. These are typically for domestic uses, irrigation, brick making and other uses. The availability of new appropriate technologies boosts innovation. Multi-purpose infrastructure is the rule; single uses are the rare exception, because rural (and peri-urban) people have multiple water needs, and multi-purpose infrastructure is more cost-effective. People also use and re-use the changing multiple water sources for greater environmental resilience.

The public sector plays a role in supporting technology development and uptake, for example by stimulating market-led equipment supply chains. The Regional Agriculture Policy (SADC 2014a) promotes the removal of import tariffs on equipment for that reason. Effective forward and backward linkages as a result of broader agricultural support for inputs, marketing and skills development are a key 'pull' factor to convince farmers to invest in infrastructure. Further, government's land and water policies, laws and regulations also affect investments for self-supply.

The third type of investments in infrastructure are those by agri-business. Colonial settlement and state formation was largely shaped around this type of investment, and it forms the basis for SADC's dual economy of highly mechanized, often export-oriented large-scale farming; alongside largely manual smallholder agriculture, lack of electricity, poverty and unemployment. The financial crisis of 2008 fuelled further foreign or national investments in SADC's abundant land and related water and mineral resources, also dubbed as 'land and water grabs' (Mehta, 2012). Governments play key roles in these investments through their national investment policies, public-private partnerships and, especially, their post-colonial custodianship of both land and water resources.

In the following, we first present findings with regard to the current climate and expected impact of climate change, followed by a quantitative assessment of SADC states' renewable freshwater resources and irrigation potential. In the sections three to five we discuss the experiences, strengths and weaknesses of investments in irrigation by government, smallholders and agribusiness. Section six identifies potential synergies between the agricultural and water sectors, including minimum monitoring indicators. Conclusions are drawn in section seven.

2. Water resource variability under climate change

2.1 Introduction

Southern African is one of the few regions in the world that will experience significantly drier conditions over the next century. At the same time, this region is warming up faster than the rest of the world (IPCC, 2014). Socio-economically, Southern Africa is among the world's poorest and most vulnerable regions. With its land and water resources already under stress, both climate change and structural poverty will create immense challenges for sustainable human development and will require unprecedented adaptive capacities to be developed.

Over 70-80 percent of the region's livelihoods depend on rainfed agriculture (Cooper et al., 2008; Twomlow et al., 2008), thereby making crop production particularly vulnerable to climate change and variability. Agriculture contributes to 35 percent of GDP and 70-80 percent of employment (Abalu and Hassan, 1998). With an annual per capita consumption averaging 91 kg (excluding South Africa), maize is the most produced and most consumed cereal in the region and contributes 40 percent of the calories consumed in peoples' diets. Millet and sorghum are also important crops, especially in the drier areas, whereas wheat is mainly produced under irrigation in South Africa and Zimbabwe. In this context, warming and drying conditions are expected to have strong negative effects on livelihoods through reduced crop yields. In this chapter, we review the main features of past and future climate variability and climate change in Southern Africa, describe their impact on agriculture and propose adaptation measures.

2.2 Past and current climate in Southern Africa

2.2.1 Overview

Climate in Southern Africa follows a gradient from arid conditions in the (south-) west to humid conditions in the north and east (see Figure 3 and Table 1).

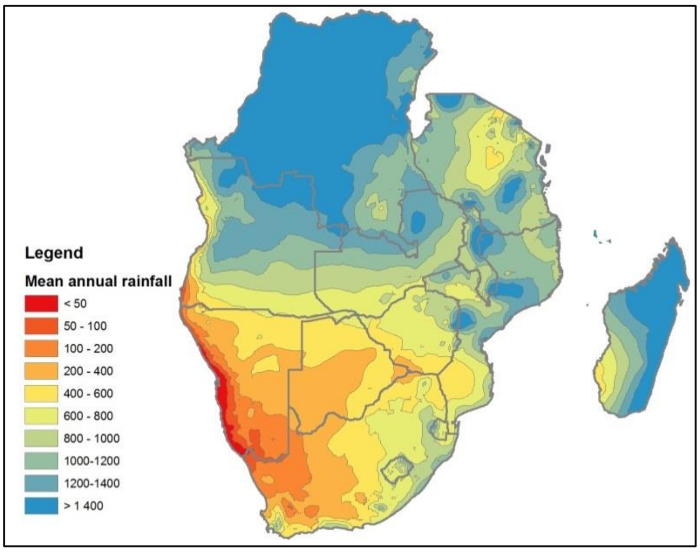


Figure 3: Mean annual rainfall in SADC

Rainfall patterns are characterised by high variability from intra-seasonal, through inter-annual to decadal and multi-decadal. Inter-annual variability is particularly pronounced in the drier part, where the inter-annual coefficient of variation can exceed 40 percent. A marked latitudinal distribution of rainfall exists in southern Africa, which divides the region into two climatic groupings: the South (Botswana, Lesotho, Namibia, South Africa and Swaziland) is dry with high inter-annual variability that exceeds that of the Sahel. The North (Angola, Democratic Republic of Congo (DRC), Malawi, Mozambique, United Republic of Tanzania, Zambia and Zimbabwe) has higher annual rainfall and lower inter-annual variability than the South (SADC, 2011).

Table 1: Average rainfall amounts and volumes in SADC countries

Country	Long-term average rainfall in depth (2012) (mm pa)	Long-term average rainfall in volume (2012) (10^9 m^3 pa)	National rainfall index (NRI) (1998-2002) (mm pa)
Angola	1 010	1 259.0	1 137.0
Botswana	416	242.0	430.4
DRC	1 543	3 618.0	1 571.0
Lesotho	788	23.9	734.9
Madagascar	1 513	888.2	1 541.0
Malawi	1 181	139.9	1 125.0
Mauritius	2 041	4.2	n.a.*
Mozambique	1 032	825.0	1 005.0
Namibia	285	234.9	339.0
Seychelles	2 330	1.1	n.a.*
South Africa	495	603,4	548.3
Swaziland	788	13,7	648.0
Tanzania	1 071	1 015.0	1 114.0
Zambia	1 020	767.7	1 065.0

Country	Long-term average rainfall in depth (2012) (mm pa)	Long-term average rainfall in volume (2012) (10^9 m^3 pa)	National rainfall index (NRI) (1998-2002) (mm pa)
Zimbabwe	657	256.7	722.5
SADC	1 078	9 892.6	921.6

*n.a. data not available

Source: Aquastat database (FAO 2013)

Southern Africa rainfall is subject to seasonality, high inter-annual and inter-decadal variability and is prone to drought and flood events. The main driver of inter-annual variability is El Niño Southern Oscillation (ENSO). Sea surface temperature (SST) of the Indian and Atlantic Oceans has also an effect on rainfall variability. Apart from oceanic factors, Southern African rainfall is also influenced by the strength and position of regional atmospheric features such as the inter-tropical convergence zone (ITCZ), Angola low and Walker circulation (Driver, 2014).

2.2.2 Seasonal variability

Southern Africa receives most of its annual rainfall during the austral summer when the ITCZ reaches its southernmost position (Tyson, 1986). Tropical temperate troughs (TTTs) and their associated cloud bands account for much of the rainfall over southern Africa south of approximately 15 °S. An enhanced Angola low (source of moisture for the TTTs) generally results in higher levels of rainfall over parts of southern Africa (Hart et al., 2013).

2.2.3 Inter-annual variability

Inter-annual variability of Southern African rainfall is controlled by several synoptic drivers of which ENSO has received the most attention to date. The greatest influence of ENSO on rainfall occurs during its mature phase between December and March when the upper westerlies have retreated poleward south of Africa (Mason and Jury, 1997). El Niño events are usually associated with drier conditions over most of Southern Africa. The area which is most frequently affected by below-average rainfall is the belt that extends from southern/central Mozambique in the east and stretches westwards to Namibia, as well as the western half of South Africa. However, an analysis of individual El Niños shows that there are considerable variations between countries from one event to another. Some El Niño events did not result in reduced rainfall. For example, during the 1987/88 and 2009/10 El Niños, some large areas received above-average rainfall. In contrast to El Niño, La Niña is a coupled ocean-atmosphere phenomenon typically associated with lower-than-average sea surface temperature across the equatorial Eastern Central Pacific Ocean and wetter conditions over Southern African countries (Reason and Jagadheesha, 2005).

2.2.4 Multi-decadal trends

Richard et al (2001) evidenced the absence of significant temporal trends in annual rainfall over Southern Africa during the 20th century. However, inter-annual variability in annual rainfall must be distinguished from both a fluctuation in intensity and the seasonal distribution. Fauchereau, et al (2003) analysed observational rainfall data for the 20th century and concluded that some regions in southern Africa experienced a noticeable shift towards more extreme rainfall events in the later decades of that century. Further evidence of an increase in the intensity of high rainfall events between 1931 and 1990 was provided by Mason et al (1999). New et al (2006) concurred with earlier findings and showed that regionally averaged total rainfall decreased between 1961 and 2000, but not to an extent that is statistically significant. However, the authors deduced that there was a statistically significant increase in the intensity of daily regional rainfall as well as a marked change in the duration of dry spells.

More than half of the population of sub-Saharan Africa relies on rainfed agriculture (FAO, 2009a). Crops are affected by the number of dry or wet spells. Staple crops such as maize, sorghum or millet need to be planted at the correct time before the rains are too heavy and the seed is washed away. On the other hand, the rains need to be sufficiently substantial to ensure proper germination of the seeds. In this context, reliable prediction of rainfall variables such as the number of dry days in the summer rainy season and the duration of dry spells would be of huge benefit to subsistence farmers in Southern Africa. Thus, dry day frequency over Southern Africa is generally of more interest than more common parameters provided by meteorological services such as seasonal rainfall totals.

2.3 Future climate projections

The Coupled Model Intercomparison Project (CMIP) is a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models. In its fifth assessment report (AR5) in 2014, the Intergovernmental Panel on Climate Change (IPCC, 2014) used the 5th version of CMIP (CMIP5) that is forced by four different Representative Concentration Pathways (RCPs). RCPs are greenhouse gas concentration (not emissions) trajectories adopted by the IPCC AR5. It supersedes the Special Report on Emissions Scenarios (SRES) projections published in 2000. Here below, we present the multi-models mean output from CMIP5 for Southern Africa, run with RCP8.5. RCP8.5 corresponds to radiative forcing values in the year 2100 which are 8.5 Watts/m^2 higher than pre-industrial values.

2.3.1 Temperature

For each degree of average global increase in temperature, Southern Africa will experience an increase of 1.25 to 1.5 degrees, meaning that this region is warming at a rate higher than the global average (Stocker et al, 2013). In absolute values, by 2050, average annual temperature is expected to increase by 1.5-2.5 °C in the south and by 2.5-3.0 °C in the north compared to the 1961-1990 average (Ragab and Prudhomme, 2002). Temperature rises will be greater in the summer than in winter, exacerbating stress on crops.

2.3.2 Precipitation

On average, Southern Africa will become drier with less annual rainfall. For each degree of average global increase in temperature, annual rainfall will be reduced by between 10 percent and 3 percent, on the western and eastern side of Southern Africa, respectively. This drying effect results from changes in the Hadley Circulation. Decrease in annual runoff, soil moisture and evaporation are likely to occur in response to this rainfall reduction. There is high confidence that the ENSO will remain the dominant mode of natural climate variability in the 21st century at global level (Cai et al 2014). How it will impact on regional climate (rainfall and temperature) in Southern Africa is less certain (Stocker et al, 2013). However, the increasing concentrations of greenhouse gases is enhancing the atmosphere ability to absorb heat and hold moisture, leading to an increase in the frequency of extreme rainfall events over the Southern African region.

2.3.3 Sea level

According to CMIP5 under the RCP8.5, the sea level along the coast of Southern Africa will experience the greatest rise among all countries globally, with changes up to 0.8 meters between the periods 1986-2005 and 2081-2100 (IPCC, 2014). Coastal systems and low-lying areas will increasingly experience submergence, flooding and erosion throughout the 21st century and beyond. The population and assets projected to be exposed to coastal risks as well as human pressures on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development and urbanization (IPCC, 2014).

2.4 Implications for water resources and agriculture

A warmer and drier climate with more frequent and intense El Niño events will reduce soil moisture, river streamflow and water resource availability hampering irrigated and rainfed agriculture. Increased aridity will accelerate land degradation, desertification and biodiversity loss. This will likely reduce the surface area of land suitable for agriculture, potentially leading to increases in clearing of native forest and pasturelands for crop cultivation, with a consequent significant increase in carbon release. In general terms, this implies greater competition for scarce land and water resources.

Simulation models are used to estimate the effect of future climate on crop yields. The last decade has a substantial body of work on rainfall and temperature change impacts on crops within Southern Africa. These studies suggest that the production of major crops is under threat due to the projected temperature increase and rainfall decline at the beginning of summer cropping (September to November) in most parts of the region. The process-based crop growth simulation model (Hertel and Rosch, 2010) was developed to simulate crop responses to environmental conditions at the plot and field levels. Jones and Thornton (2003) projected that maize yields will decline in most countries in Southern Africa by an average of

10 percent by mid-21st century under rainfed small-scale production. Thornton et al (2011) concluded that maize and bean production in Southern Africa could decline by 16 percent and 68 percent respectively, by late 21st century, with a five degree temperature increase. A global study by Parry et al (2004) concluded that total crop yield in Africa may decrease up to 30 percent in the late century. They made this assessment for wheat, maize, rice, and soybean. Cereal yields for Southern Africa showed up to 5 percent decline for all scenarios without CO_2 fertilisation for the early century, 5-30 percent decline in mid-century and a consistent 10-30 percent decline for late century. Fischer et al (2005) showed a potential 5-50 percent decline in cereal yields for most parts of South Africa by late 21st century. Chipanshi et al (2003) examined the response of maize and sorghum in Botswana. Simulated yields declined by 23 percent for maize and 20 percent for sorghum, on average.

Furthermore, recent food prices volatility showed that climate change can be an important threat multiplier to food security, and that it is introducing another source of risk and uncertainty into food systems from farm to global levels. The compounding effects of spiking food and fuel prices, the global economic downturn in 2009, and weather anomalies are estimated to have reversed the steady decline in the proportion of undernourished in the population (FAO, 2009a). Also, they could reverse the economic gains obtained by a number of African countries in recent years.

The importance of agriculture and the heavy dependence of many Southern African economies on natural resources mean that more intense and frequent droughts will have a major bearing on development in general. A collapse in national income, combined with the heavy costs of disaster response operations, has the potential to reduce the ability of governments to invest in key socio-economic sectors.

In addition to the detrimental effects on agriculture, climate change is expected to cause a number of other problems. Increased temperatures and occasional flooding due to La Niña events will increase water- and vector-borne diseases. Malnutrition due to crop failure will exacerbate diseases. More frequent climatic disasters can remove children from school due to increased poverty, food shortage, isolation (for example when roads are damaged by floods), and child abandonment. Women often get a disproportionate share of the burden when disasters strike because they have less opportunities than men. This can undermine their education and development, and affect their welfare and that of children.

Humans have adapted to patterns of climate variability through land-use systems that minimize risk, with agricultural calendars that are closely tuned to typical conditions and choices of crops, and animal husbandry that best reflect prevailing conditions. Rapid changes in this variability may severely disrupt production systems and livelihoods, requiring adaptation measures.

2.5 Adaptation options to a warming and drying climate in Southern Africa

While international agreements on climate change largely focus on mitigation, most of Southern African countries are the lowest emitter of greenhouse gas in the world (SADC, 2011). At the same time, they are already experiencing the negative effects of climate change and are more immediately concerned with issues of adaptation. Adaptions to climate change are taking place at various scales, from the farming system to the national level. "No regret" adaptations relate to measures that will prove worthwhile doing in a context of prevailing uncertainty over specific future impacts of climate change at sub-regional level, especially with regards to precipitation patterns.

2.5.1 On-farm "no-regret" options

Smallholder farmers are already using a wide variety of creative practices to deal with climate risks (Below et al 2010; Kandji et al 2006). These practices aim to reduce the immediate dependency of production systems on environmental conditions, and diversify livelihood strategies and income sources at the household level. They include on-farm water management technologies (rainwater harvesting, groundwater development and irrigation systems to secure water access over longer time periods (e.g. Knox et al 2010 in Swaziland), diversification of farm productions (e.g. food and cash crops, annual and permanent crops, rice and fish breeding), varying fertilizer and manure applications, the use of off-farm income sources (e.g., wildlife tourism), micro-insurance schemes for extreme weather events to help poor households cope with droughts and floods (Bauer and Scholz, 2010). These practices are not specifically designed to respond to a warming and drying climate but rather to face droughts, floods, pests and diseases and the associated risks of yield decline. From that perspective, they are qualified as "no regret" solutions.

2.5.2 Water infrastructure

Drying and warming climate trends and the increased frequency of weather extremes in Southern African countries will predominantly impact agriculture through a change in the availability of water resources (Schulze and Perks, 2000). At scales larger than farming systems, water infrastructure development can help buffering the increased variability of water resources and cope with the overall reduction of water resources in a drying and warming climate. Water infrastructure development for agriculture can be defined as the process of developing, financing, implementing and operating structures for water storage, irrigation and drainage. Countries in sub-Saharan Africa store only 4 percent of their annual renewable flows. For SADC, including the Kariba and Cahora Bassa Dams this is just 14 percent (SADC, 2012). However, in most industrialised countries this number ranges between 70 and 90 percent. Water storage is essential to ensure reliable sources of water for irrigation and to provide a buffer against floods and droughts. The critical issue is to store massive quantities of rain falling in very short periods so that it can be used over the entire year.

In dry regions where surface water is scarce and in rural areas with dispersed populations, groundwater provides a secure and cost-effective water supply. Groundwater is likely to play an even greater role for human survival and economic development under changing climatic conditions.

As mentioned, currently, only 7 percent of arable land in the region is equipped for irrigation. Irrigation is critical to ensure food security and rural development in the context of increased rainfall variability and extreme events. Existing irrigation systems also have to be adapted to reduce water losses and to improve water productivity. To respond to the increased frequency and intensity of floods, the construction of dikes, levees and flood embankments is required to reduce the risks of flooding and associated damages to populations and crops.

2.5.3 Water management

For an optimal use and adaptation to climate change, water infrastructure needs to be managed in order to ensure that water resources are available at the appropriate time while preserving the environment and protecting populations against floods. Proper water management requires weather forecasting, hydrological modelling, early warning systems and tools to optimize hydropower operation. On the water user side, proper water demand management should ensure water use efficiency and minimize water losses.

Data and information are required to support the assessment of current and projected climate changes, the development of adaptation strategies and to assess vulnerability hot spots. Data needed for impact modelling and subsequent vulnerability assessment includes hydro-meteorological data, morphological data and water quality data. River flow forecasting is then employed to decrease uncertainty and reduce the risks associated with the use of water resources.

Floods are a natural and inevitable part of life along the rivers of Southern Africa. Over the centuries losses of life and property associated with floods have been colossal. Just in 2000, more than 800 people lost their lives during the flood in Mozambique. In most cases, loss of life can be prevented, providing that vulnerable communities are informed in due time of impending floods. Early warning is used for alerting people and communities of the actual arrival of a flood, to enable them to move to safer places. As floods become more unpredictable because of climate change, early warning systems constitute the last defence line to protect population against the disastrous effects of floods.

The low storage capacity of most existing dams in Southern Africa suggests that they cannot be used to store major floods. The fact is that most dams in the region have been designed for other purposes than flood management, such as hydropower. Most dams are also operated in a stand-alone mode, with narrow objectives, within the framework of a single hydrological year. But if operated as systems, these same dams could play an important role in flood management.

Developed water is a scarce resource in Southern Africa. In several parts of the region, climate change will exacerbate this situation. Water resources have then to be used wisely, making sure that every drop counts. At the moment, water use efficiency is low in Southern Africa. Improvement measures are therefore justified in the context of climate change. They also make economic sense. This involves a wide range of interventions, including changing the behaviour of consumers, disseminating water efficient technologies, introducing efficiency-inducing pricing structures, reducing leakages in distribution networks, and improving operating rules in supply systems (SADC, 2011).

