ASSESSING THE CONTEXT AND PRIORITIES FOR IRRIGATION DEVELOPMENT AND AGRICULTURAL WATER MANAGEMENT (IDAWM) FRAMEWORK FOR SOUTH AFRICA

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

Introduction

Agriculture is a major driver of the African economy that sustains many livelihoods across the continent. Accelerated agricultural growth and transformation are at the heart of Agenda 2063 which is the African Union's (AU) strategic framework and master plan for transforming Africa into a global powerhouse over a 50-year period, from 2013 to 2063. It is designed as a blueprint to achieve inclusive and sustainable socio-economic development, continental integration, democratic governance, peace and security, repositioning Africa as a significant player in the global arena. A central pillar of the vision of Agenda 2063 is agriculture-led development, aiming to eliminate hunger, reduce poverty and achieve inclusive, sustainable growth. Water is recognized as a critical input for agricultural production and is foundational for realising these goals. Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification. To sustainably increase food production and reduce poverty in Africa, Agenda 2063 proposes to increase water productivity from rainfed and irrigated agriculture by 60%; harvest at least 10% of rainwater for productive use; and recycle at least 10% of wastewater for agricultural and industrial uses.

In 2020, the AU endorsed the irrigation development and agricultural water management (IDAWM) framework as a blueprint for advancing agricultural water management (AWM) in Africa. The framework consolidates the most relevant approaches to and priority actions for AWM in Africa and serves as a blueprint to align and harmonise national and regional water management policies. Learning from and building on previous AWM implementation efforts, the framework proposes investment in four parallel pathways:

- *Pathway 1*: Improved water control and watershed management in rainfed farming;
- *Pathway 2*: Farmer-led irrigation development (FLID);
- *Pathway 3*: Irrigation scheme development and modernization; and
- *Pathway 4*: Unconventional water use for irrigation (including wastewater treatment, recycling and reuse).

A rain-fed farming system is a type of agricultural practice that relies exclusively on natural rainfall for water, without the use of supplemental or artificial irrigation. In this system, crops and sometimes livestock are cultivated using only the water provided by precipitation during the growing season. FLID is a process where farmers alone or as a group, assume a driving role in improving their water use for agriculture by taking the lead in the establishments, improvements and bringing about changes in knowledge production, technology use, investment patterns, market linkages and the governance of land and water. Farmer-led irrigation (FLI) relates mainly, but not only to smallholder farmers and is not confined to any one technology.

An irrigation scheme is generally defined as an agricultural project where multiple holdings depend on a shared distribution system for irrigation water and, sometimes, shared water storage or diversion facilities. Irrigation scheme development and modernization refers to the planning, construction, improvement and the management of irrigation systems to enhance water use efficiency, agricultural productivity and sustainability. Irrigation scheme modernization is the process of technically and managerially upgrading existing irrigation schemes, going beyond simple repairs or rehabilitation. It includes introducing advanced technologies (e.g., drip or sprinkler systems, automated controls and soil moisture sensors), improving management practices and institutional arrangements to enhance efficiency, flexibility and sustainability, and reforming organizational structures, water delivery services and accountability mechanisms to better meet the needs of farmers and optimise resource use (water, labour, energy and financial resources).

Unconventional water use for irrigation refers to the practice of utilising water sources that are not part of the traditional or conventional water supply systems such as rivers, lakes and shallow groundwater. These unconventional sources often require special treatment or management before they can be safely and effectively used for irrigation. They include a variety of water types and collection methods that help address water scarcity, especially in arid and semi-arid regions.

The purposes of the framework are to: support regional and country level design and review of agricultural water management policy and strategic plans; stimulate interest in irrigation and agricultural water development efforts by providing a suite of development options that can be exploited; and act as a prompt for new ideas and detail in regional and country institutional interventions and project plans. The main focus of this study was to identify opportunities and priorities for using water as an entry point aimed at transforming South African agri-food systems to be highly productive and profitable while sustaining the natural resource base. Available data shows that the deployment of AWM practices falls short of their potential in propelling agricultural growth in the country. Therefore, it was important to understand the current policy environment, types of AWM systems, productivity and profitability, stakeholders' perceptions and participation levels, challenges and potential opportunities to enhance productivity through AWM investments in the country.

The study set out (i) to conduct context-specific literature search (i.e., desktop study) to expand knowledge base on AWM in South Africa, (ii) to identify farming systems typologies intersected with AWM solutions and document the status for each of the four pathways identified in the IDAWM framework, (iii) to document key success factors and lessons learned for sustainable implementation of AWM practices in the country, (iv) to assess opportunities, challenges and priorities for implementing the identified pathways through stakeholder engagement and (v) to identify intervention areas for promising AWM development projects to enhance climate resilience, livelihood options and level of food security in South Africa.

Research Methodology

The research methodology comprised of distinct but interrelated five work packages, which cover identifying AWM practices and policy, governance and institutional frameworks for promoting AWM practices. The first work package involved desktop study. The desktop study involved an in-depth review of literature on research themes related to AWM practices, policy, governance and institutional dimensions. The desktop study also involved a comprehensive review of scholarly articles and national and provincial reports and documents to identify relevant practices, policy, governance and institutional settings for the IDAWM practices. The desktop study also identified the communities' socio-economic context and general conditions in the study areas. The second work package involved the selection of study communities in the study area. The third work package involved identifying, mapping and assessing IDAWM practices in the study areas. The work package also involved fieldwork, surveys and observations to collect AWM-related data. The data were further analysed both inductively and deductively. The fourth work package involved analysis of policy, governance and institutional structures related to AWM practices and examine how these systems affect the implementation of AWM practices in the study areas. This work package also involved development/selection of policy and governance frameworks for supporting the implementation of AWM practices. The fifth work package involved the assessment of gaps and identification of opportunities for improving policy, governance and institutional dimensions for implementing AWM practices. This involved examining gaps in AWM policy coherence and integration and identifying opportunities for improving policy, governance and institutional structures in order to support the effective implementation of AWM approaches at national and local levels.

Literature Review

A literature review was conducted on the body of knowledge on the AWM, policy, governance and institutional dimensions of AWM. The literature review covered areas such as global perspectives of AWM, rainfed-farming systems, farmer-led irrigation development, irrigation scheme development and modernisation, unconventional water use for irrigation, policy dimensions of AWM, governance and institutional dimensions of AWM, AWM in South Africa, and policies, governance and institutional dimensions of AWM in South Africa

The literature review confirms that effective AWM practices are important for improving agricultural production, especially in water scarce countries. The review findings also show that large proportion of farming land is under rainfed farming systems, FLID systems, small-scale irrigation schemes and wastewater reuse have great roles in improving agricultural production. It is also shown that good policies and governace and institutional systems create enabling environment for improving AWM practices. The literature review findings also highlighted the need to understand the existing AWM practices and how existing policies and governance systems affect the use and management of agricultural water resources. The current research will thus leverage on the wide range of AWM practices studies and contribute immensely to the body of knowledge on the subject. The current research focuses on AWM practices and on how existing policies and governance systems affect the use and management of agricultural water resources in South Africa and hence assess the opportunities and challenges of operationalising the IDAWM framework in the country.

IDAWM Practices in South Africa

The study identified, mapped and assessed AWM practices in the country. The study used the provinces of Limpopo and Gauteng as case studies. The study focused on AWM practices under rainfed farming, farmer-led irrigation systems, irrigation scheme development and reuse of wastewater for irrigation. The study has shown that there are promising investment opportunities in the country, based on the four AWM pathways. For all four pathways, a pre-requisite for success is to ensure that policies and institutions that support sustainable, equitable implementation are in place and effective and are accompanied by realistic long-term plans. Some policies, such as agricultural and water resources policies, cut across all pathways.

Rainfed agriculture produces the vast majority of Africa's food despite receiving the lowest public agricultural water investment. In South Africa, smallholder farmers who depend on rainfed systems are central to food production and rural livelihoods. There is significant untapped potential for rainfed crop production in South Africa and with the right investment and government support, rainfed agriculture can be transformed from subsistence-level activity to a driver of commercial agricultural development, benefiting both local communities and the national economy. The study has shown that by focusing on green water management, conservation agriculture, improved governance and targeted investments, South Africa can unlock the potential of its rainfed agricultural systems.

FLID is a very important driver of increased food production, especially for urban markets. It requires very little financial investment by governments as the input and output value chains are largely driven by the private sector. Individualised irrigation technologies are easier to target women, youth and others who otherwise may be left out in the other farming systems. The farmers can be supported through special subsidies and focused capacity strengthening, which requires consultations and experimentation with these farmers to make sure those targeted really benefit.

The study has shown that the pathway of irrigation scheme development is attractive to the government as a route to achieving national food security, providing employment and encouraging rural development. While the scheme farmers face some challenges, there are significant opportunities to improve the performance of existing public irrigation schemes through a combination of institutional reform, capacity strengthening of managers and farmers, market development and either revitalisation or modernisation of infrastructure. Small-scale community managed schemes and multiple-use small reservoirs may offer greater returns than large-scale schemes. A promising but so far rare possibility is public-private partnership (PPP) models for construction and management of irrigation schemes. Schemes need to be designed to meet the demand for other water uses and users. This may be the best opportunity to offer women and youth opportunities to benefit from large-scale infrastructure investments.

The importance of effective and sustainable wastewater reuse for irrigation in the country cannot be overemphasized. The limited natural water resources, as well as periodic droughts in the country necessitate the need to find alternative sources of irrigation water to sustain yield and quality. The large volumes of treated municipal wastewater generated annually holds promise as an alternative water source. If treated properly, municipal wastewater may be beneficial when reused for irrigating agricultural crops. Possible benefits include recycling of nutrients, fertiliser savings, the addition of organic material, a reduced pressure on fresh water sources and reduced environmental contamination. However, high salt loads, in particular sodium (Na^+) can have detrimental effects on soil's physical and chemical properties, as well as crop sustainability. Therefore, it is essential to implement measures that will limit damage caused by salinity and/or sodicity. The attenuation and accumulation of toxic substances should also be managed to a minimum. This pathway offers a large potential for PPP: nutrients recovered from the water are valuable and can be marketed as can the treated water itself in many circumstances. The existence of guidelines for reuse of wastewater offers greatest opportunity of developing investment programmes in consultation with stakeholders to promote sustainable wastewater reuse and make it as safe as possible for both producers and consumers.

Policy, Governance and Institutional Dimensions

The study assessed the roles of policy, legal, governance and institutional systems and arrangements in the implementation of the IDAWM practices in the country. The study has shown that the need for IDAWM policies in South Africa is crucial for several reasons. The population in southern Africa is expected to reach 2.5 billion by 2050, necessitating increased food production. Rising temperatures and greenhouse gas emissions pose challenges to agriculture, making efficient water management essential. The importance of irrigation scheme development and modernisation cannot be overemphasized knowing that irrigation faces technical, management and financing issues and rehabilitating smallholder irrigation schemes can contribute to food output hence to address these issues, the policy environment should promote flexible low-cost irrigation technologies, liberalising equipment imports and mapping water resources.

The study has shown that integrated policy and institutional interventions that promote inclusive and sustainable farmer-led irrigation, irrigation scheme development and sustainable wastewater use for irrigation are key to irrigation development in the country. The study has also shown that rainfed agriculture builds climate resilience and helps move farmers beyond subsistence farming towards sustainable livelihoods, development and economic growth. There is a significant opportunity to maximise the capture, storage and use of green water and unlock the potential of enhanced rainfed agriculture.

South Africa has established a well-structured governance framework to provide an enabling environment for the implementation of AWM, primarily through a combination of legislative, institutional, policy, strategy and plan mechanisms. The legislative framework includes the National Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997) which provide the legal foundation for integrated water resources management. These acts promote water conservation, demand management, equitable allocation and sustainability. The other pieces of legislation include the Wate Research Act of 1971, Conservation of Agricultural Land Act 43 of 1983, Agricultural Research Act 86 of 1990, National Environmental Management Act 107 of 1998, National Environmental Management: Waste Act 15 of 2008, National Health Act 61 of 2003 and Climate Change Act 22 of 2024.

Institutional arrangements include the Water Management Areas (WMAs) and Catchment Management Agencies (CMAs) which are decentralised institutions established to manage water resources at the catchment level, the Water User Associations (WUAs), which are formed by water users (often irrigators) to collectively manage local water resources and infrastructure, main and branch canal management at farm level, lateral and tertiary canal management at sub-farm level, village committee and individuals at village and household levels. The Department of Water and Sanitation (DWS) oversees national policy, regulation and coordination. There are various policies and strategies in the agriculture, water and environment sectors which forms part of the governance system for enabling AWM practices in the country.

The policies include the White Paper on Agriculture 1995, Policy on Agriculture in Sustainable Development, Rural Development Framework Policy, Rural Economy Transformation Model One District One-Agri-Park/Every Municipality Policy, Policy Framework for the Recapitalisation and Development Programme of the Department of Rural Development and Land Reform, National Water Policy for South Africa - White Paper April 1997, National Environmental Health Policy 2013, Environmental and Social Sustainability (ESS) Policy and National Climate Change Response Policy: White Paper 2011. The strategies and plans include National Development Plan 2030, National Water and Sanitation Master Plan (2018), the Agriculture and Agro-Processing Master Plan, National Water Resources Strategy of 2004 (1) and 2013 (2) and 2023 (3), National Water Conservation and Water Demand Management Strategy (2004), National Strategy for Water Reuse (2011), Irrigation Strategy for South Africa, Strategic Plan 2020-2025, Agriculture, Land Reform and Rural Development, Water for Growth and Development Framework (2009), Second National Action Programme for South Africa to Combat Desertification, Land Degradation and the effects of Drought (2018-2030) and Strategic Water Partners Network (2011).

Based on the informing document review and outcomes of stakeholder consultations, it was concluded that the provisions of most of South Africa’s IDAWM-related sectoral laws, policies, plans and programmes provide supportive and enabling environment for the implementation of IDAWM practices in the country. However, while acknowledging that a lot has been accomplished in terms of policy and institutional support for IDAWM practices, it was nevertheless widely acknowledged that there are areas where support for the four AWM systems need to be improved, particularly for rainfed farming and farmer-led irrigation systems.

Gaps and Opportunities

The results of the study show that the FLI farmers have various opportunities, such as the ability to make their own decisions in their farms, choosing irrigation technologies based on their finances and taking the initiative in everything they require on the farm. However, the lack of proper records is a serious challenge that affects their financial situation. Furthermore, they mentioned that the lack of funding from the government is a barrier to the expansion of FLI farmers and modernisation of their farming techniques since they have to rely solely on their own meagre resource. However, while there are opportunities offered by the policy and instructional systems, there are gaps that limit access to these opportunities by the FLI farmers. The study has shown that most farmers have limited knowledge of the institutional and policy support systems such as financial products and training opportunities.

The results of the study further show that limited skills in good farming practice, poor land and water management practices, lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation farming systems. The potentials for farmer-led irrigation development include supportive laws, policies, strategies and plans that provide the enabling environment and access to established markets that enhances profitability and provides a stable income stream for farmers using irrigation. The impact of climate change and variation, limited extension, institutional and financial support are some of the threats to these AWM systems.

Easy access to state support and controlled water management are two of the main strengths of irrigation scheme development. Most of the irrigation schemes suffer from weak scheme governance, which is one of the weaknesses of this AWM system. The opportunities of irrigation scheme development and modernisation are that scheme irrigators operate within a well-defined governance system that supports scheme members and facilitates controlled water management and easy access to government support that provides financial resources, technical assistance and policy backing, which are crucial for the success of irrigation schemes. Cultural and institutional resistance to new practices or technologies, excessive government control which may limit flexibility and responsiveness to local needs and unresolved land tenure issues which can create uncertainty and limit investment in the scheme are some of the main threats to irrigation scheme development.

The availability of wastewater supplies is one of the strengths of wastewater use for irrigation. One of the weaknesses of wastewater use for irrigation is that wastewater cannot be used in certain irrigation systems, such as drip irrigation due to the risk of blockages hence it requires specific adaptations or maintenance. The potential for wastewater use for irrigation include the growing demand for peri-urban agricultural production. The potential health risks associated with wastewater use, poor wastewater quality monitoring and negative consumer perception of crops irrigated with wastewater are some of the threats to wastewater use for irrigation.

Financing for IDAWM practices

Agriculture finance plays a pivotal role in facilitating the smooth functioning of the agricultural sector. One of the key factors that determine the success of IDAWM practices is the access to sources of finance at the right time which is a cornerstone for building better living conditions for rainfed and irrigation farmers by ensuring the profitability of their operations. Finance is required for the purchase of different types of agricultural implements and high-quality seeds, for making marketing arrangements and for storage and processing, among others. Agri-finance provides farmers with the necessary capital to invest in modern technologies, high-quality seeds, fertilizers and other inputs. In terms of financial support for IDAWM practices, the analysis has shown that some financial institutions have a clear mandate and objectives to serve both commercial and emerging farmers by bringing specially designed financial services within the reach of farmers across the nation. However, it has emerged from the study that there is still more to be done to ensure that smallholder rainfed and irrigation farmers fully benefit from this important financial support.

Capacity Building

The project resulted in the development and enhancement of institutional and human capacities. The human capacity building activities of the project related to formal training of students and enhancing capacities of communities in implementing IDAWM practices. Knowledge dissemination was done through presentation at symposium. The project recruited three full-time students, one M.Sc. student and two PhD. students, who conducted their research projects on the IDAWM project. Communities which participated in the study came from Thulamela and Makhado local Municipalities in Limpopo Province. The other communities who participated in the study came for peri-urban areas of Stinkwater; Mashemong; Lephengville; Kanana; Marokolong; Majaneng; Suurman; Unit 7; Themba; Eersterust (F4); Soshanguve; Rooiwal; Unit D; and Ramotse in the Gauteng Province. Communities gained knowledge on the concept of IDAWM framework and practices (some of which they were already implementing but without realising that they fit within the IDAWM framework).

The capacity of the partner institutions was enhanced through the implementation of the project. The partner institutions were CLOVITA Consulting Services, the Faculty of Sciences, Tshwane University of Technology and the Department of Agricultural and Rural Engineering, University of Venda. The participating institutions shared knowledge on research methodologies and data analysis techniques. The research team also learned a lot about various practices related to AWM in the study areas.

Key Recommendations

The study results show that the successful implementation of IDAWM practices requires effective capacity building, financial resources and investment in AWM practices, supportive infrastructure, research and development in AWM, as well as policy reform. There is an urgent need for more investment in capacity strengthening at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers’ knowledge and skills. At the knowledge generation level, there is a need to strengthen research capacities through investing in human resources and reforming research institutions to make them more attractive places to work and more effective. At the knowledge utilisation level, there is need to build the capacity of small-scale farmers so that they are able to adopt the developed AWM technologies for effective and sustainable use and management of agricultural water resources. It is important to invest in extension services in order to improve the skills of extension workers in irrigation water management.

The results of the study show that limited skills in good farming practice, poor land and water management practices, lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation farming systems hence there is need for providing comprehensive training of smallholder farmer-led irrigation farmers in irrigation management (including irrigation scheduling), as well as in record-keeping skills so that they operate farming as a business

The importance of building and strengthening scheme governance systems to promote effective AWM practices on irrigation schemes was also supported by the study of two irrigation schemes, one in the Eastern Cape and the other in KwaZulu-Natal by Mnkeni *et al*. (2010), which revealed that most of the problems in small-scale schemes were institutional and related to governance of the schemes. The study revealed that both schemes had very weak organisational and institutional arrangements.

As for unconventional water use for irrigation, capacity building and skills development are crucial for supporting the growth of the wastewater irrigation sector. Training programs for water treatment plant operators, agricultural extension officers and farmers can help ensure that they have the knowledge and skills necessary to implement and manage wastewater irrigation systems effectively. Ultimately, a holistic and sustainable approach to water reuse in agriculture is essential for addressing water scarcity, promoting food security and protecting the environment in South Africa.

There is a need for more investment in capacity strengthening at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers' knowledge and skills. There is a need to strengthen research capacities through investing in human resources and reforming research institutions to make them more attractive places to work. At the knowledge utilisation level, there is need to build the capacity of small-scale farmers so that they are able to adopt the developed AWM technologies for effective and sustainable use and the management of agricultural water resources. It is important to invest in extension services in order to improve the skills of extension workers in irrigation water management.

Enhancing access to financial resources has consistently been identified as a major strategy to rapidly increase the use of AWM practices. Small-scale farmers, whether operating under rainfed system or farmer-led farming systems find it difficult to afford the money required to purchase essential AWM technologies such as pumps and small local agro-businesses also struggle to obtain operating capital to stock equipment and spare parts or to develop and implement new services to AWM operators such as irrigators hence what is needed are investments in local institutions, such as farmers' organisations and small-scale credit schemes, which are particularly important in this context as the study shows that many farm households cannot afford the initial costs required for small-scale AWM technologies such as water harvesting.

Public investments in infrastructure such as roads are crucial so that farm produce can be transported easily to markets. Furthermore, private investors must be attracted to invest in rainfed agriculture. Investments are also needed in capacity building as the lack of knowledge on farms and among extension service personnel regarding AWM practices such as water harvesting and conservation agriculture can limit yields in rainfed areas, engendering development initiatives is needed as women play major roles in agriculture, particularly in rainfed areas. Innovative public-private financial instruments aimed at supporting the entire AWM value chain should be scaled-up in collaboration with local banks, cooperatives and farmers' organisations.

The study has shown that one of the major constraints to AWM is the inadequacy of supportive infrastructure: transport (roads, railways), electricity, communications and storage and processing facilities for agricultural products. It is, therefore, recommended that in remote areas with land and water resources that can be exploited, there should be an increase in the pace of both public and private infrastructure investments in supportive infrastructure to make AWM investments attractive in the longer run. It is also recommended that for achieving rapid impacts, target irrigation investments to areas that already have other basic infrastructure.

The level of investments in agricultural research and development needs to be boosted, particularly in agricultural water management, including irrigation. It is recommended that the government and the private sector raise the level of funding of applied agricultural and especially water management research and also implement reforms to create the institutional support system that will encourage innovation.

Finally, but perhaps most critical, is policy reform. The attractiveness of investing in AWM technologies and services is to a large extent a function of policies related to imports, currency exchange rates, competitiveness of input and output markets and trade policies. Numerous studies have identified these policy areas as major impediments to investments – and major opportunities to encourage investments. There is a need for new water management policies and investments in human capacities, research, institutional development and specific technologies. There is need to improve enforcement of regulations concerning wastewater, which can reduce or prevent unsafe practices that threaten public health and environmental sustainability

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Municipality	Villages visited		
Thulamela	✓ Dzindi ✓ Tswinga ✓ Manamane ✓ Muledani ✓ Sibasa ✓ Tshivhilwi	✓ Dopeni ✓ Thohoyandou ✓ Dzindi ✓ Khumbe ✓ Ha-Mutsha ✓ Lambani	✓ Dwerani ✓ Manamane ✓ Tshitavha ✓ Tshififi ✓ Tswinga ✓ Tshiombo

Municipality	Villages visited		
	✓ Khumbe ✓ Shayandima ✓ Tshamutilikwa ✓ Tshitanin	✓ Lwamondo ✓ Mbahela ✓ Mbahe ✓ Dzingae	✓ Matangari ✓ Mianzwi ✓ Ha-Muraga ✓ Mangondi
Makhado	✓ Luis Trichard ✓ Kutama ✓ Maebaner ✓ Nzhelele ✓ Tshavhalobedzi ✓ Ha-Ravhele ✓ Mashau ✓ Mashau Thondoni ✓ Tshilokoni ✓ Dopeni-Tshilogoni	✓ Tshikwarani ✓ Tshikowi ✓ Maelula ✓ Gogobole ✓ Mailaskop ✓ Ha-Matsa ✓ Manvuka ✓ Ha-Makau ✓ Elim ✓ Tshikhuwane	✓ Tshiozwi ✓ Vliefontein ✓ Muduluni ✓ Madombidzha ✓ Ha-tshikota ✓ Madodonga ✓ Ha-Magau ✓ Munzhedzi ✓ Vuvha ✓ Ramahantsha ✓ Rathidili

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4MBC	4-Methyl-Benzilidine-Camphor
AAMP	Agriculture and Agro-Processing Master Plan
AEBREC	Animal, Environment and Biosafety Research Ethics Committee
AET	Agricultural Education and Training
AFASA	African Farmers' Association of South Africa
AMD	Acid Mine Drainage
APAP	Agricultural Policy Action Plan
APCF	Agro-Processing Competitiveness Fund
ARC	Agricultural Research Council
AsgiSA	Accelerated Shared Growth in South Africa
AU	African Union
AWM	Agricultural Water Management
BFAP	Bureau for Food and Agricultural Policy
CA	Conservation Agriculture
CARA	Conservation of Agricultural Resources Act
CASP	Comprehensive Agricultural Support Programme
CASP	Comprehensive Agricultural Support Programme
CBOs	Community Based Organizations
CMA	Catchment Management Agency
CMAs	Catchment Management Agencies
CMSs	Catchment Management Strategies
CoCT	City of Cape Town
CSA	Climate-Smart Agriculture
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DCPS	Departmental Committee for Postgraduate Studies
DFFE	Department of Forestry Fisheries and Environment
DLDD	Desertification, Land Degradation and Drought
DoH	Department of Health
DRDLR	Department of Rural Development and Land Reform
DWS	Department of Water and Sanitation
EHMC	2-Ethyl-Hexyl-4-Trimethoxycinnamate
ELUs	Existing Lawful Water Uses
EMF	Environmental Management Framework
FCPS	Faculty Committee for Postgraduate Studies
FCRE	Faculty Committee for Research Ethics
FGDs	Focused Group Discussions
FHDC	Faculty of Higher Degrees Committee
FLI	Farmer-led Irrigation
FLID	Farmer-led Irrigation Development
FSEA	Faculty of Science, Engineering and Agriculture
GA	General Authorisation
GDARDE	Gauteng Department of Agriculture, Rural Development and Environment
GDARDE	Gauteng Department of Agriculture, Rural Development and Environment
GDP	Gross Domestic Product
HHCB	Hexamethylindanopyran (Galaxolide)

I&D	Irrigation and Drainage
IBs	Irrigation Boards
IDAWM	Irrigation Development and Agricultural Water Management
IFSNP	Integrated Food Security and Nutrition Programme
IPAP	Industrial Policy Action Plan
IWMP	Irrigation Water Management Practices
IWRM	Integrated Water Resources Management
LDARD	Limpopo Department of Agriculture and Rural Development
MSDF	Massmart Supplier Development Fund
NAP	National Action Programme
NARS	National Agricultural Research System
NBF	NEPAD Business Foundation
NCCRP	National Climate Change Response Policy
NDP	National Development Plan
NEMA	National Environmental Management Act
NEMWA	National Environmental Management: Waste Act
NGOs	Non-Governmental Organizations
NGP	New Growth Path
NW&SMP	National Water and Sanitation Master Plan
NWA	National Water Act
NWC/WDMS	National Water Conservation and Water Demand Management Strategy
NWPR	National Water Policy Review
NWRS	National Water Resources Strategy
NWSF	National Water Security Framework
NWSFSA	National Water Security Framework for South Africa
OECD	Organization for Economic Co-operation and Development
PASAE	Pan African Society for Agricultural Engineering
PPP	Public-Private Partnership
PTEs	Potentially Toxic Elements
PTO	Permission to Occupy
R&D	Research and Development
RADP	Recapitalization and Development Programme
RDP	Reconstruction and Development Programme
RVCP	River Valley Catalytic Programme
RWH	Rainwater Harvesting
RWH&C	Rainwater Harvesting and Conservation
SADC	Southern African Development Community
SAIAE	South African Institute of Agricultural Engineers
SANParks	South African National Parks
SAPs	Sustainable Agricultural Practices
SISs	Small-scale Irrigation Schemes
SOP	Standard Operation Procedure
SPSS	Statistical Package for Social Science
SPSS	Strategic Plan for Smallholder Support
SSA	Sub-Saharan Africa
SWOT	Strengths, Weaknesses, Opportunities and Threats
SWPN	Strategic Water Partners Network
TCC	Triclocarban
TCS	Triclosan

TUT	Tshwane University of Technology
UNIVEN	University of Venda
WARD	Women in Agriculture and Rural Development Association
WAS	Water Administration System
WC/DM	Water Conservation and Demand Management
WC/WDM	Water Conservation and Water Demand Management
WfGD	Water for Growth and Development
WHO	World Health Organisation
WMAs	Water Management Areas
WRC	Water Research Commission
WSA	Water Service Act
WSAs	Water Services Authorities
WSDP	Water Service Development Plan
WSP	Waste Stabilisation Pond
WSPs	Waste Stabilization Ponds
WTP	Waste Treatment Plant
WTR	Waste Treatment Residue
WUA	Water User Association
WUAs	Water User Associations
WWTWs	Wastewater Treatment Works
YARD	Youth in Agriculture and Rural Development

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Water is a critical input for agricultural production and plays an important role in food security. Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification. Due to population growth, urbanisation and climate change, competition for water resources is expected to increase, with a particular impact on agriculture. As water plays a central role in all sectors, including agriculture, energy, mining, industry, tourism, urban growth and rural development, the allocation, development and protection of water is an essential prerequisite for inclusive economic growth, poverty reduction and the significant reduction of inequality in South Africa (DWA, 2013). Due to population growth, urbanisation and climate change, competition for water resources is expected to increase, with a particular impact on agriculture.

Food security remains high-up on the international agenda because of a number of factors such as population growth, socio-political issues, inadequate agricultural infrastructure, land degradation, heavy disease burden, poor soils and unfavourable climate. The problem is exacerbated by climate change and its effects on agricultural productivity and production stability. Large arid and semi-arid areas in the world have high potential in terms of agricultural productivity. However, water is the main limiting factor for production. As a result, one of the main challenges remains the improvement of agricultural water management (AWM) when the availability and quality of fresh water resources and the sustainable use of soil resources are under increasing pressure (Todorovic *et al*., 2015). To sustainably increase food production and reduce poverty in Africa, Agenda 2063 proposes to increase water productivity from rainfed and irrigated agriculture by 60%; harvest at least 10% of rainwater for productive use; and recycle at least 10% of wastewater for agricultural and industrial uses.

In 2020, the African Union (AU) endorsed the Irrigation Development and Agricultural Water Management (IDAWM) framework as a blueprint for advancing AWM in Africa (African Union, 2020) along four distinct development pathways: 1) Improved water control and watershed management in rainfed farming; 2) Farmer-led irrigation development (FLID); 3) Irrigation scheme development and modernisation; and 4) Unconventional water use for irrigation. According to the AU (2020), the purposes of the framework are to: support regional and country level design and review of AWM policy and strategic plans; stimulate interest in irrigation and agricultural water development efforts by providing a suite of development options that can be exploited; and act as a prompt for new ideas and detail in regional and country institutional interventions and project plans. These four IDAWM pathways are being implemented to varying degrees across Africa.

Rainfed farming is the dominant pathway, accounting for ~90% of cultivated area and producing ~95% of food in Africa. Rain-fed farming is responsible for 99% of the production of the main cereals, such as maize, millet and sorghum in Sub-Saharan Africa (Wani *et al*., 2009). It is estimated that 93% of the African population rely on rainfall to live or even survive while about 70% of citizens of the Southern African

Development Community (SADC) depend on rainfed agriculture for their livelihoods (SADC, 2003). Productivity growth in rainfed agriculture can be accelerated if controlled water can be added to the system where rain water can be stored for future use; whilst leveraging the use of irrigation technology to increase production. It is therefore important for the farmers to transform from rainfed to farmers led through application of water conservation. Ward *et al*. (2016) reported the transformational role of water and water management in rainfed agriculture and how technological and socioeconomic conditions and policy and institutional frameworks can remove barriers to adoption and allow take-up of improved AWM on a wide scale in the Sub-Saharan African drylands. Despite the dominance of AWM, the implementation of improved AWM practices and technologies has been limited to date. Poor AWM and agronomic practices are also driving land degradation and biodiversity loss due to the expansion of rainfed systems into marginal lands and forests. This amplifies rainfed systems' vulnerability to climate variability and change.

Therefore, African countries should develop and implement long-term programs to work with communities to restore degraded landscapes and move to sustainable resource management. Most African countries have considerable potential to increase the productivity and resilience of rainfed farming. The successful implementation requires supportive policies, implementation of locally relevant soil and water conservation practices and public investments for extension and educational support and to leverage farmers' own investments at a large scale. Therefore, governments may need to provide subsidies to compensate farmers for their improvements in productivity in the short term by moving from rainfed to farmer led irrigation through the application of skills aimed to conserve rainwater for sustainable irrigation.

Small-scale farmer-led irrigation development (FLID) has gained increasing importance in Africa in the last 20 years and is identified as the dominant process driving agricultural water expansion in Africa (Lankford, 2009). This sector comprises individuals and small groups who make their investments to advance irrigation and AWM practices. They are mostly smallholder, market-oriented producers; typically farming horticultural crops for urban markets (African Union, 2020). FLID has expanded rapidly in West, East and Southern African regions and studies have identified that the areas under AWM are likely much larger than what is officially recorded (Cai *et al*., 2017). However, FLI technologies and practices vary across countries but include creating shallow groundwater with tubewells or open dug wells, water lifting from rivers and streams using either manual or motorized pumps, ex-situ water harvesting in ponds or small dams, adoption of drip and sprinkler irrigation technologies and gravity-based systems, often tapping small streams (African Union, 2020). Conversely, FLI is a potential game-changer in increasing incomes and food security. Subsequently, a major focus of policymakers should be to encourage competitive efficient market-driven value chains, extending from the supply of technologies, information, access to affordable credit and after-sales services to farmers, to opportunities for farmers to sell their produce at a profit. Notably, rural infrastructure investments can support this process, especially in areas where formal irrigation schemes are not available.

Formal irrigation schemes were introduced in sub-Saharan Africa (SSA) by colonial governments in disregard of local socio-economic and biophysical contexts and primarily to meet interests in export crop production (Bjornlund *et al*., 2020a). After independence, governments in SSA continued to develop irrigation schemes with donor backing. These schemes were not driven by farmers' economic interests nor were they used to enhance production systems for local development (Bjornlund *et al*., 2020b). Rather, the development and management of irrigation schemes were driven by the political and social objectives of governments and often at odds with farmers' interests. Seemingly, large, medium and small-scale formal irrigation schemes account for most past investments in irrigation development across Africa. Furthermore, most schemes have performed poorly in terms of productivity and economic and financial returns hence poor performance of the irrigation schemes covers technological challenges such as degraded canals or non-functioning infrastructure, as well as poor governance, weak institutional and implementation arrangements (for example, failure to empower farmers to help manage and make the best use of the facilities), lack of incentives to motivate the farmers, lack of incentives for system operators to provide efficient water delivery services and inadequate investment in maintenance and operations.

This pathway has traditionally attracted nearly all the investments in agricultural water management in Africa and it remains attractive to governments as a pathway to achieving national food security, providing employment and encouraging rural development. However, the FLI frequently fails as a result of inadequate management and performance, leading to low production due to unsuccessful maintenance hence after a period of low investments, the public sector in many countries is again attracting support to revitalise and modernise existing irrigation for improved performance, as well as construct new ones. Consequently, it is essential for the government to create opportunities that utilise wastewater for irrigation, making it suitable through formal irrigation schemes and FLI initiatives.

The most common unconventional water used in agriculture in Africa is wastewater in urban and peri-urban areas, where it contributes to achieving urban food supply and greening the landscape. The use of sewage and urban wastewater for irrigation is a common practice in urban and peri-urban areas of most developing countries (IWMI, 2006). Notably, water scarcity is an increasingly serious issue across Africa and rapid urbanisation presents an opportunity for wastewater re-use as an important alternative resource to blue-water (African Union, 2020). Subsequently, untreated wastewater irrigation has risks related to environmental and health impacts that require strong management practices and high standards for quality control and protection. At the same time, wastewater contains nutrients that can boost crop growth and reduce chemical fertiliser use which makes it beneficial to use and a good alternative water source.

Wastewater has been recognised as an alternative source of water in water-scarce countries, especially for agriculture, which is the largest user and which has differentiated water quality requirements (Saldías *et al*., 2016). Unfortunately, this type of AWM has not been formally recognised or fully integrated into the irrigation sector in most countries. Its extent is substantial but undocumented; but it is the source of water used in the production of a large percentage of fresh fruits and vegetables available in urban areas. It is a valuable resource, especially as a response to water scarcity as it often contains nutrients which enhance its value from farmers' perspectives. Wastewater irrigation frees up fresh water for higher value uses and thus contributes to improving water productivity and climate resilience. It is a form of farmer-led irrigation and creates a great deal of employment.

To this end, for many water-scarce countries water reuse is the only affordable alternative (Lazarova *et al*., 2001). Unfortunately, there are trade-offs in using wastewater. These trade-offs are influenced by the poor quality of wastewater that enters into the water bodies after sewage treatment, which is often not fit for irrigation. Apparently, wastewater is not intentionally treated for re-use but to get rid of sewage. Thus, to offset the potentially adverse effects of wastewater on public health and the environment and to maximise the benefits from access to additional water, it is, therefore, important to understand the framework within which, Standard Operation Procedure (SOP) whereby, water reuse is to be implemented (Saldías *et al*., 2016) which requires a state or government decision.

A series of Decisions and Declarations of African Heads of State and Government on the need to adopt and out-scale sustainable AWM practices, as well as the widespread use of irrigation among smallholder and market-oriented farmers were the main push factors that led to the development of the IDAWM framework. There is, therefore, a need for member states to internalise the IDAWM framework hence there is need to examine how the framework can be internalised in South Africa. In this study, the focus in on presenting national information on the status, opportunities, challenges and priorities of irrigation development and promote improved AWM practices along the four pathways identified in the African Union's (2020) IDAWM framework.

In South Africa, agriculture is the largest water user sector, consuming almost 61% of the entire water resource available as illustrated in Figure 1.1 (Department of Water and Sanitation, 2023) hence one of the major challenges is to produce more food with the same or less water. It is essential to enhance the productivity of water, which improves the competitive advantage of agriculture in a global economy. Agriculture is also facing increasing competition from the domestic and industrial sectors. High climate variability and unreliability of rainfall (intensity and the water stress) highlights the importance of IDAWM in driving agricultural growth and development in the country.

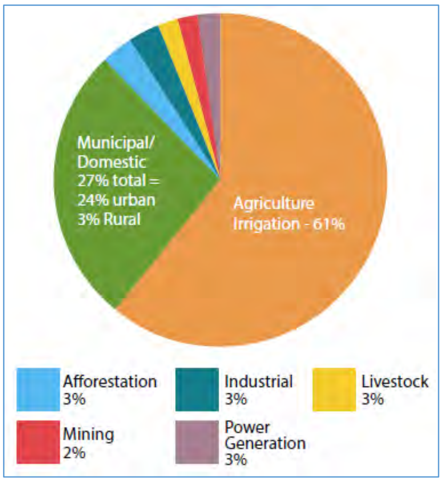


Figure 1.1. Water user by sector in South Africa
(Source: Department of Water and Sanitation, 2023)

1.2 Research aim and objectives

The main purpose of this study was to identify opportunities and priorities for using water as an entry point aimed at transforming South African agri-food systems to be highly productive and profitable while sustaining the natural resource base. The available data shows that the deployment of AWM practices in propelling agricultural growth in the country falls short of the potential. It is, therefore, important to understand the current policy environment, types of AWM systems, productivity and profitability, stakeholders' perceptions and participation levels, the challenges and potential opportunities and priorities to enhance productivity through AWM investments in the country.

This provides the basis for learning lessons, identifying game-changing options and promoting evidence-based policies needed to guide future implementation and support decisions by planners, financial institutions, businesses, implementers, farmers and other stakeholders. The identified opportunities and priorities are expected to reinvigorate national interest in the potential gains from mainstreaming AWM practices to transform agri-food systems. This study addressed these issues and provided guidance to the national stakeholders on constraints, potential investments and approaches to expand effective AWM practices in South Africa. In so doing, the study provided the national context and priorities for implementing IDAWM framework in the country.

The specific objectives of the study were:

1) To conduct context-specific literature search (i.e., desktop study) to expand knowledge base on AWM in South Africa;
2) To identify farming systems typologies intersected with AWM solutions and document the status for each of the four pathways identified in the IDAWM framework;
3) To document key success factors and lessons learned for the sustainable implementation of AWM practices in the country;
4) To assess opportunities, challenges and priorities for implementing the identified pathways through stakeholder engagement;
5) To identify intervention areas for promising AWM development projects to enhance climate resilience, livelihood options and level of food security in South Africa; and
6) Document and assess the quality and quantity on wastewater recovery/reuse; and environmental health challenges.

1.3 Scope of the project

The scope of the study involved assessing the challenges and opportunities of implementing sustainable AWM practices in South Africa within the context of the four pathways described in the IDAWM framework. The study was conducted in the Limpopo and Gauteng Provinces. The Limpopo province, which is located in the far northern part of South Africa, links the country with the rest of Southern Africa. The two provinces served as case studies for the research project.

The study involved the assessment of the AWM practices under the four pathways of rainfed farming systems, farmer-led irrigation development, irrigation scheme development and modernisation and unconventional water use for irrigation. The first part of the study involved a review of the literature on AWM practices and on how policy, governance and institutional systems affect AWM practices. The next step involved identifying, mapping and assessing IDAWM practices in the country. The study then involved an analysis of the policy, governance and institutional structures and examination of the fundamental human environment challenges of AWM in the country. The last part of the study involved an assessment of the gaps and identification of the opportunities for improving policy, governance and institutional dimensions for implementing IDAWM practices in the country.

1.4 Study limitations

At the beginning of the year, one of the PhD students who were recruited for the project deregistered from VVISD tech evaluation for Ekurhuleni Metropolitan Municipality and TUT to join another university. This created a temporary gap in the capacity building process. However, the project then recruited another student who enrolled in a PhD program at TUT as a replacement of the withdrawn student. Another challenge linked to capacity building was the delayed issuance of ethical clearance from the University of Venda (UNIVEN), which affected the data collection timeline and created a gap in the capacity-building report for the MSc student at UNIVEN. To overcome the delayed issuance of the ethical clearance certificate from UNIVEN, the student was able to use the ethical clearance issued to the PhD student at TUT combined with the gatekeepers letter issued by the Limpopo Department of Agriculture and Rural Development (LDARD) to carry out a joint data collection for the project.

Another challenge the project faced was difficulties in recruiting farmers due to limited support from extension officers who were the critical link to the farmers. It also required a lot of persuasion to recruit farmers as most of them had interview fatigue due to previous research studies which had provided little or no beneficial feedback. In cases where project staff were able to contact farmers, there was the challenge of low response rate from those who had been contacted for data collection. In some cases, there was lack of updated and reliable data on farmers which resulted in difficulties in contacting and recruiting farmers for the project. In order to overcome these access issues, snowball sampling was utilised. After multiple follow-ups, we were able to recruit more farmers by enlisting the help of chiefs and other community leaders. A workshop was conducted to assess the degree of support farmers receive from financial institutions. However, the majority of the financial institutions did not show up for the workshop. We were successful in following up with them and obtaining information.

1.5 Structure of the report

This final report follows the Water Research Commission (WRC) format for final report hence the structure of the report is laid out in line with the recommended WRC format.

Chapter 1 outlines the context of the problem at hand, which is to understand the IDAWM practices within the context of the four AWM pathways. The chapter sets out the research aim and objectives, as well as limitations which were encountered during the research work.

Chapter 2 provides a broad overview of the literature reviewed on existing knowledge on AWM practices, policy, governance and institutional frameworks as they relate to irrigation development and agricultural water management. The literature review covered what is known on the current research topic, how well this knowledge is established and where future research might best be directed hence the literature review provided the foundation of knowledge on the topic related to AWM practices and on how policy and governance systems affect the implementation of AWM practices.

Chapter 3 provides an outline of the general research methodologies applied in the research project in terms of study location, target population, sampling system, data collection instruments and data analysis.

Chapter 4 presents the identification, mapping and assessment of IDAWM practices in the country.

Chapter 5 presents an analysis of policy, governance and institutional structures and the fundamental human environment challenges as they relate to IDAWM practices.

Chapter 6 covers an assessment of the gaps and identification of opportunities for improving policy, governance and institutional dimensions.

Chapter 7 summarises and concludes the report and provides recommendations with regards to the implementation of the IDAWM framework in South Africa.

CHAPTER 2

REVIEW OF LITERATURE ON AWM

2.1 Introduction

The review was conducted to examine existing knowledge on Agricultural Water Management (AWM) practices, policy, governance and institutional structures as they relate to the management and utilisation of water in agricultural systems. The review's main focus was on the implementation of AWM practices in South Africa.

2.2 Purpose and objectives of the review

The purpose of the literature review was to determine what is known on the current research topic, how well this knowledge is established and where future research might best be directed hence the literature review was conducted to provide the foundation of knowledge on the topic related to AWM practices along the four pathways and on how policy, governance and institutional systems affect the implementation of AWM solutions.

The objectives of the literature review were to:

1) Identify inconsistencies: gaps in research, conflicts in previous studies, open questions left from other researchers related to AWM;
2) Identify the need for additional research hence justifying the current AWM research;
3) Identify the areas where other research works have contributed to the current research topic; and
4) Place the current AWM research within the context of existing literature, making a case for why the further study is needed.

2.3 Scope of the review

The review was on the literature on AWM practices and on how policy, governance and institutional systems affect AWM practices. There are a large number of studies on general aspects of the AWM practices. However, since the focus of this research is on AWM practices, policy, governance and institutional systems in South Africa, these general aspects were not reviewed in detail but were only referred to as appropriate.

2.4 Literature search strategy

Google Scholar and electronic archives, including Open-Access Theses and Dissertations, Web of Science and the Water Research Commission (WRC) Knowledge Hub were searched for publicly available reports on the water-energy-food nexus. The literature searches were also carried out in the indexed database Scopus©. A word cloud[1] of keywords was used to improve the systematic feature of the literature review. A 'word cloud' is a visual representation of word frequency, the more commonly the term appears in the text being analysed, the larger the word appears in the image generated (Gottron, 2009). Word clouds are increasingly being employed as a simple tool to identify the focus of written material (Ennis, 2010). In this case, the word cloud analysis was used to provide a visual impression of priority given to the literature research of direct relevance to AWM and related issues in South Africa.

[1] https://www.wordclouds.com/

The word cloud shown in Figure 2.1 shows the most popular words used in the literature search for this study.

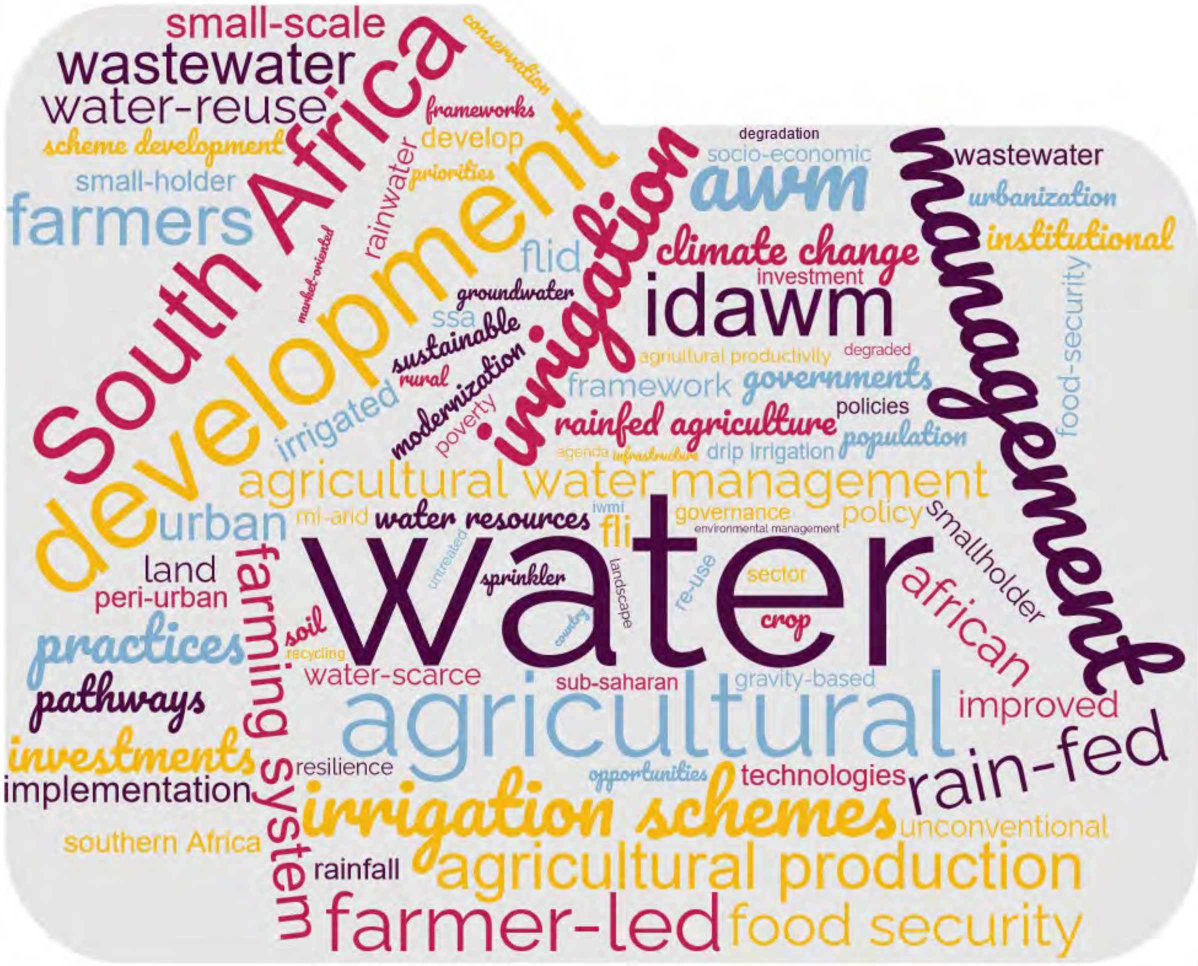


Figure 2.1. The word cloud of keywords for the literature review search

The output of the frequency analysis of the cloud is presented in Figure 2.2. The frequency and hierarchy followed the occurrences of the words: “water”, “development”, “agricultural”, “agricultural water management”, “IDAWM”, “framer-led”, “water resources”, “agricultural production”, “practices”, “policy framework”, “farming system”, “urban”, “African”, pathways”, and “climate change”.

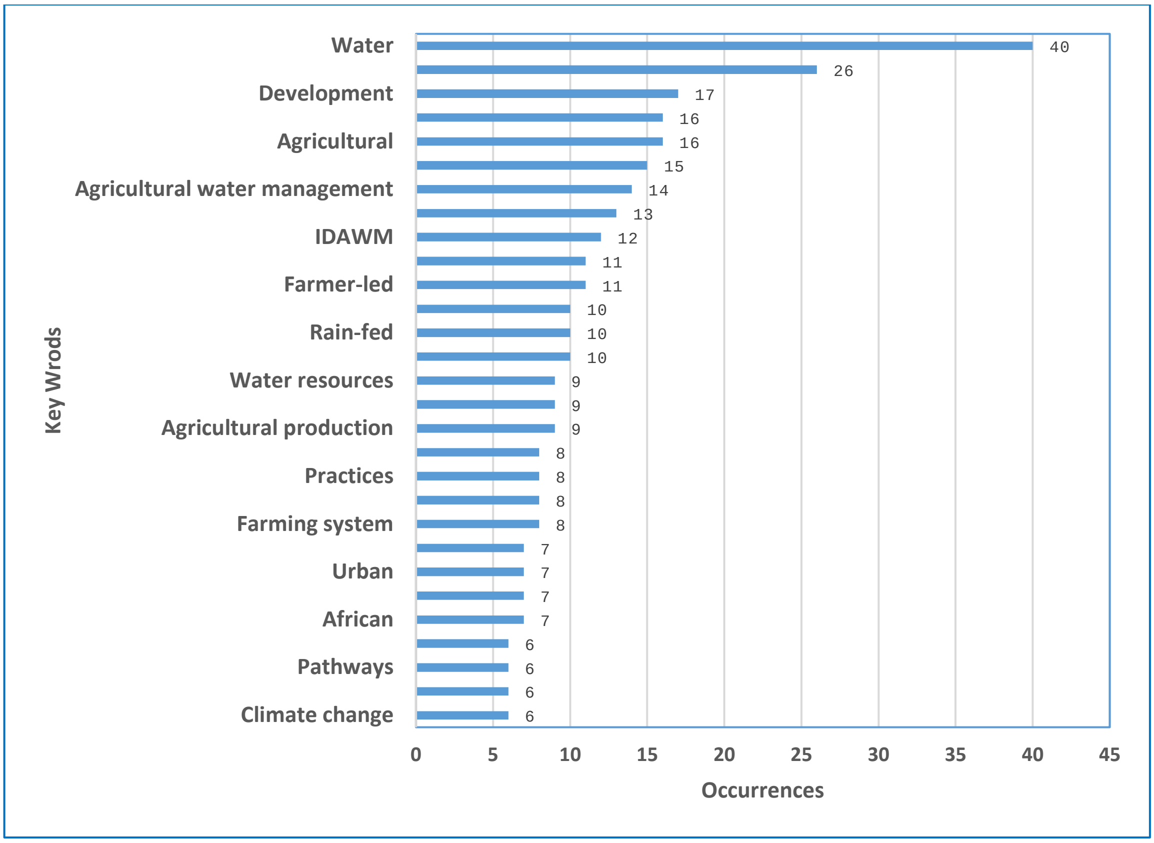


Figure 2.2. The words which occurred with the highest frequency in the dataset

2.5 The structure of the literature review

The literature review covered the following areas:

1) AWM global perspective;
2) Rain-fed farming systems;
3) Farmer-led irrigation development;
4) Irrigation scheme development and modernisation;
5) Unconventional water use for irrigation;
6) Policy dimensions of AWM;
7) Governance and institutional dimensions of AWM;
8) AWM in South Africa; and
9) Policy, governance and institutional dimensions of AWM in South Africa.

2.6 AWM global perspectives

Accelerating agricultural growth remains a high priority (Binswanger-Mkhize *et al.*, 2011). However, the agriculture sector faces many challenges and underperforms relative to its potential (NEPAD, 2013). Productivity gains must be achieved through sustainable agricultural intensification and improving AWM is a critically important pathway to achieve this. Nearly 60% of Sub-Saharan Africa's (SSA) rural population could benefit from water investment (Faurès & Santini, 2008).

The African Union's (AU) Agenda 2063 calls for increased interventions to boost irrigation development and sustainable AWM to increase agricultural production and productivity (African Union, 2015). In 2020, the AU approved a framework for irrigation development and AWM in Africa. Pillar 1 of the Comprehensive Africa Agriculture

Development Programme (CAADP) includes irrigation as part of its Framework on Sustainable Land and Water Management. Implementing sustainable AWM practices is now a high priority for the AU (African Union, 2020), many of its Member States and their partners.

Water is a critical input for agricultural production and plays an important role in food security. Irrigated agriculture represents 20% of the total cultivated land and contributes 40% of the total food produced worldwide (World Bank, 2022). Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification.

Zhu *et al*. (2019) argue that there are six dimensions in AWM as listed in Figure 2.3. The biophysical dimension encompasses everything with respect to the stock and flow of water for agricultural production purposes, including water supply and distribution infrastructure and biological factors associated with crop growth and yield at a variety of spatial and temporal scales. Accounting for water availability, use and biophysical productivity in agriculture takes place in this dimension. Water, crops and supporting infrastructure that fall into this dimension are probably most visible in every AWM system; however, the biophysical dimension alone is insufficient for effective AWM.

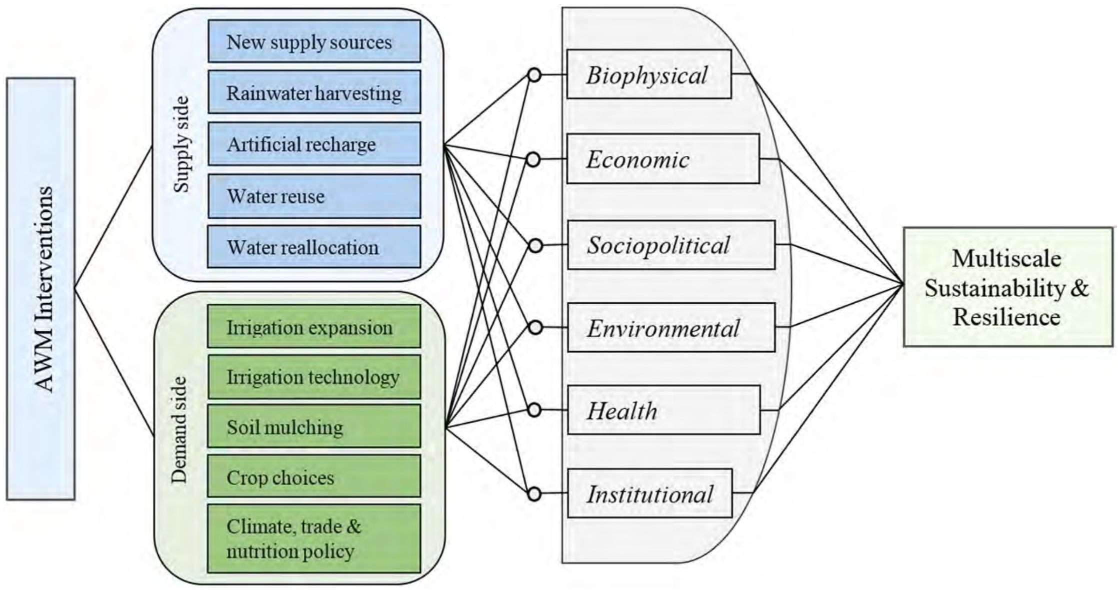


Figure 2.3: A multidimensional view of AWM
(Source: Zhu *et al*., 2019)

The economic dimension concerns broad economic aspects of AWM, including (i) cost-effectiveness and financial sustainability of AWM activities and projects; (ii) market mechanisms as tools for AWM, such as water pricing, water markets, subsidies (e.g., for energy use for irrigation or preferred irrigation technologies) and cost and benefit sharing; (iii) economic efficiency in terms of the economic value per unit of water; and (iv) impacts of AWM on farmers' incomes and the rural economy.

The socio-political dimension refers to the socio-political environment of agricultural water policy making and its impacts on AWM outcomes. Water management is mostly a social enterprise in the sense that it usually requires a large number of people to finance, build, operate and maintain a complex technical system (Lund, 2015). AWM and its transformation are inherently political and socially embedded.

The environmental dimension relates both to inputs for agriculture and outcomes or environmental or health impacts from AWM practices. On the other hand, sound ecosystems with soils that can infiltrate water and water of sufficient quality and quantity are important for both rainfed and irrigated agro-ecosystems to thrive and sound AWM is essential to reduce or avoid adverse impacts on aquatic ecosystems, such as the depletion of rivers, lakes or aquifers; water logging and salinisation; and water pollution with adverse effects on health from agricultural runoff (Gordon *et al*., 2010).

Last but not least, the institutional dimension refers to AWM entities such as irrigation agencies; water user associations (WUA); or agriculture and water ministries governed by regulations, customs or laws. AWM institutions "provide legal and economic authority" to run the agricultural water systems (Lund, 2015). Land tenure security also affects irrigation system performance. The combination of these organisations and the rules that govern agricultural water development and uses can dramatically affect AWM sustainability and resilience. There are proven successes of AWM institutions that provide appropriate roles to the state, user organisations (such as water user groups) and market institutions. However, replicating an institution that performed well in one place without examining conditions needed for the particular institution to be effective has often led to unsuccessful outcomes (Meinzen-Dick, 2014).

2.7 Rain-fed farming systems

2.7.1 Rain-fed farming systems: global perspectives

A rainfed farming system is a type of agricultural practice that relies exclusively on natural rainfall for water, without the use of supplemental or artificial irrigation.[2] In this system, crops and sometimes livestock are cultivated using only the water provided by precipitation during the growing season. Rainfed agriculture, which covers approximately 80% of the world's cultivated lands and contributes about 60% of total crop production and is a fundamental agricultural practice reliant solely on natural rainfall as its water supply (Qin *et al*., 2015; Ziye & Junying, 2016). Beyond its agricultural role, rainfed farming plays a pivotal part in global food security and the sustenance of communities worldwide (Devendra, 2016; Brouziyine *et al.*, 2020). However, it is essential to recognise that the significance of rainfed agriculture varies significantly by region, with its most profound impact often observed in economically disadvantaged populations in developing nations (Rao *et al.,* 2015).

For example, in SSA, approximately 98% of the total cropland relies on rainfed agriculture (Magesa *et al*., 2023). This agricultural practice serves as the major source of staple food production for the majority of rural inhabitants in SSA (Beyer *et al*., 2016). However, these regions face severe challenges linked to the successful cultivation of main staple crops due to irregular and unpredictable rainfall patterns, resulting in water deficits, reduced crop growth and low yields (Beyer *et al*., 2016; Lamptey, 2022).

[2] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/rainfed-agriculture

In India, rainfed lands constitute 55% of the net sown area, supporting 40% of the human population, around two-thirds of the livestock population and contributing 40% to the country's food grain production (Raghavendra & Suresh, 2018). However, rainfed agriculture in India grapples with low productivity, one of the lowest in dry and rainfed regions globally (Suresh *et al.*, 2014). This challenge is exacerbated by unpredictable rainfall, increased drought frequency, midseason droughts, fewer rainy days, extreme and untimely rainfall and a rising occurrence of natural disasters like hailstorms, all of which intensify the vulnerability of rainfed farmers (Rao *et al*., 2015). These challenges disproportionately affect marginalised and small-scale farmers (Raghavendra & Suresh, 2018).

The influence of rainfed agriculture extends globally, encompassing 90% of cultivation in Latin America, 65% in East Asia and 75% in the Near East and North Africa (Firoozzare *et al*., 2023). Despite its wide distribution, rainfed agriculture generally yields lower output compared to irrigated systems due to irregular rainfall patterns causing soil moisture stress during droughts, leading to unpredictable crop yields (Rockström *et al*., 2010; Hessari & Oweis, 2021). Meeting the food needs of the anticipated global population of 9-10 billion by 2050 necessitates significant contributions from rainfed agricultural systems (Qin *et al*., 2015). To establish rainfed agriculture as a primary source of food and livelihood security for rural communities, effective and sustainable water management strategies in rainfed regions are critical (Kahinda *et al*., 2007; Mandal *et al*., 2020).

AWM is vital in rainfed agriculture globally and encompasses diverse strategies tailored to regional needs (African Union, 2020). These strategies, as recognised by the AU (2020) and Namara *et al*. (2010) include conservation agriculture, water harvesting, full and supplementary irrigation and various wetland development techniques. Rainwater harvesting (RWH), in particular, is frequently promoted to improve water productivity in smallholder rainfed agriculture (Ziye & Junying, 2016). This practice intentionally collects, stores and manages rainfall and various forms of precipitation from different catchment surfaces (Kimani *et al.,* 2015). Storing and preserving additional rainwater for productive use can assist in managing extended periods of drought, a significant obstacle encountered by rainfed agriculture, particularly in arid and semi-arid regions across the globe (Piemontese *et al*., 2020).

Global analyses highlight the substantial potential of water harvesting in croplands to boost crop production worldwide (Aghaloo & Chiu, 2020). Historical records reveal the utilisation of rooftop rainwater harvesting (RWH) methods in several countries, including Jordan, Palestine, Syria, Tunisia and Iraq showcasing the enduring tradition of these techniques (Adham *et al*., 2016). Additionally, countries like India, China, the USA, South Africa and Europe have employed rainwater harvesting systems as sustainable water resources, providing multiple benefits such as soil moisture improvement, flood control, groundwater recharge, water scarcity alleviation and increased agricultural productivity (Aghaloo & Chiu, 2020).

Supplemental irrigation is one of the efficient technologies used to mitigate soil water stress on crops, increase yields and enhance water productivity in rainfed systems (Ndhleve *et al*., 2017; Hessar & Oweis, 2021). Studies have shown that supplemental irrigation can result in a 50% increase in maize yields in regions like Soroti, Uganda, where the mean annual rainfall is between 1 100 and 1 200 mm (Adem *et al*., 2023).

Conservation agriculture, relatively cost-effective and applicable to all soils without requiring water storage devices is pivotal for upgrading rainfed agriculture, often constrained by a lack of investment capital (Rockström *et al*., 2010). Mulching, a common practice in conservation agriculture, improves rainwater harvest, conserves soil moisture, controls weeds, enhances soil health and regulates soil temperature for plant growth and efficient crop production (Kader *et al*., 2019; Saikanth *et al*., 2023). Examples from SSA show that converting from ploughing to conservation agriculture results in yield improvements ranging between 20% and 120% with water productivity improving from 10% to 40% (Rockström *et al*., 2010). There is still a need to understand the capture and utilisation of rainwater under different mulches for clarifying the physiological progression, growth and development of the crop (Javid *et al*., 2022).

Despite the numerous opportunities for upgrading rainfed agriculture through new water management investments to reduce yield gaps and enhance water productivity, efforts in this area have so far largely been lacking. Needed now are new water management policies and investments in human capacities, research, institutional development and specific technologies (Rockström *et al*., 2010). The current lack of governance, management and investment priorities given to upgrading rainfed agriculture in developing countries is often justified by the marginal potential in rainfed areas and the major water scarcity problems in dryland areas. However, water constraints are not always related to absolute water shortage, but rather to the variability of supply. Water management to bridge dry spells can greatly reduce risks (Rockström *et al*., 2010).

The study of Abrams (2018) has shown that enhanced rainfed farming has the highest potential to improve food production and reduce poverty, enabled through managing green water in the vast tracts of rainfed cultivable land in Africa. Abrams (2021) further reports that the yield per dollar invested in improved rainfed agriculture is potentially nine times that of small-scale irrigation and six times that of large-scale irrigation and the land available is almost limitless if it is recovered and restored from the degradation caused largely by poverty.

In conclusion, rainfed agriculture plays a crucial role in global food production, but its impact varies across regions and is challenged by irregular rainfall patterns. Effective water management strategies, including rainwater harvesting, supplemental irrigation and conservation agriculture offer solutions to enhance water productivity in rainfed farming. To unlock its full potential, investments in research, human capacities and policy frameworks are essential, ensuring that rainfed agriculture can contribute significantly to food security and climate resilience globally.

2.7.2 Rain-fed farming systems in South Africa

Rainfed agriculture is prevalent in South Africa, particularly among small-scale farmers who utilise the majority of cultivated land (Mkuna & Wale, 2023). This practice supports over 13 million people across approximately 4 million farms, playing a vital role in the income of rural households and occupying about 30% of the country's arable land (Mkuhlani *et al*., 2020). However, South Africa faces significant water-related challenges due to its low annual rainfall average compared to the global average (Ogundeji, 2022; Mtyelwa *et al*., 2022).

Hartley *et al*. (2021) reported that approximately 80% of South African crop production is rainfed, with irrigated crops accounting for only 20%. For key crops and regions, rainfed agriculture is the primary activity. The negative climate impacts in these areas would therefore have a significant impact on total agricultural production. Hardy *et al.* (2011) reported that rainfed farming systems form an important part of South Africa's agricultural sector despite being constrained by the country's socio-political history, local and international economic forces, physical environmental factors such as inherently poor quality of soil, low and variable rainfall, as well as limited amounts of arable land. This is supported by Materechera and Scholes (2022) who reported from their study that most small-scale farmers in South Africa depend on rainfed agriculture. According to Mpandeli (2014), rainfed crop yields amongst small-scale farmers are generally poor due to low and erratic rainfall coupled with already poor soil fertility.