2.6 Conclusion: implications of climate change

Knowledge about climate change evolves quickly over time as new data sets and more reliable climate projection tools become available. It is now clear that Southern Africa will experience the highest rates of temperature warming, rainfall reduction and sea level rise among the regions of the world. Adapting to and mitigating climate change is an inter-generational process that requires clear understanding, long-term thinking and planning, and knowledge and skills transfer to the next generation. People are more likely to respond to a threat if they understand what they will gain from changing their practices and what they will lose if they do not. In addition, responses to the challenges of climate change are often site-specific and require localized ingenuity. Climate change adaptation cannot be achieved by individuals but by the society as a whole. Participatory approaches are required to ensure that adaptation measures account for the interest of all actors. Adaptation needs to be integrated formally into all sectors and processes susceptible to be affected by the impact of climate change.

Governments should ensure that all existing policies are in line with the requirements of climate change adaptation and that existing sector policies do not conflict with and hamper adaptation in other sectors. This exercise should be based on solid scientific and economic analysis. In most cases, water management is not integrated with other sectoral responses to climate change, and water management is often under-represented in national plans and international investment portfolios. A policy shift needs to take place to reflect the pivotal role of water in climate change adaptation. Financial constraints constitute one of the greatest barriers to adaptation. In the water sector alone, the global costs of adaptation are estimated to be over USD 531 billion from now to 2030, almost twice the SADC aggregate GDP. Current global adaptation funds are limited and will not be able to meet such funding requirements. As of December 2010, USD 42.64 million have been channelled through bilateral and multilateral climate funds and funding mechanisms to support adaptation measures in Africa. Climate change adaption will have to be funded through several financing sources, such as public and private investments and insurance arrangements.

We now turn to a further quantification of the region's and countries' available water resources, the degree of their development, and the agricultural and other uses of developed water. This quantification further corroborates the above-described immense variation in water resource availability during the seasons, years, across countries, and last, but not least, within countries.

3. Water resources availability, withdrawals and uses

3.1 Annual renewable freshwater resources

3.1.1 Total volumes

Annual renewable freshwater resources are an area's total precipitation, plus inflows, and minus outflows, and noting other changes in storage. The renewable freshwater resources of SADC are estimated to be 2 300 km^3 pa (FAO, 2013). Table 2 shows the totals and the distribution of surface and groundwater resources by country. Overall, renewable groundwater resources constitute an estimated 28 percent of total water resources.

Table 2: Renewable water resources by SADC country

Country/Region	Total renewable surface water (10^9 m^3 pa)	Total renewable groundwater (10^9 m^3 pa)	Total renewable water resources (actual amount) (10^9 m^3 pa)
Angola	145.0	58.0	148.00
Botswana	10.6	1.7	12.20
DRC	1 282.0	421.0	1 283.00
Lesotho	3.0	0.5	3.00
Madagascar	332.0	55.0	337.00
Malawi	17.3	2.5	17.30
Mauritius	2.4	0.9	2.80
Mozambique	214.1	17.0	217.10
Namibia	15.7	2.1	17,70
Seychelles	n.a.*	n.a.*	0.01
South Africa	49.6	4.8	51.40
Swaziland	4.5	0.7	4.51
Tanzania	92.3	30.0	96.30
Zambia	105.2	47.0	105.20
Zimbabwe	19.0	6.0	20.00
SADC	2 292.7 (72 %)	647.2 (28 %)	2 315.52 (100 %)

*n.a. data not available

Source: Aquastat database (FAO 2013)

Seventy percent of surface water resources in SADC are in 15 river basins that cross one or more national boundaries (see Figure 5). They range in size from the large Congo River Basin (3 730 470 km²) in the northern part of SADC, to Umbeluzi River Basin (10 900 km²) in the south east. The Zambezi River Basin (1 390 000 km²) covers eight SADC member states. The major transboundary lakes shared by Southern Africa states are Lake Jipe, Lake Victoria, Lake Tanganyika and Lake Malawi.

Groundwater is increasingly recognized as the world's most important water storage: it provides year-round storage without the problems of siltation and evaporation that affect surface dams (Villholth 2013). Based on geological setting, four groundwater provinces are distinguished in SADC: basement rocks (with shallow groundwater), sedimentary layers (also at greater depths), volcanic, and high-relief folded mountain (fragmented occurrence) (Conley, 1996; IGRAC, 2005). Shallow groundwater is relatively easy to access, but equipment and energy costs for pumping become considerably higher for larger quantities at deeper layers. It is noted that SADC also has quite some fossil ground water resources that are not renewable. Figure 5 shows these aquifers and their transboundary nature.

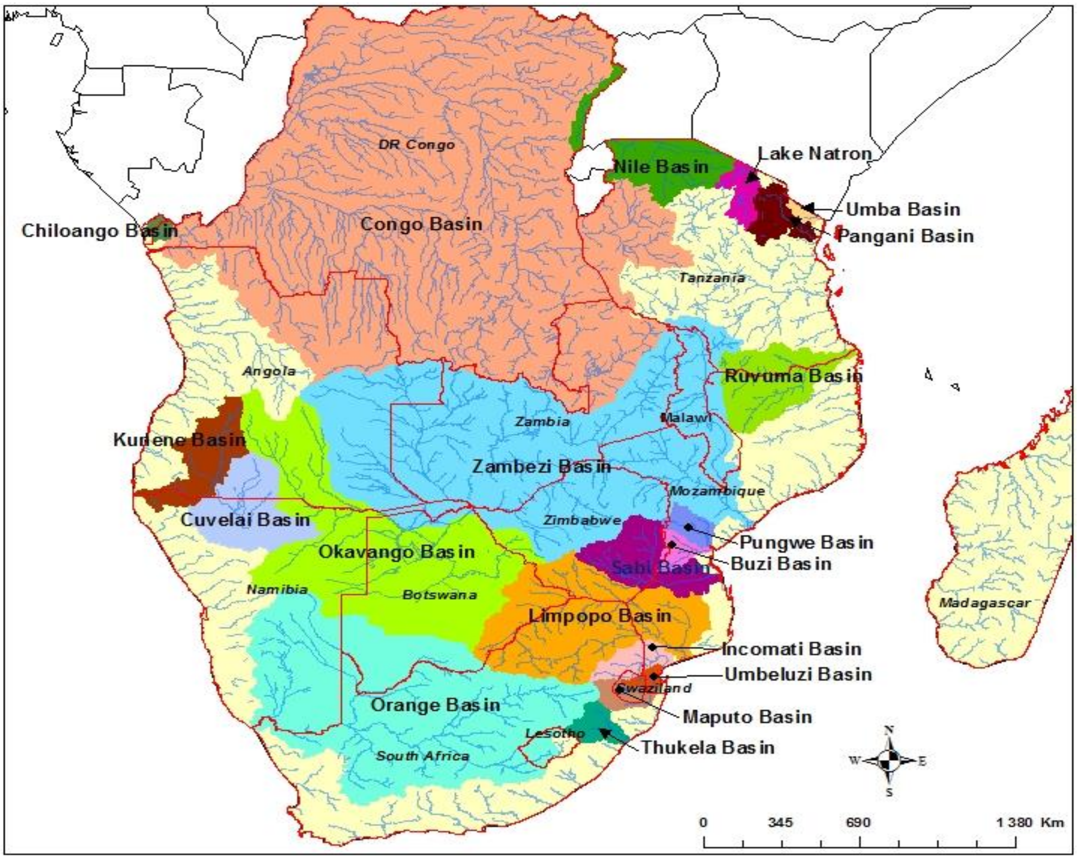


Figure 4: Map showing transboundary basins of the SADC region

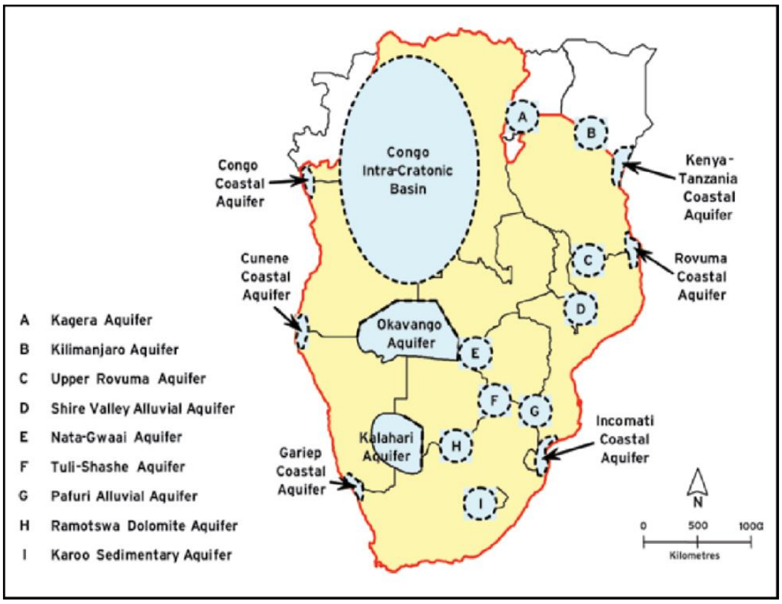


Figure 5: Map showing transboundary aquifers in the SADC region

Source: Ashton and Turton 2008

3.1.2 Volumes per capita

By dividing a country's annual renewable freshwater resources by its population, one obtains the average renewable water resources per capita for each country. As Figure 6 shows, the per capita annual renewable freshwater resources range from the average of 19 983 m^3/c pa in DRC to 152 m^3/c pa in Seychelles. The United Nations defines a country with its population as water stressed when the average annual water resource availability per capita is below 1,700 m^3. Lesotho and Zimbabwe are borderline in terms of of water scarcity. Water scarce countries, defined by the United Nations at 1 000 m^3/c pa, include Malawi, South Africa, and the Seychelles. Remarkably, arid but sparsely populated countries like Botswana and Namibia are not water stressed.

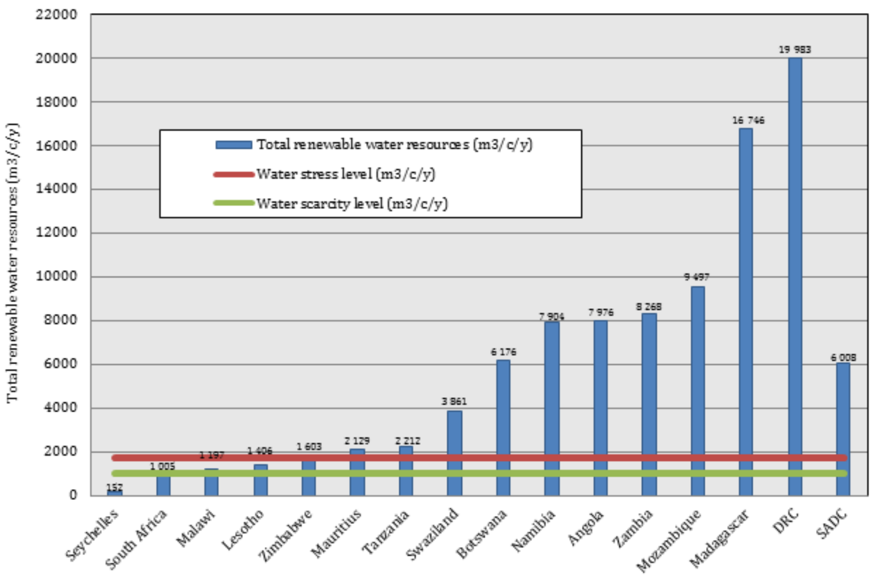


Figure 6: Per capita annual total renewable water resources per SADC country

Source: Aquastat database (FAO 2013)

3.2 Water withdrawals

As discussed above, even when total average water resources per capita are abundant, there is high seasonal, annual and decadal variability, which will exacerbate under climate change. Water development by surface- and groundwater-storage and pumping or conveyance infrastructure construction and operation buffer this. Obviously, infrastructure development is even more vital in water stressed countries. The freshwater withdrawals (or 'developed' water) refer to water resources that are made available for human uses through human-made storage and pumping and conveyance infrastructure. Table 3 shows that only a small portion, 9.7 percent, of renewable freshwater resources has been developed in SADC. Other portions are, at best, directly used in rainfed agriculture, grazing land and other beneficial rainfed land uses. However, by far the largest part of renewable water resources remain unused, flow out of the country or evaporate without contributing to wellbeing and socio-economic growth.

Moreover, Table 3 shows that there are significant differences between countries in their degree of water development. Only four SADC countries have developed a significant proportion of their water resources: Mauritius (36.4 percent), South Africa (25 percent), Swaziland (23.1 percent) and Zimbabwe (21 percent). In 7 countries it is less than 2 percent.

Table 3: Water withdrawals and development in the SADC region

Country	Freshwater withdrawals (% of total renewable resources) (2000-2005)	Agricultural water withdrawal (% of total water withdrawal) (2000-2005)	Agricultural withdrawal (% of total renewable water resources) (2000-2005)	Total reservoir storage (2010) (km^3)	Total reservoir storage/ population (2010)(m^3/c)
Angola	0.4	20.8	0.10	9.45	468.40
Botswana	1.6	41.2	0.65	0.45	221.00
DRC	0.0**	18.0	0.01	0.05	0.76
Lesotho	1.7	8.6	0.13	2.82	1 272.00
Madagascar	4.4	97.8	4.79	0.49	22.50
Malawi	5.6	85.9	6.75	0.04	2.63
Mauritius	36.4	62.7	17.85	0.09	70.70
Mozambique	0.3	78.0	0.32	77.47	3 165.00
Namibia	1.7	69.8	1.13	0.71	299.70
Seychelles	n.a.*	6.6	n.a.*	0.00	13.70
South Africa	25.0	62.7	15.25	30.53	601.70
Swaziland	23.1	96.7	22.31	0.59	479.50
Tanzania	5.4	89.4	4.81	104.20	2 187.00
Zambia	1.7	73.3	1.10	101.10	7 282.00
Zimbabwe	21.0	78.9	16.59	99.45	7 642.00
SADC	9.2	59.4	6.56	326.34	1 581.91

*n.a. data not available. **DRC: 622.2 Mm^3 is withdrawn, which is 0.049 percent, so rounded off as 0

Source: Aquastat database (FAO 2013)

The same Table 3 details the already mentioned storage capacity per country and per capita (in section two). The SADC region has total reservoir storage of 326.34 km^3 and an average water storage capacity per person of 1 581.91 m^3/person. However, the three countries with the largest volumes (Mozambique, Zambia, and Zimbabwe) reflect the region's two major dams, both in the Zambezi River: the Kariba Dam (since the late 1950s primarily for hydropower, displacing 57 000 people) and the Cahora Bassa Dam (since the 1970s, mainly for hydropower to South Africa, displacing 25 000 people). If the storage of the Kariba and Cahora Bassa Dams is included, 14 percent of the total annual renewable water resources in the SADC region is currently stored. However, if the storage of the Kariba and Cahora Bassa Dams is excluded, only 4 percent of the total annual renewable water resources in the SADC region is currently stored for various uses. This is very low compared to 70-90 percent in most industrialised countries (UNEP 2009 in SADC infrastructure plan).

The differences in surface storage development between countries are shown in Figure 7. This compares the number of large dams with a capacity of more than 3 Mm^3 per country. South Africa and Zimbabwe totally outnumber other SADC member states.

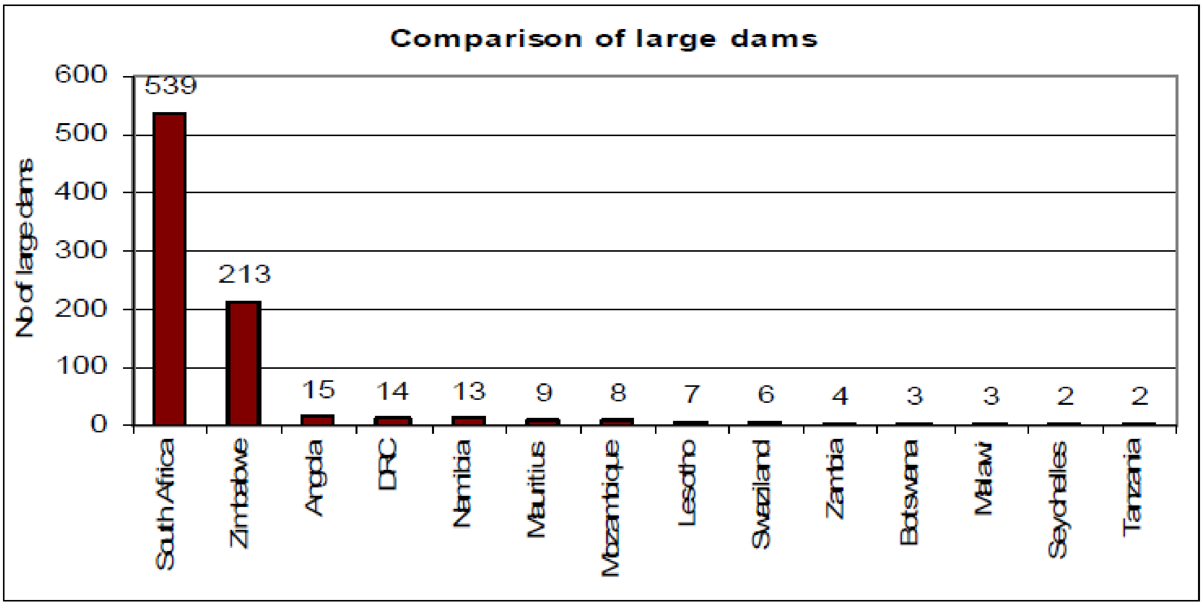
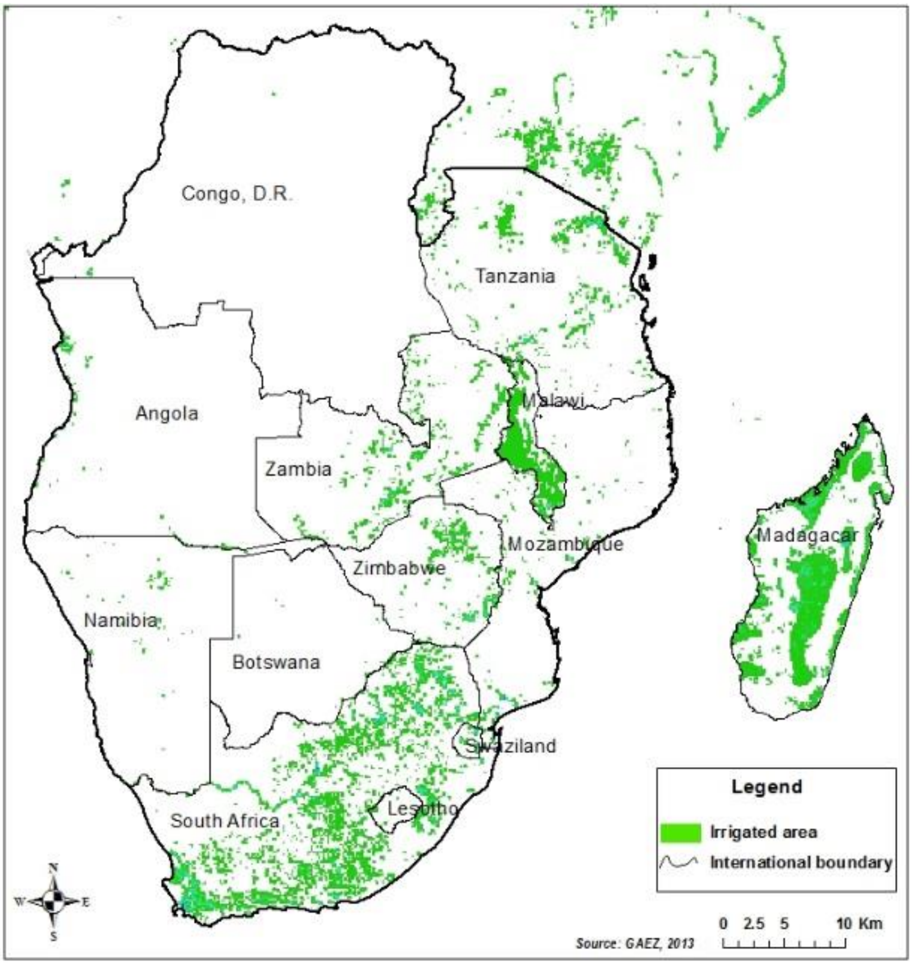


Figure 7: Number of large dams (capacity > 3 million m^3) by SADC country

Source: World Bank 2004

3.3 The uses of water withdrawals

Turning now to the uses of the water withdrawn, in particular the agricultural uses, Table 3 above shows that the proportion of withdrawals (which are 9.2 percent of total renewable freshwater resources), and the proportion that is used for irrigation is 59.4 percent. This corresponds to 0.594 x 9.2 percent = 6.56 percent of total renewable freshwater resources. The highest proportion of water withdrawals for agriculture out of renewable fresh water resources is in Swaziland, with 22.31 percent. Figure 8 shows the geographic spread of agricultural water withdrawals.