As rainfall is the primary climatic factor of interest to rainfed crop production in a dry country like South Africa, climate change is projected to impact rainfed farming through increased climate variability in most areas, with reduced mean rainfall in some areas (Strauss *et al*., 2021; van Antwerpen *et al*., 2021). These researchers argue that conservation agriculture (CA), a farming system that promotes the maintenance of a permanent soil cover, minimum soil disturbance (i.e., no tillage) and diversification of plant species (FAO, 2018) is one of the practices which can improve rainfed agricultural production particularly under the impact of climate change. Haarhoff *et al*. (2020) reported from their study that the rainfed maize (*Zea mays* L.) production systems of South Africa require an integrated approach to use the limited soil available, water more efficiently and to increase system productivity and sustainability.

2.8 Farmer-led irrigation development

2.8.1 Farmer-led irrigation development: global perspectives

FLID can be defined as a process where farmers alone or as a group, assume a driving role in improving their water use for agriculture by taking the lead in the establishments, improvements and bringing about changes in knowledge production, technology use, investment patterns, market linkages and the governance of land and water (Woodhouse *et al.*, 2017). In the process, farmers rely on and influence neighbouring farmers, agro-dealers and traders, craftspeople, agriculture extension agents and irrigation engineers, administrative authorities, local and national policymakers, civil society and development aid agents. Veldwisch *et al.* (2019) define FLID as a process in which farmers 'drive the establishment, improvement, and/or expansion of irrigated agriculture'. It is thus a characterisation of a development process, rather than a specific type of irrigation.

The definition emphasises an appreciation of farmers' agency and capability to develop and improve irrigation. According to Lankford (2009), FLID is the dominant process driving agricultural water expansion in Africa. The FLID is predominantly small-scale and informal hence its full extent may not be known. However, localised estimates indicate that FLID may cover considerable areas that are not captured in official statistics (Wiggins & Lankford, 2019).

According to the Food and Agriculture Organization (FAO's) AQUASTAT, irrigated areas can be grouped into four categories as follows: (1) full control irrigation (2) partial control irrigation (3) irrigation through water harvesting and (4) cultivation in flood recession areas and in wetlands. Official government reports typically focus on the first two categories, whereas FLID, which is predominantly informal, falls into the last two categories that are rarely reported. These informal irrigation setups are small-scale, fragmented, hard to count and sometimes hard to detect hence they are mostly underreported (Venot *et al*., 2021).

The nature of FLID is diverse with a wide range of water sources, conveyance mechanisms, land size, irrigation systems, types of crops grown and level of investments. The irrigators are distributed across a spectrum ranging from micro-irrigators to small-scale commercial growers (Wiggins & Lankford, 2019). Although relatively small, the current body of literature focusses on FLID's increased agricultural production and incomes to irrigators as the main drivers. However, there is a need to understand the extent and magnitude of FLID and its suitability by analysing its effects on crop production, productivity of water and efficiency of use, downstream water security, performance across different types of irrigation systems, energy use and social and economic costs.

Lefore *et al*. (2019) argued that there is growing evidence that the irrigated area developed by farmers is not captured in official statistics and that in many countries the numbers on irrigation extent would more than double if these areas would be counted. In their study, Woodhouse *et al*. (2017) also found that there was limited documentation and recognition of the role of farmer-led irrigation in agricultural production. However, they argue that despite this, the widespread observation of 'farmer-led' irrigation development in SSA point to the fact that it is a possible signifier not only of quickening investment in raising productivity (and associated changes in market access), but also of new and powerful forces for social change in rural areas. This view is supported by SAFI (2018) who report that although systematic data were scarce, the aggregate area of 'farmer-led' irrigation development appears to exceed that of public and corporate irrigation schemes. SAFI (2018) further argue that FLID is a 'fact' that presents development agencies with opportunities to raise both productivity and food security, alongside challenges to make this process socially equitable, environmentally sustainable and economically-broad-based, and that, in some countries, governments have already modified policies to take advantage of FLID.

According to the World Bank (WB) (2023), FLID has tremendous potential to address the gap in the water needed for food security and to boost farmers' resilience to climate change. The WB argues that FLID supports farmers in developing their own affordable, reliable and sustainable irrigation, helping to secure production through drought caused by climate change, translating into improved livelihoods and resilience. De Bont and Veldwisch (2020) reported that farmer-led irrigation development, a process in which farmers initiate the establishment of irrigation, is increasingly recognised as the driving force behind irrigation expansion, agricultural intensification and commercialisation in SSA. Farmer-led irrigation development in SSA is increasingly recognised as an important process underlying the expansion of irrigated area, as well as the intensification and commercialisation of agriculture (AGRA, 2018; WB, 2018).

2.8.2 Farmer-led irrigation development in South Africa

Smallholder farmers in the South African context are predominantly black farmers who reside in the former homelands. The smallholder irrigators in South Africa fall into four groups; namely, farmers on irrigation schemes, independent irrigation farmers, community gardeners and home gardeners (van Averbeke, 2008; Fanadzo, 2012). Most studies on smallholder farmers have focussed on smallholder irrigators operating on irrigation schemes.

According to Fanadzo and Ncube (2018), the performance of the smallholder irrigation schemes in SSA has been underwhelming. Dirwai *et al*. (2019) identified weak institutions as the major hindrance to the performance of smallholder irrigation schemes. The weak institutions may be attributed to the lack of involvement of the farmers (irrigators) during the design of the irrigation schemes. This passive treatment of farmers resulted in weak farmer commitment in the ownership and management of the schemes, leading to system breakdown (Phakathi *et al*., 2021).

Independent irrigation farmers are becoming a key feature of the expansion of smallholder irrigation. Accordingly, the National Development Plan (NDP) of South Africa identified smallholder farming as a sector that can improve the rural economy through increased irrigated agriculture in rural areas (DAFF, 2015; Cousins, 2013). Nonetheless, there is limited literature on the extent of the FLID in South Africa. Consequently, there is a need to contextualise the FLID as practiced in South Africa. Notably, there is a need to understand the extent and magnitude of FLID in South Africa, its successes and challenges.

2.9 Irrigation scheme development and modernisation

An irrigation scheme is generally defined as an agricultural project where multiple holdings depend on a shared distribution system for irrigation water and, sometimes, shared water storage or diversion facilities. Irrigation scheme development and modernisation refers to the planning, construction, improvement and management of irrigation systems to enhance water use efficiency, agricultural productivity and sustainability. Irrigation scheme modernisation is the process of technically and managerially upgrading existing irrigation schemes, going beyond simple repairs or rehabilitation.[3] It includes introducing advanced technologies (e.g., drip or sprinkler systems, automated controls, soil moisture sensors), improving management practices and institutional arrangements to enhance efficiency, flexibility and sustainability and reforming organisational structures, water delivery services and accountability mechanisms to better meet the needs of farmers and optimise resource use (water, labour, energy and financial resources).

Smallholder irrigation schemes (SISs) were developed to improve rural livelihoods through sustainable food production for food security and poverty alleviation, but these development objectives remain largely unfulfilled (Fanadzo & Ncube, 2018). Van Averbeke *et al*. (2011) reported that in South Africa, smallholder irrigation schemes are of secondary importance in terms of land area and farmer participation. However, they argued that the importance of smallholder schemes arises primarily from their location in the former homelands, which continue to be poverty nodes.

[3] https://www.fao.org/4/X6626E/x6626e04.htm#TopOfPage

Irrigated farming through irrigation scheme has the potential to contribute significantly to food security and income of participating homesteads and to create employment, both directly and through forward and backward linkages to primary production. In their study, Phali *et al.* (2022) indicated that SISs are pivotal in sustaining livelihoods and creating employment in rural communities of South Africa. However, they observed that despite the revitalisation and rehabilitation of SISs by the government, the performance of farmers is still under par.

Dumani *et al.* (2023) conducted a study to evaluate the socioeconomic impact of public private partnerships (PPP) that could be utilised to assist small-scale farmers in irrigation schemes in South Africa. Their results showed that this PPP significantly improved the livelihood and socioeconomic conditions of small-scale farmers. Mudzielwana *et al.* (2022) conducted a study in South Africa to examine whether farmworkers diversify their livelihoods when working on irrigation schemes and identify their choices of livelihood-diversification strategies and the determinants thereof. In their study, they concluded that working on the irrigation farms boosts the generation of income and that rural development policies should consider leasing land to *irrigation farmworkers* which helps to reduce poverty, achieve food security and sustain the livelihoods of *farmworkers.*

Ndlovu *et al*. (2021) conducted a study on the factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane, KwaZulu-Natal. Their results showed that off-farm income, marital status, cooperatives, access to credit, access to irrigation scheme, radio, extension officer, contact with non-government organizations and formal education significantly influenced the level of value chain participation of the smallholder farmers.

Chipfupa and Wale (2020) conducted research on linking earned income, psychological capital and social grant dependency: empirical evidence from rural KwaZulu-Natal (South Africa) and implications for policy. They found that endowment with positive psychological capital, gender, membership to an irrigation scheme and land ownership positively affect smallholders' propensity to earn their livelihoods from farm and non-farm income. The study of Chipfupa and Wale (2020) further showed that small-scale irrigation schemes remain a viable option for increasing employment and incomes in the sector, whilst social and cultural norms continue to reduce women's ability to engage in economic activities.

Regarding climate change resilience of smallholder farmers in irrigation schemes, Kativhu *et al.* (2020) argue that while there is an array of generic adaptation strategies for attaining resilient irrigation schemes in South Africa and beyond, the effectiveness and feasibility of these resilience measures at farm level particularly among smallholders in marginalised areas are not well researched in the country. Chikozho *et al.* (2020) argue that one of the key components essential to the productivity of small-scale farmers who secured farms through the land redistribution programme in South Africa is access to reliable sources of water for irrigation.

In their study, they concluded that there is need for key actors in the development sector to provide more substantive post-land transfer support and ensure better access to water for the emerging farmers. This enhances the farmers' chances of realising more meaningful agricultural production while improving their livelihoods.

Apart from access to water, water pricing at irrigation schemes is another factor which influences the performance of farmers. The results of Chipfupa and Wale (2019) demonstrated the need for irrigation water pricing to reflect irrigation intensity in order to promote agricultural production by smallholder farmers in irrigation schemes.

Fanadzo and Ncube (2018) concluded from their study that capacity building is one of the missing links in smallholder irrigation development and many failures have been attributed to the lack of adequately trained farmers and extension staff, particularly in irrigation water management. They further argue that land tenure insecurity is one of the major institutional challenges leading to poor performance of irrigation schemes. The diversity of schemes means that different kinds of interventions are needed to respond to varying farmers' needs, resources and agricultural contexts. These findings point to the need to balance the soft and hard components of the irrigation schemes for sustainability. It is therefore evident that government needs to review its priorities in revitalisation of SIS. Land tenure policies allowing increased access to arable land need to be developed urgently, together with the promotion of alternative cropping systems that are suitable for the smallholder farming sector (Fanadzo & Ncube, 2018).

One important factor influencing the performance of irrigation schemes is the access to markets by smallholder farmers. Murugani and Thamaga-Chitja (2018) argue that despite having access to irrigation water, many smallholder irrigation farmers in rural South Africa remain subsistence-oriented, with little market participation. Their research has shown that limited access to markets by smallholder farmers restricted them from producing efficiently.

Irrigation water management practices (IWMP) of the farmers at irrigation schemes are influential to the farmers' success. The study of Mabuza and Ndoro (2023) on smallholder farmers and irrigation schemes in the Nkomazi Local Municipality, Mpumalanga Province, showed that the competency of the farmers in IWMP was insufficient. Therefore, they recommended that the government, policymakers and agricultural support services embark on sustainable agricultural development planning issues and develop a relevant training programme that is informed by smallholder farmers' competency needs.

Gender issues are important in the success of irrigation schemes. Mogogana *et al.* (2018) conducted a study on knowledge and adoption of water use efficiency techniques among women irrigators in South Africa. Their study concluded that women irrigators exhibited very low knowledge on all the water use efficiency techniques that are related to irrigation scheduling and had a low level of adoption of water use efficiency techniques. They further recommended that extension services be strengthened in order to improve the knowledge and adoption of water use efficiency techniques among women farmers.

The review show that irrigation schemes have great potential of improving food security, creating jobs, generating income and improving livelihoods of participating farmers. However, the review shows that the modernisation of the irrigation scheme infrastructure and systems is crucial to the success of participating smallholder farmers. The review also shows that the factors which influence the success of farmers in the schemes are namely, access to water and land; water pricing; access to market; knowledge of irrigation water management practices; and access to extension services. The review also shows that it is important to empower women farmers in the schemes in order for them to realise their farming potential.

2.10 Unconventional water use for irrigation

Unconventional water use for irrigation refers to the practice of utilising water sources that are not part of the traditional or conventional water supply systems such as rivers, lakes and shallow groundwater (UN-Water, 2020). These unconventional sources often require special treatment or management before they can be safely and effectively used for irrigation. They include a variety of water types and collection methods that help address water scarcity, especially in arid and semi-arid regions (UN-Water, 2020).

South Africa is a water-scarce country with sporadic droughts in some parts of the country. The reuse of greywater offers one means of relieving pressure on freshwater supplies. It is an established practice in a some households, especially in low-income settlements where water is difficult to obtain and families are under financial pressure to minimise the use of all resources (Rodda *et al*, 2010). The use of greywater specifically for irrigation is practiced to a lesser extent than for other household uses, but does occur in middle- and higher-income suburbs in times of drought and in low-income areas to supplement water supplies for food production (Rodda *et al*., 2010). Fresh water for food security and human survival has become a challenge in recent years.

Water used for irrigation is becoming a biggest challenge in the 21st century. As a result, sustainable agricultural practices (SAPs) are considered the most promising pathways to enhance the productivity and resilience of agricultural production of smallholder farming systems while conserving the natural resources (Myeni *et al*., 2019). SISs are there to improve rural livelihoods through sustainable food production for food security and poverty alleviation (Fanadzo & Ncube, 2018). According to Velasco-Muñoz *et al*. (2019) the supply of food is one of the greatest challenges faced by humankind in the 21st century.

Conversely, this is influenced by the ongoing pressures brought by climate change and the lack of access to sufficient water for irrigation (Olabanji *et al*., 2020). Therefore, the unconventional water source (wastewater) is an alternative source to improve farming and the plight of food security. The active promotion of greywater use for irrigation in gardens and small-scale agriculture has the potential not only to maximize the use of limited water supplies, but also to improve food security in low-income settlements (Rodda *et al*., 2010).

According to Karimidastenaei *et al*. (2022) unconventional water sources are not adequately used because of lack of knowledge, limited scope and poor application as a result of geographic, climatic conditions, socio-economic and poor political will. In addition, Whittingham *et al.* (2023) indicated that only 11% of industrial and domestic wastewater is used worldwide. The inadequate use of unconventional water sources increases the demand for irrigation water for agricultural purposes as the principal suppliers of food.

The Agricultural sector uses between 60-90% of available fresh water resources, depending on the climate and economic development of the region (Velasco-Muñoz *et al*., 2019). Furthermore, it is estimated that 275 million hectares are dedicated to crop irrigation globally and this accounts for just 23% of farmed land (Mendoza-Espinosa *et al.,* 2019; Velasco-Muñoz *et al*. 2019). This situation is similar to what is faced by South African farmers. The country is classified as a water-scarce country and depends on agriculture for food production. The irrigation sector is the largest consumer of water in the country, accounting for about 62% of water utilisation, but also accounting for 30-40% of water loss (Fanadzo & Ncube, 2018).

Therefore, given the threat of drought and climate change, efficient irrigation systems have become a necessity, especially in the smallholder farming sector where most losses occur (Fanadzo & Ncube, 2018). As a result, crop production in South African smallholder farms remains lower than the potential for the land (Myeni *et al*., 2019). Thus, the low yields are obtained because of prolonged droughts, longer dry spells, limited water and nutrient availability, degraded soils and inefficient farming practices. To this end, wastewater reuse is becoming a need for irrigation purposes.

The use of untreated or partially treated wastewater for crops irrigation has become a common practice worldwide, especially in countries that face water scarcity such as Mexico and South Africa (Abah *et al*., 2015). The agricultural economy suffered due to water scarcity for irrigation regarded as the most important setbacks for agriculture in arid and semi-arid regions (Nzima *et al*., 2020). For example, there are few instances where wastewater for vineyard irrigation has received any attention, despite the fact that the reuse of wastewater for other purposes is common in South Africa (Mendoza-Espinosa *et al*., 2019).

Conversely, in South Africa grapes are an important crop in the Western and Northern Cape provinces. The economy of these areas is significantly influenced by the wine industry. Large amounts of wastewater of poor quality are produced by wineries, especially during harvest (Howell & Myburgh, 2018). The use of winery wastewater for vineyard irrigation could have many potential benefits for the wine industry. In addition, literature review shows that there are also very few reports on the actual amounts of wastewater produced by wineries. Small wineries produce fewer than 15 000 m3 of wastewater annually, according to estimates made by medium to big wineries (Howell & Myburgh, 2018).

On the other hand, the use of winery wastewater for vineyard irrigation could have many potential benefits for the wine industry. Irrigation with wastewater containing high levels of K+ could be beneficial for soil fertility, although long-term application could have negative effects on soil chemical properties (Howell & Myburgh, 2018). The authors further reported that in terms of South African guidelines, wineries must register their intended wastewater use with the Department of Water and Sanitation (DWS).

The quantity of wastewater irrigated on a weekly basis has to be monitored and the quality has to be measured monthly and weekly water balances should be drawn up with the assistance of a soil scientist (Howell & Myburgh, 2018). In addition, when selecting crops for irrigation with winery wastewater, soil characteristics and climatic conditions, as well as wastewater quality and quantity should be considered (Howell & Myburgh, 2018). There is also a great potential to increase the area under viticulture by better planning for irrigation with unconventional water to increase the irrigation water available to areas that are currently under rain-fed cultivation.

On the other hand, according to Busari, Senzanje, Odindo and Buckley (2019), the cultivation of effluent-irrigated rice is essential and is synonymous with the reuse, recycling and management of water resources of treated wastewater (Busari *et al*., 2019). This makes it possible to draw the conclusion that there is tremendous potential for using wastewater in non-drinking uses like irrigation (Busari *et al*., 2019). Furthermore, unconventional water resources increasingly need to be implemented to maintain adequate water supplies in areas which are becoming increasingly prone to drought (Mendoza-Espinosa *et al*., 2019).

Moreover, one such resource is reclaimed water: wastewater which has been used once and can be used again with no treatment between uses (water reuse) or wastewater which has received partial treatment to reach a quality which is lower than potable water quality so that it can be used again (water recycling) (Mendoza-Espinosa *et al*., 2019). It is therefore recommended that the use of wastewater should not be limited to the industrial water reuse but also to municipal wastewater.

Municipal wastewater in South Africa is the most abundant type of wastewater available. However, it is not adequately used for the purpose of irrigation. However, only 14% of wastewater is currently reused for agriculture according to the Water Research Commission (WRC) working paper for strengthening the implementation of water reuse in South Africa (Kalebaila *et al*., 2020). It is for this reason that unconventional water use is included in the National Water and Sanitation Master Plan (DWS, 2018).

Agricultural reuse of treated wastewater has been acknowledged as an effective pathway to circumvent water scarcity in South Africa. (Nzima *et al*., 2020). It was also acknowledged that the other wastewater reuse is unaccounted for because it is used in combination with other water resources. Similarly, the DWS (2018) confirmed that South Africa as a water scares country, coupled with the severe water droughts should call for the use of unconventional water use for irrigation (Mendoza-Espinosa *et al*., 2019).

Though municipal wastewater is abundantly available, South Africa’s municipal wastewater reuse is faced with public health threats. The 2021 Green Drop results indicated that only 50% of wastewater treatment facilities are working properly, but the rest are partially disposing its sewage into the other water resources and cause contamination which results in high nutrient build up (Green Drop, 2023). In addition, wastewater falls into the category of low-strength waste streams, characterised by low organic strength and high particulate organic matter content (Sikosana *et al*., 2019).

Seemingly, the main attributes of poor wastewater treatment includes the lack of capacity, poor infrastructure, capacity of sewage treatment plant due to the rise in population (Ally & Campbell, 2021). For instance, Gauteng Province recorded an average of 180L wastewater use per person per day and used 93% capacity; while Limpopo Province only use 138L and used 64% capacity (Ally & Campbell, 2021). This is because the majority of houses in Gauteng Province are connected to sewage as compared to the households in Limpopo Province. Limpopo’s socio-economic status is low and most of the households use pit latrines and are not connected to the sewer. The use of sewage in Gauteng is high as the majority of households are connected to a sewer. To this end, wastewater becomes contaminated and result in public health threats due to high usage and development without increasing the capacity of wastewater treatment facilities (Amoah *et al*., 2018) hence the use of wastewater should be used with caution despite its nutritional benefits.

Wastewater is an important source of essential nutrients for plants. Many environmental, sanitary and health risks are associated with the use of wastewater for crop irrigation due to the presence of toxic contaminants and microbes (Khalid *et al*., 2018). Though the practice of wastewater irrigation lessens the pressure on the aquatic environment by minimising the use of freshwater resources, this could lead to significant damage to human health and the environment (Pretap *et al*., 2021). It is widely known that recycled wastewater possesses a substantial amount of nutrients that act as fertilizers for crops and facilitate the metabolic action of microorganisms.

According to Pretap *et al.* (2021), several harmful impacts of wastewater irrigation are also prominent due to inappropriate wastewater management and irrigation practices. These include severe hazards to farmer’s health, contamination of agricultural land and crops with toxic metals, chemical compounds, salts and microbial pathogens. In addition, long-term irrigation using wastewater can significantly affect groundwater through leakage of salty and toxic metal-rich wastewater making it unfit for human consumption (Pretap *et al*., 2021). Wastewater irrigation may also alter the physicochemical properties and microbiota of soil, which in turn can disturb land fertility and crop productivity. Several factors need to be considered while using treated or partially treated wastewater for irrigation such as diversity and type of pollutants, available nutrients, pathogenic microorganisms and soil salinity (Pretap *et al*., 2021)

According to Khalid *et al.* (2018), wastewater also contains potentially toxic elements (PTEs) such lead, mercury, cadmium, nickel, zinc, chromium, copper and parasitic worms that pose serious dangers to both human health and the environment. Additionally, soil hardening and shallow groundwater contamination can result from the irrigation of crops with untreated wastewater. However, the presence of potentially hazardous substances (PTEs) is the main issue with wastewater agricultural irrigation. Food safety is impacted by soil pollution caused by the accumulation of PTEs in crops and soil due to wastewater irrigation (Khalid *et al*., 2018).

The literature review shows that the use of untreated wastewater for crop irrigation can also cause soil hardening and shallow groundwater contamination. However, the main problem of wastewater crop irrigation is the presence of PTEs. The build-up of PTEs in the soil and crops by wastewater irrigation result in soil contamination and in turn, affects food safety (Khalid *et al*., 2018). Wastewaters generally contain numerous essential inorganic and organic nutrients, which are considered necessary for plant metabolism. On the contrary, this practice provokes various hygienic, ecological and health concerns due to the occurrence of toxic substances such as heavy metals (Natasha *et al*., 2020).

2.11 Policy dimensions of AWM

Water governance relates to the enabling environment in which water management actions take place: that is, the overarching policies, strategies, plans, finances and incentive structures that concern or influence water resources; the relevant legal and regulatory frameworks and institutions; and planning, decision-making and monitoring processes. Effective water governance promotes responsible actions and measures to protect and ensure the sustainability of water resources and to optimise the services and benefits obtained from those resources.

According to the WB (2022), the ability to improve water management in agriculture is typically constrained by inadequate policies, major institutional under-performance and financing limitations. Water policy in the agricultural water sector involves complex tradeoffs. Improved agricultural water management and development presents significant policy opportunities and challenges for economic growth and poverty reduction, particularly in those regions facing increasing water scarcity (WB, 2022).

The Organization for Economic Co-operation and Development (OECD) states that practical water policy instruments for local and national governments are needed to promote effective agricultural water management (OECD, 2011). Water policy instruments are tools, strategies and mechanisms for policymakers to overcome governance obstacles in water policy; for instance, involving sub-national governments in designing water policy beyond their roles as implementers is a policy instrument to foster effective water management (OECD, 2011). The main purpose of water policy instruments is to enhance water conservation and the efficient use of water resources and a comprehensive evaluation of policy instruments is essential to achieve sustainable AWM (Feike & Henseler, 2017).

According to FAO (2006), the overarching objectives of irrigation and water management policies are:

1) *Improving efficiency of water use.* This consists not only of technical efficiency in conveyance and application of water (minimal losses in canals and fields), but also financial efficiency (net returns to farmers) and economic efficiency (value to society as a whole, taking into account externalities and alternative uses of water.
2) *Promoting more equitable access to irrigation*. There is intra-system as well as intra-sector dimensions here: in distributing water more equitably between top and bottom enders within a scheme; and facilitating small holders, women and marginal groups in undertaking irrigated agriculture efficiently and remuneratively.
3) *Ensuring sustainability of irrigation schemes and water management systems*. Both environmental and institutional dimensions of sustainability need to be built into irrigation policies: firstly, to help maintain water and soil quality without adversely affecting ecosystem and downstream of irrigation schemes and secondly in ensuring structures, organisations and processes have the capacity to function effectively over the long term.

2.12 Governance and institutional dimensions of AWM

Critical public and private institutions that encompass agricultural and water ministries, basin authorities, irrigation agencies, water users' and farmer organisations, generally lack the enabling environment and the necessary capacities to effectively carry out their functions (WB, 2022). Institutions charged with developing irrigation often limit themselves to capital-intensive larger scale schemes and tend to rely on public sector-based approaches rather than developing opportunities for small-scale private financing and irrigation management. Farmers and their organisations also often respond to highly distorted incentive frameworks in terms of water pricing and agricultural support policies, which further hinder positive developments in the sector.

The WB (2022) argue that most governments and water users fail to invest adequately in the maintenance of irrigation and drainage (I&D) systems, and that, while inadequate management and operation may play a part in the poor performance of I&D systems, it is especially the failure to sufficiently maintain systems that results in their declining performance and the subsequent need for rehabilitation. This failure to provide adequate funds for the maintenance of I&D systems has resulted in the “build-neglect-rehabilitate-neglect” cycle commonly observed in the irrigation sector.

2.13 AWM in South Africa

The unavailability of freshwater presents one of the greatest risks to South Africa and the global economy at large (Bonthuys, 2021). Other priority risks are related mainly to climate change, biodiversity and ecology. These risks would affect a wide range of economic sectors and livelihoods, impact infrastructure and catchment management and the management of demand into the future. The challenge in South Africa is to produce more food with the same or less water, given that the country is water scarce. In South Africa, the poor management of water resources threatens the resource base on which agriculture depends (Bonthuys, 2021). Water quality has deteriorated in the rivers receiving large quantities of effluent.

The majority of South Africa's interior and western regions are arid or semi-arid, receiving limited rainfall, with about 65% of the country receiving less than 500 mm of rainfall annually (Badisa, 2011; Baiyegunhi, 2015). Moreover, climate change has led to irregular rainfall patterns, prolonged droughts and dry spells during the crop-growing season (Tesfuhuney *et al*., 2020). These factors, combined with high evaporation rates, severely constrain rain-fed agricultural production (Shange, 2015).

Smallholder farmers, heavily reliant on agriculture and rainfall face the critical challenge of sustaining food security amidst climate change (Rankoana, 2022; Ogundeji, 2022). To address these challenges, comprehensive water conservation strategies are essential, including soil moisture management, crop selection and crop rotation. While irrigation might seem like a logical solution, it is generally limited because of challenges such as water scarcity, unsuitable terrain and the high cost of infrastructure (Meena *et al*., 2020; Mangisoni *et al*., 2019).

Despite these challenges, there is potential in upgrading and developing rainfed agriculture through low-cost rainwater harvesting and conservation (RWH&C) techniques (McCosh *et al*., 2017; Anderson *et al*., 2021). These techniques, adaptable to local conditions have been adopted in various regions of South Africa. In some provinces, the micro-basin tillage technique has gained popularity, encouraging runoff management, deep soil infiltration and reduced water losses (Kahinda, 2010; Shange, 2015).

Furthermore, South Africa has implemented climate-smart agriculture (CSA) practices to enhance resilience, contributing to sustainable rainfed agriculture in the region. Several CSA practices have been adopted in South Africa, including no tillage, crop diversification, crop rotation, intercropping, mulching and improved soil fertility management (Chitakira & Ngcobo, 2021).

Despite the potential of water conservation projects, many have failed due to inadequate consideration of social and economic aspects, such as financial constraints and farmers' demographics (Badisa, 2011; Tesfuhuney *et al*., 2020). Effective policies and regulations related to water management in agriculture should be examined to promote responsible water use and conservation practices, contributing to agricultural sustainability. However, it is worth noting that RWH is not being fully utilised due to the lack of clarity regarding water-related legislation at the local government level and the absence of a national umbrella body coordinating RWH implementation. These factors are hindering multisector involvement and the promotion of RWH (Kahinda *et al*., 2018).

In conclusion, addressing South Africa's water-related challenges in rainfed agriculture requires a multifaceted approach. Effective policies, comprehensive water conservation strategies and the full utilisation of RWH techniques are essential components of a sustainable solution. By considering social and economic aspects and clarifying water-related legislation, South Africa can work towards a more water-secure and resilient agricultural sector.

The water deficit caused by low and erratic rainfall and high evaporative demand limits dryland crop production in most of South Africa (van Averbeke *et al*., 2011). Irrigated agriculture presents an attractive alternative under these conditions. Irrigated agriculture plays a major role in the livelihoods of nations all over the world and South Africa is no exception (Reinders, 2011). With irrigated agriculture being the largest user of runoff water in South Africa, there have been increased expectations from government that the sector should increase efficiency and reduce consumption in order to increase the amount of water available for other uses, in particular for human domestic consumption. The irrigation systems in the country include flood, sprinkle, centre pivot, drip and micro-spray irrigation systems (Reinders, 2011). These systems are operated by large commercial farmers, individual small-scale farmers and small-scale irrigations schemes.

2.14 Policy, governance and institutional dimension of AWM in South Africa

In South Africa there are various policies and Acts governing the management and protection of agricultural water resources. The relationships between the Constitution, the NDP: Vision 2030, the National Water Act and the National Water Resource Strategy are important to understand as it provides the national framework for managing water resources, the framework for the preparation of catchment management strategies, provision of water-related information and the identification of development opportunities and constraints (Stevens & van Koppen, 2015).

The country has sectoral legislative pieces or Acts, policies and strategies. Acts provide a legal basis to a policy (Mudhara & Sezanje, 2020). A policy is a goal or an objective set by the government, which is aligned with the set laws or Acts (Kim *et al*., 2015). A strategy outlines the objectives, plans, guidelines, procedures and institutional arrangements required to achieve the desired goal (Mudhara & Sezanje, 2020). The pieces of legislation which are related to agricultural water management in the country include the Constitution (No 108 of 1996), National Water Act (Act 36 of

1998), Conservation of Agricultural Resources Act (No 43 of 1983) and Agricultural Research Act, 1990 (No. 86 of 1990).

The AWM related national policies include the National Water Policy (1997) and the Policy on Agriculture in Sustainable Development. The AWM related strategies include the National Water Resources Strategy (2013), Strategic Plan 2020-2025, Agriculture, Land Reform and Rural Development, Agriculture and Agro-Processing Master Plan 2022 (DALRRD, 2022). The governance of agricultural water is characterised by different institutions at national and provincial levels. Various public organisations and departments are involved in the administration, management and protection of water resources and implementing of policies and legislation (Table 2.1).

The National Water Act (1998) provides the framework for water resource management and outlines the different water management institutions, as well as the specific functions of the different institutions. The DWS is responsible for administering all aspects of the National Water Act delegated to it by the Minister or Director-General. CMAs represent the second tier of the water resource management framework. A CMA is established in each of the 9 water management areas where it is responsible for the progressive development and broad implementation of a catchment management strategy.

The catchment management strategy must be consistent with the National Water Resource Strategy, within its WMA. WUAs are associations of individual water users that undertake water-related activities for their mutual benefit. Water management activities may be devolved to WUAs in which case they become the third tier of water management institutions (Stevens & von Koppen, 2015). Notably, government-owned water boards play a key role in the South African water sector. They operate dams, bulk water supply infrastructure, some retail infrastructure and some wastewater systems. Some also provide technical assistance to municipalities. Through their role in the operation of dams they also play an important role in water resource management.

A WSA is defined as any municipality responsible for ensuring access to water services in terms of the Act (Stevens & von Koppen, 2015). It may perform the functions of a WSP and may also form a joint venture with another water services institution to provide water services. In providing water services, a WSA must prepare a Water Service Development Plan (WSDP) to ensure effective, efficient, affordable and sustainable access to water services (Stevens & von Koppen, 2015). The main duty of a WSP is to provide water services in accordance with the Constitution, the Water Services Act and by-laws of the WSA and in terms of any specific conditions set by the WSA in a contract. Therefore Table 2.1 outlines the role of both public organisations and departments in policy implementation as adapted from Steven and Kloppen (2015) study.