Note: The size of green spots is unrelated to size of irrigated area at the scale of the map

Figure 8: Map of irrigated areas
Source: GAEZ undated

Agriculture is not the only use of water withdrawals. Figure 9 shows the proportion of domestic, industrial/mining and agricultural uses of water withdrawals during 2000 for various SADC member states. Agriculture is generally the highest user.

Figure 9 excludes non-consumptive uses, such as hydropower, recreation, navigation, fisheries, or low-consumptive uses. Hydropower generation depends on well-regulated flows for electricity generators. The hydropower potential of the SADC region is some 150 GW, of which only 12 GW is installed (SADC, 2011). The Kariba and Cahora Bassa Schemes have a combined capacity of 3,3 MW.

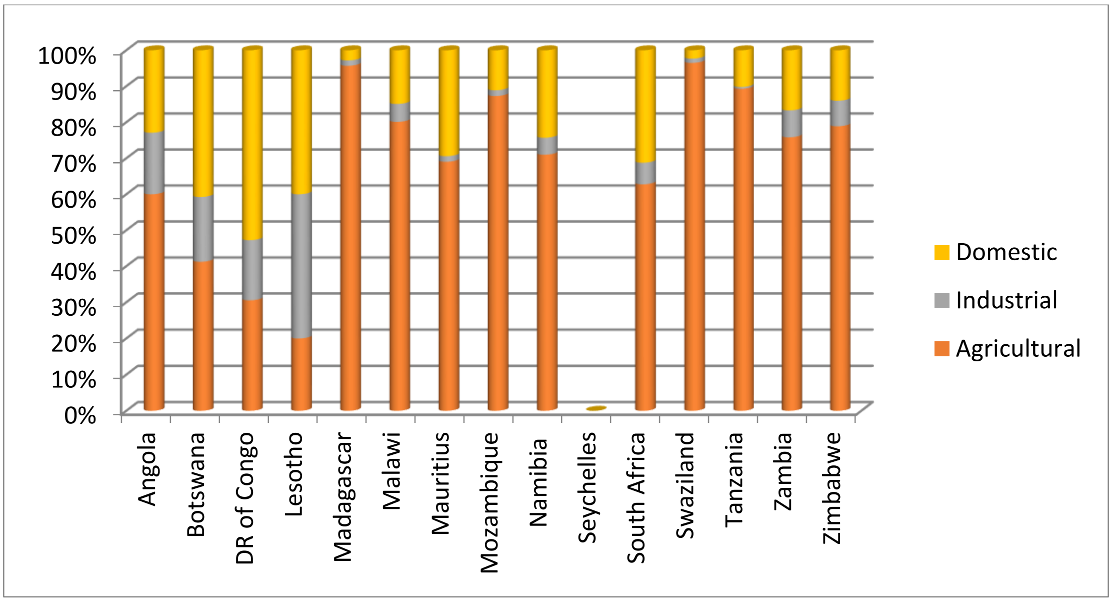


Figure 9: Share of water use in SADC countries

Source: FAO 2009b

With further industrialization and urbanization, *more* water resources will be developed. It is still unclear whether and how the relative proportions of the different uses will change. Proportions can stay the same if these new water developments seek to equally augment all water uses, thus simultaneously ensuring urban water supplies and year-round food security for the growing urban and rural population.

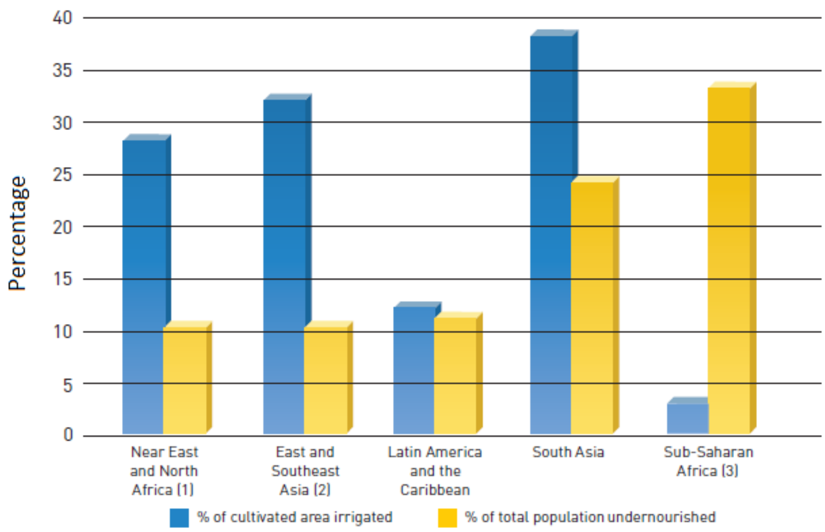
This is not always understood. Figure 9 is sometimes interpreted as an 'either/or' choice. The implicit assumption is that urban and industrial water development can only happen by taking water from agriculture, so curtailing existing water withdrawals for agriculture by emphasizing the need for the thirsty over-user to become more efficient. Such zero-sum game would be the case if all water resources had already been developed, and if there were no ways anymore to store more water resources during the rainy season (whether surface dams or groundwater recharge management) for use during the dry seasons. Then, 'physical water scarcity' would prevail. However, even in South Africa this upper limit of physical water scarcity and an inevitable zero-sum game has generally not been reached, even though South Africa has the highest proportion of water withdrawals in SADC at 25 percent. The point is that the *costs* of developing infrastructure, for example, sea water desalination or bringing water from the Zambezi River, are becoming higher because the most cost-effective sites for dams have already been taken. Water waste management and re-use and water curtailment, where possible, become more cost-effective.

In other SADC countries, water scarcity is 'economic water scarcity' in the sense that water resources are sufficient, if not abundant, but the financial, technical and institutional means to invest in infrastructure to develop water resources are lacking. Any assumption that water development can only happen when irrigation is curtailed and stopped is incorrect, and misses the opportunity to find solutions for the real problem.

3.4 Current and potential expansion of irrigated area

3.4.1 Share of irrigated area and nutritional status

We now focus on the most common indicator for irrigation investments: irrigated areas as proportion of total cultivated area, their current proportions and untapped potential for expansion. This combines available water and land resources, and other factors that affect investments. Generally, a higher share of irrigated land of total cultivated area represents a more productive agricultural sector therefore more food security at both household and national levels and, hence, overall better nutrition. This inverse relationship between proportion of land irrigated and under-nourishment is found in South Asia, East and South East Asia, and Near East and North Africa and, to a lesser extent, in Latin America. In Sub-Saharan Africa, this same relationship highlights how the very low levels of irrigation in Sub-Saharan Africa go together with the continent's highest share of under-nourished people (see Figure 10).



(1) excluding Israel; (2) excluding Japan; (3) excluding South Africa

Figure 10: Irrigation and under nourishment, 1998-2000

Source: FAO 2011

3.4.2 Current and potential irrigated area as share of arable and cultivated area

In estimating the current and potential irrigated area, it appears, first, that arable land resources are abundant and only very partially cultivated as yet. As shown in Table 4, out of SADC's total land area of about 1 billion ha, 266.8 million ha are arable land, but only 52.8 million ha are cultivated.

Table 4: Areas of different land use categories in SADC countries

Country	Total land area (1 000 ha)	Arable land (1 000 ha)	Cultivated area (1 000 ha)
Angola	124 670	32 000	3 300
Botswana	58 173	2 909	380
DRC	234 541	80 000	7 800
Lesotho	3 036	308	334
Madagascar	58 704	8 000	3 550
Malawi	9 428	3 600	2 440
Mauritius	204	78	106
Mozambique	79 938	36 000	4 435
Namibia	82 562	25 000	820
Seychelles	46	1	7
South Africa	122 081	18 320	15 712
Swaziland	1 736	175	190
Tanzania	88 580	40 000	5 100
Zambia	75 261	16 350	5 289
Zimbabwe	39 076	4 100	3 350
SADC	986 474	266 841	52 813

Source: FAO 2005; Aquastat database (FAO 2013)

Table 5 combines estimates of potentially irrigable land per country and actually irrigated area. Estimates of potentials have been set at 20.2 million ha at regional level (see first column). Various country or regional studies have assessed this value according to different methods; for example some consider only land resources suitable for irrigation; others consider land resources plus water availability; others include in their assessment economic aspects (such as distance and/or difference in elevation between the suitable land and the available water) or environmental aspects, etc. Whatever the case, it includes the area already under agricultural water management: http://www.fao.org/nr/water/aquastat/irrigationmap/glossary.pdf[1].

Of this total potential, 6.7 million ha is already equipped for irrigation (Table 5 second column). This leaves 13.4 million ha of high-potential area for new irrigation development (third column). Again, there are important differences between countries. South Africa has all potential used. In Madagascar, Mauritius and Swaziland, more than half of this potential has been used. In all other countries there is still a major unused potential. In addition, the last column of Table 5 shows that the region is estimated to have about 5.3 million ha of land under agricultural water management but not equipped (i.e. non-equipped areas under

[1] The values in AQUASTAT differ from other, formal estimates. For example, the draft Tanzanian National Irrigation Policy (GoT 2009) mentions 12.8 million ha as its irrigation potential, in contrast to 2, 1 million in Table 5. Similarly, the Green Belt Initiative in Malawi aims at 1 million ha of irrigation development. The figure in Table 5 is 162 000.

cultivated wetlands and inland valley bottoms as well as under flood recession cropping areas).

Table 5: Irrigation potential area and area under water management in SADC countries

Country	Irrigation potential (1 000 ha)	Irrigation potential equipped for irrigation (1 000 ha)	Potential area for new irrigation development (1 000 ha)	Area under non-equipped agricultural water management (1 000 ha)
Angola	3 700	85.5	3 614.5	0.4
Botswana	13	1.4	11.6	6.5
DRC	7 000	10.5	6 989.5	3.0
Lesotho	13	2,6	9.9	0.0
Madagascar	1 517	1 086.0	431.0	10.0
Malawi	162	73.5	88.4	0.0
Mauritius	33	21.2	11.8	0.0
Mozambique	3 072	104,4	2 967.6	13.7
Namibia	47	7.6	39.7	2.0
Seychelles	1	0.3	0.7	0.0
South Africa	1 500	1 500.0	0.0	170.0
Swaziland	93	49.9	43.4	4 935.1
Tanzania	2 132	184.2	1 947.8	0.3
Zambia	523	155.9	367.1	100.0
Zimbabwe	366	173.5	192.1	20.0
SADC	20 172	6 733.7	13 437.9	5 260.9

Source: Aquastat database (FAO 2013)

Table 6 further specifies the irrigated area. As shown in the first column, the proportions of areas equipped for irrigation of total cultivated land reflects Figure 1 in the Introduction: only some 7-8 percent of cultivated area is equipped for irrigation. Ten of the 15 SADC countries have less than the target of 7 percent of total cultivated area under irrigation, and five of them even less than 1 percent under irrigation.

However, not all this area equipped for irrigation is actually irrigated. The average utilization rate of the area equipped for irrigation for the region is about 73 percent; a figure which is below that of the world utilization rate (Svendsen, et al 2009). Often, part of the equipped area is not irrigated for various reasons such as lack of water, absence of farmers, land degradation, damage and organizational problems. According to the assessment of You et al (2009), more than 200 000 ha of small-scale irrigation schemes in Southern Africa require rehabilitation. The share of irrigation-equipped area in need of rehabilitation varies dramatically across countries, from almost zero in Botswana, Namibia, Zambia, Mauritius, Malawi and South Africa to almost 100 percent in Lesotho.

Table 6: Areas equipped for irrigation as proportions of cultivated area and use rates in SADC countries

Country	Percentage of cultivated areaequipped for irrigation (%)*	Percentage of areaequipped for irrigation actually irrigated (%) *	Irrigation area in need of rehabilitation (ha) **
Angola	2.3	29.0	45 000
Botswana	0.6	100.0	100
DRC	0.3	76.2	22 200
Lesotho	0.9	2.5	2 600
Madagascar	30.6	50.6	5 400
Malawi	2.4	96.0	29 500
Mauritius	22.8	98.0	
Mozambique	2.5	33.9	78 100
Namibia	0.9	100.0	1 400
Seychelles	8.7	76.9	
South Africa	13.4	95.9	
Swaziland	26.0	90.0	5 000
Tanzania	1.8		
Zambia	6.0	100.0	
Zimbabwe	4.6	71.4	50 000
SADC	8.2	72.9	239 300

*Source: *Aquastat database (FAO 2013); **You et al 2009*

3.4.3 Potential of groundwater irrigation

Altchenko and Villholth (2015) further detailed existing and potential irrigated areas specifically for groundwater resources (Table 7). They calculated groundwater irrigation potential based on annual groundwater recharge, and compared with current areas equipped for groundwater irrigation. Table 7 shows the scenario in which 30 percent of recharge remains unused as environmental requirements. In all cases, the potential for groundwater irrigation expansion is enormous. Even South Africa has not yet tapped into half its potential.

Table 7: Cultivated area and gross groundwater irrigation potential per SADC country

	Area equipped for irrigation with groundwater (103 ha) (Siebert et al 2010)	Area of cropland irrigable with groundwater(a) (103 ha), providing for 30 percent environmental reserve
Angola	16	7 032
Botswana	0.7	66
DRC	0	23 060
Lesotho	0.1	21
Madagascar	0	6 753
Malawi	0	640
Mozambique	0.6	2 171
Namibia	1.6	98
South Africa	127.3	270

	Area equipped for irrigation with groundwater (103 ha) (Siebert et al 2010)	Area of cropland irrigable with groundwater(a) (103 ha), providing for 30 percent environmental reserve
Swaziland	1	21
Tanzania	17.5	3 007
Zambia	6.7	3 952
Zimbabwe	20	370

Source: Adapted from Altchenko and Villholth 2015

In the foregoing we quantified water resources availability, withdrawals to buffer against climate variability (and future change) for agricultural uses and potential expansion of irrigation. These were all averages per country. They showed major differences between countries, which were related to physical variables, in particular climate, land sizes, and water resources, but also to differences in past investments in water development. However, averages per country ignore differences within countries. For poverty alleviation and broad-based agricultural growth, these differences are even more important, as discussed next (Castillo et al, 2007).

3.5 Water, poverty and inequalities

3.5.1 Access to safe water for domestic purposes

Access to safe water supply and sanitation is the most widely used indicator to measure the distribution of benefits from water supplies. Of SADC's population of 260 million people, 39 percent has no access to an adequate, safe drinking water supply, while 61 percent has no access to adequate sanitation services (SADC, 2011).

Table 8 shows the differences in access rates from 2000 to 2012 between countries, and between rural and urban areas. With the exception of Malawi and Swaziland, progress has generally been slow and some coverage rates even declined. This may be partially attributed to the fast growing populations to be served. In 2012, access to safe water in urban centres ranged from 68 percent in Angola to 100 percent in Mauritius. Access in the rural areas ranged from 26 to 90 percent. In about half of the SADC countries, access to safe water supply in the rural areas is less than 50 percent, and relatively higher in urban areas. The health and socio-economic implications are enormous in terms of mortality and sickness from waterborne diseases, children kept out of school, and women deprived of time for productive pursuits due to daily drudgery of fetching water and caring for sick family members.

Table 8: Access to improved drinking water, by country, 2000 to 2012

Country	% of urban population with improved water supply						% of rural population with improved water supply					
	2000	2002	2004	2005	2008	2012*	2000	2002	2004	2005	2008	2012*
Angola	34	70	75	54	60	68	40	40	40	39	38	34
Botswana	100	100	100	99	99	99	-	90	90	90	90	93

Country	% of urban population with improved water supply						% of rural population with improved water supply					
	2000	2002	2004	2005	2008	2012*	2000	2002	2004	2005	2008	2012*
DRC	89	83	82	82	80	79	26	29	29	28	28	29
Lesotho	98	88	92	96	97	93	88	74	76	79	81	77
Madagascar	85	75	77	71	71	78	31	34	35	27	29	35
Malawi	95	96	98	94	95	95	44	62	68	70	77	83
Mauritius	100	100	100	100	100	100	100	100	100	-	-	100
Mozambique	86	76	72	76	77	80	43	24	26	29	29	35
Namibia	100	98	98	99	99	98	67	72	81	82	88	87
Seychelles	-	100	100	94	100	-	-	75	75	-	-	-
South Africa	92	98	99	99	99	99	80	73	73	75	78	88
Swaziland	-	87	87	90	92	94	-	42	54	56	61	69
Tanzania	80	92	85	82	80	78	42	62	49	45	45	44
Zambia	88	90	90	87	87	85	48	36	40	42	46	49
Zimbabwe	100	100	98	99	99	97	77	74	72	72	72	69
SADC	88	90	90	88	89	89	57	59	61	56	59	64

- Data not available

*Source: http://www2.worldwater.org/data.html; * WHO/UNICEF (2014) estimates*

3.5.1 SADC's dual economy and inequalities in water for productive purposes

Undoubtedly the major inequalities in SADC are related to its dual economic structure. South Africa's role as SADC's economic hub is depicted in Figure 11, which shows the shares of member states in SADC's overall gross domestic product (GDP). South Africa's expansion in SADC and migration patterns to South Africa are closely related.

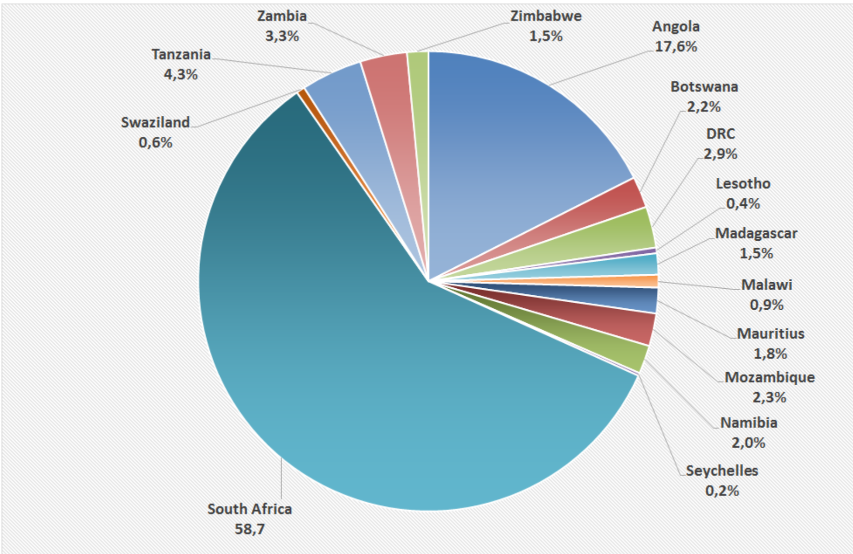


Figure 11: National share of GDP (%) for SADC member states, 2012
Source: SADC 2012

The benefits of this dual capital-intensive economy are highly unequal: unemployment rates are high. South Africa has the world's highest Gini coefficient for income: 0.66.

The current distribution of water in South Africa is even more unequal than the income distribution. For rural water uses, it was found that only 1.2 percent of the rural population uses almost all water resources, 95 percent (see blue line Figure 12). This equals a Gini coefficient of 0.93. The pink line in Figure 12 represents the distribution of the *benefits* of water use under the (most positive, but unrealistic) assumption that the benefits created by that water use for part of the rural households through employment created, were shared equally. The resulting Gini coefficient is higher (0.83) than for (national) income. The contributions to employment creation of the various sectors by volume unit of water differed, in order of most positive contribution: water supply services that support light urban industries and tertiary services; urban industry and power; mining; and, with the least contribution to jobs per drop: mechanized large-scale agriculture. Thus, the past investments in water development that have led South Africa's economy, have further *widened* inequities.