Table 2.1: The role of public organisations and departments in the management and implementation of policies and legislation

Public Organisations and Departments	AWM-related Function
National Level	
Department of Agriculture, Land Reform and Rural Development (DALRRD)	Legislation, administration, farmer support programs, development of infrastructure on small scale irrigation schemes and aquaculture and agrarian reforms
Department of Water and Sanitation (DWS)	Legislation, administration, bulk water supply, regulation and pricing, water strategies
Department of Forestry, Fisheries and the Environment (DFFE)	Environmental impact assessment (biodiversity) and protection of wetlands, lakes, mountain catchment areas, mineral and petroleum resource development and estuaries
Research organisations such as: Water Research Commission (WRC) Council for Scientific and Industrial Research (CSIR) Agricultural Research Council (ARC)	Research and development (R&D) on various aspects regarding water use and agricultural water management
Council of Geoscience (CoG)	Mining and pollution related to acid mine drainage (AMD)
Department of Tourism (DoT)	Protection of conservation areas (South African National Parks (SANParks): all the declared conservation parks; Ecological Reserve and pollution)
Department of Energy (DoE)	Power generation for agriculture (irrigation), use of coal, integrated resource planning
Department of Trade, Industry and Competition (theDTIC)	Industrial Policy Action Plan: job creation, agro processing
Provincial Level	
Provincial Departments of Agriculture (9)	Implementation of agriculture policy at provincial level (Landcare and Farmer Support Programme)
Catchment Management Agencies (CMAs)	Management and administration of water at catchment level (9)
Water Boards (15)	Supplying water to municipalities
Water Services Providers (WSPs)	The main objective is the implementation of the Water Services Act (Act 108 of 1997), which incorporates providing for the right of access to basic water supply
Water Services Authorities (WSAs)	Any municipality responsible for ensuring access to water services in the Act. It may perform the functions of a WSP
Water User Associations (WUAs)	Associations of individual water users that undertake water-related activities for their mutual benefit

(Adapted from Stevens & von Koppen, 2015)

2.15 Synthesis and analysis of the existing body of literature

2.15.1 Summary of key findings on the existing body of literature

The review focused on the body of literature that covers areas such as global perspectives of AWM, rainfed-farming systems, farmer-led irrigation development, irrigation scheme development and modernisation, unconventional water use for irrigation, policy dimensions of AWM, governance and institutional dimensions of AWM, AWM in South Africa and policies, governance and institutional dimensions of AWM in South Africa.

The literature shows that increased land and water productivity in rainfed systems requires appropriate technologies and practices, as well as capacity building support, financing, marketing systems and adequate policies and institutional changes. The main stakeholders in the improvement of rainfed systems include farmers, land-owners, extension services in agriculture and rural development, local governments and national governments.

The literature shows that agricultural growth remains a high priority globally and in South Africa. However, the agriculture sector faces many challenges and underperforms relative to its potential. The literature also shows that improving agricultural water management is a critically important pathway to achieving agricultural productivity gains. There is general agreement in the literature that enhanced rainfed farming has the highest potential to improve food production and reduce poverty. However, it has also emerged from the literature that despite the numerous opportunities for upgrading rainfed agriculture through new water management investments to reduce yield gaps and enhance water productivity, efforts in this area have so far largely been lacking.

It is also evident from the literature that rainfed farming systems form an important part of South Africa's agricultural sector despite being constrained by the country's socio-political history, local and international economic forces, physical and environmental factors such as inherently poor quality of soil, low and variable rainfall, as well as limited amounts of arable land and by climate change. Moreover, it is evident from the literature that FLID, a process in which farmers initiate the establishment of irrigation, is increasingly recognised as the driving force behind irrigation expansion, agricultural intensification and commercialisation in SSA. In South Africa, FLID has great potential to improve food security and create employment. However, the challenges that the sub-sector faces include weak institutional and extension support. There is limited literature on the extent of the FLID in the country.

It is argued that the importance of smallholder irrigation schemes arises primarily from their location in the former homelands, which continue to be poverty nodes. The literature shows that, in South Africa, SIS were developed to improve rural livelihoods through sustainable food production for food security and poverty alleviation, but these development objectives remain largely unfulfilled due to, among other factors, limited access to water and land, water pricing, limited access to markets, limited knowledge of irrigation water management practices and limited access to extension services. The literature showed that despite the importance of wastewater reclamation, unconventional water sources are not adequately used because of lack of knowledge, limited scope and poor application as a result of geographic and climatic conditions.

The literature showed that water governance relates to the enabling environment in which water management actions take place: that is, the overarching policies, strategies, plans, finances and incentive structures that concern or influence water resources; the relevant legal and regulatory frameworks and institutions; and planning, decision-making and monitoring processes. Effective water governance promotes responsible actions and measures to protect and ensure the sustainability of water resources and to optimise the services and benefits obtained from those resources. In South Africa there are various policies and Acts steering the management and protection of agricultural water resources. Various public organisations and departments are involved in the administration, management and protection of water resources and the implementation of policies and legislation.

2.15.2 Assessment of the gaps in the existing body of literature

The review findings showed that while so much research has been conducted on AWM, there are some areas that still need more research. It is clear from the existing body of literature that there is a lot of research on rainfed farming systems, FLID, irrigation scheme development and modernisation, unconventional use of water for irrigation, policy, governance and intuitional dimensions of AWM. However, more research is needed to address the role of rainfed farming, FLID and irrigation schemes in promoting agricultural development and food security in South Africa. There is a need for more research to assess how wastewater can be managed and used to contribute to both water and food securities in the country. The role of good policy, governance and institutional systems in supporting effective AWM practices is very critical, particularly in South Africa. There is a need for more research to assess how these create the much needed enabling environment which promotes effective AWM practices.

Most of the studies have examined the various aspects of AWM in isolation. There is a need to conduct a study which investigate the linkages among the various factors which affect AWM and which assesses the opportunities and challenges of implementing AWM practices in the country. This is why the current research focuses on the opportunities and challenges of implementing AWM in South Africa by pondering the four pathways of improved water control and watershed management in rainfed farming, FLID, irrigation scheme development and modernisation and unconventional water use for irrigation (including wastewater treatment, recycling and reuse).

2.15.3 The link of current research to the existing body of knowledge

There are clear links of the current study to the existing body of knowledge as contained in the reviewed literature. Much of the reviewed literature shows that AWM practices provide a critical key to improving agricultural production particularly in water scarce countries. The literature also shows that to operationalise the IDAWM framework requires clear understanding of the factors affecting AWM in the country and the linkages of the four pathways and the enabling environment created by national and provincial policy, governance and institutional systems.

All these need to be viewed from the perspectives of the opportunities and key challenges. The literature review findings show that there is a need to understand the existing AWM practices and how existing policy, governance and institutional systems affect the use and management of agricultural water resources in the country. The current study is focusing on these areas and thus shall contribute immensely to the body of knowledge.

2.16 Conclusions and recommendations

A review was conducted on the body of knowlledge that covers areas such as global and national perspectives of AWM, rainfed farming systems, FLID, irrigation scheme development and modernisation, unconventional water use for irrigation and policy, governance and institutional dimensions of AWM. The review findings show that there are effective AWM practices that are important for improving agricultural production especially in water scarce countries. The review findings also show that large proportion of farming land is under rainfed farming systems, FLID systems, small-scale irrigation schemes and wastewater reuse have great roles in improving agricultural production. It is also shown that good policies and governance and institutional systems create an enabling environment for improving AWM practices.

The literature review findings also highlighted the need to understand the existing AWM practices and how existing policies and governance systems affect the use and management of agricultural water resources. The current research focused on AWM practices and on how existing policies and governance systems affect the use and management of agricultural water resources in South Africa hence assesses the opportunities and challenges of operationalising the IDAWM framework in the country.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Purpose and objectives

The main purpose of the research methodology was to provide the research study legitimacy and to ensure that the research provides scientifically sound findings. It also provided a detailed plan that helped to keep the research team on track, making the process smooth, effective and manageable. The methodology was designed to provide the basis upon which readers of the report can understand the approach and methods used to reach the research conclusions.

3.2 Research methods and approaches

The research methodology comprised of four distinct but interrelated work packages, which covers the identification of IDAWM practices and policy, governance and institutional frameworks. To achieve the study objectives, both quantitative (document analysis, questionnaires and observations) and qualitative (Interviews, focus group discussions and surveys) study design were imployed.

Work Package 1: Selection of study communities and sectors

The study focused on the small-scale farmers in rural and peri-urban areas in Limpopo and Gauteng provinces. Limpopo is the 2nd poorest Province in South Africa, with gross domestic product (GDP) per capita of R46,336 compared to R94,179 for Gauteng in 2013[4]. About 80% of the province is rural. Whilst Gauteng is the richest Province, there are multitudes of emerging farmers who are using shared irrigation schemes, farmer-led irrigation and rain-fed irrigation. In Gauteng there are farmers who use wastewater released from the sewage system as a source of water supply, whilst some use rivers, dams, boreholes and depend on rain. The majority of farmers in Limpopo Province are rural and depend on the rain to grow their crops. However, there are farmers who use shared and farmer-led irrigation schemes. Therefore, it was important to use both Provinces to determine the processes of AWM.

The research assessed individual farmers, group companies and those who use shared irrigation facilities in both urban and rural areas. Various support and roles provided by National, Provincial and Local government were explored. In addition, Non-Governmental Organizations (NGOs), Community Based Organizations (CBOs), research organizations and private entities were assessed i.e., stakeholders, agricultural officials and management. These determine the role in which every organization plays in terms of governance, financial, capacity building and any other support. The constraints and gaps were identified as well.

The farmers were purposefully selected with the assistance of government officials from the Department of Agriculture such as extension officers. The extension officers and farmers assisted in the identification of key stakeholders who play a role and support matters related to AWM. Extension Officers work with farmers and they know different areas where farmers are based. They assisted in the identification of farmers using different sources of irrigation, as well as practices and implementation of AWM. On the other hand, extension officers assisted with the identification of specific units in various departments that have specific role in AWM.

[4] https://en.wikipedia.org/wiki/List_of_South_African_provinces_by_gross_domestic_product_per_capita

Work Package 2: Identifying, mapping and assessing IDAWM practices

The study used focus groups to determine the irrigation practices, type of water sources used and availability, access, environmental and health issues, impact on climate change, adaptability and mitigation as well as support systems available for the farmers in relation to IDAWM. Farmers, managers, government representatives such as officials from the Department of Agriculture, Water and Sanitation Department and the Department of Health, research organizations such as ARC, WRC and academics, private, NGOs and CBOs were selected to assess policy implementation and support given to the farmers in relation to IDAWM and irrigation.

Work package 3: Policy, governance and institutional structures analysis

The study used a resource-policy approach to examine the fundamental human-environment challenges of AWM in the country. It also examined how the implementation of AWM approaches feeds back to national change processes, economic growth (particularly in expanding urbanisation), rural community development, climate change and variability (through resource use that influences emissions) and interlinked markets. These are fundamental policy challenges that stem from the inextricable linking of the rain-fed and irrigated agricultural systems and the reuse of wastewater resources.

Assess how the existing policy, governance and institutional systems affects the implementation of the AWM practices

There are various legislations, policies, guidelines and statutory documents that determine the practice and implementation of AWM. However, such documents are found in different Ministries such as the Department of Agriculture, Department of Health, Department of Forestry, Fisheries and Environment as well as the Department of Water and Sanitation. On the other hand, such legislations are fragmented and address specific issues related to each ministry hence others are duplicates and approach matters related to AWM differently. This study assessed such discrepancies and determined any challenges or gaps in relation to practices and implementation.

Work package 4: Assessment of gaps and identification of opportunities for improving policy, governance and institutional dimensions

This involved examining gaps in AWM policy coherence and integration and identifying opportunities for improving policy, governance and institutional structures in order to support the effective implementation of AWM approaches at national and local levels. At the end we provided recommendations to be integrated into the policy/decision making processes and appropriate governance and institutional structure changes based on the outcomes of the study.

3.3 Study locations

The study was conducted in the Limpopo and Gauteng Provinces. The Limpopo province, which is located in the far northern part of South Africa links the country with the rest of Southern Africa. The province comprises five districts; namely, Sekhukhune, Mopani, Capricorn, Waterberg and Vhembe (See Figure 3.1). These districts are made up of three distinct climatic regions: the low-veld (arid and semi-arid) regions, the middle veld, high-veld, and semi-arid regions (Serote *et al*., 2021). In the context of agriculture, the Limpopo province is described as the "Garden of South Africa" because of its rich production of fruits and vegetables (Cai *et al*., 2017). The province, which is predominantly rural, has been identified as the second-poorest province in the country after the Eastern Cape province (Odiyo & Makungo, 2012; Chikozho *et al*., 2020). However, despite the availability of varied water sources such as springs, boreholes, canals and rivers, communities in the province have been suffering because of erratic water supplies (Karodia & Khan, 2015; Makaya *et al*., 2020). As a result, smallholder agriculture has become intensely reliant on rainfall, making it highly vulnerable to the impacts of climate change (Shikwambana *et al*., 2021). High levels of inter-annual precipitation variability led to regular droughts and vulnerability with regards to food and water security (Makaya *et al*., 2020). Although the Province has more irrigation schemes than the rest of the country combined, the operational data indicates that out of the 183 SIS implemented in the province, 17% of gravity schemes (81 in total) are no longer functioning, while 35% of the pumped schemes (215 in total) are also no longer functioning (Dension, 2018).

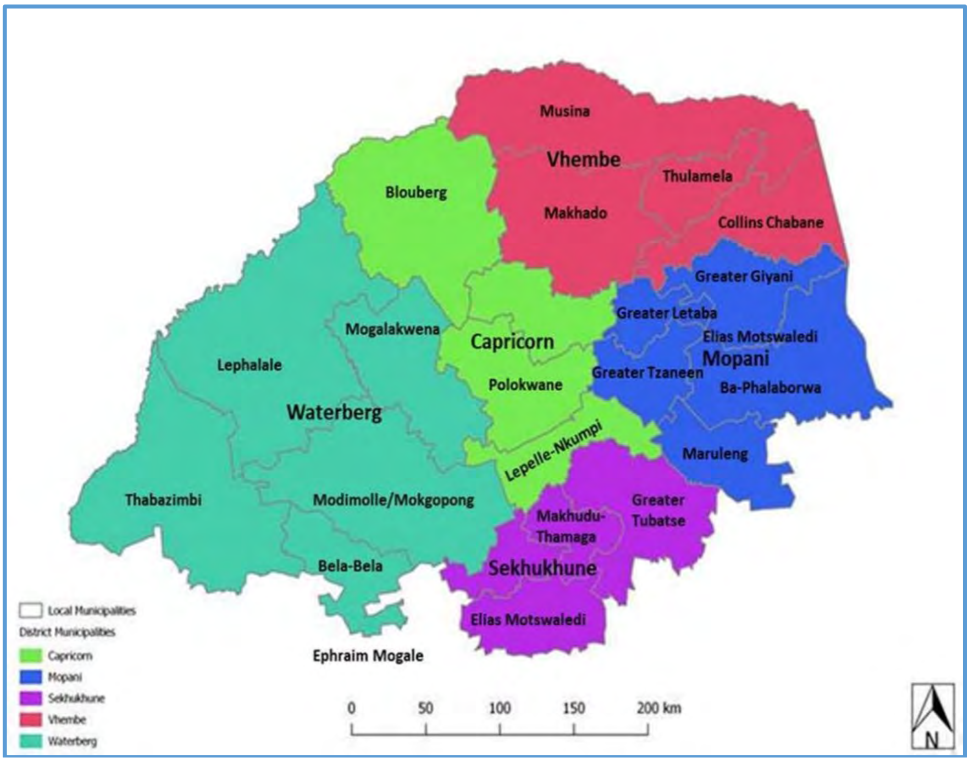


Figure 3.1: Map of the Limpopo Province
(Source: Serote et al., 2021)

Gauteng Province is both the richest and the smallest province in South Africa (Chitakira & Ngcobo, 2021). Unlike the Limpopo Province, Gauteng Province (Figure 3.2) is divided into three metropolitan municipalities (City of Ekurhuleni, City of Johannesburg and City of Tshwane) and two district municipalities (Sedibeng and West Rand). The two districts are further divided into six municipalities: Emfuleni, Lesedi, Merafong City, Midvaal, Mogale City and Rand West City. This province, located in the central north-eastern part of the country, is one of the most populated provinces with an estimated population of around 12.3 million people (Nesamvuni *et* *al*., 2016). However, 22.4% of the country's total population reside in poor peri-urban areas in the province, enabling diversity in the types of farming systems and levels of agricultural production (Mothetha, 2016). This huge population tends to place water resources under stress due to extensive human activities such as agriculture, industry and mining that generate waste and negatively impact the environment and water quality in particular (Mothetha, 2016). In the context of water use in agriculture, some farmers use wastewater released from the sewage system as a water source while others rely on rivers, dams, boreholes and rain. Therefore, the transformation of identified farming systems in the two provinces through AWM is essential to ensure the sustainable use of available water.

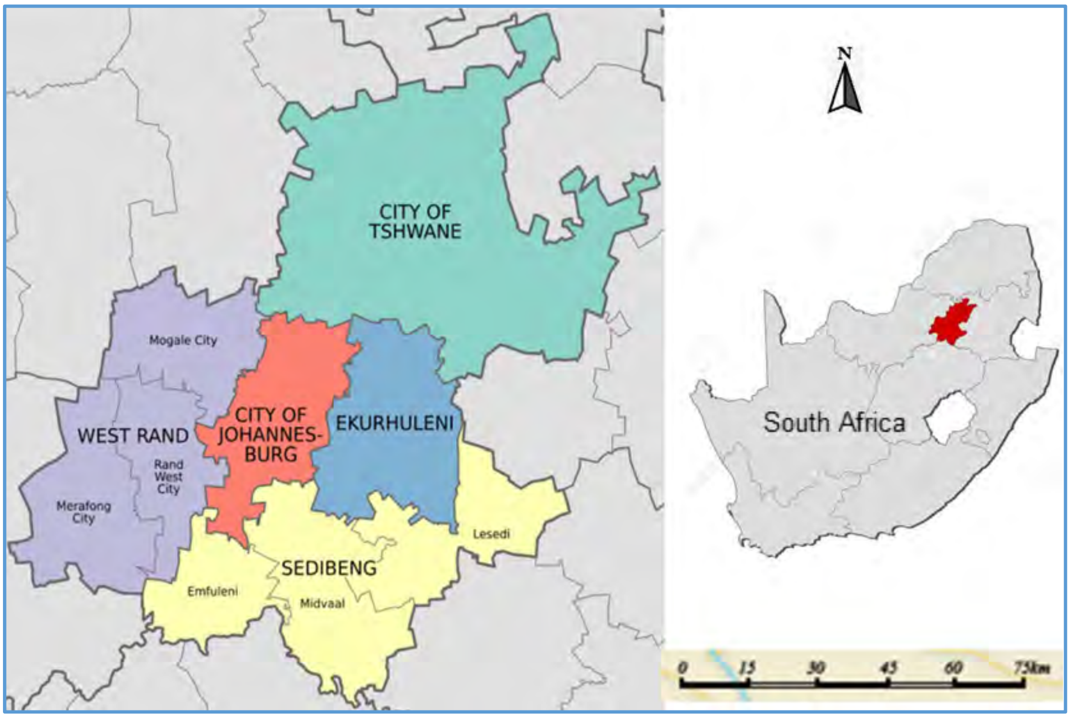


Figure 3.2: Map of the Gauteng Province
(Source: Nhamo et al., 2021)

3.4 Population and Sampling procedures

The population of the study included farmers in the study area. The Department of Agriculture provided a database of all farmers in the Vhembe and the Tshwane districts to sample from. A stratified random sampling approach was used to collect data from farmers involved in the four pathways in both provinces. The study purposively selected the Vhembe district and the Tshwane district due to their high population of farmers who directly and indirectly rely on those 4 pathways for irrigations. A representative sample of at least 300 respondents was randomly sampled selected using a simple random sampling. The simple size was identified using the following equation:

$$n = \frac{z^2 * p(1-p)}{e^2} \quad \text{Equation (1)}$$

where

n = desired sample size
Z = Standard normal deviate at 95% level of confidence = 1.96
p = proportion of target population estimated to have the characteristic under investigation (40% or 0.4) to maximize sample size (precision)
e = level of precision corresponding to statistical significance level of .05 or 5%

The study also used the snowball sampling. In this method, initial subjects with the desired characteristics are identified using purposeful sampling technique. The few identified subjects name others that they know have the required characteristics until the researcher gets the number of cases he or she requires. In this study, we used snowball sampling to identify some of the public and private actors that deal with water policy and governance.

3.5 Data collection

In this study, data were collected through interviews, focused-group discussions and a workshop.

3.5.1 Data collection tool

The tool which was used for data collection is presented in Appendix A. The tool had two parts, Part 1 was the general questionnaire for the farmers and Part 2 contained key stakeholder interviews and informant interviews schedules which covered an analysis of strengths, weaknesses, opportunities and threats (SWOT) for AWM. It also covered analysis of the enabling environment for IDAWM, institutional and financial support and opportunities and challenges for IDWAM in the country.

3.5.2 Interviews

Face-to-face interviews were conducted in Limpopo and Gauteng Provinces to collect data for rainfed farming (Pathway 1) and farmer-led irrigation development (Pathway 2). The data were collected through a structured questionnaire from farmers in Thulamela and Makhado Municipalities (Fig. 3.3) and in Hammanskraal (Fig. 3.4) in July and August 2024.

Figure 3.3: Some of the farmers interviewed in Thulamela and Makhado Municipality in Limpopo Province

Figure 3.4: Field assistant and enumerators interviewing farmers in Hammanskraal in Gauteng Province during a field survey

3.5.3 Focused-group discussions

This study used a focused group discussion (FGDs) with the relevant stakeholders. A questionnaire was developed and administered to the identified key stakeholders. In the Limpopo Province, FGDs were conducted with stakeholders from the Department of Agriculture, Land Reform and Rural Development (DALRRD) in Thulamela Municipality and the provincial stakeholders from DALRRD in Limpopo Province. The purpose of the FGDs was to identify and gather information about the farmers under the following pathways: Pathway 1: Improved water control and watershed management in rainfed farming; Pathway 2: Farmer-led irrigation development; Pathway 3: Irrigation scheme development and modernisation; and Pathway 4: Unconventional water uses for irrigation. The information included the number of farmers operating in rainfed and farmer-led, name and number of beneficiaries in the irrigation schemes, the scale of operation (land size in ha), location, types of crops, irrigation system, source of water and the support by the government. The study was conducted in the Vhembe district. In Gauteng Province, the focus was on the Tshwane municipality, where consultations were held with farmers, managers and government officials from the Department of Agriculture, Water and Sanitation.

The FGDs were also held with rainfed farmers (Pathway 1) and irrigation scheme farmers (Pathway 3) in Limpopo province to collect their views. They were organised and held on the 18th and 19th of September 2024 at the Tshiombo Irrigation Scheme and Lwamondo to collect data from farmers in the irrigation schemes (Pathway 3) and rainfed farmers (Pathway 1), respectively. The FGDs aimed to identify and gather information on the gaps and identify opportunities for improving policy, governance and institutional dimensions. The focus group discussion inputs were collected through a face-to-face interview using a structured questionnaire with closed and open-ended questions from the farmers.

The Tshiombo irrigation scheme in Thohoyandou in the Vhembe district of was selected for the study (Fig. 3.5). The scheme is among the best irrigation projects in the province. The Tshiombo community is made up of seven villages, including

Matangari, Maraxwe, Tshiombo, Mianzwi, Muhotoni, Mbahela and Mutshenzheni, which make up the seven blocks in the irrigation scheme.

Figure 3.5: Tshiombo irrigation scheme
(Source: Mwadzingeni et al., 2020)

The project team and extension officers from the LDARD in the Thulamela Municipality organised a focused group discussion with a diverse group of irrigation farmers in the Tshiombo irrigation scheme (Fig. 3.6).

Figure 3.6: Focused-group discussions with farmers at Tshiombo irrigation scheme in Matangari, Thulamela Municipality

A total of 35 farmers were interviewed, each bringing a unique perspective based on their location in the scheme and the position they hold (e.g., chairperson of one block or an ordinary farmer). The focus group was used to determine the farm characteristics, support services (market access, extension services, financial support), training and capacity building, water user association, perception of water-saving strategies, water costs, water access and availability and the impacts of climate change on water availability.

The rainfed farmers were found in the Lwamondo area outside Thohoyandou (Fig. 3.7).

Figure 3.7: Focused-group discussions with rainfed farmers at Lwamondo, Thulamela Municipality

3.5.4 Stakeholder workshop and meetings

A stakeholder workshop was organised and held in August 2024 as part of the FGD process. The workshop was held on the 8th August 2024 at Manhattan Hotel in Pretoria. The workshop was on policy and governance frameworks for implementing IDAWM in South Africa. The objective of the stakeholder workshop was to solicit inputs from key stakeholders on the policy, governance and institutional systems for creating an enabling environment for the implementation of the IDAWM framework in the country. Stakeholder inputs were collected through a number of questionnaires or worksheets. The areas covered in the workshop were:

- Enabling environment: The degree of support of legislation, policies and strategies for the four AWM systems in South Africa; and
- IDAWM-related legislation, policies, plans, strategies and guidelines.

The workshop was attended by officials from WRC, DWS, LDARD, ARC, DoH, TUT, UNIVEN and Clovita Consulting Services. The workshop was conducted through group discussions (Figs. 3.8 and 3.9) and a report-back plenary session (Fig. 3.10).

Figure 3.8: Group 1 in session during the stakeholder workshop

Figure 3.9: Group 2 in session during the stakeholder workshop

Figure 3.10: Plenary session in progress during the stakeholder workshop

Effective AWM is crucial for sustainable farming, ensuring water availability and addressing challenges posed by climate change. To address these issues, several meetings were held with key stakeholders. These were representatives from the Gauteng Department of Agriculture, Rural Development and Environment (GDARDE), DALRRD, Department of Water and Sanitation (DWS), as well as farmers. The primary objectives were to source information on the status of AWM both at national and provincial level. In addition, to identify challenges in AWM and discuss potential solutions and strategies for effective water use.

With regards to a meeting with officials from DALRRD, data of the national status of AWM was supplied. Some of the information was sourced through emails from the officials. Information on the status of rainwater, farmer-led irrigation and irrigation schemes at the national level was provided by DALRRD. There was an outcry about the use of municipal wastewater for irrigation, however the government is investing in wastewater treatment plants for agricultural use. Currently, some farmers are using grey water for irrigation purposes.

In Limpopo Province, the stakeholders engaged with included the local extension officers from the LDARD in Thulamela Municipality. The aim was to find ways to identify farmers in all the four pathways in Thulamela. During one of the stakeholder meetings, the project team made a presentation of the project's background, aims and objectives, people involved in the project, study locations (project methodology) and discussed in detail the four pathways and how different they are from one another. The stakeholder meetings were held with extension officers from the LDARD (Fig. 3.11) and irrigation scheme management officials (Fig. 3.12). The team also showed the extension officers the typical farm characteristics of the various pathways and described the kinds of farmers needed in each pathway.

Figure 3.11: Stakeholder meeting with the extension officers from the LDARD in Thulamela Municipality

Figure 3.12: Stakeholder meeting with irrigation scheme management officials in Thulamela Municipality

3.6 Data analysis

The collected data were analysed using the Statistical Package for the Social Sciences (SPSS 22), Statistical Software for Data Science (STATA 15) and Atlas.ti. Descriptive statistics was employed to describe smallholder farmers' characteristics. Econometric models such as logistic regression (binary, ordered, etc), factor analysis, OLS, etc. were also used to investigate the objectives of the study. Apart from the questionnaire, data and information on AWM practices in the country were obtained through desktop review of various reports and documents from key institutions.

3.7 Ethical considerations

This study was approved by the Faculty Committee for Research Ethics of the Tshwane University of Technology (TUT) [FCRE 2023/07/006 (SCI) (FCPS 01)] and the Research Ethics Committee of the University of Venda (UNIVEN) [Ethical Clearance No. FSE/24/PSS/01/1311]. Permission was also obtained from the LDARD and the Gauteng Department of Agriculture, Rural Development and Environment. The participants signed a consent form after the study purpose was explained to them.

CHAPTER 4

IDENTIFYING, MAPPING AND ASSESSING IDAWM PRACTICES

4.1 Overview of AWM practices

4.1.1 Concept of AWM

The term "agricultural water management" is broad, covering a wide range of technologies and practices aimed at improving water and land management. It includes capture and storage (in dams, in groundwater), as well as the drainage of any water used for agriculture (crops, livestock, fish); lifting and transporting water from where it is captured to where it is used for agricultural production or removing excess water from where agriculture is practiced; and infield application and management of water, including land management practices that affect water availability to crops (Merrey *et al*., 2006). Thus, AWM encompasses the management of water used in crop production (both rainfed and irrigated), livestock production and inland fisheries. Improved AWM in these production areas is crucial for global food security and poverty reduction.[5] Namara *et al*. (2006) argue that in-field application and the management of water and land are the common denominators, regardless of the water source and are critical elements of all agriculture. Therefore, AWM is essential for successful agricultural production.

4.1.2 AWM practices

AWM comprises a suite of water management practices in agriculture, including but not limited to watershed management, water capture, storage, conveyance and application. This holistic focus is strategic because the sustainable and productive water management in agriculture requires attention to several factors, including inter alia, climate change and variability, crop selection, animal nutrition, maintaining ecosystem goods and services and soil quality. For example, irrigation alone does not guarantee increased crop productivity on nutrient-poor soils; pests and diseases can severely diminish water productivity; and changes in precipitation or temperature may render some agricultural options untenable (Jones & Thornton, 2009).

Improving management practices must be approached on multiple levels: from individual farmer to basin management, to national law and policy on water use. Management at the watershed and landscape scale is critical for mitigating risks from floods and droughts, thus enhancing resilience to climate change and variability. In some cases, large-scale infrastructure water management interventions are not the best investment. Numerous studies have shown that supplemental irrigation – irrigating only during critical crop growth and development periods – can result in greater crop and water productivity (Fox *et al*., 2005; World Bank, 2006). Coupling supplemental irrigation with rainwater harvesting can increase yields 2-3 times more than conventional rainfed agriculture. The reuse of wastewater and recycled water can reduce the demand for additional freshwater withdrawals and energy consumption (World Bank, 2006).

Some practices may provide multiple benefits and have multiple trade-offs, e.g., bunds store water and reduce run-off, but the increased water surface area may result in more cases of malaria and greater evaporative losses. Constructing water storage structures with a low surface area to volume ratio mitigates these issues. Practices

[5] https://eos.com/blog/agricultural-water-management/

such as minimum tillage and mulching can retain or increase soil organic matter, increasing the soil's capacity to hold water and decrease evaporation, thus facilitating groundwater recharge (Leakey *et al*., 2009). According to Barron *et al*. (2009), AWM practices involve changes in the partitioning of water when reaching the soil surface. Thus, most in-situ (including most soil and water conservation technologies) and ex-situ water management practices qualify.

The source of water for AWM interventions, which include irrigation can be rainwater harvesting, groundwater, re-located stream flow or recycled water. Other crop management activities can also directly and/or indirectly alter the water balance at the field level, potentially impacting the management of agricultural water at a landscape scale. Barron *et al.* (2009) identified eight AWM clusters. For each of these clusters, there are AWM practices with associated changes in the field water balance as presented in Table 4.1. Some AWM practices are often combined; for example, development of irrigation is often coupled with changes in cropping systems.

Table 4.1: AWM clusters, technologies and principal change in water balance at field scale

AWM Clusters	AWM Practices	Principal change in field water balance
In-situ on/off farm	Conservation tillage, terracing, soil conservation technologies, other rainwater harvesting structures in landscape	Increase infiltration into unsaturated soil (recharge) and reduce surface runoff
Development of storage	Ponds, dams, shallow wells	Increase residence time of water in specific landscape and if used as irrigation, reduce surface runoff and potentially increase transpiration and/or field evaporation
Development /adoption of irrigation	Sprinkler, furrow, drip/micro irrigation, bucket irrigation, treadle pump	Potentially increase transpiration ana/or field evaporation, other impacts depend on source of irrigation water
Develop water supply	Irrigation canal construction and/or rehabilitation (i.e., lining, etc.)	Reduced use of water for other purposes, including aquatic and/or other ecosystems services
Develop source of water	Greywater, wastewater treatment and reuse, spring development, borehole development	Potentially increase transpiration and/or field evaporation, other impacts depend on alternative uses of this water source
Reclaim/expansion of crop land	Rehabilitation of degraded land and gully, live fencing	Increase infiltration into unsaturated soil (recharge), more water available from biomass production (transpiration and/or evaporation, recharge groundwater) and reduce surface runoff

AWM Clusters	AWM Practices	Principal change in field water balance
Increased use of organic matter (OM)	Use of manure, compost, plant residues	Increase infiltration into unsaturated soil (recharge), increased water holding capacity, more water available from biomass production (transpiration and/or evaporation), better water uptake by plants (due to improved nutrient availability with OM) and reduce surface runoff
Change of crop system	Crop variety adoption, tree planting, kitchen garden	Increased uptake of water for transpiration and evaporation, reduced recharge (if multiple crops, sequential cropping)

(Source: Barron *et al*., 2009)

Namara *et al.* (2006) identified AWM practices and three main groups of technologies; namely, technologies for water control and storage, technologies for water lifting and conveyance and field water application technologies. Table 4.2 presents the AWM practices under the three groups of AWM technologies.