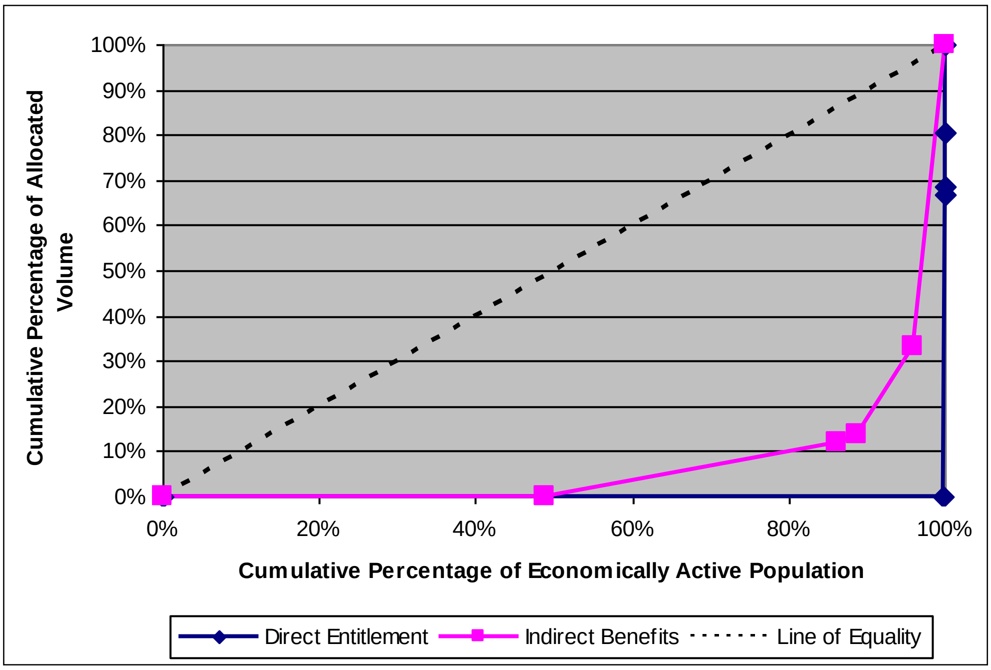


Figure 12: Distribution of the direct benefits through registered use and indirect benefits through employment of registered water use across the economically active population of South Africa
Source: Cullis and Van Koppen 2008

The lessons to be learnt are how investments in water and irrigation have contributed to certain patterns of growth, and what options exist for the future. As elaborated in the South Africa Country report, the colonial state created these inequalities by dispossessing Africans of most of their land and all of their water resources, and forbidding, for example, the use of wetlands and rivers. At the same time, vital state support was provided to white agriculture and irrigation, which forms the basis for today's large-scale mechanized agriculture. The country's current 'first world economy' is highly capital intensive and virtually 'job-less'.

Persistent structural unemployment, especially among the growing numbers of young people, is the result.

In these conditions of highly unequal distribution of water resources with limited new opportunities to newly develop water resources, the South African government has put distributive water reform on its policy agenda (GoSA, 2013). However, this is hardly implemented. South Africa's large-scale farmers have joined the foreign investors looking for large-scale deals in land and water resources in SADC, in particular Zambia and Mozambique, and elsewhere (see section 6).

The very partial usefulness of averages and the need to further differentiate between people for poverty alleviation analysis and policy, is also illustrated by the above-mentioned use rates of area equipped for irrigation. While the average for South Africa is that all area equipped for irrigation is also used, the actual situation on the ground is different for smallholder irrigation schemes. They only occupy 3 percent of South Africa's irrigated area, with large-scale farmers using the 97 percent. While 'disappearing' in this total size, their use rate is much lower. In 2010, van Averbeke et al (2011) reported that out of 302 small-scale irrigation schemes in South Africa, 206 were operational and 90 were not, and the operational status of six schemes could not be determined. Significant was that the likelihood of schemes to be operational was 83 percent for gravity-fed canal schemes, 70 percent for pumped surface irrigation schemes, 65 percent for overhead irrigation schemes and 56 percent for micro-irrigation schemes. This finding illustrates the role of the affordability of the irrigation technology, an issue we will further discuss below.

This shows the need to consistently differentiate between large-scale mechanized irrigation and smallholder irrigation, to realize the continued socio-economic regional nature of options and policy choices to be made, and possible adverse effects of mechanized large-scale agriculture on broad-based economic growth.

In the remainder of the report, a further analysis is made of the irrigation investments by governments, smallholders and agro-business that underpinned the above-mentioned water withdrawals for agriculture and that affect the patterns of growth. First, governments' investments are discussed, which is followed by smallholders' investments in self-supply and agri-business.

4. Trends in government investments in irrigation

4.1 Introduction: functions of government

Three domains of government policy formulation and implementation are distinguished. Governments are investors in irrigation infrastructure construction and sometimes in O&M,

and in agriculture in general, including its forward and backward linkages. They are also regulators of irrigation, for example of irrigation equipment supply chains, and agriculture in general. Lastly, they are the custodians of land and water resources in SADC's gradual reforms of customary land and water tenure, in which tribal authorities continue to play important roles. In all domains, governments play a role in setting tariffs and taxes and revenue collection procedures.

Based on the approach of Svendsen, et al (2009), Table p lists the presence, and envisaged presence or absence of key supporting institutions and instruments in each country: agricultural policy, water policy and legal reform, irrigation strategy, and irrigation action plan. The main institutions are: specialised agencies for basin-level management, dedicated irrigation infrastructure development entities, and water user associations (WUAs).

Table 9: Institutional framework indicators in SADC countries

Country	Agricul-tural policy	Water Policy and legal reform	Specialized agency for basin-level management	Dedicated irrigation infrastructure development entity	Empower-ment of water user associations	Irrigation strategy	Irrigation action plans
Angola	Ongoing process	Ongoing process	Not available	Not available	Not available	Ongoing process	Not available
Botswana	Available	Available	Not available	Not available	Not available	Not available	Not available
DRC	Ongoing process	Available	Not available	Not available	Not available	Not available	Not available
Lesotho	Available	Available	Available	Not available	Available	Not available	Not available
Madagascar	Available	Available	Available	Not available	Available	Available	Available
Malawi	Available	Available	Available	Not available	Available	Available	Not available
Mauritius	Available	Available	Not available	Available	Available	Not available	Not available
Mozambique	Available	Available	Available	Not available	Not available	Not available	Not available
Namibia	Available	Available	Available	Not available	Available	Not available	Not available
Seychelles	Available	Available	Not available	Available	Not available	Not available	Not available
South Africa	Available	Available	Available	Available	Available	Available	Available
Swaziland	Available	Available	Not available	Not available	Available	Not available	Not available
Tanzania	Available	Available	Available	Available	Available	Available	Not available
Zambia	Available	Available	Available	Not available	Not available	Available	Available
Zimbabwe	Available	Available	Available	Available	Available	Ongoing process	Not available

Key: Available Ongoing process = not available

Source: Adopted from Svendsen et al 2009

In addition, at regional SADC level, the legal framework of the SADC Revised Protocol on Shared Watercourses was adopted by member states in 2000 (SADC 2000). This has forged closer cooperation for judicious, sustainable and coordinated management, protection and utilisation of the 15 SADC shared watercourses and the advancement of the SADC agenda of regional integration, poverty eradication and economic development.

Six transboundary organizations are active:

- Commission Internationale du Bassin Congo-Oubangui-Sangha (CICOS)
- The Komati Basin Water Authority (KOBWA)
- The Permanent Joint technical Committee (PJTC) in the Kunene basin
- Limpopo Watercourse Commission (LIMCOM)
- The Orange-Senqu River Commission (ORASECOM)
- The Zambezi Watercourse Commission (ZAMCOM)

It is noteworthy that the Strategic Foresight Group (SFG), an international independent evaluation group, has assessed the water cooperation quotient in 184 countries and their 205 shared watercourses. SADC has been rated highest in the world with a score of 100 out of 100 (SADC, 2015).

4.2 Government investments in irrigation schemes in historical perspective

Government investments in irrigation, and their goals and performance in terms of poverty alleviation and broad-based agricultural growth, were part of broader political and economic developments. Lessons were learnt from failures, and also influenced governments' evolving roles *vis-à-vis* investments by smallholders for self-supply and agri-business. Therefore, an historical perspective is warranted. Across SADC, broadly three different eras can be distinguished: pre-1960s; 1960s-1980s; and after 1990. In each country, eras were further shaped by the liberation struggles in each country and the region between the 1960s and 1994.

4.2.1 Pre-1960s

Before the 1960s, the colonial settlers, supported by their colonial states, were the main investors in irrigated agriculture, often in large-scale estate mode and as companies (for example for sugar, tea, coffee, cotton, tobacco). In South Africa, white smallholders were settled in these schemes, but elsewhere land and water resources were appropriated, while Africans provided the labor. In some cases, as in Tanzania's coffee cooperative, smallholders provided the crops to the colonial traders. Other examples are cotton, rice or tobacco. In countries such as Zambia (Northern Rhodesia), settlers hardly invested in irrigated agriculture. At the same time, smallholders kept investing for self-supply. A few smallholders started providing the emerging urban consumer markets.

4.2.2 1960s-1990s

The new independent states (all countries except Zimbabwe and South Africa) adopted a three-pronged strategy. First, in many cases they nationalized the settlers' estates for operation either as government-run schemes or by re-settling smallholders. The Chokwè irrigation scheme in Mozambique is an example of this 'African socialism' where smallholders were settled. The Tanzanian state also transformed the successful smallholders' cooperatives into state authorities.

Second, the young states and their donors pro-actively invested in new smallholder schemes. Engineering and agronomy expertise was developed, among others in universities in Europe and USA. Initially, the investments took a similar top-down authoritarian approach in which the government not only constructed the schemes, but also ran the schemes. Crop choice, such as rice, was dictated. Farmers remained mainly laborers on their own fields, bearing the risks. Dependency was purposively *created*. Although at considerable costs, schemes did produce and contribute to broader economic goals of improving food security and bringing in immediate revenue (including foreign exchange).

Financially, though, both the old and new schemes appeared to drain state coffers. Under the Structural Adjustment programs of the 1980s, state support had to be withdrawn under what was sometimes called 'irrigation management transfer'. Smallholders bore the brunt. Most schemes started deteriorating and collapsing. Previous conflicts about land claims re-emerged in some settlement schemes.

By the end of the 1980s, with limited public resources and a softening of the unpopular dictatorial approach, a division of tasks emerged. Governments and other public sector agencies committed to lead and fund the infrastructure construction and installation, but O&M became, in theory, entirely the responsibilities of the 'beneficiaries'. In Malawi, this approach was called 'self-help'. In anticipating the future responsibilities of beneficiaries, planning became more participatory as well. However, especially in new re-settlement schemes, technology choice and land allocation remained government- or NGO-driven. The sophisticated expensive technologies continued requiring a highly disciplined internal organization and cultivation and guaranteed markets before irrigated cultivation could be profitable. Continuous public support to the irrigator groups was indispensable.

Third, some governments started investing in public-private partnerships (PPPs), both as shareholder and also as custodian of most land resources and all water resources. In that role, government enabled large-scale agri-business to appropriate land for cultivation. An example is the irrigated sugar estate of Nakambala, Zambia, of 1970, which gradually expanded to 30 000 ha.

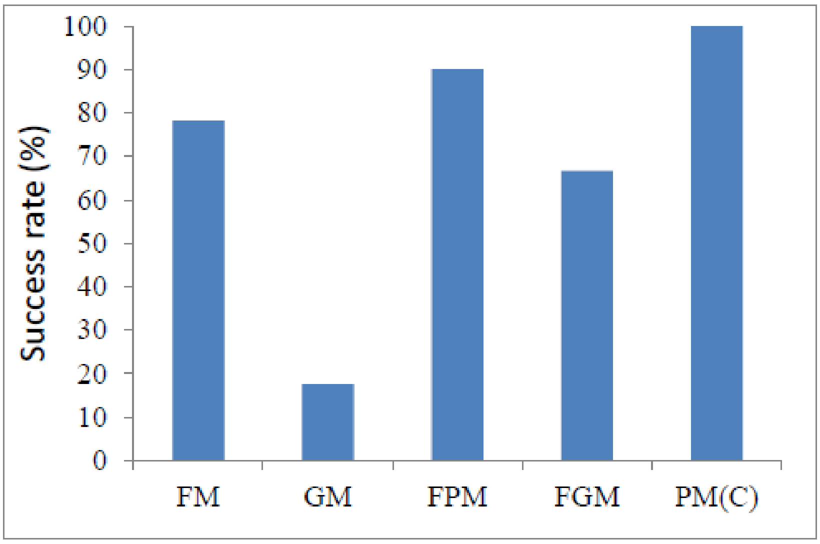
In this era 1960s-1980s, the colonial governments in Zimbabwe and South Africa also established new top-down government-run smallholder schemes in communal areas, dictating crop choice (for example wheat, maize, tobacco) and cultivation calendars on centrally managed irrigation schemes. Besides improving food security, these investments served political goals of patronage and control, as well as job creation for white managers. Investments targeted allied chiefs. In South Africa, moreover, communities that had been forcefully removed from white areas, were settled. These schemes were further expected to halt especially male migration to the white Republic of South Africa. In Zimbabwe, these schemes were to 'protect' villagers against liberation fighters. The first investments in irrigation schemes after Zimbabwe's independence in 1980 adopted the same authoritarian approach, and met the same resistance as elsewhere in SADC.

4.2.3 Post 1990

The period after 1990 is characterized by, first, emerging multi-party politics, now also in South Africa; second, by decentralization to local and district government; and, third by 'neoliberal development thinking with its emphasis on private sector initiatives, redefinition/reduction of the role of the state, and promotion of new decentralized, stakeholder-driven, and community-based management institutions' (Ferguson and Mulwafu, 2007). With even more limited resources, governments and development partners realized the dependency they had created through still costly, large-scale technologies in self-help schemes that required continued support by government to avoid the vicious cycle of breakdowns, lower yields, and less income to reinvest. The affordability of technologies received attention (GoM, 2012). Gradually smallholders' own informal investments in infrastructure, including non-equipped water management areas (WMAs), also started being recognized. This contributed to government's considerably stronger support to self-supply (see Section 5).

The failing state-run estates were put up for sale to foreign and national private agro-business companies, in some – and not always transparent – form of collaboration with nationals and government officials (as discussed in Section 6). Other schemes, including the smallholder irrigation schemes in South Africa that were mentioned in the previous section, continued sub-optimally or collapsed. The still top down and centralized approach to revitalize the collapsing schemes through joint ventures in the 2000s failed. In parallel, South Africa increasingly moved to the promotion of water harvesting around homesteads.

In the light of the above, it is not surprising that Mutiro and Lautze (2015) found that government-managed schemes were the lowest performers among the 100 schemes in SADC of different ages that they studied. As shown in Figure 13, only 18 percent of government schemes were successful. The next lowest performer is the farmer-government managed scheme. (Note that the sample of 100 was too small to identify statistically relevant relationships among the many factors influencing performance.)



FM = farmer managed
GM = government managed
FPM = farmer-private managed
FGM = farmer government managed
PM(C) = private managed commercial

Figure 13: Success rate of schemes differentiated by management form

In this study, depending on available data, 'performance' was measured in terms of internal rate of return, gross margin, net income, yield, and/or proportion of irrigable area factually irrigated (Mutiro and Lautze 2015).

The same is found in the success rate differentiated by financier (Figure 10). This also shows the higher success rates of schemes funded by development banks than those funded by donors and aid agencies. More in-depth research is needed to explain these differences.

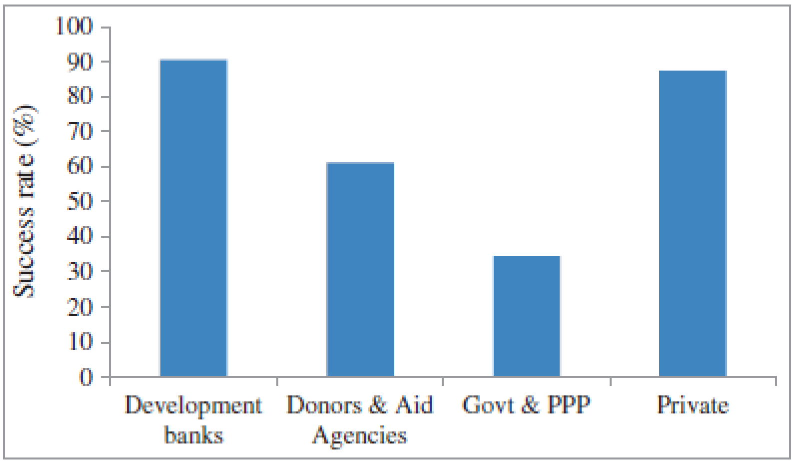
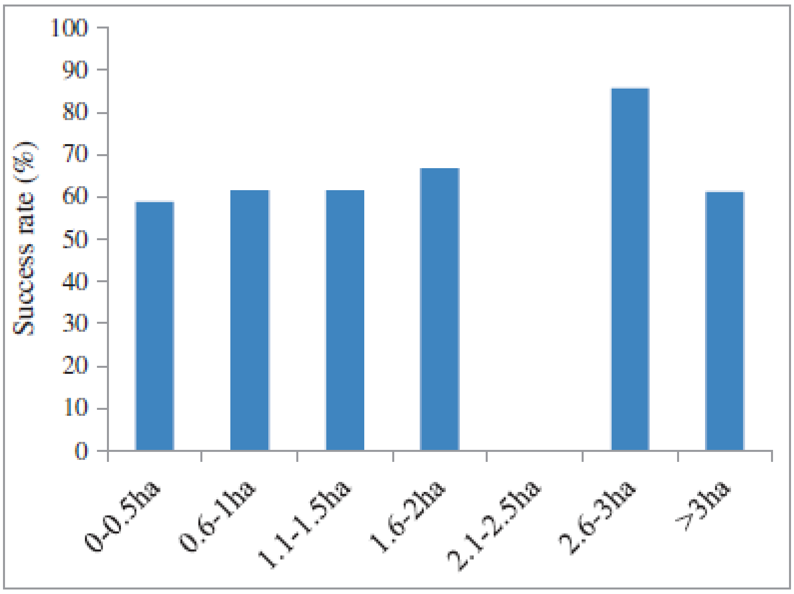


Figure 14: Success rates of irrigation schemes by type of financier
Source: Mutiro and Lautze 2015

A remarkably different finding of this study that is relevant for poverty-focused irrigation investments, is that no relation was found between the sizes of individual plots and success rates. In other words, irrigation on very small plots is as successful as irrigation of larger plots. As shown in Figure 15, only the plot size of 2.6 to 3 ha performed slightly better.



Note: the sample did not have 2.1-2.5 ha plots

Figure 15: Success rate of irrigation schemes by plot size
Source: Mutiro and Lautze 2015

What do these and other developments and lessons imply for future government investments in irrigation?

4.2.4 Government's future investments in irrigation: lessons learnt

Four sets of lessons can be identified with regard to government schemes, both those that need rehabilitation (which is often cheaper than new construction (Svendsen, 2009) and new investments by government. The latter can still be justified because of substantive economies of scale or because of social and long-term economic goals besides short-term financial profitability.

One common lesson is the need for affordable infrastructure and for a life cycle approach to infrastructure from the planning phase onwards (World Bank et al 2012). Infrastructure construction, maintenance, rehabilitation and operational costs should be affordable, and technical know-how and spare parts easily available. Mutual commitments about longer-term maintenance should be spelled out during the planning phase. Daily water service delivery cannot be expected for free from 'communities', but should be remunerated. The very limited electrification of rural SADC and high tariffs are major handicaps for the expansion of mechanized irrigation.

Certain designs can split the infrastructure costs. Government can only design and implement bulk water delivery, leaving the further water distribution for the respective uses to the villagers. Village reservoirs in Zambia are an example. Here, multiple users find their ways to derive multiple uses and benefits from these reservoirs, relying with some success on local sharing and conflict management arrangements.

A considerably more harmonized, sector-wide approach that government departments, NGOs and donors adhere to in mutual commitments for long-term rehabilitation and replacement would be a major improvement. Currently, each (short-term) project has its own approach. So farmers are right that there is always a chance that any external public agency might provide support at some stage. Even if chances are small, it is a disincentive for farmers to invest themselves. It both creates confusion and reinforces the dependency already created from the start by financing and designing the infrastructure. This state of paralysis may warrant tough decisions by government to entirely withdraw from some schemes. But it clarifies for other schemes where the impact of public support is likely to be highest.

Secondly, it is widely understood by now that both the hardware and software needs to be considered holistically and in a participatory manner. This includes the agronomy, forward and backward linkages, and credit facilities. Markets and crop choice are often the most critical 'pull factor' for successful irrigation but often overlooked in a supply-driven mode of irrigation promotion. Agri-business might fill gaps here. Production and sale in bulk in irrigation schemes are advantageous for both seller and buyer.

Related to that is the need for farmers' participation from the planning phase onwards to accommodate their priorities in the range of software and hardware needs. With the decentralization of democratic governments, local planning processes are gradually becoming more robust. Iterative planning processes by communities can respond most appropriately to locally specific problems and local solutions in the short and longer term. It is at this intermediate level that the various – often parallel – streams of support by different sectoral government departments, NGOs, and others are to be matched with bottom-up integrated needs.

Across Africa and Asia a new community-driven development approach is emerging: participatory employment generation or development programs that leave the prioritization and choice of individual projects in the hands of communities, either through implementing agents or local government, or a combination (World Bank, 2004; 2011). Within the broad menu of options, communities may well opt for water and irrigation projects according to their immediate local priorities. In the case of India's National Rural Employment Guarantee Scheme, two thirds of the assets created with the guaranteed labor were about water management and drought proofing. This rendered this employment guarantee scheme the largest rural water supply program in the world (Van Koppen, et al 2014a). The financial support and technical, engineering, agronomic and marketing expertise is made available as and when needed. Such a demand-driven approach renders investments more sustainable.

Thirdly, land tenure contributes to success when land titles and membership criteria are vested in the plot cultivators. When women are the main cultivators, plot titles and membership of the farmer group should be vested in women, or jointly with their husbands. In SADC, both women heads of households and married women are more than half of the cultivators. Yet, in formalization processes and leadership, men often dominate. Further, changes over time in farmer composition need to be accommodated. Rental markets can solve the problem that plot holders who stop cultivating still hold on to the plot. Customary land tenure seems to accommodate individual irrigators quite well.

Lastly, a strict focus on one single water use alone, irrigation (or domestic uses for that matter), has shown to miss opportunities to cost-effectively meet people's multiple domestic and productive water needs. In reality most, if not all, irrigation schemes are also used for other purposes, such as domestic uses, livestock watering or brick making. Similarly, domestic water supply systems are used for homestead gardening, livestock and water-related small-scale enterprises. These uses meet genuine needs. Water supplies to homesteads are especially relevant for the marginalized and landless, as the homesteads are often the only place where they can use water productively. These unplanned uses can cause damage mainly because they are not planned for. The answer is to plan for such uses. An approach with that goal is the 'multiple use water services' (MUS) approach (www.musgroup.net). For village reservoirs and larger-scale storage, enabling multiple uses has become the norm (Venot, et al 2012). For smaller-scale storage and conveyance up to household level the same principle holds: multi-purpose infrastructure is typically more cost-effective to meet multiple needs than (supposedly) single-use infrastructure. So, instead of a rigid focus on crop water uses only, projects to rehabilitate or construct new schemes can adopt the participatory MUS approach. The RSAP IV (SADC, 2015) also highlights how water management at local level is integrated as people meet their multiple water needs through multi-purpose infrastructure and by combining multiple water sources. The RSAP IV prioritizes local-level Integrated Water Resource Management project according to people's priorities. Similarly, South Africa's National Water Resource Strategy (GoSA, 2013) calls for participatory planning approaches that holistically meet communities' multiple water needs.

More research, exchange, and convergence around these and other lessons is needed, so that a more robust and harmonized approach crystallizes to rehabilitation or new construction of schemes sponsored by government and development partners from local to central levels.

4.3 Government as custodian of land and water resources

Governments are also the custodians of most land resources and all water resources, and managers of complex reforms from customary to 'modern' tenure. On the one hand, land tenure reform of customary land rights seeks to empower communities, including women, *vis-à-vis* tribal authorities. On the other hand, clauses in the land laws can declare customary land as public land, and, thus, facilitate buying of land by foreign and national investors (Van Eeden 2014). Especially in Zimbabwe and South Africa land reform is about redistribution of land to redress inequities from the past. Such land reform raises fundamental questions about agrarian reform and patterns of broad-based growth. In Malawi, options are explored to settle farmers on unused estate land (USAID, undated). Land reform has intensely been debated and even more under multi-party democracy.

In contrast to these land debates, the revision of water laws from the late 1990s onwards across SADC has largely gone unnoticed by the public. The law still largely exists on paper only; implementation has been piecemeal – and has unrealistic logistical implications. Moreover, the laws treat informal small-scale users unfairly, and reinforce colonial legacies instead of redressing them. The colonial settlers vested ownership of all the nation's water resources in their overseas rulers (on paper) (Van Koppen et al 2014). This dispossessed Africans with a stroke of the pen from all claims to their water resources, overriding local claims to water and its management. The settlers granted permits to water users declaring that only such water uses were formally lawful. Initially, Africans were excluded from that 'option'. Other regulatory measures were also promulgated. For example, rulers forbad Africans to use the riparian strips along surface streams. As these strips determine access to and control over the stream, the settlers controlled the stream at the same time.

At independence the new presidents shifted ownership from the overseas rulers to themselves (on paper). However, the option to apply for a permit now became an *obligation* for every water user. Only micro water users were exempted from this obligation. The definition of such exempted micro-users differed, but in countries like Tanzania, even treadle pump owners are obliged to apply for a permit. For a while these slightly revised colonial laws remained dormant. However, in the 1990s, nation-wide permit systems were revived. This not only consolidated the colonial cancellation of legal pluralism and local water law on paper, but was now also meant to be implemented (Van Koppen et al 2004).

South Africa had another legal system: the riparian doctrine. As land in former homelands was state land, the legal status of water in those homelands was state-controlled as well. In the post-independence National Water Act (1998), South Africa also shifted to permit systems, but only for the new uptake of water after 1998. Pre-1998 uses, with their immense inequalities, were recognized as 'Existing Lawful Uses', as negotiated by the powerful (white) vested water users (Van Koppen and Schreiner 2014).

Across SADC, the major change in the new laws was the transformation of permits (a legal entitlement) into a taxation measure by tying once-off and annual payment to permits. This revenue was to finance the new basin organizations for their water resource management tasks.

This implies for micro water users that their local water rights regimes are ignored. Being redefined as an exempted user implies that their legal status *vis-à-vis* permit holders is weaker (Hodgson, 2004). For small-scale users who are formally obliged to apply for a permit (and for the state), the logistical burdens are relatively higher than for large-scale users. Any collection of volume-based tax from thousands of small-scale users costs more money than it generates. The South African National Water Resource Strategy (2013) recognizes that the current formulation of permits are an administrative burden and a system that is unreachable for many South Africans. Other SADC governments have even less capacity to implement. So, across SADC, small-scale water users are obliged to apply for a permit while the bureaucracies to handle those applications is non-existant. This is through no fault of small-scale users. But it impacts negatively on them. On the other side are administration-proficient foreign and national investors. For them, the application for a permit is a relatively easy way to vest first-class entitlements in the resource. In some countries, these free entitlements obtained on a first come first serve basis, can be traded so become a monetary asset. Regulation through permits, which is the stated goal, is jeopardized. Except for tax collection, capacity (and power) is often lacking to monitor, let alone enforce, whether the large-scale users observe the conditions in the permits (such as caps to permitted volumes or amount of pollution). The relatively higher fees that large-scale users pay become a perverse incentive for the regulator to swiftly issue such permits.

Thus, in addition to being treated unfairly, small-scale users also bear the brunt of over-use and pollution by large-scale users. This contradicts governments' goals and efforts towards poverty alleviation and broad-based agricultural growth. A possible solution is to revise current interpretations of permit systems and (finally) recognize customary or local water law, and prioritize water uptake by micro- and small-scale water users, instead of punishing them. This could be with a stroke of the pen through Priority General Authorizations, as South Africa is implementing (Van Koppen and Schreiner 2014). Also, local governments could obtain stronger powers not only in local land issues, but also in water management, for example by vesting area-wide permits in local government. Such solutions are also important for the next category of investors: smallholders for self-supply. Similarly, in the negotiations with agri-business about the allocation of a permit, specific conditions for accessing the nation's water resources can be stipulated and enforced, instead of giving precious water resources away to anyone who can pay.

5. Trends in self-supply

5.1 Assessing self-supply

Investments in infrastructure for self-supply have existed since time immemorial; otherwise agrarian communities would not have survived the vagaries of climate. Self-supply is dynamic and innovative. Examples include the large network of canals for transportation, irrigation, fisheries, and drainage in the Barotse flood plain in Zambia since the 1880s, overseen by King Lewanika. In the Uluguru mountains in Tanzania, villagers copied the irrigation canals that German mining prospectors had started, expanding to a highly intensive production system. The so-called majaluba rain-fed rice system is widely used in the lowlands, where seasonal rainfall is 600-900 mm, and runoff naturally collects in the valley bottoms, making it ideal for paddy rice. It has spread widely since Indian migrants introduced it in the 1920s. Official data now shows that the majaluba systems contribute 35 percent of total rice production in Tanzania (Hatibu, 1999; cited in CAADP, 2009). Migration contributed to the spread of informal irrigation innovations as well. The first adopter of mechanized pump irrigation in Ndonga, a village along the Limpopo River in Mozambique, was a farm worker in South Africa, where he saw irrigation and saved money to invest. River diversions in the Mpika region in north-east Zambia were also started by a migrant from central Zambia.

Self-supply has spread widely. Annex 1: Smallholder agricultural water management technologies in SADC provides details of the most common technologies. In Zambia, developed (equipped) lowlands and wetland cultivation is estimated to cover 100 525 ha, while the total irrigated area in Zambia is 50 000 ha (37 000 ha out of the 50 000 ha is large-scale irrigation) (GoZ 2004).

A survey was conducted of 1 935 households in four areas across Zambia that were known to have high agwater management adoption rates. Of these, 1 230 (64 percent) had adopted an agwater management technology (adopters), while 581 households (30 percent) had not (non-adopters). Six percent of the sample (124 households) had once adopted a technology but had abandoned it (dis-adopters) (Colenbrander et al, 2012).

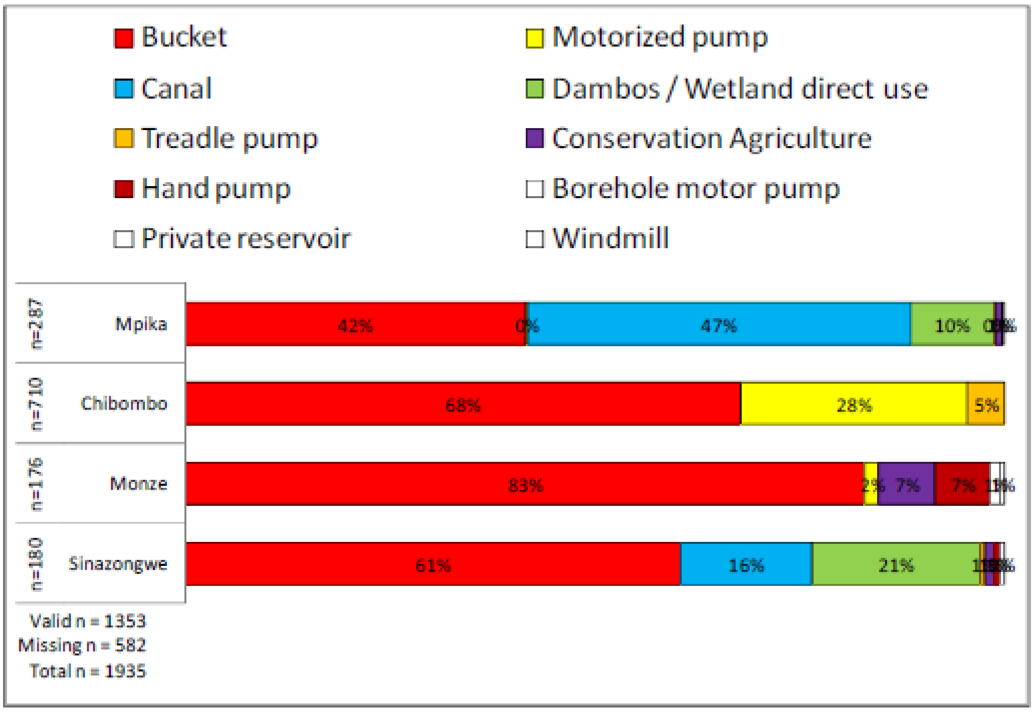


Figure 16: Technologies of adopters in four regions in Zambia

Source: Colenbrander et al 2012

Figure 16 shows the technologies adopted. Between 42 and 83 percent of the adopters use buckets. In Mpika, canals (informal river diversions) were slightly more frequent. In Sinazongwe, on the shores of the Lake Kariba, the 'canals' refer to a government-supported pump irrigation scheme constructed for the displaced communities. Only 16 percent of the population benefitted from this. In Chibombo, which is just north of Lusaka with its major demands for vegetables, rental markets of motor pumps were found. Water resource assessments in this aquifer of the Mwembeshi watershed found that water resources were still abundant (Colenbrander et al, 2012).

Similar proportions were found in Tanzania. Here, a survey of 335 farmers found that watering with buckets and watering cans is the most common (88 percent) irrigation technology, followed by motor pumps (10 percent) and treadle pumps (2 percent). All smallholder farmers indicated their preference for motorized pumping, but were held back by the high upfront costs and lack of finance at the beginning of the season (Keraita, 2010). In addition, the Tanzanian government has always recognized traditional (mountainous) smallholder irrigation as the most important contributor to total irrigated area: 80 percent (GoT, 2009).

Obviously, the major strengths of self-supply is that all these investments in irrigation are self-financed, at no cost to the tax payer. Further, these initiatives echo the findings by Mutiro and Lautze (2015) for collective irrigation schemes, in which the cultivators of the smallest plots appeared to be as successful in irrigation as those with larger plots.

5.2 Recent drivers of self-supply

At least four recent trends have accelerated investments in self-supply in SADC: growing population pressure, new market developments, availability of technologies, and state support. We briefly discuss these factors.

In well-watered but densely populated mountainous areas, peri-urban areas, former black communal areas as in Zimbabwe and South Africa, or entire countries, as Malawi, population growth is an increasingly important push factor for intensification, even though cultivated land areas expand as well. Overall, land holdings tend to decline. For example, in Malawi, 55 percent of the population has less than 0.5 ha, and landlessness and near-landlessness is on the increase. For increasing numbers of people, the homestead will remain the only site for productive (and domestic) water uses. Intensification through irrigation will become an increasingly important survival strategy.

Across SADC the growing markets, especially for vegetables, became the strong 'pull' for smallholder investments in high-value irrigated horticulture. Improved roads, public transport and taxis to take produce to selling points, mobile phoning with traders, and improved market facilities, such as the Soweto market in Lusaka, supported both farmers and traders. The onion production in Zambia has reversed the trade of onions from South Africa to trade of onions to South Africa.

The availability of appropriate and affordable irrigation technologies on shop shelves and affordable energy will increasingly determine whether more smallholders will start irrigating and whether plot sizes can significantly expand and replace current buckets and watering cans. An analysis of the market-led supply chain for motor pumps in Zambia showed a wide variation in types and prices of (increasingly Japanese and Chinese) pumps; concentration of sales points in main cities because the demand in thinly populated remote areas was too low to justify further outreach; limited after-sale services; and lack of clarity on import duties (even though government had removed such import duties in 2009). The relatively high costs of treadle pumps compared to mechanized pumps implied strong competition (Colenbrander and Van Koppen 2012).

One of the few weaknesses of investments for self-supply is that gender gaps tend to widen. Especially for mechanized pumps, it was found that men and boys operated those relatively more often than women, compared to the ways in which other activities were usually quite equally shared between women and men (Colenbrander, et al 2012). Men were found to take more initiative in the construction of new irrigation canals, even in SADC's widespread matrilineal societies. The latter prevails in most of the southern half of Malawi, half of Zambia (mainly in north east), and in the broad coastal belt of Tanzania (south of Tanga). However, there are no taboos around women owning and operating technologies. Therefore, equal access to new technologies can successfully be encouraged. More research is needed on why (even in matrilineal societies) men seem to dominate in taking the initiative to construct new canals.

The fourth driver of the expansion of self-supply is that governments have started recognizing and supporting self-supply. This has been a significant change in irrigation policy since independence, and is reflected in government's trend figures.

In Zambia, for example, the irrigated area expanded rapidly after 1998. However, one of the reasons was that, from 1998 onwards, informal irrigation was included for the first time in the figures.

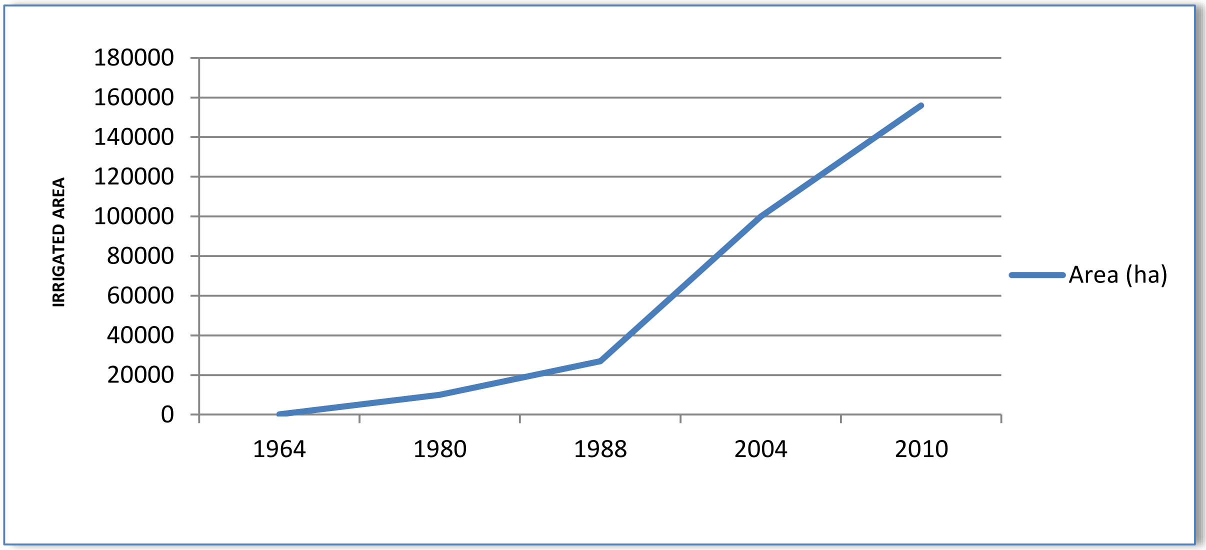


Figure 17: Increase in irrigated land (ha) in Zambia
Source: AfDB 2010

In Malawi, irrigated area by smallholders rapidly expanded since 2005/6 (see Figure 18). (The size of irrigated estate land remained the same at around 50 000 ha). This increase in small-scale irrigation from 15 988 in 2005/6 to 42 986 ha in 2010/11, is mainly because of the expansion of the technologies that are also typical for self-supply. The government and donors pro-actively supported this.