Table 4.2: Some of the AWM practices

AWM technologies	AWM practices	AWM examples and/or details
Technologies for water control and storage	In situ soil and water conservation	Ripping only the planting line using a tractor or animal-drawn 'ripper tine', rather than normal ploughing
		Tied ridges for holding water and facilitating infiltration in low rainfall areas (there are a variety of types of ridges
		Mulching using both crop residue and material from non-cultivated areas for holding water, returning nutrients to the soil and in some cases reducing the temperature of the soils
		Agroforestry and green manure or cover crops, many of which contribute to nitrogen fixation
		Conservation agriculture
	Ex-situ water harvesting and storage	Small storage tanks
		Charco dams
		Rooftop rainwater harvesting and above ground storage tanks
		Underground tanks to catch surface runoff
		Hand dug shallow wells
		Boreholes
Technologies for water lifting and conveyance	Treadle pumps	A foot powered water pump widely used in Asia and increasingly in Africa
	Mechanised pumps	Water-lifting devices used to withdraw water from surface water sources,

AWM technologies	AWM practices	AWM examples and/or details
		groundwater sources and reservoirs or to pump water into distribution systems
	Pipe network	Water conveyed through a network of pipes
	Canal network	Water conveyed through a network of canals (lined or unlined)
Field water application technologies	Drip/micro irrigation systems	Drip irrigation allows thr precise application of small amounts of water directly to the root zone hence it enables the farmer to make use of limited amounts of water and fertilizer which can be applied together with the irrigation water to grow high value crops
	Clay pot (sub-surface irrigation), also called '*pitcher*' irrigation	This is a low-cost indigenous sub-surface drip system achieved by use of unglazed fired clay pots that remain micro-porous and are moulded by hand by rural women
	Sprinkler systems	Sprinkler Irrigation is a method of applying irrigation water which is similar to rainfall
	Flood irrigation	Furrow
		Basin

(Adapted from Namara *et al*., 2006)

4.1.3 AWM practices under rainfed systems

AWM is vital in rainfed agriculture globally and encompasses diverse strategies tailored to regional needs (African Union, 2020). These strategies, as recognized by the AU (2020) and Namara *et al.* (2010) include conservation agriculture, water harvesting, full and supplementary irrigation and various wetland development techniques. Rainwater harvesting (RWH), in particular, is frequently promoted to improve water productivity in small-scale rainfed agriculture (Ziye & Junying, 2016). This practice intentionally collects, stores and manages rainfall and various forms of precipitation from different catchment surfaces (Kimani *et al*., 2015). Storing and preserving additional rainwater for productive use can assist in managing extended periods of drought, a significant obstacle encountered by rainfed agriculture, particularly in arid and semi-arid regions across the globe (Piemontese *et al*., 2020).

Water management under rainfed systems involves a suite of management practices which include soil and water conservation practices that reduce erosion and increase water infiltration into soil. Slope stabilisation, bunds and terraces are some of the more commonly used practices with these aims. Care must be taken to use practices appropriate for the context. Diversified agricultural systems can make more productive use of water. For example, agroforestry systems close their canopies earlier, which reduces soil evaporation and run-off and they tap water from deeper soil horizons (Riha & McIntyre, 1999). Farmers have historically coped with climate change and variability by diversifying their agricultural systems (Mortimore, 2010). Integrating crop and livestock production is a common risk mitigation strategy in semi-arid and arid environments.

Supplemental irrigation is one of the efficient technologies used to mitigate soil water stress on crops, increase yields and enhance water productivity in rainfed systems (Ndhleve *et al*., 2017; Hessar & Oweis, 2021). The majority of the rural poor depend on rainfed farming systems for their livelihoods, which account for about 72% of the world's harvested crops and rangelands (IWMI, 2007). AWM practices in rainfed farming systems improve water retention and percolation at field level – such as no till, mulching, contour ridging, infiltration pits, among others – and these result in more water being available in the soil for plant growth, thus increasing productivity and groundwater recharge as well.

The water management practices in rainfed farming systems include: (i) flood-based farming systems (spate irrigation), whereby flood water is diverted from a river to low-lying areas for crop, rangeland and forest watering, as well as for harvesting livestock drinking water; and (ii) water harvesting, i.e., the collection and storage of water in reservoirs and tanks (natural or man-made) or facilitating the infiltration of water into the ground (Chitima & Rutten, 2015). Some techniques for in-field water harvesting are contour ridges, bunds, grass cover strips, micro-catchments around the crop and terracing. Under rainfed systems, the main aim of managing agricultural water are to increase water availability to plants and increase plant water uptake (Namara *et al*., 2006). The rainwater management systems, the purposes and the rainwater management practices under these broad aims are presented in Table 4.3.

Table 4.3: Rainwater management strategies and corresponding management options

Aim	Rainwater management strategy	Purpose	Rainwater management practices
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,

Aim	Rainwater management strategy	Purpose	Rainwater management practices
			agroforestry, early plant vigour, 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: Namara *et al*., 2006)

4.1.4 AWM practices under farmer-led irrigation development system

Farmer-led irrigation development is defined as a process where farmers assume a driving role in improving their water use for agriculture by bringing about changes in knowledge production, technology use, investment patterns and market linkages and the governance of land and water (Woodhouse *et al*., 2017). In the process, farmers rely on and influence neighbouring farmers, agro-dealers and traders, craftspeople, agriculture extension agents and irrigation engineers, administrative authorities, local and national policy-makers, civil society and development aid agents.

Farmer-led irrigation systems may consist of several furrow irrigation systems which take water from one stream, sometimes additionally capturing water from side streams, springs or neighbouring catchments. The other water management practices associated with FLID are the use of shallow groundwater in valley bottoms as well as of petrol or diesel pump irrigation from open water bodies and shallow groundwater (Woodhouse *et al*., 2017). Under FLID, farmers invest their own resources and access water from shallow groundwater, rivers, lakes and reservoirs.

These are an attractive option to small-scale farmers because they use simple affordable equipment, including buckets, watering cans, treadle pumps, drip systems and conservation agriculture technologies, such as terracing and in-situ rainwater harvesting[6]. In some cases, small-scale farmers irrigate vegetable crops using buckets, watering cans and small motorised pumps. Small-scale farmer-led irrigation involves the diversion of water from one area into a relatively small area for the purpose of supplementing available water for crops. The techniques of diverting the water include the use of gravity through canals or pipes and lifting water through the use of pumps for application in the fields through various irrigation methods (FAO, 2001).

[6] https://www.future-agricultures.org/blog/fao-recognises-farmer-led-irrigation-as-a-major-contributor-to-agricultural-development/

4.1.5 AWM practices under irrigation scheme development

The water management practices in an irrigation scheme are influenced by the physical and management systems. The physical system consists of water sources which may be a dam, diversion weir or a well. The water may be abstracted by a pump into a primary canal, whose function is to conveying the large volumes of water. Secondary canals provide the bulk distribution of water to the outlets serving upper command areas. Tertiary canals are situated in the upper command areas with turnouts which serve the individual farms or fields in the upper command area. The excess water from the field is removed by above and/or below ground drainage systems. The basic management system of an irrigation scheme consists of:

- The public or private agency responsible for the main water supply system;
- Sets of upper command area water user associations (WUAs);
- Formal or informal WUAs or community management groups; and
- Individual farmers.

Another way of looking at AWM in irrigation schemes is to consider South African Framework for Improved Efficiency of Irrigation Water Use which Reinder (2011) developed. The framework covers 4 levels of water-management infrastructure: the water source, bulk conveyance system, the irrigation scheme and the irrigation farm (Table 4.4).

Table 4.4: Four levels of water management infrastructure

Water management level	Infrastructure system components	
Water source	Dam/reservoir	
Bulk conveyance system	River	Canal
Irrigation scheme	On-scheme dam	
	On-scheme canal system	
	On-scheme pipe system	
Irrigation farm	On-farm dam	
	On-farm pipe system	
	On-farm canal system	
	In-field irrigation system	

(Source: Reinder, 2011)

According to Mabuza and Ndoro (2023), although irrigation water management practices (IWMP) of the farmers at irrigation schemes are influential to the farmers success, small-scale irrigation farmers on irrigation schemes have limited competency in IWMP.

4.1.6 Wastewater use for irrigation

Wastewater irrigation is a common established practice in urban and peri-urban areas in Africa. Practices range from the use of polluted surface water, to raw wastewater to the piped distribution of secondary or tertiary treated wastewater to irrigate different kinds of crops and trees. This illustrates the challenge of estimating the extent of “wastewater” irrigation with global figures ranging from 4 to 20 million ha (IWMI, 2006). There are only a few countries in Africa such as South Africa, Tunisia or Namibia with experience in planned reuse and a record of wastewater treatment plants producing a safe effluent (Bahri *et al*., 2008). In most of the other countries, urban wastewater is widely used to irrigate vegetables, rice and fodder for livestock.

Wastewater irrigation can be both a major health risk for farmers and consumers and a major economic contribution in terms of jobs and food supply. Among the health risks that are of particular concern are endemic and epidemic diseases (cholera, typhoid, etc.) (WHO, 2006). Wastewater irrigation also raises issues related to environmental protection as its nutrient, salt and other contaminants contents can be high. However, it is usually not a choice for farmers to use “wastewater” or not as it is often difficult to find clean water sources in and around most cities.

it has many advantages for farmers as it can contain – depending on the degree of dilution – significant amounts of nutrients for food crop production that reduce the need for chemical fertilisers. Wastewater content in organic matter, nitrogen, phosphorus and potassium may improve soil fertility, enhance plant development and increase agricultural productivity. More important, however, it is a reliable water supply, usually free-of-charge and continuously available in urban market vicinity. Wastewater reuse supports the livelihood of many farmers and traders and plays a significant role in poverty alleviation. It also provides a niche for urban food supply complementing rural production (Drechsel *et al*., 2006, 2007).

From the IWRM perspective, reuse is desirable as it conserves freshwater and contributes to reduce unplanned wastewater discharge and pollution of water bodies and the environment in general. The integration of urban and peri-urban agriculture into urban sustainable sanitation planning is therefore critical in African cities and should be considered as a contribution to sanitation services if the lack of full urban wastewater treatment can be compensated for by treatment options for health risk reduction at the farm level as outlined by the World Health Organisation (WHO) (2006).

Health risks related to wastewater irrigation should be targeted in the general context of poor water supply and sanitation and not in isolation. What is generally known is that the lack of clean, adequate, safe and affordable water and of safe sanitation facilities affects people’s life, health, growth and development. It affects more particularly women and children in charge of water collection and raises issues of personal safety and dignity (Norström, 2007). It jeopardises children’s education and gender equity (WHO & UNICEF, 2006).

On the other hand, the impact of safe water for irrigation is huge as it can increase economic well-being at the household level, mainly through saving large amounts of people’s time and energy. The growing water demand and the discharge of mostly untreated wastewater pose a huge challenge for managing water resources in an integrated manner. Direct reuse of wastewater as well as the use of freshwater resources polluted by wastewater in farming are very common throughout urban and peri-urban Sub-Saharan Africa (SSA) (Bahri *et al*., 2008). Bahri *et al.* (2008) argue that despite a positive impact on local economies with large socio-economic benefits from the irrigated areas, public health risks arising from the use of wastewater for irrigation are undeniable.

4.2 AWM practices in South Africa

The identification, mapping and assessment of the IDWAM practices investigated practices related to agricultural water under rainfed and irrigated farming systems. The study focused on AWM practices under the four pathways of rainfed farming, farmer-led irrigation system, irrigation scheme systems and wastewater reuse for irrigation. The various AWM systems are associated with both commercial and subsistence farming systems. Most of the irrigated agricultural practices are linked to commercial farming while most of the rainfed agricultural practices are linked to subsistence farming (Table 4.5).

Table 4.5: Degree of link of AWM systems to commercial and subsistence farming

AWM System	Commercial farming (degree of link)	Subsistence farming (degree of link)
Rainfed farming	10%	60%
Farmer-led irrigation development	80%	20%
Irrigation scheme development and modernisation	60%	30%
Unconventional water use for irrigation	40%	30%

(Source: DAFF, 2015)

Table 4.6 presents the distribution of the AWM systems in the country
Table 4.6: Prominence of the various AWM systems in the Country

AWM System	Prominence of the AWM in the Country
Rainfed farming	Limpopo
Farmer-led irrigation development	All provinces
Irrigation scheme development and modernisation	Limpopo, Eastern Cape, KwaZulu-Natal, North West
Unconventional water use for irrigation	All provinces

(Source: Stevens & van Koppen, 2015)

The major crops produced under the various AWM practices are presented in Table 4.7.
Table 4.7: Major crops under the various AWM systems in the Country/Province

AWM system	Major crops
Rainfed farming	Wheat, barley, sorghum and maize (DEA, 2013)
Farmer-led irrigation development	Maize, sunflower, wheat, Lucerne, vegetables, citrus, cotton, sugar cane, fruits and ground nuts (Botlhoko, 2012)
Irrigation scheme development and modernisation	Maize, sugarcane, tomatoes, potatoes, beans, peas, cotton, wheat, ground nuts (Botlhoko, 2012).

AWM system	Major crops
Unconventional water use for irrigation	Fodder, grass, vegetables, tree crops (Botlhoko, 2012).

In the country, the largest contribution to agricultural production comes from farmer-led irrigation systems (50%) and followed by irrigation schemes (25%) as presented in Table 4.8.

Table 4.8: Contribution of agricultural production by the various AWM systems

AWM System	Contribution of agricultural production (%)
Rainfed farming	20%
Farmer-led irrigation development	50%
Irrigation scheme development and modernisation	25%
Unconventional water use for irrigation	5%

(Source: DAFF, 2015)

4.3 Rainfed farming systems in the country

Rainfed agriculture is a predominant form of farming in South Africa, whereby approximately 80% and more of the land that is cultivated is used for rainfed agriculture. There are a number of farmers practicing rainfed farming across the country. However, the details of rainfed farming are scanty as the DALRRD does not have records and data regarding these farmers and as to where they are located in the municipalities, as well as the crops they grow. Generally, the land size for most rainfed farmers is between 1-3 ha. However, there are some rainfed farmers who have larger land size greater than 5 ha. The most common crops which these farmers normally grow include maize, sorghum, tobacco, cotton, beans, nuts and sunflower. The available data show that the total land under rainfed farming system in the country is 10,779,615 ha, which is 80% of the agricultural land. Under rainfed farming system supplemental irrigation is practiced as a mitigation measure against intra-seasonal droughts. The main AWM practices in rainfed farming system are presented in Table 4.90.

Table 4.9: Irrigation practices and AWM practices employed in rainfed agriculture

AWM domain	AWM practices
Irrigation practices	• Furrow Irrigation • Infield rainwater harvesting
Water management practices	• Conservation agriculture • Rain/water harvesting • Pasture farming • Mixed farming • Drainage

(Source: Cai *et al*., 2017)

Rainfed farming in the country is supported by the government in various ways. There are pieces of legislation, policies and strategies which government has developed to support rainfed farming. The following are the pieces of legislation, policies and strategies which support rainfed farming:

- National Water Act (No. 36 of 1998)
- Water Services Act (No. 108 of 1997)
- The National Water Policy (1997)
- National Water Policy Review (2013)
- National Water Resources Strategy (2013)
- National Water Conservation and Demand Management Strategy 2004
- Conservation of Agricultural Resources Act (No. 43 of 1983)
- Irrigation Strategy 2015

Successful cases of rainfed farming practices include rainwater harvesting and faming drip system projects in Mpumalanga, North West and Eastern Cape provinces and the Agricultural Research Council (ARC) infield rainwater harvesting project in Thaba Nchu, Free State Province. Rainfed farming system is affected by climate variability and change through drought which reduces crop productivity and through floods which destroy crops. Rainfed agriculture is a farming practice that relies solely on rainfall for water. It is crucial for food security, especially in regions where irrigation infrastructure is limited or non-existent.

Figure 4.1 shows a harvested field of maize in the Gauteng Province. Most of the farmers depending on rainwater for irrigation are farmers producing maize, soyabean, groundnuts, dry beans, sorghum etc. Others produce indigenous vegetables (some grown by themselves during rainy season). On average, these farmers produce on a 20 ha of land, in particular for grain farmers on their own land. They are using a conventional way of tillage, practicing intercropping. None of these farmers received training on water management and there is a need for them to attend that training. None of them are aware of the water user associations.

(a) (b)

Figure 4.1: Fields of maize (a) and soyabean (b) under rainfed farming in Bronkhorstruit, Gauteng Province.

One of the major challenges faced by rainfed farmers is climate change. The problems associated with climate change include: rainy season starting later than usual; unreliability and unpredictability of rainfall; high temperatures that cause drought; and heavy rainfalls that damage crops. Some of the small-scale farmers practice rainwater harvesting using jojo tanks for both irrigation and home consumption.

In Kanana, Hammanskraal, rainfed farmers rely on hand-dug wells for supplementary irrigation during dry periods (Fig. 4.2). In the absence of rainfall, they manually draw water from the wells using buckets. Although the wells may appear shallow in photographs, they are actually quite deep. A rope is tied to one of the buckets, allowing it to be lowered into the well and pulled back up with ease. The water is then transferred to another bucket, which is carried to the field for irrigation purposes (Fig. 4.3).

Figure 4.2: Hand-dug well

Figure 4.3: Rianfed farmers using water collected from a hand-dug well for supplemental irrigation in Kanana, Hammanskrall, Pretoria

4.4 Irrigation water resources and systems

The study also assessed the water resources that farmers use for irrigation in the country as these influence the irrigation systems and the AWM practices.

4.4.1 Irrigation water resources

Irrigation water resources data were obtained from the DWS. The data were analysed to determine the amounts of water issued by the DWS to farmers for irrigation at regional and district municipality levels. The data were also analysed to determine the main water resource types for irrigation in the country as well project team managed to obtain irrigation water data from the DWS. The data were for different numbers of years and they were statistically analysed to determined mean values.

Farmers who want to irrigate their crops are obliged to obtain permits from the DWS to obtain water from various sources for their irrigation systems. The volumes of water per year issued by the DWS to irrigation farmers at regional level are presented in Figure 4.4. The largest volume is issued in the Mpumalanga region which is a reflection of the high irrigation production in the region.

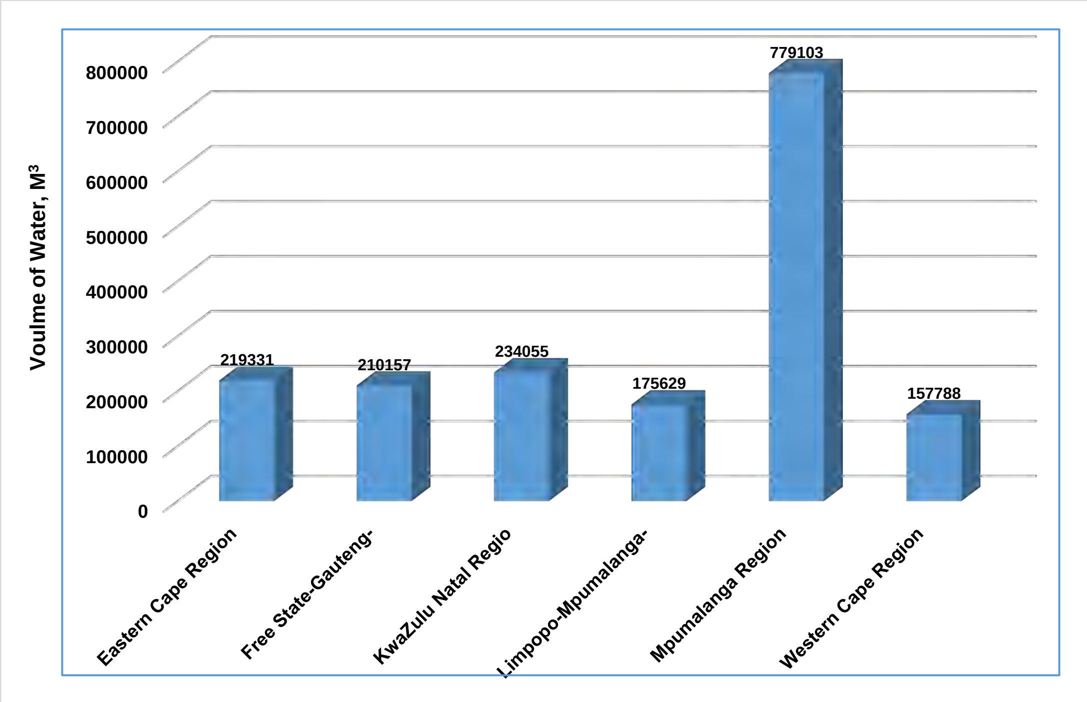


Figure 4.4: Mean volume of water issued for irrigation at regional level (Data Source: Department of Water and Sanitation, 2024)

The largest mean volume of irrigation water issued at a district municipality level is in Frances Baard District Municipality in the Northern Cape Province (Fig. 4.5). The water resource type with the largest number of irrigation farmers at national level is schemes followed by wetland (Fig. 4.6). This means the largest number of farmers obtain their irrigation water through scheme sources.

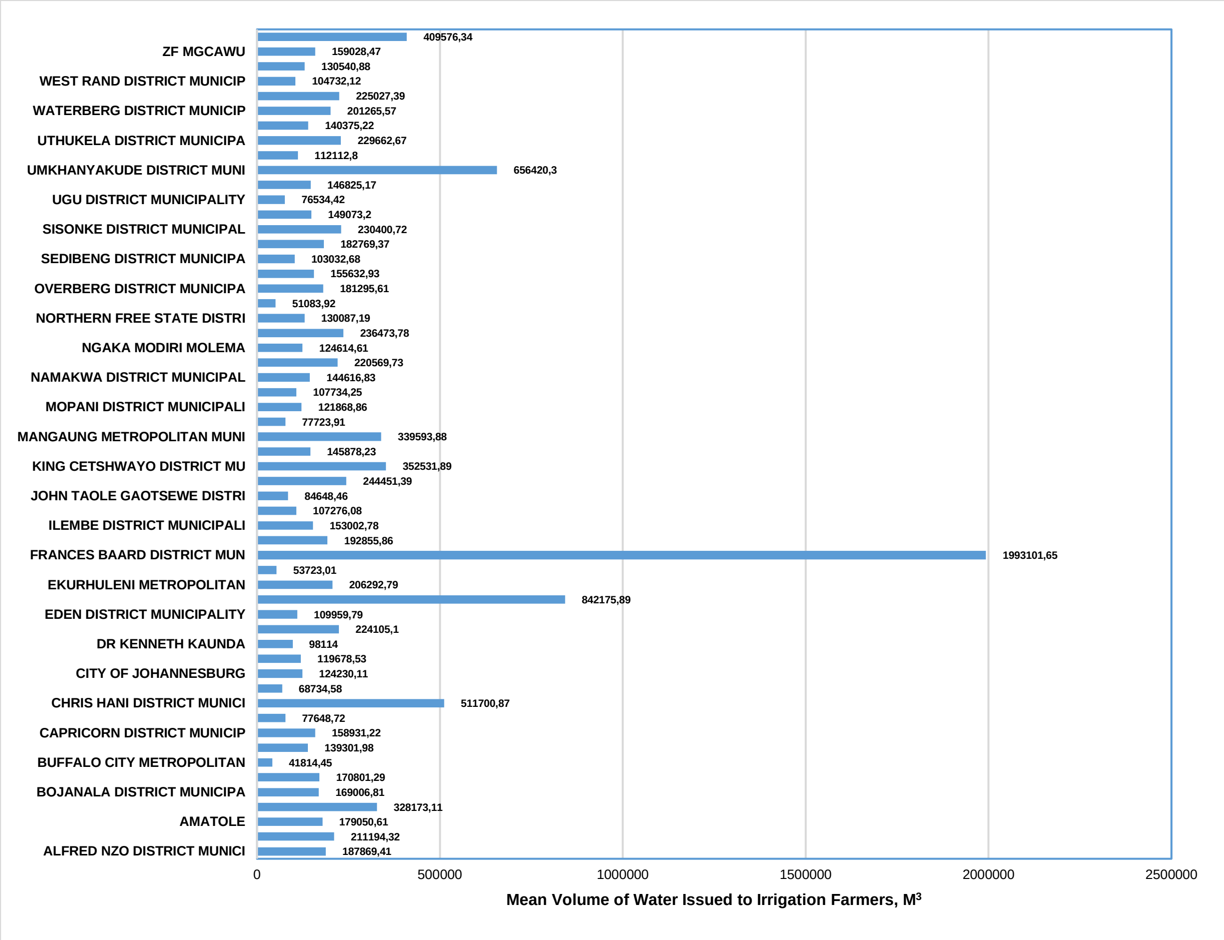


Figure 4.5: Mean volumes of water issued to irrigation farmers at the District Municipality level
(Data Source: Department of Water and Sanitation, 2024)

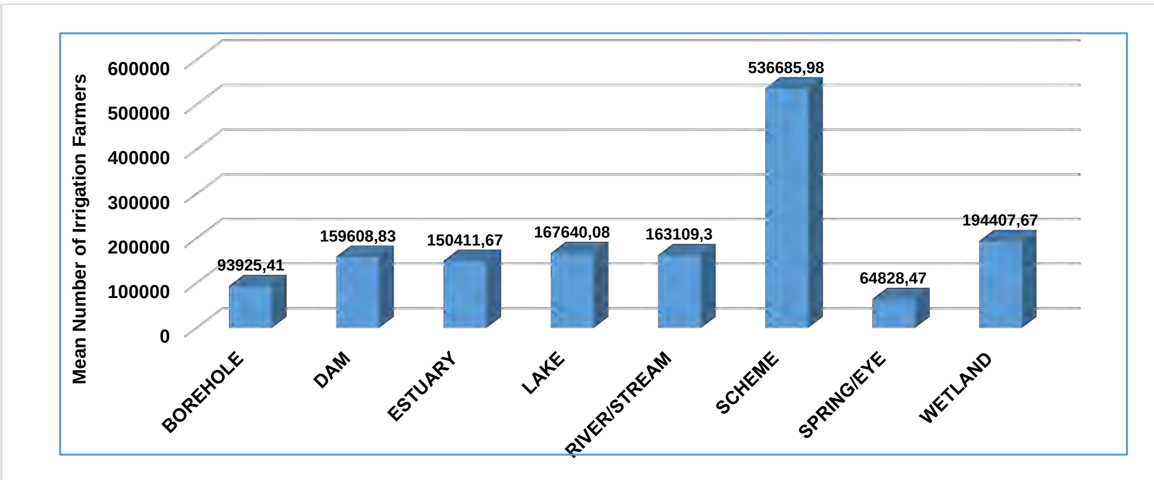


Figure 4.6: Mean number of irrigation farmers sourcing water from the different resource types in the country
(Data Source: Department of Water and Sanitation, 2024)

The largest mean volume of irrigation water at regional level is scheme and Mpumalanga Region has the largest volume followed by Free State – Gauteng Region – Northern Cape Region (Fig. 4.7).

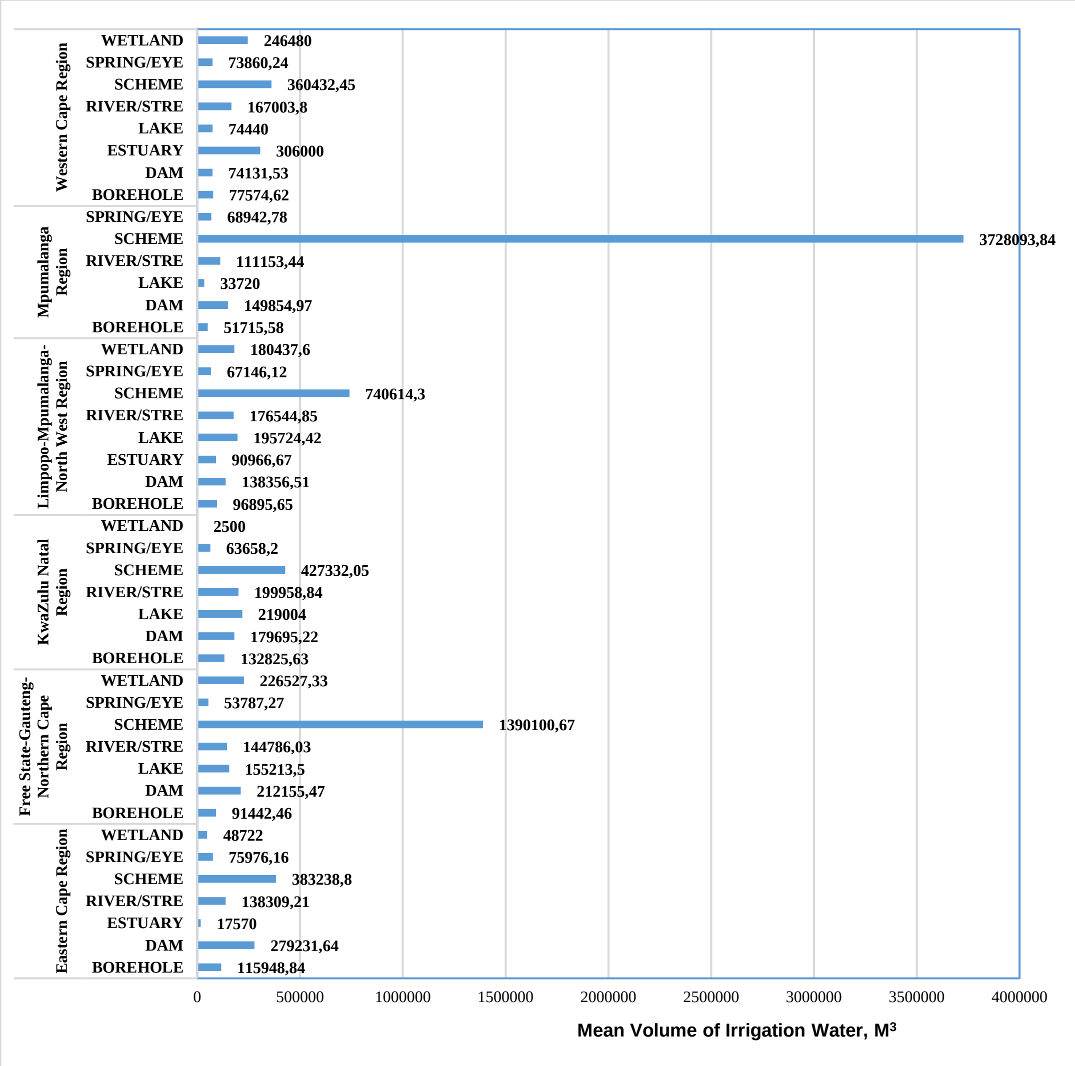


Figure 4.7: Mean volumes of irrigation water sources at regional level (Data Source: Department of Water and Sanitation, 2024)

4.4.2 Irrigation systems

The two irrigation systems considered in this study are farmer-led irrigation and irrigation schemes. This sub-section covers the irrigation system used in the country. The total irrigated land as a percentage of agricultural land is 65% (Table 4.10). As presented in Table 4.10, the irrigation practices in the country include surface (where water is conveyed and distributed by lined canals (10%) or earth canals (5%), sprinkler system, drip, micro-spray and centre-pivot. Centre-pivot covers the largest area (29%), followed by drip irrigation (22%).

Table 4.10: The current situation regarding irrigation development

Irrigation system	Area covered
Total irrigated land (% of agricultural land)	65%
Land under surface irrigation (Flood lined canal supplied) (% of irrigated land)	10%

Land under surface irrigation (Flood earth canal supplied) (% of irrigated land)	5%
Land under sprinkler irrigation (% of irrigated land)	15%
Land under drip irrigation (surface and subsurface) (% of irrigated land)	22%
Land under micro-spray irrigation (% of irrigated land)	5%
Land under centre pivot (% of irrigated land)	29%

The distribution of the irrigation systems in the country is presented in Table 4.11. Surface irrigation with lined calas is prominent in the KwaZulu-Natal Province, while centre pivot irrigation systems are prominent in the Nort West and Western Cape provinces.

Table 4.11: The prominence of irrigation system in the country

Irrigation system	Province where the system is prominent
Land under surface irrigation (Flood lined canal supplied)	• KwaZulu-Natal
Land under surface irrigation (Flood earth canal supplied)	• North West • Western Cape • Northern Cape
Land under sprinkler irrigation	• Free State • Mpumalanga • Gauteng
Land under drip irrigation (surface and subsurface)	• Limpopo • Free State • KwaZulu-Natal,
Land under micro-spray irrigation	• Gauteng • Northern Cape • Western Cape
Land under centre-pivot	• North West • Western Cape

4.5 Farmer-led irrigation farming

The FLI farmers are independent farmers who play a role in improving their water use for agriculture by taking the lead in the establishments and improvements through their own initiatives. The majority of these farmers get water from the rivers, groundwater (borehole) and the municipal water and they use different ways/equipment's to irrigate. The characteristics of these farmers include that they use watering cans, bucket, drip and sprinkler irrigation to irrigate their crops. Furthermore, the majority of the farmers practicing farmer-led irrigation have a land size less than 1.5 ha and they practice both conventional and conservation agriculture (minimum tillage, mulching and different cropping systems). These farmers plant a variety of crops each season due to access to water to irrigate, but the majority of the crops planted include maize, beans and vegetables (tomatoes, onions, peppers, carrots, lettuce, spinach and cabbage).

While FLID varies in its appearance, there are several irrigation practices developed through FLID that are widespread in the country, including irrigation from earthen canals in mountainous areas, the use of shallow groundwater in valley bottoms, petrol pump irrigation from open water bodies and peri-urban agriculture using wastewater. The study has shown that the system involves practices such as diversion of streams using earthen main canals carrying the water from the stream to the field often referred to as the furrow. Usually, along a stream, several diversions are constructed, sometimes creating networks of interlinked canals on the hill slopes. Water is predominantly used for intensive production of marketable vegetables, but also for supplementary irrigation of staple crops, particularly in times of droughts.

Valley bottoms in dry regions can be relatively wet due to their shallow ground water levels. Over the past 40 years, there has been a gradual shift in the use of such valleys from dry season grazing to intensive dry season vegetable production. During the wet seasons, they are more commonly used for rice production. Supplementing available soil water moisture, water is collected by manually scooping it from shallow dug wells and through the use of pumps on such wells (Muturi *et al*., 2019). After the rainy season, farmers try to drain access water as soon as possible, while drains are closed later in the season to hold on to as much water as possible to sustain growth in the dry season.

Petrol and diesel pumps have emerged as an irrigation technology for small holder farmers to pump water from open water bodies, such as lakes and rivers for intensive horticultural production. In some cases, small pumps are used to draw water from reservoirs behind dams in order to irrigate larger areas upstream of the dam rather than by gravity downstream (de Fraiture *et al*., 2014). In other cases, horticultural production by means of petrol pumps provides an alternative to declining fisheries hence an important alternative economic opportunity for young people in the area (Bosma, 2015).

Small-scale horticultural producers in cities and peri-urban areas often make use of waste water – diluted or raw – creating serious health risks both for those handling the water and for consumers buying the products of such irrigation (Muturi *et al*., 2019). Watering cans are commonly used for this type of irrigation. Though laborious, this technology often suffices for the generally small plot sizes in the city, which are mostly limited to between 0.01 and 0.02 ha per farmer (Muturi *et al*., 2019). Motorised pumps are increasingly being used, especially where farmers can share a pump and where distances between the water source and the fields are large. Even in these cases, farmers continue to use the watering cans, drawing from a reservoir on the farm that is filled by the pump. In all these cases, FLID is strongly oriented towards producing crops for the market and almost 40% of irrigators adopt intensive production practices using fertilisers and improved seeds, while only 10% of non-irrigators do so (SAFI, 2018).