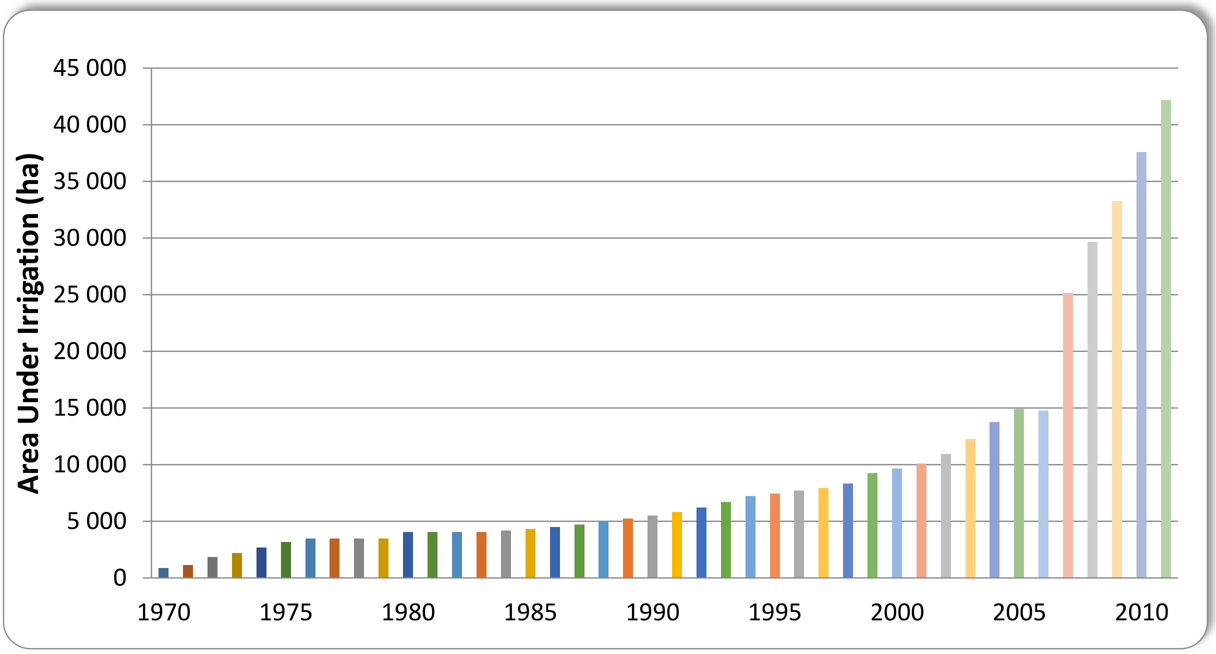


Figure 18: Trends in smallholder irrigated area in Malawi
Source:GoM 2012

Data differentiated by technology in Figure 19 shows that gravity fed irrigation, which is usually communal, contributed most to this the expansion of irrigated area. Treadle pump adoption was strongly promoted through subsidized dissemination of treadle pumps, but this trend halted after 2007. One of the reasons seemed to have been that government withdrew its support because of fierce critique by environmentalists, invoking the colonial law that riparian borders should be left untouched over 20 m.

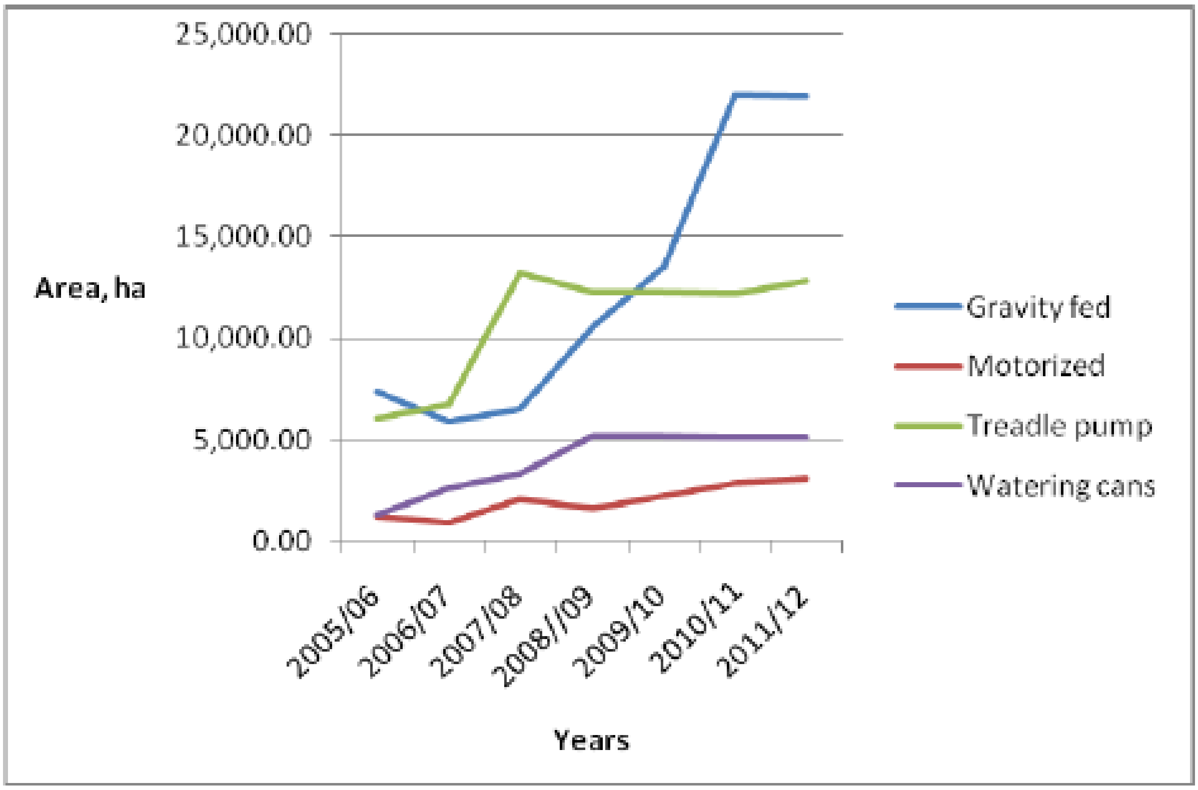


Figure 19: Trends in areas irrigated by type of technology between 2005/6 and 2011/12
Source: GoM 2012

This shift to supporting self-supply was also endorsed by other governments and by donors and financiers such as the Japan International Development Agency (JICA) and the International Fund for Agricultural Development (IFAD). Support to self-supply recognized and improved what already existed, instead of starting a completely new investment. For example, JICA provided technical and material support to reinforce weir and division structures in existing gravity streams, while ensuring that part of the flow continued for downstream users. Or canals and pipes were strengthened to bridge difficult terrain.

Another form of support provided was by innovating appropriate technologies and establishing sustainable market-led supply chains. This widened the technology options for buyers. In addition to the already mentioned treadle pump, NGOs also promoted the cheaper rope-and-washer pumps, groundwater recharge technologies, drink water filtration, manual drilling, etc.

In the design, spread and uptake of new technologies, governments play an important role as regulator. An analysis of obstacles in the supply chains for motorized pumps in Zambia found that the structure of the supply chain and financing facilities in urban hubs was highly centralized. Information was concentrated among a few people only. Many dealers, especially the smaller ones, were not aware of the government's import duty waiver of 2003 on irrigation equipment and pumps. Individual smallholders incurred high travel costs to purchase pumps and spare parts from urban centres. They lacked information about prices, which is especially relevant because of the extraordinary variation in prices of the same products. They were not informed and trained on the proper use and maintenance of the pumps; and lacked after-sales services. They also lacked financing facilities to purchase pumps. The conclusion was that farmers' organizations, such as the Zambia National Farmers Union (ZNFU), can play an important role in the motor pump supply chain by providing information to smallholders on importation procedures, pump types, prices and credit facilities. They can also help to improve smallholders' access to pumps through the negotiation of favourable terms for the supply of pumps, spare parts and after-sales services (Colenbrander and Van Koppen, 2012).

One of the weaknesses identified for self-supply is that the poorest and most marginalized, including HIV/AIDS victims and other sick and disabled people, and the elderly, are often unable to invest in self-supply. The above-mentioned MUS approach, which also builds on and improves existing practices, can mitigate this by water service delivery for multiple uses to homesteads. By teaming up with the Water, Sanitation and Hygiene sector, more water, for example 50-100 litres per capita per day, can be provided. Only 5 litres per capita per day needs to be safe for drinking and cooking. This would meet both social and production goals in a cost-effective manner (Renwick, 2007).

Another weakness of individual self-supply is related to a typical government perspective: governments prefer investing in groups rather than individuals, as this allows reaching more people and avoids the problem of advantaging only one person out of many. Obviously, the scale of beneficiaries reached and legitimate eligibility and targeting criteria are important. However, there are many options to achieve this, including a stronger requirement for an own contribution by those who can pay. A rigid application of this norm only would hold smallholders hostage to collective work. Instead, new forms of public support need to be developed in which demand-driven support aligns with the decentralization of government and community-based natural resource management.

In sum, self-supply can be boosted by developing the technologies, but also the forward and backward linkages (inputs, markets, extension support, credit, etc.). Undue regulation should be removed, such as the requirement for treadle pump owners to get a permit from a distant basin institution.

Ultimately, public support to smallholder irrigation and to self-supply may merge. Governments and smallholders would become co-investors according to their respective strengths and weaknesses but, above all, according to smallholders' priority needs in their incremental steps to improve wellbeing and contribute to broad-based agricultural growth.

The next question is how agri-business can play a role in these partnerships.

6. Trends in agri-business

An important distinction is between, on the one hand, agri-business in which smallholders continue cultivating their (customary) land and liaise as outgrowers or contract farmers with agri-business for inputs, extension, and marketing (which can be at any scale) and, on the other hand, agri-business estates or plantations, in which communities have to give up their land and water resources for control by agri-business (dubbed as 'land and water grabs'). Some community members can benefit as wage workers or newly established outgrowers. Some crops, such as sugar or tobacco, are grown in either mode. For cotton and other crops outgrower arrangements prevail.

6.1 Outgrowers

Outgrower arrangements are usually a voluntary (and therefore less contested) win-win arrangement for both parties. The production risks remain with the smallholders but they have a guaranteed market. The agri-business partner risks that smallholders, in whom they have heavily invested, sell their produce elsewhere for better prices. The price to be paid to farmers is subject to continuous negotiation (Bangwe and Van Koppen, 2012).

In the case of irrigated sugar production, outgrowers can be linked to adjacent centralized irrigation infrastructure. This is the case, for example, for the outgrowers in the Inkomati Basin in South Africa, who are linked to the large-scale water supplies of TSB's sugar estates. This also occurs with the Kaleya Smallholder Company (KASCOL) in Zambia, which is linked to Illovo's Nakambala sugar estate.

Some earlier government smallholder schemes were also outgrower systems, for which agri-business, or agri-business and government provided inputs, irrigated, and bought in bulk. The ongoing revitalization of underperforming irrigation schemes might benefit from new partnerships with agri-business around solid 'contracts'. Farmers' robust organization could level the playing field.

In other situations, agri-business and government can promote outgrowers' irrigation and agricultural water management for self-supply. In this way, the successful cotton giant Dunavent in Zambia was one of the promotors of conservation agriculture and irrigation of its outgrowers (Bangwe and Van Koppen, 2012).

However, hardly any comparative research has been done into such options.

6.2 Land and water grabs

Estate irrigation requires transfer of land and water titles. This is increasingly contested by an increasingly vocal citizenry who faces rapid population growth and more land pressure. Land transfers remained less contested when state land was privatized. The purchase of ailing nationalized and re-privatized colonial estates was generally accepted, if only by lack of an alternative. Illovo bought quite a few sugar estates in this way, including the Kilombero scheme in Tanzania. This is run well and seems it will further expand without major protest.

However, during the privatization of Mbarali state rice farm in Tanzania, old land claims of surrounding communities resurfaced, which the elite captured (Greco, 2015). Also, opportunities were missed to sell the land to the farm workers who wanted to become shareholders, as in the Mtibwa sugar estate (Van Eeden, 2014).

The multi-national sugar industry has especially rapidly expanded in SADC during the past two decades, both through the purchase of state farms and expansion. Sugar is a 'flex' crop that can also be used for biofuel. Illovo, Africa's largest sugar company, is active in six SADC countries (South Africa, Malawi, Mozambique, Swaziland, Tanzania and Zambia). Tongaat Hulett has some 40 000 employees working in six countries, South Africa, Botswana, Namibia, Swaziland, Mozambique and Zimbabwe. There are Brazilian, French, Japanese and Indian investors in sugar. However, as highlighted by the Southern Africa sugar research framework, this expansion was controversial. It was shaped by the favourable sugar export arrangements for low-income countries and by preferential treatment by national governments, such as low to zero levels of corporate tax. The transfer of large areas of both public and community land and elite capture of land by state officials and customary leaders, were in essence an unfolding land grab.[2]

This is part of global developments. However, 11 African countries have become the hotspot for large-scale land deals. Figure 20 lists the 20 countries in the world with most cases of land deals, based on the Land Matrix established in 2009. This includes four of the 15 SADC member states at the receiving end: Mozambique, Tanzania, Madagascar and Zambia. At the investors' end, out of the 22 top investing countries, South Africa ranks number 8. The detailed analysis of the Land Matrix also shows that only 8 percent of the land acquired is currently under production (Anseeuw, 2015).

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[2] (http://www.future-agricultures.org/research/land/7923-southern-africa-sugar-research-network).

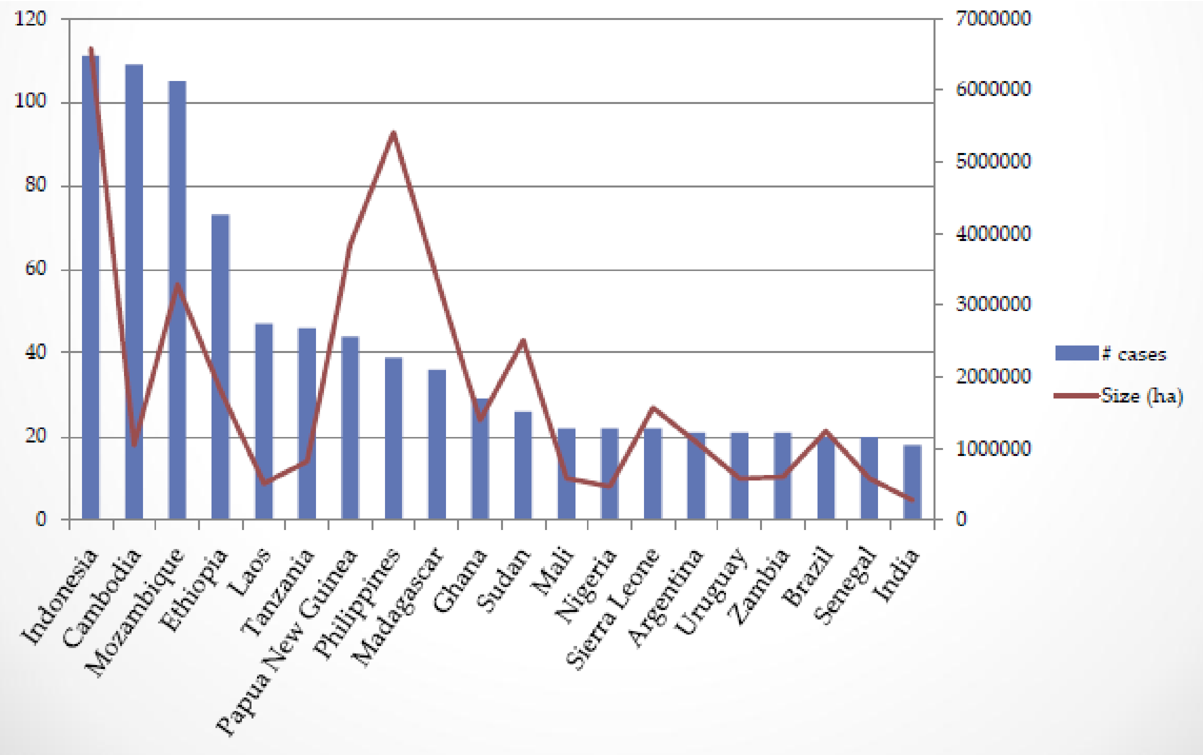

Figure 20: Twenty top countries with large-scale land deals based on Land Matrix
Source: Anseeuw 2015

The deals come in different forms. In 2010, the Southern Agricultural Growth Corridor of Tanzania (SACGOT) was established. This USA-led multi-stakeholder platform of corporate sector, donors, and government seeks to invest in sugar, rice, maize, and cassave production at massive scales, on the fertile and well-watered land of the Rufiji basin (and parts of the Wami/Ruvu and Lake Rukwa basins). USA-based universities are leading the Integrated Water Resource Management plan for the basin. Criticism of the envisaged wage labor relations is that it will render Africans 'slaves on their ancestors land'.

In contrast to the usual (and at least partially international) nature of large-scale land deals, Malawi's Green Belt Initiative of 2009 is the government's own brainchild. In this Initiative, the government offers local and international investors land lying within 20 km of the country's three lakes and 13 perennial rivers, an area amounting to about 1 million ha, for irrigated agriculture. The Initiative does not target the idle land owned by the political and bureaucratic elite; instead it targets land held by smallholder farmers, which in the continuing absence of a definitive legislative framework, is defined as state land (Chinsinga and Chasukwa, 2012). The land policy's potential strengths for local communities have not been operationalized into legal frameworks, let alone applied.

Various best practice procedural approaches for land transfers have been compiled and are formally and widely accepted, such as the principles of prior, voluntary and informed consent in the Voluntary Guidelines on the Responsible Governance of Land Tenure (2012). The key concepts of inclusiveness, consultation, transparency, accountability, respect for existing land and water rights, avoidance and mitigation of negative social, economic and environmental impacts, fair compensation and effective appeal mechanisms, have always been emphasized. However, they have hardly ever been applied (Williams, 2015). Instead, investment contracts between government and foreign companies may render the latter so powerful that they can hold governments accountable in the courts (Cotula, 2011).

In these land claim procedures, water is hardly considered; yet, investors seek land and water. In only about 30 percent of the cases does water explicitly figure in the deals, and only when production has actually started (Anseeuw, 2015). Williams (2015) also found that an investor in Ghana had started with iatrofa, which does not need much water. However, over-time it changed to full irrigation of highly water demanding crops. Van Eeden (2014) describes how sugar estates in Tanzania divert water to their sugar fields, directly depriving downstream users. Their permits and permit conditions are very generous. Eco-Energy, a new large sugar investment in the coastal region of Tanzania, received government assistance to obtain a permit.

Without storage development and setting and enforcing conditions in the permits, large-scale uses inevitably compete with many small-scale neighbours.

6.3 Alternatives?

In order to avoid seriously contested wholesale land and water grabs, one solution that the Irrigation Development and Support Project, supported by the World Bank has started to implement is the three tier PPP (Figure 21).

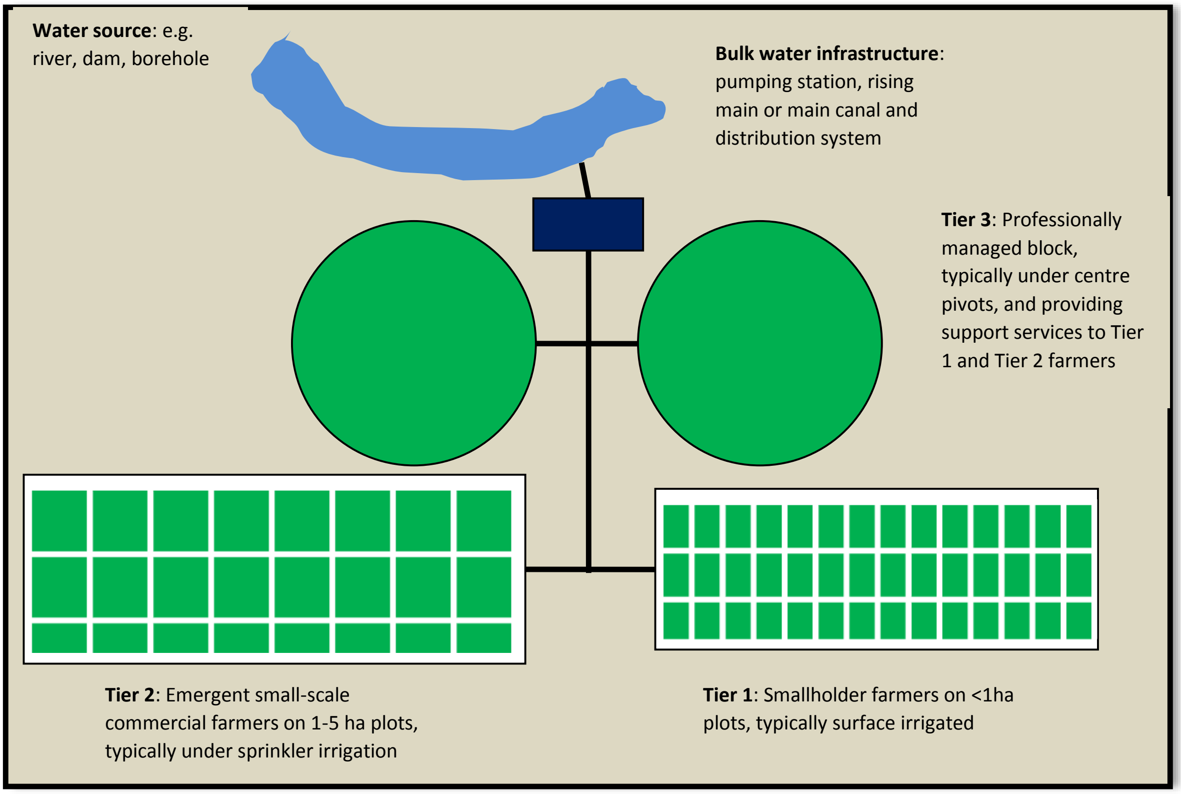

Figure 21: Three tier concept

Tier 1 farmers are agri-business professionals, who are responsible for the water abstraction and the distribution of water to their own fields upstream (equipped with large-scale equipment such as center pivots), and then to the tier 2 irrigators (emerging farmers on plots between 1 and 5 ha, with sprinklers), and the tier 3 irrigators (with less than 1 ha and practicing flood irrigation). Early experiences with this approach have shown that local community buy-in is essential. Establishing land tenure and formalizing land titles takes time. And lastly, transferring risk to private investors requires a commercial farming opportunity of an appropriate scale (CEPA, 2015).