An increasing number of small-scale farmers are independently utilising irrigation. They purchase or rent irrigation equipment and source water from nearby dams, rivers, underground, operating without licence or interference from public agencies or water user associations. Most of the farmers using private or farmer-led irrigation are females operating on an average of 4 ha of land. Some are using community land such as school and church gardens producing leafy vegetables (cabbages, spinach, lettuce etc), tubers (potatoes, sweet potatoes) and root vegetables in Gauteng Province. Most of the farmers are using crop rotation. Very few farmers received AWM training, so there is a need for training. Farmers have no knowledge of the Water User Associations (WUA) and training on the importance of WUA is crucial.

Most farmers source water from dams, boreholes and municipalities. Then a sprinkler irrigation system is used for irrigation as they believe that it covers all the plants and saves time. Some source their water from the wells. The main challenges faced by farmers are theft of boreholes, boreholes damaged due to lightning during heavy rainfalls and low supply of water from the municipality. On average, a typical farmer irrigates 4 times a week and pay R600 per month for water. In addition, the level of food security is low and it can improve when access to irrigation water is improved.

The individualisation of AWM has been progressing for several decades in SSA, where most irrigation now relies on privately owned wells. Some farmers are using wells and ponds as a source for irrigation water for their crops. Water is collected through containers or pipes to the field. Crops produced and irrigated through these methods are sweet potatoes, root vegetables and leafy vegetables. Figure 4.8 shows a broken-down borehole while Figure 4.9 shows a farmer drawing water for irrigation from a well in Gauteng due to his boreholes not working.

Figure 4.8: A broken down well in Winterveld, Gauteng Province

Figure 4.9: A farmer drawing water from a well in Winterveld, Gauteng Province

Figure 4.10 shows a canal system with water flowing from the main Bon Accord dam to the private farm dam (Fig. 4.11), then a diesel pump is used to pump water from the farm dam to the field where workers are busy with their operations (Fig. 4.12). Some of the challenges faced by farmers is that the Bon Accord board may switch off the water flow from the main dam if the farmers fails to adhere to the monthly administration payment, although the source of this water is the municipality.

Figure 4.10: A canal system from Bon Accord dam feeding into a farm dam

Figure 4.11: Farm dam in Bon Accord, Gauteng Province

Figure 4.12: Farmers working on irrigation field in Bon Accord, Gauteng Province

In addition, most of the small-scale farmers are using municipal water for irrigation. The water is drawn from home taps (Fig. 4.13) through the use of containers or pipes to irrigate their fields. Crops produced are mainly leafy vegetables (both exotic and indigenous), tubers (carrots, carrots, potatoes, etc.) and chilies. Figure 4.14 shows a subsistence farmer irrigating her crops using a pipe connected to a tap for home consumption.

Figure 4.13: A farmer turns on water tap to irrigate a garden in Shoshanguve, Pretoria

Figure 4.14: A farmer irrigates a home garden with a hosepipe in Shoshanguve, Pretoria

It is common to see some farmers use dilapidated pipes used for conveying municipal water to irrigation farms (Fig. 4.15) among farmer-led irrigation farmers.

Figure 4.15: Dilapidated pipes for conveying municipal water to a farm, Thohoyandou, Thulamela Municipality

Some FLI farmers have tractors (Fig. 4.16) used for ploughing, tilling, disking, harrowing, planting and similar tasks on their irrigation farms. Furrow irrigation system (Fig. 4.17) is also common among small-scale irrigators. The fact that most of these farmers operate mostly outside the government and they are not easy to identify and map because they are not documented. In addition, the irrigated area established by farmers is not included in the government's database and FLID which is primarily small-scale and not formal falls into the group of the farmers who are rarely recorded (Venot *et al*., 2021).

Figure 4.16: Water tank and tractor at an irrigation farm, Malskop, Makhado Municipality

Figure 4.17: Furrow irrigation system at an irrigation farm, Malskop, Makhado Municipality

These irrigators operating outside formal irrigation schemes often lack access to the institutional and financial support systems. Such support includes agricultural advice, training, input support and infrastructure development. Furthermore, the FLID farmers use their home savings, pension funds and income from other sources to support the farms. One of the challenges that the farmers face is poor water quality or polluted water from rivers, the lack of access to extension services, capacity building and resources such as fertilisers. The climate change and variability (heat) affect crop development leading to crop failure.

4.6 Irrigation schemes

The country has larger and small-scale irrigation schemes (Table 4.12) situated in various provinces (Table 4.13). The Limpopo Province has the largest number of small-scale irrigation schemes, followed by the Eastern Cape Province.

Table 4.12: Current situation regarding irrigation scheme development

Irrigation schemes	Hectares or %
Total land under irrigation schemes (Ha)	2,280,000 ha
Land under large-scale irrigation schemes (Ha)	1,300,000 ha
Land under small-scale irrigation schemes (Ha)	1,354,000 ha

Table 4.13: Distribution of the various irrigation schemes in the Country

Irrigation schemes	Distribution (spatial/locations) in the Country
Large-scale irrigation schemes	North West/Northern Cape - Vaalharts Irrigation Scheme KwaZulu-Natal - Makhathini Irrigation Scheme North West - Taung Irrigation Scheme
Small-scale irrigation schemes	183 schemes in Limpopo Province 75 schemes in Eastern Cape Province 36 schemes in KwaZulu-Natal Province

In Gauteng Province, the government has established Agri parks which operate at the same level of irrigation schemes. Appendix B presents a summary of the small-scale irrigation schemes and their status in Thulamela Municipality, Limpopo Province. The revitalisation of small-scale irrigation schemes comprises an integral part of the land and agrarian reform and food security objective of Department of Agriculture, Land Reform and Rural Development (DALRRD), but lessons must be learnt from previous initiatives. The Business Plan on Revitalisation of Irrigation Schemes draws up from these lessons and a summary of these lessons is included in this document.

Initially, DALRRD set a target to revitalise 2% of small-scale government irrigation schemes that amounts to a total of 1 000 ha as its contribution to outcome 7, where it was envisaged that 250 ha would be revitalised every year. This decision was mainly due to financial constraints as the revitalisation of irrigation schemes at that time was estimated to cost about R200 000 per hectare. The funding for this initiative was sourced mainly from the Comprehensive Agricultural Support Programme (CASP) and Ilima/Letsema programmes.

The Business Plan for the Revitalisation of Irrigation Schemes was approved by the Minister of DALRRD in 2013. Annexure B is obtained from the business plan for the revitalisation that includes a list of small-scale irrigation schemes to be considered for funding. A summary of the budget required per province is also included. Subsequent discussions with the PDAs have indicated that the budget requested for the revitalisation of small-scale irrigation schemes indicated should be over a 10-20-year period. This is based on current expenditure patterns due to various challenges faced by the various provinces.

The Government of South Africa supports small-scale irrigation to create jobs, alleviate poverty and promote pro-poor sustainable agricultural and economic growth. In Gauteng Province, the functions of irrigation schemes are mainly performed by Agri parks. According to DALRRD (2024), an Agri park is a networked innovation system encompassing agro-production, processing, logistics, marketing, training and extension services in a District Municipality.[7] This network facilitates a market-driven integration of various agricultural activities and rural transformation services. Farmers from the Rooiwal Agri park participated in the study.

The Agri park consists of 3 members (only 2 participated as 1 had attended a market day at the Tshwane Fresh Produce Market) sharing 1 borehole for irrigation water. The average distance from the borehole to the crops is 20m. Farmers are mainly producing herbs (coriander), leafy vegetables (both exotic and indigenous) and cucumber. Some farmers' plots are located at the head due to unaffordability of pressure pumps and they irrigate their crops informed by the volume of the water in the water tanks. Farmers hardly have conflicts in this Agri park as they follow the agreements amongst themselves, although there is no committee. Water is distributed fairly according to the times (2 hours per farmer) allocated per farmer, but sometimes other farmers do not follow the rules. Borehole water in pumped in Jojo tanks (Fig. 4.18) and drip-irrigate green leafy vegetables (spinach and mustard greens) and herbs such as coriander (Fig. 4.19) at the Rooiwal Agri park.

[7] https://www.dalrrd.gov.za/index.php/about-us/agriparks

Figure 4.18: Borehole water pumped in Jojo tanks at Rooiwal Agri park

Figure 4.19: A scheme farmer using a drip system to irrigate vegetables at Rooiwal Agri park

During summer, the challenge is that crops die due to lack of water as farmers irrigate their crops. Farmers have a good knowledge of water saving strategies such as drip irrigation, soil moisture monitoring, mulching and irrigation scheduling. However, they do not use drought resistance crops. In addition, they adopt them.

The main challenge faced by farmers in the irrigation scheme is that only one borehole is working and there is a need for two more for the farmers to work efficiently. On average, farmers irrigate three times a week, however, in summer they irrigate every day. Water is available all year round. They do not use rainwater and they see no reason for rainwater harvesting. The AWM techniques that the farmers use are crop rotation, drip irrigation and soil moisture monitoring. With regards to water payment, there are middlemen that they pay so they do not have any idea as to what the cost of water is. The farmers also need training in water management practices.

During the meeting with small-scale irrigation scheme management officials in the Limpopo Province, it was reported that the challenges irrigation schemes face includes poor roads in the irrigation schemes, theft of irrigation pumps and fences, encroachment of residential buildings on scheme farmers, the absence of proper irrigation schedules for the farmers to follow and the destruction of scheme dam walls.

4.7 Unconventional water use for irrigation

4.7.1 Overview of Wastewater use in South Africa

Over 60% of the total water use in the country is dominated by irrigation. The irrigation sector is the largest consumer of water accounting for about 61% of water utilisation (Department of Water and Sanitation, 2023), but also losing 30-40% (Fanadzo & Ncube, 2018). Statistics South Africa (2020) reported the total number of farms/farming unit involved in the commercial agriculture industry in 2017 was 40 122. Furthermore, field crops farming was reported to be the lowest with 21.3%, followed by mixed farming with 31.1% and the highest being livestock farming with 39.8%. In addition, the highest province with the highest number of farms/farming in 2017 was the Free State with 19.8%, followed by the Western Cape with 17,3%, North West 12,3% and Northern Cape with 17.3%. The lowest province with the lowest farms/farming in 2017 was Gauteng Province with 5.7%, followed by Mpumalanga 7.0% and Limpopo 7.6%.

Most farmers use fresh water for irrigation which depletes the valuable resource meant for drinking to preserve life. Though the country faces droughts and water scarcity, the use of treated wastewater for irrigation is not fully utilised. The main reason could be that out of the total of 850 Waste Water Treatment Works (WWTWs) in 144 municipalities assessed, 334 were not effectively treated and performed below 31% (Green Drop, 2023). Furthermore, the results indicated that only 50% of wastewater treatment facilities are working properly, but the rest are partially disposing its sewage into the other water resources and cause contamination which results in high nutrient build up (Department of Water and Sanitation, 2018).

A total of 208 were found at critical risk (24%) whereas 250 at high risk (29%). As a result, such facilities are not suitable for discharging its effluent into any river or catchment. The South African municipalities have substantial potential to reuse wastewater for irrigation to alleviate the demand for fresh water. It is therefore necessary to ensure that all municipalities are encouraged to take part in a Blue Drop assessment to improve their WWTWs to make them ready for reuse. It remains a challenge to note that a total of 98 municipalities did not take part in the Green Drop assessment and the reason being that they did not meet the criteria. This also affects the rivers tremendously.

For example, in 2014, the DWS (2014) reported that Limpopo Province had the highest number of polluted rivers and that includes the Crocodile West and Marico River systems. Furthermore, Moyo *et al.* (2020) reported a similar situation in the Sand River, which receives effluent discharge from Polokwane WWTWs. To this end, the other challenge observed was the use of untreated or partially treated wastewater for crop irrigation, which is a common practice in South Africa which could cause health risks.

The database on the use of both treated and untreated wastewater for irrigation in South Africa is not known. However, Myburgh (2018) reported that 2000 ha of grapevines situated in the City of Cape Town were using treated municipal wastewater in Swartland and surrounding areas which are 55 km away. This treated wastewater was supplied by Postdam WWTW in Milnerton and Malmesbury municipalities. The grapevine farm that uses treated wastewater for irrigation is a good example of how the treated wastewater from WWTWs can be utilised to sustain agricultural production.

In light of the capacity of the volumes of wastewater produced by the WWTWs facilities per day, Abah *et al*. (2015) and Adewini *et al.* (2010) further reported that 39.90 ML/d of wastewater were reused in informal/indirect areas in the city of Cape Town in the year 2007 with 43% of the wastewater used for agricultural purposes in the Scottsdene area. Furthermore, 25.00 ML/d of wastewater was used in informal settlements and 100% of treated wastewater was used for agricultural purposes in Kraaifontein and Scottsdene in the City of Cape Town. Small wineries in Cape Town produce fewer than 15 000 m3 of wastewater annually, according to estimates made by medium to big wineries (Howell & Myburgh, 2018) cited by Van Schoor (2005).

There are 23 wastewater treatment facilities in the Cape Town metropolitan municipality, with the capacity to treat 324 m^3 of wastewater per year (CoCT, 2017 cited by Hoogendijk *et al*., 2023). The DWA (2010) reported that 2.18 x 108 m3 of treated effluent were released from 16 WWTWs in the Cape Town area in 2007/2008 according to Hoogendijk *et al*. (2023). As a result, the majority of treated municipal wastewater is released into rivers, canals, wetlands, aquifers or the ocean after undergoing adequate treatment. Reclaimed and treated 5% of the city's consumed potable water is used for irrigation and other non-potable purposes (Hoogendijk *et al*., 2023)

According to Saldias *et al.* (2015), most farmers use rainfall runoff that has been retained for irrigation purposes and about 37% use treated wastewater in the Western Cape Province. Furthermore, more than half of the participants in the Western Cape indicated they would use treated wastewater for irrigation in the future (Saldias *et al*. 2015). Gauteng Province recorded an average of 180 L/person/day and used 93% capacity while Limpopo Province only uses 138 L/person/day and uses it at 64% capacity (Ally & Campbell, 2021).

4.7.2 Wastewater capacity in South African Waste Water Treatment works

The information on the capacity of inflow and outflow volumes of wastewater in WWTWs is limited. However, the 2023 Green Drop report indicated an average of 6.971 ML/day wastewater produced by 850 municipal WWTWs assessed in 2022/2023 (Green Drop, 2023) as indicated in Table 4.14. In 2016 Gauteng alone was capable of producing 2595 ML/day of wastewater from 56 WWTWs facilities.

Table 4.14: The capacity of wastewater discharge in South Africa

Area	Type of wastewater	# of Wastewater facilities	Capacity	Year	Source
CoCT	Municipal WWTWs	16	324 m^3/yr	2016	CoCT, 2016
All municipalities	Municipal WWTWs	850	6,971 ML/day	2022	Green Drop 2023
All municipalities	Industries	185	962 ML/day,	2008	Van der Merwe *et al.* 2009
Gauteng	Municipal WWTWs	56	2,595 ML/day	2016	Ngila et al. 2020

(Source: Green Drop, 2023)

On the other hand, a study by Van der Merwe (2009) indicated that of the 185 industries evaluated on wastewater, 962,000 kL/day was produced; although other data were missing due to lack of records. The pulp and paper industry was identified as the biggest contributor to wastewater generation. Conversely, power generation, mining and petroleum industries were also categorised as big contributors. The study further reported that the fresh water used by paper and pulp is between 0.1 to 150 ML/d, while wet-cooled power stations require up to 100 ML/d hence dry-cooled power stations require 10 ML/d. In addition, sugar mills consume 0.6 to 6.8 ML/d, while oil refineries consume between 5 and 10.5 ML/d. The reuse of treated wastewater could alleviate the needed fresh water. Therefore, the capacity of the wastewater produced could be a good resource for the sustainability of irrigated agriculture if wastewater is effectively treated to prevent public health risk.

The main challenge of using wastewater is for public health reasons. The wastewater in South Africa does not meet the standards and most of it does not comply with the water quality standards. These apply to both industries and WWTWs. There are no proper records for wastewater treatment and the majority discharge the wastewater to the local municipal WWTW reticulation in the area. These practices should be corrected as the industries continue to burden the WWTWs. Consequently, most of the WWTWs are operating beyond their limits and they are under stress due to high wastewater load in the system.

On the other hand, almost all the WWTWs discharge their treated wastewater into rivers, canals, wetlands, aquifers or the ocean. Once discharged, it is difficult to track the farmers who use wastewater for irrigation. Currently, there is no clear definition of wastewater that is discharged into the rivers, wetlands and canals. This could be one of the reasons why it is not clear to know the number of farmers who use wastewater for irrigation, but rather mention other resources when they are asked to do so. To fully utilise and have valuable database of this resource, a clear identification of treated wastewater users is important. Therefore, a proper mapping of the wastewater discharged from each specification and the development of specifications could assist in the definition of wastewater use by farmers for irrigation.

4.7.3 Emerging contaminants of concern in wastewater used for irrigation

South Africa is encouraging farmers to reuse wastewater for circular economy and sustainability of irrigation. However, the WWTWs are not 100% efficient and compliant with the quality required for use without concerns about contaminants. The recent Green Drop (2023) report showed the number of WWTWs that did not comply with the requirements and showed poor performance as indicated in Table B. It is of concern to note that 98 WWTWs did not take part in this valuable assessment. As a result, these WWTWs continue to dispose of contaminated effluent into the water sources. This practice causes threats to human health. Out of the total 850 WWTWs, 258 did not comply. There is no single province with 100% compliance. Notably, Gauteng and the Western Cape Provinces recorded fewer numbers of WWTWs at risk, according to Table 4.15.

Table 4.15: WWTWs in critical and high-risk performance

Provinces	# of WWTWs	2021 Average CRR/CRRmax % deviation	# of WWTWs in critical and high-risk space			
			Critical Risk (90-100% CRR)	%	High Risk (70-<90% CRR)	%
Eastern Cape	123	72.3	24	20	47	38
Free State	96	81.2	42	44	34	35
Gauteng	60	58.8	4	7	12	20
KwaZulu-Natal	147	60.3	10	7	42	29
Limpopo	64	84.7	24	38	31	48
Mpumalanga	76	74.1	26	34	24	32
Northern Cape	78	89.7	46	59	27	35
North West	48	85.0	29	60	8	17
Western Cape	158	53.1	3	2	25	16
National Totals	**850**	**70.1**	**208**	**24**	**250**	**29**

(Source: Blue Drop, 2023)

On the other hand, 334 compliance letters were issued in all provinces. This is of great concern, though (168%) 50% of those who got compliance letters already responded by sending Corrective Action plans to the DWS as shown in Table 4.16. The unreliability of wastewater treatment in most of WWTWs poses risks to health. Farmers should be aware of the emerging contaminants of concern that could affect growth or affect human health.

Table 4.16: Compliance status of WWTWs in South Africa and national summary of the corrective action planning

Province	# WSA	# WWTWs (<31% GD score)	Compliance letters issued	WSA Requested Support/ Extension	# (%) CAPs Received by DWS	# CAPs Implementation Status @ 31 March 2023

				to Develop the CAP		
Eastern Cape	10	48	48	17	45 (94)	2
Free State	17	64	64	None	10 (16)	None
Gauteng	4	9	9	5	8 (89)	2
KwaZulu Natal	4	20	20	13	0 (0)	None
Limpopo	10	50	50	None	50 (100)	None
Mpumalang a	8	33	33	2	10 (30)	None
Northern Cape	23	59	59	5	14 (24)	8
North West	7	33	33	1	13 (39)	9
Western Cape	7	18	18	None	18 (100)	13
National Totals	**90**	**334**	**334**	**43**	**168 (50)**	**34**

(Source: Blue Drop, 2023)

Table 4.17 shows the emerging contaminants of the concerns that could be transferred to the plants and soil through irrigation. Most of the pharmaceutical contaminants were found not to be at high risk. However, when the pH is too low or very high, it can have an effect on plants and on soil. According to Compagni (2019), high pH causes the degradation in soil and morphological variations inside plants. The human health risk was very low in rice and wheat when assessed. The availability of chemicals can increase the chemicals found in plants as well.

However, the studies by Abdallat *et al*. (2022) and Shi *et al*. (2021) confirmed that 60% of pharmaceuticals can be removed from wastewater if treated effectively. In addition, the study by Moyo *et al.* (2020) on heavy metals in crops, recorded a lower dose of chemicals in onions and tomatoes irrigated with wastewater. The authors further reported the concentration of the heavy metals in soils under tomatoes and onions at the same magnitude. It is thus recommended that experiments be carried out to investigate the sensitivity of onions and tomatoes to the target heavy metals. No studies have been conducted in South Africa on this aspect. All these studies confirm that the uptake of any contaminants always depends on the type of plant, its uptake and the type of irrigation used, as well as the quality of water.

Table 4.17: The contaminants of concern in wastewater used for irrigation

Contaminants of concerns	Contaminant type	Affect crops and soil	Topic	Source
Physical	pH, EC, TDS, Turbidity	Low	Evaluation of heavy metal and microbiological contamination and assessment of the	Moyo *et al*., 2020

Contaminants of concerns	Contaminant type	Affect crops and soil	Topic	Source
			suitability of the Sand River water for irrigation in the Limpopo Province	
Chemical	Na+, CL_, BOD, SO_4, Fe, Cu, Mn, Pb, Cd	Medium	Emerging contaminants in wastewater treated for direct potable reuse: The human health risk priorities in South Africa Evaluation of contaminants of emerging concern absorption and accumulation in plant irrigated with treated municipal wastewater: preliminary results	Swartz *et al*., 2017 Minini *et al*., 2023
Pharmaceutical	Chlortetracycline, tetracycline, tylosin, sulfamethoxazole, sulfamethazine and trimethoprim, triclosan (TCS), triclocarban (TCC), galaxolide (HHCB), parabens, 2-ethyl-hexyl-4-trimethoxycinnamate (EHMC), 4-methyl-benzilidine-camphor (4MBC)	Low to medium	Pharmaceuticals as emerging pollutants in the reclaimed wastewater used in irrigation and their effects on plants, soils and groundwater. Contaminants of emerging concerns in recycled water: Fate and risks. Risk assessment of contaminants of emerging concern in the context of wastewater reuse for irrigation: An integrated modelling approach	Abdallat *et al*., 2022 Shi et al., 2021 Delli Compagni et al., 2019

4.7.4 Practices of wastewater use for irrigation

The use of wastewater for irrigation in South Africa is limited and little is known about the use of treated municipal wastewater for irrigation (Hoogendijk *et al*., 2023). The reuse of treated wastewater (TWW) in South Africa is historically limited to irrigation of recreation facilities (sports fields, urban parklands) and commercial horticultural and agricultural activities such as the cultivation of instant lawn and animal fodder (Steyn & Jagals, 2000). In some instances, the uses of these waters are allowed for food-related activities such as grazing pasture maintenance for dairy and meat animals. There is increasing demand from communities in and around urban areas in the country to use treated wastewater for food production in small-scale farming practices (Steyn & Jagals, 2000).

The reuse of wastewater by communities for irrigation has to follow the guideline conditions and criteria thresholds provided in Appendix C and Appendix D, which contains a summary of reuse types found in the South African Guide compared to similar reuse types, applications, categories and conditions in international guides, ranked in order from the most sensitive use (on crops usually eaten raw) to the use for the least likely to cause adverse public health effects. International guides classify treated effluents based on a combination of non-treatment criteria such as purpose of reuse, water quality, irrigation techniques, as well as worker and other group exposure to irrigation water (Jagals & Steyn, 2002). By contrast, wastewater treatment methods serve as the primary benchmark for classification of effluent in the South African Guide. Non-treatment options such as crop types and irrigation restrictions, as well as microbiological effluent quality criteria (based on the numbers of Ecoli per 100 mL instead of faecal coliforms are used to supplement the various treatment options) (Jagals & Steyn, 2002).

In practice, the South African 1978 Guide proposes measures to control microbiological health hazards in the reuse of treated domestic wastewater through the following:

- Treatment method;
- Microbiological effluent quality based solely on the levels of *Ecoli* per 100 mL;
- Some crop restriction; and
- Irrigation type regulation.

Irrigation techniques are included in wastewater reuse guides to maximise crop safety for consumers by controlling the application rates of potential pathogens that may have survived the treatment processes to a minimum – especially where effluents are of a lesser quality and to reduce human (especially worker) exposure to irrigation wastewater. Health risks are greatest when spray/sprinkler irrigation is used as this distribute contamination over the surface of crops (the opposite occurs with nematode eggs, which tend to be washed off during spray irrigation). Localised irrigation (drip, trickle and bubbler irrigation) provides the greatest degree of health protection by reducing the exposure of most edible crops to wastewater as well as reducing the exposure of workers to wastewater. Flood and furrow irrigation exposes field workers to the greatest risk, especially if earth moving is done by hand and without protection.

In South Africa, the use of wastewater for irrigation requires approval from the Department of Health (DoH). Any persons who wish to use treated effluent for agricultural purposes are in terms of Section 21 of the National Water Act (Act 36 of 1998), required to apply for a conditional water-use licence under the Act (Steyn & Jagals, 2000). The DWS processes applications for any type of treated effluent re-use. If the intended re-use involves public health issues such as the production of food or sports facilities that promote probable direct contact with surfaces irrigated with treated wastewater, the provincial DoH become involved. To protect public health, officials of the DoH recommend issue or refusal of such licence applications to DWS on the strength of the South African Guide (Appendices A and B) for the Permissible Utilisation and Disposal of Treated Sewage Effluent (Department of National Health and Population Development, 1978).

Wastewater reuse in agriculture involves the collection of wastewater at a central location from domestic and non-domestic sources in an urban/agricultural area. The effluent is then processed and used for non-drinking requirements such as irrigation at the sources of generation or elsewhere. This category of reuse in South Africa is found in the eThekwini metropolitan area, the KwaZulu-Natal Province and the City of Cape Town (CoCT) and the Western Cape Province (Adewumi *et al*., 2010). The degree of use of wastewater for irrigating cereal crops is presented in Table 4.18.

Table 4.18: The degree of wastewater use for irrigation

AWM System	Degree of use for irrigating crops
Treated wastewater reuse	30%
Informal use of partially treated or untreated wastewater	30%
Informal use of partially treated or untreated wastewater as is commonly practiced in urban and peri-urban agriculture areas. Recycling sewage to supply organic matter and nutrients for agriculture	10%
Desalinated water	10%

When properly treated, municipal wastewater can be beneficial for irrigating agricultural crops. The potential advantages include nutrient recycling, savings on fertilizers, the addition of organic material, reduced pressure on fresh water sources and decreased environmental contamination. However, the use of municipal wastewater in Gauteng Province is very limited. Subsistence farmers use grey water for irrigation. Grey water is wastewater generated from dish washing, laundry and bathing and can be easily recycled for domestic and irrigation use. Figures 4.20 and 4.21 show a subsistence farmer irrigating her crops with grey water. Crops irrigated are leafy vegetables, tubers, chilies and indigenous crops. There is a need for training with regards to the use of grey water by farmers.

Figure 4.20: A farmer carries grey water in a bucket in Akasia, north Pretoria

Figure 4.21: A subsistence farmer uses grey water to irrigate vegetables in Akasia, north Pretoria

Farmers practicing wastewater irrigation in Marokolong, Hammanskraal, rely on water drawn from the Apies River, which has been contaminated by untreated sewage discharged from the Rooiwal Wastewater Treatment Plant (Fig. 22). To irrigate their crops, these farmers use petrol-powered pumps to extract the river water through pipes that direct it to their fields.

Figure 4.22: A farmer pumping wastewater to irrigate his crops in Marokolong, Hammanskraal, Pretoria

4.8 Government support for AWM practices

The government, through extension officers, supports rainfed farmers by providing extension services to the farmers. The extension services include technical advice, training and information on crop production and soil management. In addition, the government also provide farmers with resources such as fertilisers, seeds and tractors to improve their productivity. The government supports AWM practices through strategies and policies (Table 4.19) and programmes (Table 4.20).

Table 4.19: Government policies/strategies in support of AWM systems

AWM System	Government policies	Government strategies
Rainfed farming	• Conservation of Agricultural Resources Act (No. 43 of 1983)	• National Water Conservation and Demand Management Strategy 2004
Farmer-led irrigation development	• Conservation of Agricultural Resources Act (No. 43 of 1983) • National Water Act (Act 36 of 1998) • Integrated Growth and Development Policy • (Mudhara & Senzanje,2020)	• National Water Resource Strategy 2 • Agrarian Transformation Strategy • (Mudhara &Senzanje, 2020)
Irrigation scheme development and modernization	• Conservation of Agricultural Resources Act (No. 43 of 1983) • National Water Act (Act 36 of 1998) • Integrated Growth and Development Policy • (Mudhara & Senzanje, 2020)	• National Water Resource Strategy 2 • Agrarian Transformation Strategy (Mudhara & Senzanje, 2020)

AWM System	Government policies	Government strategies
Unconventional water use for irrigation	• The Water Services Act of 1997 • National Water Act of 1998 (van Niekerk & Schneider, 2013)	• The National Strategy for Water Re-use (van Niekerk & Schneider, 2013)

Table 4.20: The nature of government support for the AWM systems

AWM System	Government support (financial, technical, etc.)*
Rainfed farming	CASP/Ilima Letsema Extension Services
Farmer-led irrigation development	CASP/Ilima Letsema Extension Services
Irrigation scheme development and modernization	CASP/Ilima Letsema Extension Services
Unconventional water use for irrigation	CASP/Ilima Letsema Extension Services

*CASP: Comprehensive Agricultural Support Programme

The DALRRD assist farmers who are often organised into WUA through two programs: the CASP, which provides infrastructure such as pumps, canals and packhouses and Ilima/Letsema which assist farmers with agricultural inputs. The working capital support is offered until the farmers are able to become self-sufficient. The South African government allocated approximately 2 billion rands from public funds, which is equivalent to roughly R40,000 per hectare, for the establishment, revitalisation and rehabilitation of small-scale irrigation schemes (SIS) (Fanadzo & Ncube, 2018).

4.9 Promising AWM investment opportunities in South Africa

There are promising investment opportunities for AWM practices in the country. For all four pathways, a pre-requisite for success is to ensure that policies and institutions that support sustainable, equitable implementation are in place and effective and are accompanied by realistic long-term plans. Some policies, such as agricultural and water resources policies, cut across all pathways. Table 4.21 presents a summary of the investment opportunities for the four pathways in South Africa.

Table 4.21: Investment opportunities for the four pathways in South Affrica

Rainfed	Farmer-led irrigation	Irrigation scheme development and modernization	Unconventional water (wastewater) reuse
Draw on strong research capacity to target capacity building of previously disadvantaged	High potential to produce for local and international markets; high potential in peri-urban areas.	Focus on revitalising small-scale schemes in partnership with farmers from previously	Focus on using wastewater for irrigation in peri-urban areas safer through partial treatment and information and

farmers on locally adapted soil-water conservation practices. Prioritise inclusive community-led programs to restore and sustain watersheds to achieve multiple benefits locally and downstream. Encourage sustainable land and water management practices by commercial rainfed farmers.	Make affordable equipment available targeted to formerly disadvantaged communities, including women and youth. Promote solar-powered pumps.	disadvantaged communities. This requires strong efforts at capacity strengthening, improving market links and some infrastructure revitalisation and modernisation. On schemes serving commercial farmers, encourage investments to make water more productive.	education campaigns. Explore the use of wastewater for irrigation of non-food crops.

4.10 Land tenure systems

The land tenure systems under which the AWM practices are implemented are presented in Table 4.22. Rainfed farming system is found on communal/customary and state-owned lands.

Table 4.22: The land tenure system under the AWM systems in the Country

AWM System	Private (Free hold & leasehold)	Communal/ customary	State-owned lands/Public
Rainfed farming		Yes	Yes
Farmer-led irrigation development	Yes		
Irrigation scheme development and modernisation	Yes	Yes	
Unconventional water use for irrigation	Yes		

4.11 Challenges for AWM

Some of the challenges farmers face when implementing AWM practices include:

- The lack of access to water due to the plot's position in the irrigation scheme has been one of the major reasons why farmers are giving up on farming.
- As presented in Appendix B, the challenges that irrigation schemes face includes damaged canals and earth dams that supply water to the irrigation schemes, siltation of dams, poor condition of infield roads, damaged fences or absence of perimeter fences. The lack of perimeter fence exposes a scheme to

the risks of vandalism and theft of irrigation infrastructure such as irrigation pumps.

- The other challenge is that in some schemes there are no proper irrigation schedules to regulate the distribution of irrigation water, as well as the timing of irrigation session by members.
- The other challenge that the farmers face is the lack or limited access to markets for their produce as well as inputs.
- While women make up the majority of participants in irrigation schemes, their voices are often marginalised during meetings and this is particularly prevalent in rural areas.
- The majority of farmers are elderly, which poses challenges when their children inherit the plots. Often, the children lack interest in farming and leave the land unused.
- Although the responsibility for managing irrigation schemes has been transferred from government agencies to farmers through the Irrigation Management Transfer (IMT), some farmers remain confused about who is actually in charge. This confusion has led to their reluctance to participate in activities such as fixing damaged infrastructure, resulting in the deterioration of the scheme.
- In most cases independent irrigators often operate outside the scope of policymakers, donors and the scientific community thus resulting in their exclusion from official irrigation data, government policies and agricultural support systems (Dube, 2023).
- The semi-invisibility of FLID, its diverse and autonomous character and the large range of actors interacting with farmers in the process pose important challenges for those seeking to provide support to the initiatives and address key challenges that cause low water use efficiencies, reduced productivity, poor marketing and limit FLID expansion.