Shared water storage and provision of water for both domestic and productive uses are other ways for investors to share benefits and compensate residents for the loss of their resources. These and other community-driven solutions should also be at the heart of governments' negotiations about water permits, in which the close linkages between land and water should be recognized.

In sum, while outgrower arrangements have strengths that could be further utilized, large-scale land deals still contain many unsolved weaknesses for poverty alleviation and broad based agricultural growth. More exchange and research are needed to compare outgrowers models with estate models. Further, for land tenure issues in estate models, evidence-based best procedural practices need to be identified as well as land and irrigation designs that can counteract communities' general discontent about displacements. This analysis should specifically include the poorest who are the main victims of land deals and elite capture. Moreover, the costs, jobs created and other benefits of agri-business involvement should be systematically compared with the alternative spending of public resources: directly investing in smallholders' land and its higher productivity through participatory government irrigation schemes or support to self-supply, also in the longer-term perspective of the majority's agriculture, are engines of economic growth.

7. Conclusions and recommendations

7.1 Hydrological hazards

What are the precise hydrological hazards of climate variability and change, and what is the meaning of 'water scarcity' for agriculture in SADC?

Water resources in most SADC countries are abundant; there is no water stress in terms of annually renewable freshwater sources available per capita. Only Seychelles, South Africa, Malawi and Lesotho are bordering such per capita water stress. In these four countries and anywhere else in SADC, the key problem is the high variability and unpredictability of rainfall, which affects rainfed agriculture more than any other sector. Predictions are that this variability will increase because SADC is a global hotspot of climate change. The region will warm up faster and become drier than elsewhere, with more extreme events of droughts and floods, while the sea levels will also rise faster. This renders 'no regret' infrastructure development to cushion against climate variability and change even more urgent, not only in the four almost water stressed countries, but also elsewhere.

In response to the vagaries of climate, South Africa has already developed its water resources with major infrastructure development over the past century. This has underpinned its current status as SADC's economic hub. It is the only country in SADC that has developed its limited water resources to such an extent that it is now approaching 'physical water scarcity' in the sense that the costs of further water development become prohibitively high. Anywhere else, economic water scarcity prevails: water resources are available, if not abundant, but the means to develop water resources are lacking. The foreign rush for SADC's land and water resources confirms this availability.

South Africa also shows that averages have limited meaning if the ultimate goals of water development are poverty alleviation and broad based economic growth. With an extremely skewed distribution of water, benefits of water development benefit a minority only. High unemployment rates have become structural in a dual economy that relies on capital-intensive, high-skilled large-scale agriculture, mining, industries, and tertiary sectors. In other countries, the agrarian question as to which economic growth path to follow is still open and affects the large majority of citizens.

The often cited figure that 'agriculture uses 60-70 percent of water' refers to 60-70 percent of *water withdrawals* of water that *has been developed*. It conveys an achievement: at least some water has been developed for the sector that provides a living for the country's majority. There is no competition for supposedly scarce water resources whatsoever when water storage and conveyance will be further developed to supply urbanizing and industrializing areas: water resources are abundant, but underdeveloped. Withdrawals for irrigated agriculture still only cover just 1-2 percent of the total cultivated area in most SADC countries. Only South Africa, Swaziland and the islands of Madagascar and Mauritius have reached the CAADP threshold for irrigated area of 7 percent of cultivated land. However, this irrigated area is mainly taken up by a minority of large-scale farms and estates, and not smallholders. Hence, the question is: how can the hydrological potential for agwater management be unleashed for SADC's people? The analysis of past investments provides some answers.

7.2 Lessons from past and current investments

<u>What lessons can be learnt from past and current investments in agwater management, in particular from their strengths and weaknesses in sustainably contributing to poverty alleviation, food security and agricultural and economic growth?</u>

<u>How can governments, NGOs and donors build on these strengths and overcome the weaknesses?</u>

7.2.1 Irrigation scheme investments by government, donors and NGOs

The independent SADC member states inherited a colonial authoritarian mode of government-financed and often government-run smallholder irrigation schemes. Nationalization of existing schemes or construction of new schemes in this mode did not bring desired results. With the Structural Adjustment Programs of the 1980s, government support was reduced or withdrawn. The revitalization of these schemes was complex. Governments may need to take some hard decisions for some schemes on whether to continue support at all. Hand-over to or collaboration with agri-business, especially in outgrower arrangements, has worked in some cases. Insights into best practice in this regard are still rare.

Learning from these failures, and still constrained by limited public resources in the neo-liberal era since the 1990s, governments, donors and NGOs adopted considerably more participatory approaches. Public support concentrated on the infrastructure investments and left the O&M and rehabilitation and all internal organization, cultivation and marketing, in principle, to the smallholders. In a number of cases, such as village reservoirs, this worked to some extent. However, external support in other domains often appeared indispensable. Especially the rehabilitation and replacement of expensive infrastructure appeared difficult to manage by smallholders alone. Also, production was often higher than markets for smallholders could absorb. Land rental arrangements emerged to deal at least partially with changing composition of irrigators over time.

Similar questions as the above remain: can outgrower arrangements with agri-business play a stronger role in input provision and marketing, taking advantage of bulk production? These questions apply to all past and future cases in which government investments can achieve economies of scale that are impossible to achieve by either isolated smallholders or agri-business on their own. In any case, public support would considerably improve if there was greater harmonization between intervention approaches. Currently, a wide range of government departments, donors, and NGOs each have their own approaches, often working in parallel. A more harmonized approach would especially clarify the long-term commitments by both communities and service providers upfront, and avoid unrealistic and unfruitful expectations from both sides.

Learning from more participatory approaches, government and donor emphasis gradually shifted to more affordable technologies. Support was provided to the manufacturing and setting up of market-led supply chains for treadle pumps or rope-and-washer pumps. Import duties for mechanized pumps were waived. These technologies appeared to overlap with what smallholders had adopted through own investments for self-supply. In line with participatory approaches that start with what communities have been doing since time immemorial, service delivery has also increasingly been decentralized to local government level. This allowed better response to community priorities within a longer-term perspective.

In addition to being a key investor in infrastructure, governments also took up their unique authorities as custodians of land and water resources, with the daunting task to reform land and water tenure inherited from colonial pasts. Land tenure has been widely debated. Voices became increasingly stronger, and more best-practice examples of community empowerment, also for women's land rights, has emerged. On the other hand, though, customary land rights remain weak *vis-à-vis* the power of the state and national and foreign investors to 'grab' customary land.

In contrast to land, this research found that the colonial legacy of water law has hardly been unravelled or publicly debated. Instead, colonial permit systems have been revived, and are now meant to be enforced, although there is no government logistical capacity (even in South Africa) to issue permits to hundreds of thousands of smallholders. While customary land tenure is entirely accepted as reality and starting point of reform, customary or local water tenure has remained cancelled ever since the colonial settlers vested ownership of the country's entire water resources in their overseas rulers, and claimed that only permit holders had lawful access to those resources. Initially, only settlers could obtain permits. At independence, ownership shifted to the new states with a stroke of the pen. However, the new states changed the right to a permit for the minority settlers into an obligation to apply for a permit for all citizens, with hardly any exemptions. This reinforced the dispossession of customary and local water law; relegated exempted users to second-class legal status; and obliged small-scale users to apply for a permit without sufficient state capacity to deal with the applications. On the other hand, the relative ease with which foreign and national large-scale investors obtain permits as first-class entitlements continues the 'water grab'. Solutions are emerging, including the possibility for the state to better negotiate the sharing of benefits of large-scale investments in water infrastructure.

7.2.2 Investments by individuals or groups for self-supply

As mentioned, it is increasingly recognized that most smallholder irrigated areas across SADC have been developed thanks to smallholder investments in self-supply. (Yet, the term 'private sector' is still mainly reserved for agri-business). This age-old response to climate variability has been accelerated by population pressure and growing land scarcity in SADC's more densely populated rural areas; by fast growing demands especially for high-value vegetables with the opening up of markets; by the improved availability of affordable technologies especially for groundwater use; and by recent public support. Public support not only improved the availability of irrigation technologies on the shelves, but also strengthened the entire agricultural value chain of backward and forward linkages.

It is recommended that such broad approach be strengthened, anchored in local planning processes to tap local priorities and opportunities. Smallholders and public agencies are co-investors who contribute their respective strengths to bottom-up broad based agricultural growth. The poorest can be reached in at least two ways: first, by teaming up with the Water, Sanitation and Hygiene sector around homestead-based MUS services; and second, by collaborating with poverty-focused programs that are aimed at development, employment generation and/or social safety nets. Wherever the poor prioritize water development out of the range of options, public support in agwater management and other agricultural expertise can strengthen the investments and positive impacts on livelihoods.

7.2.3 Investments by agri-buisiness

As already mentioned, outgrower arrangements have strengths that should be further explored. Input provision and guaranteed marketing channels can especially assist under-performing government schemes, but they can also be developed for new government-financed schemes. Bulk input and sales are an advantage. However, outgrower arrangements can also work for scattered smallholders' who invest in agwater management for self-supply. Such outgrower arrangements can be explored at all scales.

In contrast, past agri-business investments that require land acquisition have seriously been criticized for not observing even minimal procedural rights. Especially the poorest and women lost their basic means of subsistence, while elite capture and patronage at all levels has created deep mistrust. Addressing these weaknesses requires both extensive genuine participation and substantive benefits from wage work by a majority of former land title holders.

7.2 Synergies

What are the untapped synergies between the public sector agencies with mandates in agriculture and those with mandates in water management, so that both sectors can achieve their goals more effectively?

In the past, investments in agwater management and irrigation were the orphan of both the agricultural and water sectors. Hence, more attention to agwater investments represents a major untapped opportunity for both sectors to capitalize on the close linkage between water and agriculture, which will only become stronger under climate change. Both sectors will better achieve their overall goals of poverty alleviation and broad based agricultural growth.

A renewed understanding of the agrarian question in SADC is vital to inform the allocation of both public resources and water resources. More comparative research is needed to map the different modalities and combinations of all three types of investments, and to assess their respective costs and benefits to the public sector, agri-business and smallholders. Findings will be vital information for evidence-based answers to SADC's agrarian question. Further, the suggestion of the RSAP IV (SADC, 2015) to examine rights-based approaches in the water sector in order to reach a better shared understanding across SADC, can support this endeavour.

A low hanging fruit is to iron out current clear contradictions between both sectors. A win-win example would be a formal recognition of local water law, and an adjustment of current permit systems to first target the few high-impact users that should, and that logistically *can*, be regulated.

Perhaps the most important untapped synergy is a cross-country comparison of agwater management investments. As shown by this research, the shared history of SADC's smallholders and regional agribusiness has yielded similar approaches and learning processes. Yet, they have hardly ever been put together and compared for mutual learning. Even a joint base line assessment is lacking (SADC, 2014).

7.3 Indicators

What are possible 'must have' variables for national and regional monitoring?

As basic minimum to inform the above-mentioned exchange, we propose a list of agwater and irrigation investment indicators in Table 10 below. In all cases, differentiation between smallholder and estate cultivation will be considerably more informative, for example as a simple dichotomy with a cut-off point of 50 or 100 ha. For a more extensive list of possible indicators, see Annex 2: Comprehensive list of indicators for monitoring agwater investment.

Table 10: Impact indicators for irrigated agriculture

Indicator theme	Indicators	Measure
Institutional framework (disaggregated by farm size)	Do local water users and water-user associations have adequate power and authority?	
	Does the country have an irrigation strategy?	
	Does it have an irrigation action plan?	
	Is there a designated fund and expertise for agwater infrastructure development?	
	Does a specialized agency exist to handle basin-level management and issuance of permits?	
Water resource utilization (disaggregated by farm size)	Total water withdrawals as share of total renewable water resources	%
	Agricultural water withdrawals as share of total renewable water resources	%
	Dam numbers and capacity as share of total available surface water	%
	Groundwater pumped as a percentage of total renewable groundwater	%
Irrigation area and irrigation technology (disaggregated by farm size)	Irrigation equipped area as share of cultivated area	%
	Area actually irrigated as share of irrigation equipped area	%
	Water managed area as share of cultivated area	%
	Average annual expansion of irrigated area	%
Agricultural productivity (disaggregated by farm size)	Value of irrigated output as share of total agricultural output	%
	Value of irrigated output compared to value of rain-fed output	
Poverty and food security	Number of farmers (m/f) applying irrigation and farm size	
	Agricultural workers (m/f) as % of economically active population	%
	Land tenure customary – public – freehold / matrilineal – patrilineal	

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ANNEX 1: Smallholder agricultural water management technologies in SADC

Annex 1 provides technical information about current smallholder agricultural water management technologies in SADC: rainwater harvesting, wetland cultivation and small-scale irrigation. All technologies mentioned on FAO's global list (Table 1), are also used in SADC, with the exception of documented examples of animal-powered pumps. Solar pumps for smallholder irrigation have recently been introduced into SADC.

Table 1: Indicative list of agricultural water control and water use technologies

<table>
<tr><th>USES</th><th>Water capture</th><th>Water storage</th><th>Water lifting</th><th>Water use/ application</th></tr>
<tr><td rowspan="2">Irrigated crops (including urban and small plot cropping)</td><td>Shallow tubewells:
o dug wells
o drilled wells
Spring diversion
Deep tubewells</td><td>Elevated tanks/drums</td><td rowspan="2">Human-powered pumps:
o hand pulleys and buckets
o hand pumps
o treadle pumps
Animal-powered pumps:
o mohte
o Persian wheel
Motorpumps:
o petrol
o diesel</td><td rowspan="2">Aboveground:
o shallow trenches or ditches
o family/drum drip irrigation kit
o low cost hose irrigation system
Belowground:
o porous ceramic jars
o porous and sectioned pipe</td></tr>
<tr><td colspan="2">Water harvesting systems, composed of:
o catchment area and a water storage structure aboveground (e.g. excavated pond, impounded reservoir)
o catchment area and a water storage structure belowground (e.g. cistern)</td></tr>
<tr><td rowspan="2">Supplementary irrigation</td><td>Shallow tubewells:
o dug wells
o drilled wells
Deep tubewells</td><td>Small dams/reservoirs</td><td rowspan="2">Human-powered pumps:
o hand pulleys and buckets
o hand pumps
o treadle pumps
Animal-powered pumps:
o mohte
o Persian wheel
Motorpumps:
o petrol
o diesel</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Run off the river diversion
Water harvesting systems composed of:
o catchment area and a water storage structure above ground (e.g. excavated pond, impounded reservoir)
o catchment area and a water storage structure below ground (e.g. cistern)</td></tr>
<tr><td>Enhanced water management for rainfed</td><td colspan="2">Soil and water conservation and management (runoff farming):
o stone bunds, ridges, broad beds, furrows
o no-tillage
o infiltration pits
o contour bunds (semi-circular, triangular)
o vegetative bunds
o terraces (eyebrow, Negarim)
o mulching</td><td></td><td></td></tr>
<tr><td>Aquaculture and inland fisheries</td><td>Run off the river diversion</td><td>Small dams and reservoirs
Integrated paddy and fish production</td><td></td><td>Basins
Ponds
Water-level control in small streams</td></tr>
<tr><td rowspan="3">Livestock watering</td><td>Shallow tubewells:
o dug wells
o drilled wells
Spring diversion</td><td></td><td rowspan="3">Human-powered pumps:
o treadle pumps
Animal-powered pumps:
o mohte
o Persian wheel
Motorpumps:
o petrol
o diesel</td><td rowspan="3">Watering facilities:
o watering troughs</td></tr>
<tr><td colspan="2">Water harvesting systems composed of:
o catchment area and a water storage structure above ground (e.g. excavated pond, impounded reservoir)
o catchment area and a water storage structure below ground (e.g. cistern)</td></tr>
<tr><td colspan="2">Micro-catchment water harvesting systems for rainwater runoff:
o contour bunds (semi-circular, triangular)</td></tr>
</table>

Source: Faurés et al 2011

1. Rainwater harvesting

The principle of agricultural rainwater harvesting is based on the concept of depriving part of the land of its share of precipitation, which is usually small and non-productive, and giving it to another part to increase the amount of water available to the latter part, which originally was not sufficient, and to bring this amount closer to the crop water requirements so that an economical agricultural production can be achieved (Oweis and Hachum, 2009). Such concentration of rainfall in a smaller area is called rainwater harvesting and may be defined as:

- The process of collecting natural precipitation from prepared watersheds for beneficial use.
- Collecting and concentrating various forms of run-off from precipitation and for various purposes.
- The process of concentrating precipitation through run-off and storing it for beneficial use.

There are several rainwater management strategies to improve crop yields and green water productivity (Table 2). One set of strategies aims at maximizing plant water availability in the root zone (maximizing the green water resource) through practices that reduce surface runoff (blue water flow) and that redirect upstream runoff to the farm (local storage of blue water for supplemental irrigation).

Table 2: Rainwater management strategies and corresponding management options

Aim	Rainwater management strategy	Purpose	Management option
Increase plant water availability	External water harvesting systems	Mitigate dry spells, protect springs, recharge groundwater, enable off-season irrigation, permit multiple uses of water	Surface micro-dams, subsurface tanks, farm ponds, percolation dams and tanks, diversion and recharging structures
	In-situ water-harvesting systems, soil and water conservation	Concentrate rainfall through runoff to cropped area or other use	Bunds, ridges, broad-beds and furrows, micro-basins, runoff strips
		Maximize rainfall infiltration	Terracing, contour cultivation, conservation agriculture, dead furrows, staggered trenches
	Evaporation management	Reduce non-productive evaporation	Dry planting, mulching, conservation agriculture, intercropping, windbreaks, agroforestry, early plant vigor, vegetative bunds
Increase plant water uptake capacity	Integrated soil, crop and water management	Increase proportion of water balance flowing as productive transpiration	Conservation agriculture, dry planting (early), improved crop varieties, optimum crop geometry, soil fertility management, optimum crop rotation, intercropping, pest control, organic matter management

Source: Rockström et al 2007

A second set aims at maximizing plant water uptake capacity, which involves crop and soil management practices that increase root water uptake and minimizes drainage to the water table. There is a wide spectrum of integrated land and water management options to achieve these aims. Some of the integrated land and water management options to achieve these aims focus on increasing water productivity, such as mulch practices, drip irrigation techniques, and crop management to enhance canopy cover, while most aim at improving crop production by capturing more water (water productivity increases simultaneously because the on-farm water balance is used more effectively) as crop production increases.

1.1 In-field rainwater harvesting

With in-field rainwater harvesting rainfall runoff is promoted on a 2 m wide strip between alternate crop rows and stored in basins. Water collected in the basins infiltrates deep into the soil beyond the surface evaporation zone. After the basins have been constructed no-till is applied and a crust forms on the runoff strip which enhances runoff. Mulch can be placed in the basins to further reduce water losses through evaporation from the soil surface and to create a cooler cropping environment. The stored rainwater is used productively to grow a variety of grain and vegetable crops for household consumption (Mati 2005).

1.2 Stone terracing

Agricultural practices such stone terracing to retain rainwater and soil is an agricultural water management technology which has been practiced in Southern Africa for thousands of years. In semi-arid areas where stones are plentiful, they have been used to create bunds or terraces both as a soil conservation measure and for runoff harvesting (Duveskog, 2001; Critchley, et al 1992). Stones are arranged in lines across the slope to form a strong wall (Picture 1), and since the lines are permeable, they slow down the runoff rate, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion (Critchley and Siegert, 1991).