4.12 Discussions

4.12.1 Irrigation development

The study has shown that the total irrigated land as a percentage of agricultural land in the country is 65%. The irrigation practices in the country include surface (where water is conveyed and distributed by lined canals or earth canals), sprinkler system, drip, micro-spray and centre-pivot. Centre-pivot covers a large area, followed by drip irrigation. Surface irrigation with lined canals is prominent in the KwaZulu-Natal Province, while centre pivot irrigation systems are prominent in the North West and Western Cape provinces. The two irrigation systems considered in this study are farmer-led irrigation and irrigation schemes. The study also assessed the use of waste water for irrigation, whether under farmer-led irrigation system or irrigation schemes.

4.12.2 Pathway 1: Improved water control and watershed management in rainfed systems

One of the major challenges faced by rainfed farmers is climate change. The problems associated with climate change include: rainy season starting later than usual; unreliability and unpredictability of rainfall; high temperatures that cause drought; and heavy rainfalls that damage crops. Rainfed farmers are likely to invest in improved

AWM practices if they see real benefits within a fairly short time. While government is supporting the farmers in various ways, the policies of government should support adoption of improved soil and water management in rainfed agricultural systems, implemented through long-term investment programmes in close collaboration with local communities.

Most of the rainfed farmers that depend on rainwater for irrigation are those that produce maize, soyabean, groundnuts, dry beans, sorghum etc. and the others produce indigenous vegetables (some grown by themselves). The farmers also practice supplemental irrigation using furrow and infield rainwater harvesting. Their water management practices include conservation agriculture, rainwater harvesting, pasture farming, mixed farming and wetland farming.

The study has shown that, when implemented well, better AWM practices improve productivity and resilience of rainfed systems, reduce erosion and downstream siltation and help recharge groundwater and stream flows. These benefits depend on factors such as the supporting environment, effectiveness of extension and other information services drawing on locally relevant research and farmers' capacities and incentives.

Gender issues are critical in determining the success or failure of AWM and watershed management programmes. Success requires governments to offer specific opportunities for women to fully participate and benefit. Effective capacity development, information transfer and extension systems supported by well-resourced, locally relevant, gender-sensitive applied research are needed to promote innovative locally appropriate practices.

The issue of land tenure is important when considering AWM practices. Where land tenure systems do not incentivise AWM investments, consultations with local communities supported by government policies should aim to overcome this impediment. Where government resources are limited, investments by financial institution partners and policies to stimulate public-private partnerships and co-investment with farmers should be explored.

4.12.3 Pathway 2: Farmer-led Irrigation

Farmer-led irrigation is widespread in the country. While the government has no specific policies or programmes to support farmers' own irrigation investments, the government provides more support for farmers' investments in technologies such as pumps and drip and sprinkler systems. NGOs and research institutions play important roles in raising awareness of the potential benefits of FLID.

Most farmer-led irrigators operate outside formal irrigation schemes and often lack access to the institutional and financial support systems. Such support includes agricultural advice, training, input support and infrastructure development. Furthermore, the FLID farmers use their home savings, pension funds and income from other sources to support the farms. FLID farmers face poor water quality or polluted water from rivers and they have limited access to extension services, capacity building and resources such as fertilisers. The climate change and variability (heat) affect crop development leading to crop failure.

Although FLID is largely invisible to policymakers, it is a potential game-changer for millions of small-scale farmers. Investments can generate multiple synergies and impacts by improving farmers' livelihoods, enhancing the food security of consumers, creating jobs and promoting economic growth. This high-priority pathway has a lower cost per farmer than large-scale irrigation investments, begins generating returns immediately and can leverage private investments from farmers and private firms and does not require large financial investments by the government.

The actions needed to support rapid scaling out of FLI include ensuring affordable access to irrigation technologies, ensuring there is a level playing field for private firms to market and even manufacture locally, irrigation technologies; and encouraging local financing institutions to provide credit to enable small-scales, including women and youth to purchase equipment.

4.12.4 Pathway 3: Irrigation scheme revitalisation and development

The government of South Africa has made large investments in developing public irrigation schemes at various scales. The country has larger and small-scale irrigation schemes situated in various provinces. The Limpopo Province has the largest number of small-scale irrigation schemes, followed by the Eastern Cape Province. The government has also established Agri parks which operate as irrigation schemes. An Agri park is a networked innovation system encompassing agro-production, processing, logistics, marketing, training and extension services in a District Municipality. This network facilitates a market-driven integration of various agricultural activities and rural transformation services. The challenges that irrigation schemes face includes poor roads in the irrigation schemes, theft of irrigation pumps and fences, encroachment of residential buildings on scheme farmers, the absence of proper irrigation schedules for the farmers to follow and the destruction of scheme dam walls

4.12.5 Pathway 4: Unconventional water use for irrigation

The reuse of treated wastewater (TWW) in South Africa is historically limited to the irrigation of recreation facilities (sports fields, urban parklands) and commercial horticultural and agricultural activities such as the cultivation of instant lawn and animal fodder. When properly treated, municipal wastewater can be beneficial for irrigating agricultural crops. The potential advantages include nutrient recycling, savings on fertilizers, the addition of organic material, reduced pressure on fresh water sources and decreased environmental contamination. Grey water is wastewater generated from dish washing, laundry and bathing and can be easily recycled for domestic and irrigation use. Subsistence farmers irrigate crops with grey water. Crops irrigated are leafy vegetables, tubers, chilies and indigenous crops.

In South Africa, the DoH is responsible for drinking water or consumption of raw vegetables irrigated by wastewater hence it can just give recommendations. The use of wastewater for irrigation requires approval from the DWS hence any persons who wish to use treated effluent for agricultural purposes are, in terms of Section 21 of the National Water Act (Act 36 of 1998), required to apply for a conditional water-use licence under the Act. The DWS processes applications for any type of treated effluent re-use. If the intended re-use involves public health issues such as the production of food or sports facilities that promote probable direct contact with surfaces irrigated with treated wastewater, the provincial DoH becomes involved.

4.13 Conclusion

The study identified, mapped and assessed AWM practices in the country. The study used the provinces of Limpopo and Gauteng as case studies. The study focused on AWM practices under rainfed farming, farmer-led irrigation systems, irrigation scheme development and the reuse of wastewater for irrigation.

It has shown that there are promising investment opportunities in the country based on the four AWM pathways. For all four pathways, a pre-requisite for success is to ensure that policies and institutions that support sustainable, equitable implementation are in place and effective and are accompanied by realistic long-term plans. Some policies, such as agricultural and water resources policies, cut across all pathways.

The rainfed farming system is a high-priority area for investment with potentially large benefits as it involves the majority of the small-scale farmers in the country. The country should develop specific policies and implement long-term investment programmes to work with local communities to restore degraded landscapes and move to sustainable resource management.

FLID is a very important driver of increased food production, especially for urban markets. It requires very little financial investment by governments as the input and output value chains are largely driven by the private sector. Individualised irrigation technologies are easier to target to women, youth and others who otherwise may be left out in the other farming systems. The farmers can be supported through special subsidies and focused capacity strengthening, which requires consultations and experimentation with these farmers to make sure those targeted really benefit.

The country should strengthen value chains, both for making equipment and inputs available at competitive prices and improving linkages to produce markets. This requires both policy support and investing in upgrading roads and communications and encouraging private investment to support the farmers. The study has shown that the pathway of irrigation scheme development is attractive to the government as a route to achieving national food security, providing employment and encouraging rural development.

While the scheme farmers face some challenges, there are significant opportunities to improve the performance of existing public irrigation schemes through a combination of institutional reform, capacity strengthening of managers and farmers, market development and either revitalisation or modernisation of infrastructure. Small-scale community managed schemes and multiple-use small reservoirs may offer greater returns than large-scale schemes. A promising but so far rare possibility is public-private partnership (PPP) models for the construction and management of irrigation schemes. Schemes need to be designed to meet the demand for other water uses and users. This may be the best opportunity to offer women and youth opportunities to benefit from large-scale infrastructure investments.

The importance of effective and sustainable wastewater reuse for irrigation in the country cannot be overemphasised. The limited natural water resources, as well as periodic droughts in the country necessitate the need to find alternative sources of irrigation water to sustain yield and quality. The large volumes of treated municipal wastewater generated annually holds promise as an alternative water source. If treated properly, municipal wastewater may be beneficial when reused for irrigating agricultural crops. The possible benefits include recycling of nutrients, fertiliser savings, the addition of organic material, a reduced pressure on fresh water sources and reduced environmental contamination.

However, high salt loads, in particular sodium (Na+), can have detrimental effects on soil's physical and chemical properties, as well as crop sustainability. Therefore, it is essential to implement measures that limit the damage caused by salinity and/or sodicity. The attenuation and accumulation of toxic substances should also be managed to a minimum. This pathway offers a large potential for PPP: nutrients recovered from the water are valuable and can be marketed as can the treated water itself in many circumstances. The existence of guidelines for reuse of wastewater offers the greatest opportunity of developing investment programmes in consultation with stakeholders to promote sustainable wastewater reuse and make it as safe as possible for both producers and consumers.

4.14 Recommendations

The successful implementation of AWM practices requires effective capacity building, financial resources and investment in AWM practices, supportive infrastructure, research and development in AWM, as well as policy reform.

Capacity building: There is an urgent need for more investment in capacity strengthening at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers' knowledge and skills. At the knowledge generation level, there is a need to strengthen research capacities through investing in human resources and reforming research institutions to make them more attractive places to work and more effective. At the knowledge utilisation level, there is need to build the capacity of small-scale farmers so that they are able to adopt the developed AWM technologies for effective and sustainable use and the management of agricultural water resources. It is important to invest in extension services in order to improve the skills of extension workers in irrigation water management.

Effective AWM practices on irrigation schemes requires the support of effective governance systems in terms of institutions and organisations. Since farmers on irrigation schemes are dependent on each other because they share the water distribution system, their interdependence requires a willingness of the farmers to work collectively in order to achieve their individual objectives. The effective and sustainable functioning of collective action requires rules to govern collaboration (institutions) and structures to enforce these rules (organisations) (Fanadzo, 2012). It is usually difficult for irrigation scheme farmers and their volunteer leadership structures, usually in the form of elected schemes committees, to enforce rules on the schemes (Van Avebeke *et al*., 2011). Farmers pursuing individual instead of collective goals challenge institutions and erode organisations of irrigator communities (Letsoalo & Van Avebeke, 2006; Orne-Gliemann, 2008).

The importance of building and strengthening scheme governance systems to promote effective AWM practices on irrigation schemes was also supported by the study of two irrigation schemes, one in the Eastern Cape and the other in KwaZulu-Natal by Mnkeni *et al*. (2010), which revealed that most of the problems in small-scale schemes were institutional and related to governance of the schemes. The study revealed that both schemes had very weak organisational and institutional arrangements.

Financial resources and investment in AWM practices: Enhancing access to financial resources has consistently been identified as a major strategy to rapidly increasing the use of AWM practices (DWFI, 2018). Small-scale farmers, whether operating under rainfed system or farmer-led farming systems find it difficult to afford the money required to purchase essential AWM technologies such as pumps and small local agro-businesses also struggle to obtain operating capital to stock equipment and spare parts or to develop and implement new services to AWM operators such as irrigators. Therefore, what is needed are investments in local institutions, such as farmers' organisations and small-scale credit schemes, which are particularly important in this context as the study shows that many farm households cannot afford the initial costs required for small-scale AWM technologies such as water harvesting.

Public investments in infrastructure such as roads are crucial so that farm produce can be transported easily to the markets. Furthermore, private investors must be attracted to investments in rainfed agriculture. Investments are also needed in capacity building as the lack of knowledge on farms and among extension service personnel regarding AWM practices such as water harvesting and conservation agriculture can limit yields in rainfed areas (Rockström *et al*., 2009), engendering development initiatives that are needed as women play major roles in agriculture, particularly in rainfed areas. Innovative public-private financial instruments aimed at supporting the entire AWM value chain should be scaled-up in collaboration with local banks, cooperatives and farmers' organisations.

Supportive infrastructure: The study has shown that one of the major constraints to AWM is the inadequacy of supportive infrastructure: transport (roads, railways), electricity, communications and storage and processing facilities for agricultural products. It is, therefore, recommended that in remote areas with land and water resources that can be exploited, there should be an increase in the pace of both public and private infrastructure investments in supportive infrastructure to make AWM investments attractive in the longer run. It is also recommended that, for achieving rapid impacts, target irrigation investments to areas that already have other basic infrastructure.

Agricultural research and development: The level of investments in agricultural research and development needs to be boosted, particularly in AWM, including irrigation. It is recommended that the government and the private sector raise the level of funding of applied agricultural and especially water management research and also implement reforms to create the institutional support systems that encourage innovation.

Policy reform: Finally, but perhaps most critical of all, is policy reform. The attractiveness of investing in AWM technologies and services is to a large extent a function of policies related to imports, currency exchange rates, competitiveness of input and output markets and trade policies. Numerous studies have identified these policy areas as major impediments to investments – and major opportunities to encourage investments (e.g., Jayne *et al*., 2010; Giordano and de Fraiture, 2014; Fanzo, 2017). There is need for new water management policies and investments in human capacities, research, institutional development and specific technologies.

CHAPTER 5

ANALYSIS OF POLICY, GOVERNANCE AND INSTITUTIONAL STRUCTURES AND THE FUNDAMENTAL HUMAN-ENVIRONMENT CHALLENGES

5.1 Introduction

The study assessed the policy, legal, governance and institutional systems related to agricultural water management (AWM) under rainfed and irrigated farming systems. The chapter presents the IDAWM-related policy, legal, governance and institutional systems, as well as the degree of support of legislation, policies and strategies to IDAWM in the country. The analysis focused on legislation, policies and strategies, governance and institutional systems in the water, agriculture, environment and health sectors. The analysis also assessed institutional and financial support for the four AWM systems in the country.

5.2 Legal framework of agricultural water management in South Africa

The country has sectoral legislative pieces or Acts, policies and strategies. Acts provide a legal basis to a policy (Mudhara & Sezanje, 2020). A policy is a goal or an objective set by the government, which is aligned with the set laws or Acts. A strategy outlines the objectives, plans, guidelines, procedures and institutional arrangements required for achieving the desired goal (Mudhara & Sezanje, 2020). The identified pieces of legislation include the Constitution (No 108 of 1996), National Water Act (Act 36 of 1998), Conservation of Agricultural Resources Act (No 43 of 1983), Agricultural Research Act, 1990 (No. 86 of 1990) and the National Environmental Management Act (No 107 of 1998).

The national water policies and legislations are transformational masterpieces that not only resolve the complications of the past, but also assist in building a better future (Karodia & Weston, 2002). The resolution of the NWA of 1998 explicitly states this, which is to ensure that the country's water resources are protected, used, developed, conserved, managed and controlled in ways that take into consideration factors such as, among other things, meeting the basic human needs of the present and future generations, promoting equitable access to water, redressing past discrimination, facilitating social and economic development and protecting aquatic elements and their associated ecosystems (Adom & Simatele, 2021).

In addition, the National Environmental Management Act (NEMA) 107 of 1998 and the Water Service Act (WSA; Act 108 of 1997) are linked to the sixth objective of the Sustainable Development Goal 6 (Clean Water and Sanitation), which is the cornerstone of social and economic development, as well as alleviating poverty and enhancing sustainable livelihood. Appendix E presents a summary of the pieces of legislation related to IDAWM practices while the details of IDAWM-related legislation are presented in the following sections.

5.2.1 Constitution of the Republic of South Africa Act 1996 (Act 108 of 1996)

In South Africa, the Constitution is the supreme law of the country and any other law should conform to its provisions. The Constitution of the Republic of South Africa (No. 108 of 1996) creates provisions for water legislations. The Bill of Rights in the Constitution guarantees fundamental human rights to all people of South Africa (Republic of South Africa, 1996). Among other things, it affords everyone the right to live in an environment that is not harmful to health and well-being and to have access to sufficient water and extending these benefits to future generations. The Constitution sets out the objectives of local government, including to provide water services sustainably and to promote a safe and healthy environment.

The local government legislation gives effect to this constitutional imperative and it provides for municipalities to promote a safe and healthy environment in their localities and cooperate with other spheres of government for the realisation of the fundamental rights contained in Sections 24, 25, 26, 27 and 29 of the Constitution (Green Paper on Local Government, 1997). The Constitution emphasises that the national government is the custodian of groundwater and surface water resources and that local government has the responsibility of providing municipal water supply and sanitation services.

Section 27 of the Constitution provides that: 27(1) everyone has the right to have access to (b) sufficient food and water; and (2) the state must take reasonable legislative and other measures within its available resources to achieve the progressive realisation of each of these rights. In essence, water matters with regard to the determination of public and/or private rights towards water resources are pre-described in the Constitution. In South Africa, water is a public, not a private good which is managed by the state on behalf of all South Africans. Sections 27(1) (b) and 27(2) of the Constitution state that everyone in South Africa is entitled to adequate water resources and the state is duty bound to achieve the realisation of sufficient water provision through the use of legislature and other measures (Republic of South Africa 1996).

The country has entrenched constitutional commitments to protecting the environment and for sustainable development. Section 24 of the Bill of Rights provides everyone with the right 'to an environment that is not harmful to their health or well-being'. The Bill of Rights calls for the protection of the environment to the benefit of present and future generations through reasonable legislative and other measures (National Department of Agriculture, undated). The constitution also provides for the restitution of land rights.

5.2.2 National Water Act 36 of 1998

The National Water Act (NWA) 36 of 1998 was established and enacted to ensure that water resources in South Africa are protected, used, developed, conserved, managed and controlled in ways that take into consideration factors such as, among other things, meeting the basic human needs of the present and future generations, promoting equitable access to water, redressing past discrimination, facilitating social and economic development and protecting aquatic elements and their associated ecosystems (Republic of South Africa, 1998a). The NWA was founded on three key principles; namely, sustainability, equity and efficiency (Schreiner, 2013; Soyapi, 2017). The sustainability principle aims to promote social and economic development and to protect the environment for future use. The equity principle ensures that everyone has the right of access to water and that the water allocation decisions favour all people.

The efficiency principle ensures that water is used efficiently and not wasted. In order to achieve the aims and objectives of NWA, the National Water Resource Strategy (NWRS) was established with the sole aim of managing water resources, as well as establishing two water resource management institutions. The water resources management institutions that were established were the Catchment Management Agency (CMA) and Water Users Association (WUA) (DWAF, 1997). These institutions allowed users to participate in decision making by decentralising water management at catchment and local levels (Perret, 2002).

According to Backeberg (1997), the participation of water users in water management can be achieved by establishing organisations representing their interest at a local level. The National Water Policy requires water users to join water user associations (WUAs) to register as water users through licencing, to apply for water rights and pay application and user fees (Sokile *et al*., 2005). On the other hand, the NWRS provides the national implementation framework and divides the country into 19 Water Management Areas (WMAs). The National Water and Sanitation Programme, an international partnership programme, was designed to enhance access to safe and affordable water supply and sanitation for the poor in South Africa (Department of Water and Sanitation, 2018).

The NWA has transformed the water regulatory landscape from the riparian system to a system aimed at achieving equitable water allocation for the benefit of all (Madigele, 2018). The national government has replaced the riparian rights system with an administrative permit system (Department of Water Affairs, 2013). Subsequently, the NWA has established a public rights system in the water sector, wherein the government plays the role of ‘‘public trustee’’ (Stein, 2005). The public trust principle not only gives the state a set of constitutional obligations, such as equitable provision of water resources, but also provide ways through which the state could give effect to such obligations.

In South Africa, the public trust gives the state power over water resources as the NWA entrusts the ownership and control of water resources to the state (Stein, 2005). Despite the state’s ownership of water resources, Section 56 (1) of the Act makes provisions and/or considerations for water allocation through the market by instituting price strategies for users and polluters. Through the imposition of pricing strategies, the Act aims to create incentives for effective and efficient water allocation, as well as water use. The NWRS stipulates that in order for the supply of water to be reliable, three sets of costs should be considered; namely, direct infrastructure and management costs, economic costs and full costs (Madigele, 2018). Direct infrastructure and management costs include costs of planning, monitoring and regulating, the cost of capital, as well as operation and maintenance costs.

The NWA limits the direct discharge of waste treatment residue (WTR) into watercourses. The NWA under Section 20 forbids any discharge of a pollutant to any water body (including wetlands) without a disposal permit. The direct discharge of untreated residues to most surface water is currently controlled by the waste discharge system described in Section 21 of the NWA. The control of discharge of residue from waste treatment plant (WTP) into a water course falls under Section 21 of the NWA and should be authorised according to Section 21(g).

The discharge of drinking water residues to sanitary sewer requires a permit whereby the discharge must comply with discharge limits. The pre-treatment requirements are usually site specific and intended to ensure that the operation of the wastewater works is not upset by the acceptance of the water treatment residue (Mokonyama *et al*., 2017). The limits further ensure that the quantity or quality of the WTR do not adversely impact the final method wastewater works sludge such as land application.

The NWA gives effect to the post-1994 water law reforms and is a significant piece of legislation to establish the principles of efficiency, equity and sustainability in the water sector (Mogomotsi, 2017). The reforms introduced by the NWA require the equitable allocation of water to all water users and it places importance on managing the effects of water use on land, especially the water environment and resources. The NWA identifies 11 types of water use, which may have a detrimental effect on water resources. Water uses in Sections 21(f), 21(g), 21(f) and 62 relate to the management of Wastewater Treatment Works.

In other words, the NWA 36 of 1998 strived to transform how water was controlled and managed, from a system of rights based on land ownership (the riparian system) to a system designed to allocate water equitably in the public interest. The progressive reallocation of water to sectors of society that were previously excluded from access can help to bridge the divide between the first and the second economies, while maintaining existing beneficial water uses and encouraging greater efficiencies needed in our dry country. With the promulgation of the NWA in 1998, groundwater lost its previous status of private water and became public water. This has enormous implications for all users and essential benefits for municipalities as public users. It is now possible for municipalities to exploit groundwater resources even where these can only, or best, be accessed on private land.

The NWA requires the development of Water Management Plans by irrigation schemes, which involve the analysis of current water use, the setting of targets for improved water efficiency and planning of realistic means to reach targets. It is thus critical to ensure that all water supplies and uses are measured and are part of irrigation agriculture (Department of Water Affairs, 2013). This justifies the enforcement of the principle of universal water measurement for irrigation agriculture as a priority action.

The NWA of 1998 is the major piece of legislation addressing the use and disposal of water. Regarding waster reuse in irrigation, the Act makes no specific reference to greywater, but refers to ‘disposal of waste or water containing waste’. The discharge or use of water containing waste requires that the use is listed in a General Authorisation (GA) of the Act or alternately requires the issue of a licence (Rodda *et al*., 2011). The GA provided under the NWA were revised in 2004 to allow, amongst others, the limited use of biodegradable industrial wastewater for irrigation (DWAF, 2004). Although greywater is not mentioned among the types of wastewaters considered, this is probably the closest that existing legislation comes to providing guidance for the quality of greywater intended for irrigation use.

5.2.3 Water Services Act (WSA) 108 of 1997

The WSA of 1997 (Act 108 of 1997) is the fundamental governing framework for water services institutions, which are primarily municipalities, giving effect to the Bill of Rights by providing for access to essential water supply and sanitation services necessary to secure sufficient water and an environment not harmful to human health or well-being

(Republic of South Africa, 1997a). The WSA further established and empowered people with the right of access to basic water supply and sanitation.

The Act provided a regulatory framework and the establishment of water service institutions such as water boards and water service providers (StatsSA, 2017). The Act created a comprehensive legislative framework for the provision of water supply and sanitation services to support life and personal hygiene in a manner that is consistent with the broader goals of water resource management (Meissner *et al*., 2013). The Act encouraged cooperative governance with an emphasis on capacity building at all levels. It spelled out the roles and powers of the DWS in the event of non-performance by provincial departments and local governments.

The WSA aims to ensure that everybody has access to basic water supply and sanitation services (Mokgope *et al*., 2001). The Act deals explicitly with water services or potable water and sanitation services provided by municipalities to households and other municipal water users. It embraces guidelines and regulations regarding what and how municipalities ought to supply water and sanitation services. The Act outlines the municipal roles of guaranteeing water services provision and sets out strategies for the WSA as well as Water Service Providers (WSP). The functions and responsibilities of both WSA and WSP in terms of water resource management are not openly specified, but can be inferred from their diverse roles in the provision of water services.

5.2.4 Water Research Act 34 of 1971

The Water Research Act 34 of 1971 intends to provide for the promotion of research in connection with water affairs; for that purpose, to establish a Water Research Commission (WRC) and a Water Research Fund; and to provide for matters incidental thereto (Republic of South Africa, 1971). The objects of the commission are to co-ordinate, to promote, to encourage or to cause to be undertaken as determined by the Minister specifically or in broad outline, research in respect of:

- the occurrence, preservation, conservation, utilisation, control, supply, distribution, purification, pollution or reclamation of water supplies and water; and
- the use of water for agricultural, industrial or urban purposes.

The functions of the Commission include to cause by itself or in collaboration with the Council for Scientific and Industrial Research (CSIR), any state department, university or other institution, research to be undertaken in respect of matters relating to water, and to promote the research and in connection therewith to establish research programmes or to alter research programmes so established (Republic of South Africa, 1971).

The WRC is South Africa’s designated water research and knowledge hub. The Commission is dedicated to providing information that drives innovation in the water sector, informs water policy and decision-making, supports water services for socio-economic development and empowers communities across the country.

The WRC was founded in 1971, after a period of serious water shortages. It began at a time when water research and development in South Africa was limited to a few institutions, with an inadequate funding level and no research coordination. In addition, there was little strategic direction for the identification of priority research areas or the appropriate sharing of information.

As South Africa is still under threat of a lack of sufficient water, while water quality and availability issues are becoming more acute, the country is much better prepared to deal with this problem due to the Commission's meaningful contribution to the development of the capacity of the water sector, the broadening of the country's water-centred research and development base, as well as the WRC's continued commitment to channel and fund research on critical water issues such as IDAWM practices.

5.2.5 Conservation of Agricultural Resources Act 43 of 1983

The Conservation of Agricultural Resources Act (CARA) 43 of 1983 is a South African law that aims to promote the conservation of the soil, water sources and vegetation and the combating of weeds and invader plants (Republic of South Africa, 1983). The Act provides for control over the utilisation of the natural agricultural resources of the Republic in order to promote the conservation of the soil, water sources and vegetation and the combating of weeds and invader plants.

The objects of this Act are to provide for the conservation of the natural agricultural resources of the Republic through the maintenance of the production potential of land, through the combating and prevention of erosion and weakening or destruction of the water sources and through the protection of the vegetation and the combating of weeds and invader plants. This legislation involves environmental impact by promoting the sustainable use of natural resources in order to ensure long-term productivity of the plant production sector (National Department of Agriculture, Undated).

5.2.6 Agricultural Research Act 86 of 1990

The Agricultural Research Act No.86 of 1990 provides for the establishment of a juristic person to deal with agricultural research; the determination of its objects, functions, powers and duties (Republic of South Africa, 1990). It establishes the Agricultural Research Council (ARC). The Act defines the council's composition, objects, functions and powers and provides with respect to its administration and internal organisation. The council's objects are to promote agriculture, having regard to the environment through research, development and technology transfer (Republic of South Africa, 1990).

The objects of the ARC are, through research, development and technology transfer, to promote agriculture and industry and thereby to contribute to the improvement of the quality of life of the people of the Republic and having regard to the protection of the environment to perform such other functions as may be assigned to the ARC by or under this Act (Republic of South Africa, 1990). The fields of research include AWM areas such as rainwater harvesting, irrigation, wastewater reuse in agricultural, climate smart agriculture (CSA) and conservation agriculture (CA).

5.2.7 Provision of Land and Assistance Act 126 of 1993

Provision of Land and Assistance Act (Act No. 126 of 1993) as amended in 2008) provides for the designation of certain land, the regulation of the subdivision of such land and the settlement of persons on it. In addition, it provides for the acquisition, maintenance, planning, development, improvement and disposal of property and the provision of financial assistance for land reform purposes (Republic of South Africa, 1993). The Act is the key legislation that governs the Recapitalisation Programme. It provides, in Section 10, the government with the power to utilise money from Parliament not just to purchase land and other property for reform but to also (Republic of South Africa, 1993):

- Make available state land administered or controlled by him or her or made available to him or her;
- Maintain, plan, develop or improve property or cause such maintenance, planning, development or improvement to be conducted by a person or body with whom or which he or she concluded a written agreement for that purpose;
- Provide financial assistance by way of an advance, subsidy, grant or otherwise to any person for the acquisition, maintenance, planning, development or improvement of property and for capacity building, skills development, training and empowerment.

The Act provides important support for smallholder farmers who are involved in rainfed and farmer-led irrigation systems as well as those that operate under irrigation schemes.

5.2.8 Restitution of Land Rights Acts 22 of 1994

The Restitution of Land Rights Acts, 1994 (Act No. 22 of 1994 as amended) provides for the provisioning of restitution of rights in land to persons or communities dispossessed of such rights after 19 June 1913 as a result of past racially discriminatory laws or practices (Republic of South Africa, 1994). To administer this task, the Act provides for the establishment of a Commission on Restitution of Land Rights and a Land Claims Court and for matters connected with land restitution.

The Act states, in Section 42C, that "The Minister may from money appropriated by Parliament for this purpose and on such conditions as he or she may determine, grant and advance or subsidy for the development or management of or to facilitate the settlement of persons on land which is the subject of an order of the Court in terms of this Act or an agreement in terms of Section 14 (3) or 42D to:

a) Any claimant to whom restoration or the award of a right in land has been ordered;
b) Any claimant who has entered into an agreement contemplated in Section 14 (3) or 42D;
c) And person resettled as a result of an order of the Court.

The law affirms the right to restitution and defines the process by which those who were deemed eligible could lodge their claims. The law provides a framework for redress to those dispossessed of land through racist policy or legislation, where "claims can be compensated by transfers of land or other means, including cash payments" (Republic of South Africa, 1994). The law was passed to offer a solution to people who had lost their land as a result of racially discriminatory practices such as forced removals. These include smallholder farmers who operate as rainfed farmers, farmer-led irrigation farmers or members of irrigation schemes.

5.2.9 National Environmental Management Act 107 of 1998

The National Environmental Management Act (NEMA) (Act 107 of 1998) is a national environmental management framework legislation that defines the environment as the surroundings in which humans exist and includes land, water and atmosphere (Republic of South Africa, 1998b). In addition, it includes the interrelationships, combinations, properties and conditions of all organisms that exist in the surroundings. This extensive definition of the environment ties into the concept of integrated environmental management, which the NEMA promotes (Day, 2015).

Section 24 of the NEMA provides that: everyone has the right to have the environment protected for the benefit of the present and future generations. Similar to the WSA and the NWA, the NEMA prescribes national norms and standards for environmental governance to achieve social, environmental and economic sustainability. Similarly, the NEMA promotes a 'polluter pays' principle for the rehabilitation of the environment (Department of Water and Sanitation, 2018).

Pollution in the context of the NEMA is any emission from an activity related to the provision of services that can hurt human health or the well-being of the ecosystem in the present or the future. The NEMA, 107 of 1998, provides that any government department whose activity affects the environment must exercise these functions in accordance with the NEMA principles or Environmental Implementation Plan which is instituted by the Minister of Environmental Affairs and Tourism and the Environmental Co-ordination Committee (Section 16) with emphasis on sustainable development. 'Sustainable development' is defined in Section (1) of the NEMA 107 of 1998 as 'the integration of social, economic and environmental factors into planning implementation and decision-making to ensure that development serves present and future generation'.

Boshoff (2010) also defined sustainable development as the right to development that must be fulfilled to equitably meet the developmental and environmental needs of the present and future generations. To achieve sustainable development and a higher quality of life for the people, it is critical to reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies (Boshoff, 2010).

The NEMA provides for co-operative, environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state (Republic of South Africa, 1998b). Essentially, it provides the framework for enforcing Section 24 of the Constitution, which guarantees everyone the right to an environment that is not harmful to their health or well-being. The environmental management framework (EMF) of the Act focuses on critical environmental conflict areas which include conservation, natural resources protection, land-use planning, waste management, river health and groundwater use and quality.

5.2.10 National Environmental Management: Waste Act 59 of 2008

The National Environmental Management: Waste Act (NEMWA) (Act No 59 of 2008) is a framework legislation developed under NEMA as amended. In terms of NEMWA, listed waste management activities that have or are likely to have a detrimental effect on the environment must be licenced according to Section 20 and Chapter 5 of the Act (Republic of South Africa, 2008). The NEMWA in terms of the NEMA "as amended" has evolved over the years. This was primarily to conserve the natural resources and to minimise the effects caused using processed material towards the environment.

The NEMWA provides reasonable measures for preventing pollution, ecological degradation and securing ecologically sustainable development. The Act covers institutional arrangements, national norms and standards, specific waste management measures, licensing and control of waste management activities, remediation of contaminated land, a national waste information system, compliance, enforcement and related matters.

5.2.11 National Health Act 61 of 2003

The National Health Act 61 of 2003 provides a framework for a structured uniform health system in the Republic, taking into account the obligations imposed by the Constitution and other laws on the national, provincial and local governments with regard to health services; and to provide for matters connected therewith (Republic of South Africa, 2003).

The law takes into account the obligations imposed by the Constitution and other laws on the national, provincial and local governments with regard to health services (Republic of South Africa, 2003). The law also covers matters related to health services, such as norms and standards, health establishments, health workers, health information,and health research, waste management, water quality monitoring and environmental pollution control.

The National Norms and Standards for Environmental Health clearly outline monitoring standards for the delivery of quality Environmental Health Services, as well as acceptable standards requirements for surveillance of premises, such as business, state occupied premises and for the prevention of environmental conditions that may constitute a health hazard for the protection of public health. Some of the norms and standards guide the use of wastewater in irrigation.