Picture 1: Stone terrace for retaining rainwater and soil
Photo: Jonathan Derison

Stone lines are commonly practiced in areas receiving 200-750 mm of annual rainfall, and are usually spaced about 15-30 m apart, with narrower spacing on steep slopes, and which can be reinforced with earth or crop residues to make them more stable (Duveskog, 2001). In Tanzania, stone lines are commonly used for erosion control and to create terraces for retaining irrigation water, for example, in the Pare Mountains, Dodoma and Arusha regions (Thomas and Mati, 2000; Lundgren and Taylor, 1993).

2. Wetland farming

A more well-known pre-colonial agricultural water management system in southern Africa is wetland farming. The system of agriculture goes by different names in the region, such as *dambos, mapani, matoro, amaxhapozi* or *vlei's*. The areas are primarily situated in wetland environments that retain water close to the surface for the greater part of the year. For thousands of years, rural farmers in many parts of Southern Africa have managed to plant sorghum, pumpkins and a variety of gourds (Picture 2). These crops were later largely replaced by maize. One of the wetland crops is a crop called *amathapu*or *amadumbe* (*colocasia esculenta*) with large elephant-ear shaped leaves. This is one of the most widely grown traditional crops in Swaziland, as well as in the Provinces of Mpumalanga and KwaZulu-Natal in South Africa. It is grown mainly for its underground starchy corms, which have small starch grains and are easily digestible. Leaves are also used as spinach, providing a useful supplement to maize. *Amadumbes* are also part of Indian cooking and in Durban one can find a tasty delicacy called *puripatha* that is contained within a delicate wrapping of *amadumbe* leaves (WESSA, undated). Another wetland crop is river pumpkin (Gunneraperpensa known as *Iphuzilomlambo* in the Eastern Cape Province in South Africa. In

Swaziland, crops grown by smallholders in wetlands include taro (*Dioscoreaalata*), okra (*Hibiscus esculentus*), pumpkins (*Curcubitapepo*), cabbage (*Brassica oleraleavarcapitata*), spinach (*Beta vulgaris varcicla*), green beans (*Phaseolus vulgaris*), green pepper (*Capsicum annuum*), beet root (*Beta vulgaris*) spinach (*Spinacia olereceae*), carrots (*Davcuscarota*), onion (*Allium cepa*) and tomatoes (*Lycoperscon esculentum*) (Mwendera, 2003).

Picture 2: Crop under contract farming at Indaba Dambo in Chipata, Zambia
Source: Daka 2001

Some of the early irrigation systems were and continue to be used along wetland areas where shallow water tables provide easy water for irrigation (Picture 3).

Picture 3: A contemporary wetland irrigation scheme, the Mugabidambo, in Zambia
Photo: Daka 2001

3. Irrigation

3.1 Bucket and watering can irrigation system

The use of buckets (Picture 4a) and watering cans (Picture 4b) for irrigating crops is common among resource poor farmers.

(a)

(b*)*

Picture 4: Bucket (a) and watering can (b) irrigation systems in Mozambique

3.2 Direct applicator hose

A common irrigation method among smallholder farmers is to apply water to the field using a hose pipe (Picture 5). The water source can be an uphill reservoir or a raised tank.

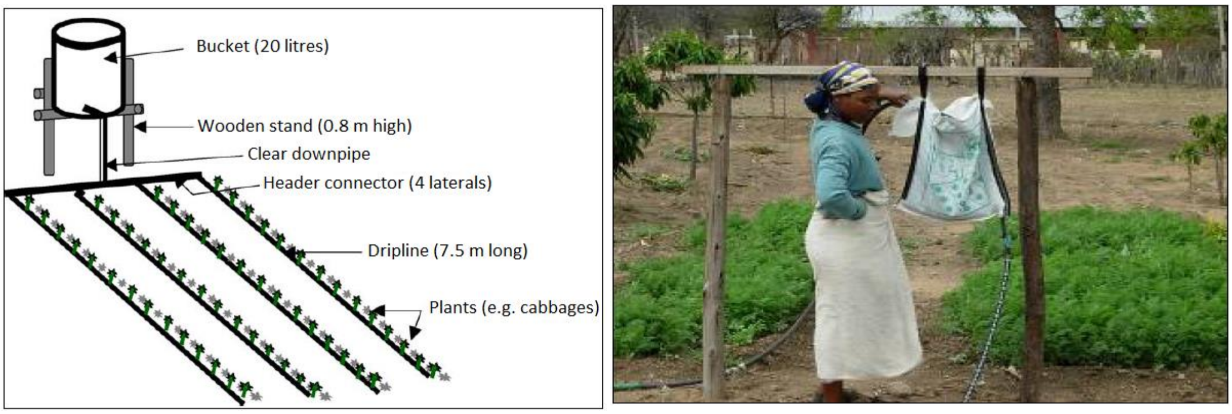
Picture 5: Irrigation using direct applicator hose in the Lowveld, Swaziland

3.3 Drip irrigation

Drip irrigation is an efficient water saving technology that delivers water through small holes or emitters in plastic tubes installed on or below the soil surface almost directly to the roots of the plant. Irrigation water drips directly onto the soil, preventing losses due to evaporation or runoff, and if the flow rates are set correctly, water losses due to deep percolation can be minimized. This provides a moist environment for the roots which optimizes growth, while keeping the rest of the plant relatively dry, which helps prevent diseases. Furthermore, with drip systems, one can control where the water is applied, which increases water efficiency and helps minimize weed growth. Drip irrigations systems are typically about 90 percent efficient, as compared to sprinkler systems which are about 75 percent efficient. Water savings can be as high as 50 percent and crop yields can be increased by up to 40 percent.

3.4 Low-cost drip irrigation

Conventional drip irrigation systems cost between USD 1 200 and USD 3 000 per ha (10 000 m^2), which makes them inaccessible to small-scale farmers in developing countries. The low-cost drip systems cost less than USD 500 per hectare and are available in a variety of sizes, ranging from the home garden kit, which costs only USD 2.50 and covers a plot of 20 m^2, to a large custom system that costs USD 45 for 1 000 m^2. Designed with affordability as the driving factor, the kits uses thin-walled flat plastic tubing and simple knotted-tube emitters and will last one to two years. Figure 1 shows a typical low cost drip system used in Southern Africa.



(a) (b)

Figure 1: Typical 20 litre bucket kit low-head drip irrigation system

Source: Ngigi et al 2005 (a); Andersson 2005(b)

3.5 Commercial drip irrigation system

Some farmers, who have adequate resources, use a drip irrigation system that consists of an elevated water tank (reservoir) that serves as a pressure regulator and a fertilizer injection point (Picture 6). A high-pressure pump is not required. Operating costs are low.

(a) (b)

Picture 6: Water source (a) for drip irrigation (b) system at Pedstock, Harare, in Zimbabwe

3.6 Furrow irrigation system

One of the most common water application methods in the SADC region is the furrow irrigation system (Picture 7).

Picture 7: Furrow irrigation system at Fuve Panganai, Masvingo Province, Zimbabwe

3.7 Pitcher irrigation

Pitcher or clay pot irrigation involves the use of unglazed clay pots, which are buried adjacent to the crop root zone (Figure 2). Such pots are made by women in the traditional way, but the clay is mixed with sawdust to create porosity when the pot is fired during curing. The pot is filled with water and covered with a clay slab or polythene paper, to reduce evaporation losses. Water seeps slowly through the porous sides of the pot. The minute hairs of nearby plants pull the water out from the pots. The method encourages deeper rooting and reduced evaporation. The method is commonly used for fruit-tree crop production.

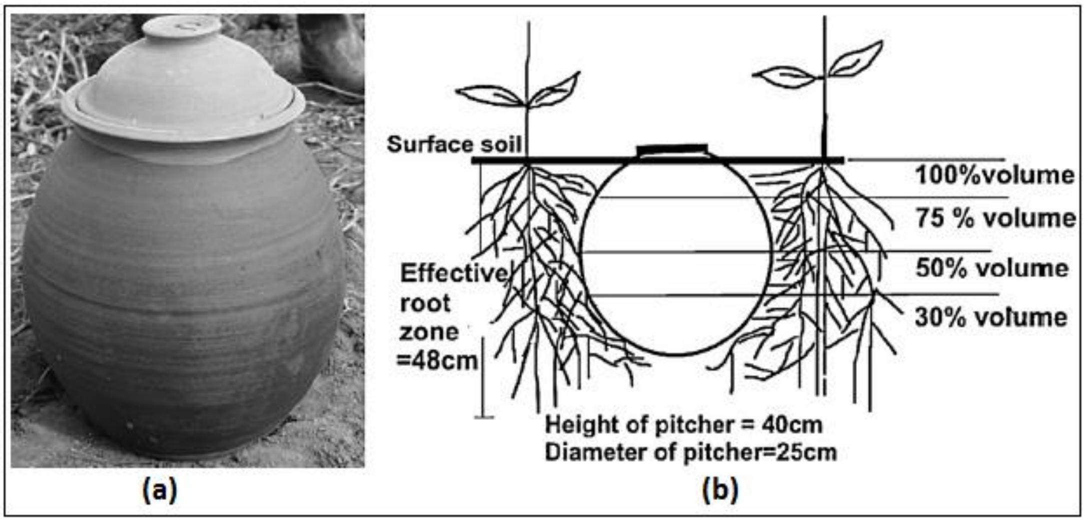


Figure 2: Pitcher (a) and position (b) of pitcher in root zone
Source: Pachpute, 2010

3.7 Treadle pumps

A treadle pump is a low-lift, high-capacity, human-powered pump designed to overcome common obstacles of resource-poor farmers to irrigation. There are different models of treadle pump in use in Southern Africa (Picture 8). The treadle pump can lift five to seven cubic meters of water per hour from wells and boreholes up to seven meters deep, as well as from surface water sources such as lakes and rivers (IWMI, 2006). There are two types: those that lift water from a lower level to the height of the pump commonly called *suction pumps*, and those that lift water both from a lower level and lift it to a height greater than the height of the pump, known as *pressure pumps*.

Swaziland South Africa Zambia

Picture 8: Treadle pumps for small-scale irrigation in Southern Africa
Source: IWMI 2006

During an IWMI (2006) survey, the use of treadle pumps was reported in Lesotho, Malawi, Mozambique, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. In all forms, water is pumped by two direct displacement pistons, which are operated alternately by the stepping motion of the user. The treadle pump has an important advantage over motorized pumps for irrigation of agricultural land of less than one ha: it is considerably less expensive to purchase and operate, needing no fuel and only limited maintenance.

ANNEX 2: Comprehensive list of indicators for monitoring agwater investment

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
1. INPUTS				
WATER STOCKS AND FLOWS				
Surface water	Annual renewable water resources	Annual water available	mcm	I, N
	Total annual use from surface water	Total annual use from surface water	mcm	I, N
	Transboundary water	Amount of water coming from upstream countries	mcm	N
	Transboundary water	Amount of water flowing downstream	mcm	N
Groundwater	Groundwater potential	Total estimated groundwater resources (not capturing transboundary aquifers)	mcm	I, S
	Groundwater potential developed	Groundwater that has been developed	mcm	I, S
	Groundwater potential used	Groundwater that is being abstracted	mcm	I, S
	Groundwater level declining	Aquifers with declining groundwater levels	m/yr	I, S
	Groundwater level rising	Aquifers with rising groundwater levels	m/yr	I, S
Rainfall	Rainfall	Mean annual rainfall	mm	N
Water use	Mean annual crop water use - Et	Actual crop evapotranspiration	mm	N
WATER QUALITY				
Surface water	pH	pH value	value	N
	TDS	Total dissolved solids	mg/l	N
	EC	Electrical conductivity for water salinity	mS/m	N
Groundwater	pH	pH value	value	N
	TDS	Total dissolved solids	mg/l	N
	AR	Arsenic concentration	umg/l	N
	Si	SI concentration	umg/l	N
	Nitrate	Nitrate concentration	umg/l	N
	EC	Electrical conductivity for water salinity	mS/m	N
Environment	Soil quality	Land degradation affecting cropland	ha	I, N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
	Water logged area	Area under salinity and water logging	ha	I, N
WATER INFRASTRUCTURE				
Reservoirs (WCD definition for small, medium, large)	Small reservoirs	Number and capacity of reservoirs in the country	#, mcm	I, N
	Medium	Number and capacity of reservoirs in the country	#, mcm	I, N
	Large	Number and capacity of reservoirs in the country	#, mcm	I, N
Canals (where available)	Lined canals	Length of lined canals	km	N
	Unlined canals	Length of unlined canals	km	N
Pipes	Length of piped systems	Total length of piped systems	km	N
	Length of piped systems new	Total length of piped systems new	km	N
	Length of piped systems old	Total length of piped systems old	km	N
	Discharge volume of piped systems	Total discharge volume of piped systems	mcm	N
	Discharge volume of piped systems new	Total discharge volume of piped systems	mcm	N
	Discharge volume of piped systems old	Total discharge volume of piped systems old	mcm	N
	Discharge volume of piped systems	Total discharge volume of piped systems	mcm	N
Pump stations	Total number of pumping stations	Total number of pumping stations in the country	#	N
	Total capacity of pumping stations	Total capacity of pumping stations in the country	mcm	N
	Functional stations	Total number of functional pumping stations in the country	#	N
Water courses (same as canals above)	Lined canals	Length of lined canals	km	N
	Unlined canals	Length of unlined canals	km	N
	Dysfunctional canals	Length of canals requiring rehabilitation	km	N
WATER REVENUE				
Farmers	Water charges per ha	Water charges if paid per ha	$/ha	I, N
	Water charges per	Water charges if paid per	$/cum	N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
	volume	volume		
	Water charges per month	Water charges if paid per month	$	N
	Water charges per season	Water charges if paid per season	$	N
	Annual water charges	Water charges if paid per annum	$	N
Residential	Water charges per month	Water charges if paid per month	$	N
	Annual water charges	Water charges if paid per annum	$	N
	Recovery rate of water charges per volume	Proportion who pay the charge	%	N, S
	Recovery rate of water charges per month	Proportion who pay the charge	%	N
Industry	Ditto			
Business	Ditto			
WATER INVESTMENTS – CHARGES PAID BY USERS				
Farmers (drainage charge)	Water drainage charges per ha	Water pollution charges if paid per ha	$$/ha	N
	Water drainage charges per volume	Water pollution charges if paid per volume	$/ML	N
	Water drainage charges per month	Water pollution charges if paid per month	$	N
	Water drainage charges per season	Water pollution charges if paid per season	$	N
	Annual drainage water charges	Water pollution charges if paid per annum	$	N
	Atual recovery rate of water charges	Proportion who pay the actual charge levied	%	N
Residential (wastewater)	Water charges per volume	Water pollution charges if paid per volume	$/ML	I, N
	Water charges per month	Water pollution charges if paid per month	$	N
	Annual water charges	Water pollution charges if paid per annum	$	N
	Recovery rate of water charges per volume	Proportion who pay the charge	%	N
	Recovery rate of water charges	Proportion who pay the charge	%	N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
Industry (pollution licence)	ditto			
Business (connection fee)	ditto			
2. OUTPUTS				
CROP PRODUCTION				
Agricultural land	Area	Area under crop production	ha	I, N
	Land ownership	Private, communal, local chief	type	N
Agricultural labor	Number, male	Number of male farmers	number	I, N
	Number	Number of female farmers	number	I, N
	Household size	Number of persons per household	number	I, N
	Labor use	Person-days per ha	days	I, N
	Labor wage rate	Wages paid per day	$	N
Fertilizer	Fertilizer use per ha	NPK use	kg	N
	Total fertilizer use	Per annum	tons	N
Energy	Energy consumption in agriculture	Total energy consumption for pumping water	kWh	N
	Energy cost	Total annual energy cost	$	N
IRRIGATED AGRICULTURE				
	Irrigated area	Area equipped with irrigation infrastructure	ha	I, N
	Cropland	Area under croplands	ha	I, N
	Cropland, annual	Annually planted area under cropland	ha	I, N
	Cropland, permanent	Area under permanent cropland	ha	I, N
	GDP irrigated agriculture	Contribution of irrigated agriculture to DGP	$	N
	GDP agriculture	Contribution of agriculture to DGP	$	I, N
	GDP	Total national income	$	I, N
	Agricultural productivity	Value added per agricultural worker	$	I, N
	Agricultural productivity - irrigated	Value added per agricultural worker - irrigated	S	N
RAINFED AGRICULTURE				
	Rainfed area	Area under rainfed system	ha	N
	Cropland	Area under croplands	ha	N
	Cropland, annual	Annually planted area under cropland	ha	N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
	Cropland, permanent	Area under permanent cropland	ha	N
	GDP rainfed agriculture	Contribution of rainfed agriculture to DGP	$	N
	Agricultural productivity, rainfed	Value added per agricultural worker	$	N
FORESTRY				
	Forest area	Area under permanent forest plantation (by type)	ha	I, N
	GDP forestry	Contribution of forestry to DGP	$	I, N
	Forestry productivity	Value added per agricultural worker	$	I, N
FISHERIES				
	Fishery economy	Total annual fish catch (by type, source)	Tons, $	I, N
	GDP fish	Contribution of forestry to GDP	$	I, N
	Fish productivity	Value added per fishery sector worker	$	I, N
	Aquaculture	Area under fresh and brackish water aquiculture	ha	I, N
LIVESTOCK				
	Livestock population	Total number of TLU in the country	number	I, N
	Livestock type	Total number of TLU in the country by type	number	I, N
	Value	Total estimated value of livestock	$	I, N
	Livestock GDP	Contribution of livestock to GDP	%	I, N
	Livestock productivity	Value added per livestock sector worker	$	I, N
Gross margin	Gross margin	Gross margin per unit of land, kg or animal of selected product (crops/animals)	$	N
INVESTMENTS IN WATER				
Investments in AWM	Public	Public investments in water, annual	$	N
	Private	Private investments in water, annual	$	N
	NGO	NGO investments in water, annual	$	N
	International (donor, ODI, FDI)	International investments in water, annual	$	N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
	Total	Total investments in water, annual	$	N
Training	Investment in farmer training	Annual expenditure on agricultural extension (proxy)	$	N, S
3. INTERMEDIATE OUTCOMES – PRODUCTIVITY				
	Crop output	Total annual crop output	t	I, N
	Crop yield	Average crop yield (maize, rice, soya)	t/ha	I, N
	Corp yield, irrigated	Average crop yield (maize, rice, soya, sugarcane)	t/ha	N
	Crop yield, rainfed	Average crop yield (maize, soya)	t/ha	N
	Crop output, irrigated	Total annual crop output	t	N
	Crop output, rainfed	Total annual crop output	t	N
4. IMPACTS AND OUTCOMES - RESULTS				
Livelihoods	Livelihoods, agriculture	Total agricultural labor force	millions	I, N
	Livelihoods, irrigated	Total labor force engaged in irrigated systems	millions	N
	Livelihoods, rainfed	Total labor force engaged in rainfed systems	millions	N
	Livelihoods, fisheries	Total labor force engaged in fisheries	millions	I, N
	Livelihoods, livestock	Total labor force engaged in livestock	millions	I, N
	Livelihoods, forestry	Total labor force engaged in forestry	millions	I, N
Food security	Food stocks	Annual food balance sheets	t	I
	Food availability	Annual food availability per capita	t	I
	Food consumption	Annual food consumption per capita	t	I
	Food imports	Share of national calorie consumption coming from food imports	%	I
	Food exports	Total annual food exports	$	I
	Food imports	Total annual food imports	$	I
Food dependency	Food-irrigation dependency	Irrigated food production as ratio of total food production	%	S
Poverty	National poverty rate	% of people living below the national poverty line	%	I, N
	Poverty rate	% of people living below the $1	%	I, N

M&E Systems	Indicator	Definition	Unit	Data sources International, National, Secondary)
		day poverty line		
	Poverty rate, irriagetd	% of people living below the $1 day poverty line, irrigated	%	N
	Poverty rate, rainfed	% of people living below the $1 day poverty line	%	N
	Poverty rate, forest dominated areas	% of people living below the $1 day poverty line	%	N
	Poverty rate, fish dominated areas	% of people living below the $1 day poverty line	%	N

Source: M. Hanjra; Hanjra and Gichucki 2008; Hanjra et al 2009