5.2.12 Climate Change Act 22 of 2024

Climate Change Act 22 of 2024 intends to enable the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society for South Africa in the context of sustainable development; and to provide for matters connected therewith (Republic of South Africa, 2024). The objects of this Act (Republic of South Africa, 2024) are to:

- provide for a coordinated and integrated response by the economy and society to climate change and its impacts in accordance with the principles of cooperative governance;
- provide for the effective management of inevitable climate change impacts by enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to building social, economic and environmental resilience and an adequate national adaptation response in the context of the global climate change response;
- make a fair contribution to the global effort to stabilise greenhouse gas concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system;

- to ensure a just transition towards a low carbon economy and society considering national circumstances;
- give effect to the Republic's international commitments and obligations in relation to climate change; and
- protect and preserve the planet for the benefit of present and future generations of humankind.

Under the National Greenhouse Gas Inventory, the Act empowers the Minister who may by notice in the Gazette identify a list of activities and thresholds for which measurements or estimations of greenhouse gas emissions and carbon sinks from stationary, mobile, fugitive, process, agriculture, land use and waste sources must be carried out.

The provisions of the Act are based on the principle that everyone has the constitutional right to an environment that is not harmful to their health and well-being and to have the environment protected for the benefit of present and future generations through reasonable legislative and other measures that secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development.

The interpretation and application of this Act is guided by principles which include: the need for climate change mitigation and adaptation responses to be informed by evolving climate change, scientific knowledge and decisions which must be based on the best available science, evidence and information; an effective climate change response which requires preventative measures to mitigate the causes of climate change and to strengthen resilience through the adoption of adaptation measures; the costs of responding to the adverse impacts of climate change and of mitigation which must be paid for by those responsible for causing the adverse impacts; and an integrated climate change response which requires the enhancement of public awareness of climate change causes and impacts and the promotion of participation and action at all levels (Republic of South Africa, 2024). While rainfed farming is most impacted by climate change, both rainfed and irrigated agriculture systems are affected by climate change hence these principles apply to all the IDAWM practices.

5.2.13 The Land and Agricultural Development Bank Act 15 of 2002

The Land and Agricultural Development Bank Act 15 of 2002 establishes a juristic entity known as the Land and Agricultural Development Bank (Republic of South Africa, 2002). Its key provisions include defining the bank's mandate, governance structure, management, funding mechanisms and risk management. The Act aims to support agricultural development and land-related initiatives in South Africa. The objects of the Bank shall be the promotion, facilitation and support of; (a) equitable ownership of land by historically disadvantaged persons; (b) agrarian reform and land distribution; (c) land access for agricultural purposes; (d) agricultural entrepreneurship; (e) increase of productivity and profitability in the agricultural sector; (f) proper use of land programs; (g) food security; and (h) other objects set out in Section 3. The Bank shall provide financial services to promote and facilitate access to ownership of agricultural land and mobilise and facilitate the private sector banking to do the same. (54 sections) (Republic of South Africa, 2002).

The sole objective of the Land Bank is to serve South African commercial and emerging agriculture by bringing specially designed financial services within the reach of farmers across the nation. These services enable farmers to finance land, equipment, improve assets and obtain production credit.[8] The bank supports rainfed and irrigation farmers (farmer-led and irrigation scheme farmers). Although the bank does not have explicit provisions for supporting wastewater use for irrigation, it is expected that smallholders who use wastewater for irrigating their field may obtain financial support from the bank.

5.3 Policies related to AWM

The section covers policies related to AWM in the agriculture, water and environment sectors. Appendix F presents a summary of policies related to IDAWM practices while details of the IDAWM-related policies are presented in the following sections.

5.3.1 White Paper on Agriculture 1995

The White Paper on Agriculture of 1995 contained an agriculture policy aimed at ensuring equitable access to agriculture and promoting the contribution of agriculture to the development of all communities, society at large and the national economy in order to enhance income, food security, employment and quality of life in a sustainable manner. The South African constitution states that the governance of agriculture functions falls within the competence of provinces, that governance needs to be guided by policy on a national level in which the distinction between the role of provincial and national agricultural administration and governance are clear (Department of Agriculture, 1995). Through its nine provincial Departments of Agriculture, the South African government has the mandate to implement agricultural policies using agricultural extension services. The objective of the white paper suggested that the National Department of Agriculture has the obligation to establish a policy that promotes sustainable agriculture through inclusive consultation with the relevant stakeholders. Such a policy should integrate the five pillars of sustainable agriculture.

Water in South Africa is a limited resource and is, naturally, essential to both urban and rural areas leading to conflict amongst the users. In the past water tariffs were heavily subsidised by the government but now as detailed in the white paper, the government ensures that the benefits and real cost of natural resources are reflected in the pricing of resources so as to discourage abuse. The government ensures that the catchment management committees are fully represented in catchment areas irrespective of the members' gender, class and race and that management decisions on the use of water are transparent, consultative and accountable. The government further ensures that all sectors of the South African community have equitable access to resources so that all the inhabitants' basic needs are met and that appropriate mechanisms to resolve disputes concerning the natural resources are set up (Department of Agriculture, 1995).

5.3.2 Policy on Agriculture in Sustainable Development – 8th Draft

The Policy on Agriculture in Sustainable Development forms part of the process of incorporating principles and objectives of sustainable development into the ethos of the agricultural sector of this country. It aims at integrating and harmonising the three pillars of sustainable development viz. social (people), environment (planet) and

[8] Our Business (landbank.co.za)

economic (prosperity). Its goals should be to ensure socially responsible economic development while protecting the resource base and the environment for the benefit of future generations. The policy recognizes the shared goals of government, farmers and conservationists and the need for all stakeholders to work together to achieve a sustainable agricultural sector in South Africa. The success of this policy depends largely on the support and participation of farmers, consumers, government departments, parastatals, the private sector, non-governmental organisations (NGOs), community-based organisations (CBOs) and other stakeholders (National Department of Agriculture, Undated).

The sustainable use of water in agriculture should be accompanied by better husbandry of soils, fertilisers, improved plant varieties etc. Increasing the efficiency of water use in agriculture and improving irrigation system performance in a sustainable manner is a key goal for agricultural development. Efficiencies can be improved through a combination of both technical and managerial means. Efficiency could be further increased through the promotion of small-scale irrigation, water conservation, secure water rights for users and user group management of systems where appropriate. Water use efficiency in agriculture can be optimised through irrigation management, including rehabilitation of existing schemes using appropriate technologies, as well as the development and promotion of innovative water harvesting techniques under rain-fed conditions. The strategies for policy development include (National Department of Agriculture, Undated):

- Enhance in a sustainable manner the productivity of land and the efficient use of water resources in agriculture and aquaculture, especially through indigenous and local community-based approaches;
- Prevent water pollution to reduce health hazards and protect ecosystems through effective irrigation technologies and mitigation of the effects of groundwater contamination;
- Improve prevention and protection measures to promote sustainable water use and to address water shortages through integrated water resources management and water efficiency plans, including water harvesting under rain-fed conditions;
- Integrate river basin, watershed and groundwater management and introduce measures to improve the efficiency of water infrastructure to reduce losses and increase recycling of water and water harvesting;
- Promote the scientific understanding of the sustainable use, protection and management of water resources to farmers and encourage knowledge sharing and integration with indigenous knowledge systems to advance long-term sustainability of water resources;
- Promote and create incentives and awareness programmes for agricultural enterprises and farmers to monitor and manage water use and quality, inter alia, by applying such methods as small-scale irrigation and wastewater recycling and reuse;
- Expand agro-forestry to minimise the impacts of salinity and high-water tables;
- Expand small-scale irrigation schemes through policy, institutional framework, external and national public funding and enabling conditions for private sector investments;

- Encourage re-vitalisation, upgrading and maintenance of irrigated land through irrigation development programmes;
- Maximise water retention capacity of soils;
- Promote development of drought resistant crops through genetic engineering;
- Develop and promote appropriate water harvesting technologies especially for dryland production; and
- Improving the efficiency and effectiveness of water use in agriculture.

5.3.3 National Policy on Food and Nutrition Security (2014)

The National Policy on Food and Nutrition Security (2014) is a policy aimed at ensuring that all citizens have access to sufficient, safe and nutritious food at all times. It reflects South Africa's commitment to realizing the constitutional right to food, aligning with the National Development Plan (NDP) and international obligations like the United Nations Sustainable Development Goals (SDGs). The policy is a comprehensive government framework aimed at ensuring the availability, accessibility and affordability of safe and nutritious food at both national and household levels (DAFF, 2013).

This policy framework serves as a foundation for various strategies and programs, including the Household Food and Nutrition Strategy and the Fetsa Tlala Integrated Food Production Initiative, aiming to streamline and harmonise food security interventions across the country (DAFF, 2013). It is a multi-dimensional, integrated strategy designed to tackle food insecurity through coordinated government action, enhanced agricultural investment, nutrition education and risk management, with a strong emphasis on supporting emerging farmers and protecting agricultural resources.

5.3.4 Rural Development Framework Policy

The policy addresses the problem of environmental degradation by introducing conservation measures and making people aware of the benefits through education. The policy also advocates for the use of community-based natural resources management as an approach to encourage better resource management whereby local communities and stakeholders play an important part in the process. Through the Land Care Programme, the government made the first step to involving communities in conservation.

The policy also introduced the River Valley Catalytic Programme (RVCP), which offers a framework for integrating water planning and management with environmental, social and economic development along the river banks (watershed development). The AWM-related components of the RVCP include soil and land management, water management, crop management and afforestation.

5.3.5 Conservation Agriculture Policy 2017

The Conservation Agriculture Policy 2017 was developed by the Department of Agriculture, Forestry and Fisheries (DAFF) to promote sustainable agricultural practices that address soil health, water conservation, climate change adaptation and food security (DAFF, 2017). The policy includes a policy framework embracing minimal tillage, soil cover and crop diversification. Through consultation, institutional support and measurable targets, the policy is designed to operationalise CA across commercial and smallholder farms. The policy aligns with the South African

Constitution's provisions for a secure and sustainable environment and supports the NDP's (Vision 2030) call for ecological approaches to agriculture (DAFF, 2017).

5.3.6 Rural Economy Transformation Model One District One-Agri-Park/Every Municipality Policy

Rural areas are characterized by the under-utilisation and unsustainable use of natural resources. The natural resource base has been depleted by population growth, migration and consumption patterns and the need for residential land and services. The problems also include overgrazing, depletion of woodlands, depletion of water resources and deterioration of irrigation systems and overfishing. The policy stipulates that one of the guiding principles for Agri-Park establishment is the demonstration of how available high value agricultural land and other important production resources (e.g., rivers and irrigations schemes) are most beneficially utilised.

5.3.7 Policy Framework for the Recapitalization and Development Programme of the Department of Rural Development and Land Reform

The Recapitalization and Development Programme (RADP) is a policy framework implemented by the Department of Agriculture, Land Reform and Rural Development (DALRD) in South Africa (Department of Rural Development and Land Reform, 2011). The RADP aims to revitalise and develop land reform farms by providing support, resources and strategic interventions. The objectives of RADP are to:

- increase food security;
- graduate small farmers into commercial farmers;
- create employment opportunities in the agricultural sector; and
- establish rural development rangers.

The RADP applies to all emerging farmers needing and deserving of support, as well as future land beneficiaries. The programme also covers all categories of property acquired and to be acquired for land reform purposes (Department of Rural Development and Land Reform, 2011). The RADP policy aims to support emerging farmers by providing specialised agricultural financing in the form of financial guarantees to those financial institutions that the farmers are indebted to. The RADP provides strategic support for value chains on land reform farms. It also ensures recapitalisation and development on acquired land through targeted clusters. Most of these are rainfed and farmer-led irrigation farmers. The RADP also applies to irrigation scheme and state farms in communal areas.

5.3.8 National Water Policy for South Africa - White Paper April 1997

The National Water Policy is based on the principle that water is an indivisible national resource, but it has limited value in and of itself. Water is valued for the many ways in which it serves our needs and it is this, as indicated in the principles, which guides the water policy. Specifically, Principle 7 states that:

> *"The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from their use".*

The White Paper on a National Water Policy (1997) for South Africa outlines the government's policy for managing both the quality and quantity of our scarce water resources. It emphasises that water is a basic human right and a giver of life. The paper acknowledges the historical exclusion of many South Africans from direct access to water and calls for a review of water use policy and law based on fairness and equity. This document represents a crucial milestone in the reform of South Africa's water sector, addressing social, economic and environmental issues as it is implemented over the next two decades.

This White Paper outlines the direction to be given to the development of a new National Water Bill in South Africa. The policy is placed within the context of the South African constitution, the country's social and economic context, the Reconstruction and Development Programme (RDP) and within the international context. It draws on an earlier document entitled *"Fundamental Principles and Objectives for a New Water Law in South Africa"*. The principles of the new policy are based on equity and optimum resource use and protection. It distinguishes three main priorities: basic needs, environmental requirements and international obligations. Under water resource management activities, the Paper identifies the following activities: water use authorisation; water resource protection; water utilisation and conservation; water pricing; water resource development; public safety and disaster prevention; monitoring, assessment and auditing; and international cooperation. It then addresses the institutional, human resource and research policy requirements needed to implement the above activities.

5.3.9 National Water Policy Review: Water Policy Positions (2013).

The National Water Policy Review (NWPR) 2013 was conducted by the DWS to assess and update the existing national water policy framework (Department of Water and Sanitation, 2013). The review aimed to address policy gaps, unintended oversights and challenges observed during the 17 years since South Africa's democratic transition and the implementation of its foundational water legislation — the National Water Act of 1998 and the Water Services Act of 1997. The key drivers of the review were:

1) ***Equity and redress:*** despite progress in expanding access to water services, a significant portion of South Africa's water resources remained inequitably distributed, with much of the allocated water controlled by a small minority. The NWPR 2013 prioritised equity, aiming for fairer, more inclusive access and use of water resources.
2) ***Service delivery:*** The government focused on accelerating water and sanitation service delivery — particularly to rural communities and informal settlements — to fulfill constitutional rights and developmental goals; and
3) ***Legislative Alignment***: recommendations from the NWPR were intended to inform broader legislative reforms, creating the potential for a single, streamlined Water Act to replace the existing National Water Act (1998) and Water Services Act (1997).

The amendments recommended by this policy review reflect the policy positions which outline additional, new or updated courses of actions which the government intends to adopt in pursuit of national water objectives in the future (Department of Water and Sanitation, 2013). The Policy emphasises the importance of water resilience in adapting to climate change. Water conservation technologies should be actively researched through pilot projects. It also mentions that capacity building efforts in terms of water conservation should be focused on rural women.

5.3.10 National Environmental Health Policy 2013

The National Environmental Health Policy 2013 serves as a broad guideline and framework for the effective implementation of Environmental Health Services in South Africa. The overall goal of the Environmental Health Policy is to ensure the right to an "environment that is not harmful to the health and wellbeing of South Africans" (Department of Health, 2013). The policy aims to address environmental-related diseases by improving hygiene, sanitation practices, waste management and pollution control. Strengthened environmental health services play a crucial role in achieving the country's health goals. Climate change effects are also considered in the policy, emphasizing the need for sustainable practices.

The policy defines Environmental Health Services as the assessment, monitoring, correction, control and prevention of environmental factors that can adversely affect human health (Department of Health, 2013). This includes, but not limited to, anticipation and identification of environmental health hazards and risks associated with rainfed and irrigated farming systems and the use of wastewater for irrigation.

5.3.11 Environmental and Social Sustainability (ESS) Policy

The Environmental and Social Sustainability (ESS) Policy of the Land and Agricultural Development Bank of South Africa outlines the bank's commitment to responsible practices. The policy aims to promote land stewardship, protect the environment and support communities impacted by the bank's activities. It recognises the bank's dependency on natural resources and its role in securing long-term sustainability (Land Bank, undated).

The Land Bank's mandate aligns with government policies and socio-economic needs, emphasising agriculture and rural development. The availability of suitable land is crucial for the bank's operations. The Land Bank recognizes that it has an opportunity to play an important role in promoting land stewardship, protection of the environment and communities impacted by its activities and to help secure the long-term sustainability of natural resources, communities and society at large. The Land Bank also recognizes its dependency on the environment and the resources it provides for the achievement of its objectives. As such the Bank aims to be a responsible steward in the protection of the environment and human rights to strengthen its social license to operate (Land Bank, undated). The fact that the policy commitments of the Bank include promoting land stewardship through the efficient use of resources, prevention and pollution reduction and enhancement of biodiversity protection shows that the Bank support safe and environmentally sustainable use of wastewater for irrigation.

5.3.12 National Climate Change Response Policy: White Paper 2011

South Africa's National Climate Change Response Policy was published as a White Paper in October 2011 (Republic of South Africa, 2011, 2011). It is a comprehensive plan to address both mitigation and adaptation in the short, medium and long term (up to 2050). The policy considers agriculture as the largest consumer of water (through irrigation) and that it is vulnerable to changes in water availability, increased water pollution (particularly from toxic algal or bacterial blooms) and soil erosion from more intense rainfall events and increased evapotranspiration (Republic of South Africa, 2011, 2011). Under-resourced, small-scale and subsistence farmers are particularly vulnerable to the impacts of climate change.

At the same time, conventional, commercial input-intensive agriculture has a range of negative environmental, social and economic externalities, which increasingly render it an unsustainable model (Republic of South Africa, 2011). However, commercial agriculture remains a significant contributor to gross domestic product (GDP) and employment. Its full contribution, with multipliers, comprises up to 12% of GDP and 30% of national employment (Republic of South Africa, 2011). Crop failures can therefore have a significant economic impact. A climate resilient agricultural response depends on the recognition that agriculture should provide not only food, but also a range of other environmental and socio-economic benefits. The policy supports research and development systems which prioritise technologies for climate change adaptation in rural areas, including low water-use irrigation systems, improved roll-out of rainwater harvesting strategies and drought resistant seed varieties.

5.4 Plans, strategies, frameworks, programmes and networks related to AWM

The section presents plans, strategies, frameworks, programmes and networks which are related to the implementation of IDAWM practices in the country. Appendix G presents a summary of plans, strategies, frameworks, programmes and networks related to IDAWM practices while details of the IDAWM-related plans, strategies, frameworks, programmes and networks are presented in the following sections.

5.4.1 National Development Plan (NDP) 2030

The NDP is a broad strategic framework. It sets out a coherent and holistic approach to confronting poverty and inequality. One of the NDP's objectives under economic infrastructure is to ensure that all people have access to clean, potable water and that there is enough water for agriculture and industry, recognising the trade-offs in the use of water (Republic of South Africa, 2013).

The planned actions under this objective include the timely development of several new water schemes to supply urban and industrial centres, new irrigation systems in the Umzimvubu river basin and Makhathini Flats and a national water conservation programme to improve water use and efficiency (Republic of South Africa, 2013). It substantially increases investment in irrigation infrastructure in Makhathini Flats and Umzimvubu River Basin.

The NDP proposed a differentiated rural development strategy that focuses on agricultural development based on successful land reform, employment creation and strong environmental safeguards (Republic of South Africa, 2013). To achieve this, the NDP proposed that irrigated agriculture and rainfed agricultural system be expanded, with emphasis on smallholder farmers where possible with established agricultural industries as key enabling partners.

Under the agricultural sector, the NDP actions include substantial investment in irrigation infrastructure, including water storage, distribution and reticulation throughout the country where the natural resource base allows, as well as in water-saving technology. The NDP considered that as the primary economic activity in rural areas, agriculture has the potential to create close to 1 million new jobs by 2030, a significant contribution to the overall employment target. To achieve this, it was proposed that the country needs to expand irrigated agriculture given that evidence showed that the 1.5 million hectares under irrigation (which produce virtually all South Africa's horticultural harvest and some field crops) can be expanded by at least 500 000 hectares through the better use of existing water resources and developing new water schemes.

The other actions involve the use of underused land in communal areas and land-reform projects for commercial production and support for commercial agriculture sectors and regions that have the highest potential for growth and employment. The plan prioritised land that has the potential to benefit from irrigation infrastructure, support for successful farmers in communal areas which would support further improvement of the area; and industries and areas with high potential to create jobs. It was expected that all these would increase collaboration between existing farmers and the beneficiaries of land reform.

5.4.2 National Water and Sanitation Master Plan Volume 1: Call to Action (2018)

The National Water and Sanitation Master Plan (NW&SMP) aims to guide the water sector's investment planning for water resource development and sanitation services until 2030 and beyond (Department of Water and Sanitation, 2018). The NW&SMP acknowledges that South Africa faces a water crisis due to factors such as insufficient infrastructure maintenance, recurrent droughts, inequities in access to water and sanitation, deteriorating water quality and a shortage of skilled water engineers.

The plan predominantly focuses on the vulnerability of the water sector to climate change. It does, however, focus on the vulnerability of the agricultural sector due to growing water demand and reduced reliability on rain-fed agriculture. The key planned actions of the NW&SMP include to reduce the water demands and water losses at all major irrigation and agricultural schemes by 2030, without affecting productions and implement the Water Administration System (WAS) on all government irrigation schemes for transformation (Department of Water and Sanitation, 2018). It also promotes the upscaling of early warning system tools and other innovative technology developments to improve efficiency of agricultural production. The plan targets increased research and monitoring and evaluation of water resource management. It recognises the capacity gap to manage water resources at the national and institutional scale.

Therefore, a key action is to educate, train and develop capacity of the DWS, Catchment Management Agencies, municipalities and young people. The plan covers various facets, including identifying future water sources for the growing population, water resource development options, infrastructure operation and maintenance, water quality management, climate change resilience and water conservation. The plan outlines key programs, projects and actions needed to protect and develop national water resources. Additionally, it allocates roles and responsibilities across government tiers, the private sector and other stakeholders for effective implementation.

The NW&SMP addresses institutional arrangements, legal frameworks, funding models and monitoring and evaluation methods. Overall, the plan encompasses collaborative efforts which aims to ensure adequate and reliable water and sanitation services for all citizens, emphasizing the importance of water security for South Africa's economy and development.

5.4.3 National Water Security Framework for South Africa (NWSFSA): Summary, Principles and Recommendations (2020)

The NWSFSA frames a national pathway to a water secure country up to 2050 to enable inclusive economic growth, poverty eradication and reducing inequality in line with the NDP imperatives (Nepfumbada, 2020). The National Water Security Framework (NWSF) acknowledges the importance of water security for the country and addresses issues at national, regional and local levels through the various facets which include:

- identifying future water sources for the growing population, economic development and the attendant future water resources development and wastewater management (including sanitation) options;
- the development, operation and maintenance of water and sanitation infrastructure;
- the management of water quality and water supply services, as well as the resilience of our country to climate change and its associated impacts; and
- water conservation and water demand management as a consistent national paradigm.

The NWSFSA is based on 10 focus areas which represent the "hooks" from which all institutions attach/hang the interventions as they relate to national water security which must be adhered to at every level, across all sectors and sub-sectors interested and affected by water security as per their respective mandates or needs (Nepfumbada, 2020). The focus areas are: narrowing the inequality gap; water infrastructure and finance; diversifying water sources; water research, monitoring and information; nexus aspects of water security; ecological infrastructure; water and spatial [planning; managing water risks] and communication and stakeholder empowerment.

The NWSF promotes technology and research development to enhance water security resilience and to manage water-related disaster risk through water conservation, reuse and alternative approaches. It advocates for strong monitoring and evaluation systems at the institutional level to enable interventions to address water security issues. In the agricultural sector, decision-making should be informed by the local context, for example, appropriate crop choices. The framework promotes actively raising awareness and education on climate-related risks.

5.4.4 The Agriculture and Agro-Processing Master Plan

The Agriculture and Agro-Processing Master Plan (AAMP) signed in May 2022, operates as a social compact, emphasising collaboration among stakeholders (DALRRD, 2022). These stakeholders include all spheres of government (national, provincial and local), commercial and emerging agriculture, the banking sector, labour unions, civil society and other related parties. The strategic goals of the plan are: to set commodity-specific transformation targets, jobs, exports, investments and growth rates; and to build on the NDP and focus on commercial agriculture, land reform, rural areas and infrastructure to enhance food production and support farmers.

The plan aims to provide comprehensive farmer support, development finance, research and development (R&D) and extension services (DALRRD, 2022). The plan aims at ensuring food security, expanded production (under rainfed and irrigated agriculture) and employment creation, enabling market expansion, improving market access and facilitating trade and developing localised food, import replacement and expanded agro-processing. The AAMP represents a collaborative effort to unlock the potential of South Africa's agriculture and agro-processing sectors, fostering inclusive growth and sustainable development.

5.4.5 National Agricultural Research and Development Strategy (2008)

The National Agricultural Research and Development Strategy (2008) is a sectoral policy developed through extensive consultations within the National Agricultural Research System (NARS). Its primary mission is to guide and direct agricultural research, development and technology transfer to accelerate investment and efforts in these areas for sustainable agricultural growth (Department of Agriculture, 2008). The strategy laid out a long-term vision to enhance agricultural research and development to support economic growth, food security and poverty eradication. It emphasises improving the efficiency, profitability and competitiveness of the agricultural sector and it focuses on the sustainable use of resources and addressing challenges such as climate change, land and water scarcity. The strategy was formulated with input from all major stakeholders in the national agricultural research system to ensure broad alignment and relevance. It aims to increase investment in agricultural R&D, both public and private to meet national development goals and improve rural livelihoods (Department of Agriculture, 2008). The strategy also includes governance and institutional arrangements to support implementation.

The strategy laid the foundation for subsequent policies and initiatives aimed at boosting agricultural productivity and innovation in the country, recognising the critical role of research and development in addressing socio-economic challenges and ensuring sustainable growth in the sector. The strategy serves as a comprehensive framework to strengthen agricultural R&D, promote sustainable agricultural development and contribute to South Africa's broader economic and social objectives.

5.4.6 National Education and Training Strategy for Agriculture and Rural Development in South Africa (2005)

The National Education and Training Strategy for Agriculture and Rural Development in South Africa was developed to address the critical need for skills development, capacity building and equitable access to education and training in the agricultural sector (Department of Agriculture, 2005). The strategy is a comprehensive framework aimed at supporting sustainable agricultural growth, rural development and poverty alleviation through targeted educational initiatives. The objectives of the strategy are to enhance the skills-base in the agriculture sector to support economic growth and sector transformation, broaden access to agricultural education and training (AET), especially for historically disadvantaged groups and rural populations, address fragmentation, improve coordination and ensure quality and relevance of training programs, align with national programs such as AgriBEE, Integrated Food Security and Nutrition Programme (IFSNP) and the Comprehensive Agricultural Support Programme (CASP) (Department of Agriculture, 2005). The National Education and Training Strategy for Agriculture and Rural Development serves as a foundational policy document, guiding the development of a coordinated, inclusive and effective education and training system for the country's agricultural sector (Department of Agriculture, 2005). Its implementation is critical for achieving sustainable rural development, food security and economic transformation in the country.

5.4.7 Strategic Plan for Smallholder Support 2011-2014/15

The Strategic Plan for Smallholder Support (SPSS) 2011-2014/15 is a comprehensive initiative by DAFF aimed to support and strengthen smallholder farmers as a key pillar for achieving national food security, job creation and rural development, aligning with the New Growth Path, Medium-Term Strategic Framework (MTSF) and the NDP (DAFF, 2011). The key objectives of the plan are to expand the number of smallholders and improve their productivity and competitiveness, integrate smallholders into the mainstream value chain (input supply, production, processing and marketing) and enhance institutional support and coordination for effective smallholder development.

5.4.8 National Water Resources Strategy of 2004 (1) and 2013 (2) and 2023 (3)

The National Water Resource Strategy (NWRS) of 2004(1) is a crucial document and a legal instrument for implementing or operationalising the NWA (Act 36 of 1998) (Department of Water Affairs, 2013). The first edition of the NWRS defined the fundamentals of integrated water resource management and presented a clear perspective of the water situation in South Africa and the critical interventions required. It is a binding document on all authorities and institutions implementing the Act. The purpose of the second edition of the NWRS is to ensure that national water resources are managed towards achieving South Africa’s growth, development and socio-economic priorities in an equitable and sustainable manner over the next five to 10 years (Department of Water Affairs, 2013). The major focus of the National Water Resource Strategy 3rd Edition (NWRS-3) is protection and equitable and sustainable access and use of water by all South Africans while sustaining our water resource (Department of Water and Sanitation, 2023). Equity and redistribution are achieved through the authorisation process and other mechanisms and programmes, such as water allocation reform, financial support to emerging farmers and support to urban and rural local economic development initiatives.

In general, the NWRS provides the framework for the protection, use, development, conservation, management and control of water resources for the country as a whole. It also provides the framework within which water is managed at the provincial, regional or catchment levels in the defined WMAs. Furthermore, this policy document provides relevant information about how water resources can be managed and the institutions to be established. It also provides quantitative information about the present and future availability of, and requirements for, water in each of the 19 WMAs. The key components and drivers of the NWRS of 2004 are its progressive decentralisation of the responsibility and authority of water resource management to catchment management agencies and, at a local level, to the WUAs. These institutions, representative of water users and other stakeholders, facilitate active participation in the management of water resources in their areas. The NWRS provides the DWS to make a shift from its current multiple roles as an operator, developer and regulator to become the sector leader, policymaker, regulator and monitor. In addition, the NWRS of 2004 provides a platform for essential collaboration and cooperation among all departments in all spheres of government involved in economic development.

The NWRS is the legal instrument for implementing or operationalising the NWA (Act 36 of 1998) and it is thus binding on all authorities and institutions implementing the Act. It is the primary mechanism to manage water across all sectors towards achieving national government's development objectives. In terms of the NWA, the purpose of the NWRS is to:

- facilitate the proper management of the nation's water resources;
- provide a framework for the protection, use, development, conservation, management and control of water resources for the country as a whole;
- provide a framework within which water is managed at regional or catchment level, in defined WMAs; and
- provide information about all aspects of water resource management; and
- identify water-related development opportunities and constraints.

The NWRS 2013(2) has been developed in a changing environment and acknowledges that monitoring and collecting relevant data does not only provide accurate assessments of the status of water resources and the magnitude of water problems, but also vastly improve planning and policy formulation processes. The national water legislation (Section 68 of the WSA) requires the minister concerned to maintain a national information system to record and provide data on the development, implementation and monitoring of national policy. This monitoring should not be done only for the sake of addressing national concerns, but should be in response to the obligations committed in international river basins. Approximately 60% of the streamflow in rivers is shared through trans-boundary water systems. The policy on this stresses that Integrated Water Resources Management (IWRM) should be implemented in a manner that conforms to international water protocols and treaties, while being compliant with the legislation governing water resource management in South Africa.

The regulation policy is to ensure standard values and principles are set and maintained and that there is compliance with the regulatory provisions. This is a strategic focus of the policy. The attainments of all country and sector goals must be sustained within an environment that protects the integrity of the NWA and all other legislations that have an impact on water resource management. Additionally, this policy underscores that the realisation of the goals and objectives requires robust institutional support, a knowledgeable and capable workforce, coupled with indispensable financial resources to implement interventions. An investment strategy, with financial capital backing, needs to be devised to implement all vital programmes under the NWRS efficiently. This can be achieved only if the government, developmental organisations, the private sector and other funders collaborate to provide the necessary funding to support water resource management in South Africa.

The NWRS acknowledges that the agricultural sector accounts for approximately 61% of water utilisation in South Africa (DWA, 2023). It supports a significant portion of the South African economy and contributes massively to rural development. It assures food security for the country and contributes to job creation and employment throughout the food production value chain. The NWRS stresses that water conservation and water demand management (WC/WDM) must thus become entrenched in the agricultural sector. The implementation of the NWRS is founded on the following principles (DWA, 2013).

- Many irrigation schemes experience water losses of between 35-45%. In the past, much of agricultural support tended to focus on issues relating to the repair of the infrastructure to ensure well-functioning irrigation schemes. Currently, however, many of these schemes are in a state of disrepair and some have exceeded their economic lifespans.

- The efforts to save water by this sector should be given high priority. A small percentage improvement in water use efficiency could result in a substantial reduction in water losses. In terms of water delivered on farms, all efforts must be made to use water efficiently from on farm storage, distribution systems and in-field application supported by best management practices.
- The greatest potential impact of WCWDM in the agricultural sector can be achieved by addressing wastage from conveyance losses and the inefficient application of water. Water wastage is classified as water intended to perform a specific task, but not used for that purpose due to losses in transit. Examples of water wastage in the agricultural sector are seepage from irrigation canals (which causes water logging of adjacent land), loss because of percolation, evaporation from land surfaces or polluted return flows.
- Employing efficient irrigation systems is paramount in improving water use efficiency on farms, such as drip irrigation, which when managed and operated effectively, results in significant improvements in water use efficiency.
- Create an enabling environment to facilitate technology transfer about water use efficiency and productivity improvement technologies, such as the water accounting system (WAS) developed by the WRC for irrigation schemes.
- Improve scheduling of irrigation through the use of soil moisture content monitoring instruments (probes and wetting front detectors).
- The development of Water Management Plans by WUAs is central to implementing WCWDM in the agricultural sector. WMPs are similar to the Water Services Development Plans (WSDP) currently developed by municipalities. Essentially, the process aims to conserve water, to improve water supply services to irrigation farmers and to enable them to use irrigation water more efficiently.
- The process involved in analysing current water use, setting targets for improved efficiency and planning a realistic means of reaching these targets is very important in this sector and should be given priority.
- The DWA is promoting and has initiated the development of water management plans by all irrigation schemes. A pilot project in 14 irrigation schemes has identified considerable reductions in water losses to be achieved, essentially through infrastructure asset management and operation. It is thus important that irrigation schemes develop water management plans.

The NWRS articulates DWA’s support for a national water harvesting programme (rainwater and fog harvesting), which has important focus on the provision of above- and below-ground water storage tanks for rural households and other institutions such as clinics, schools and hospitals (DWA, 2013). The collected water is primarily intended for irrigation of food gardens to improve food sufficiency and for other productive water uses. The harvested water can also be used for domestic purposes where communities do not have a reliable source of potable water.

The NWRS-3 provides for robust and sustainable water sector institutions (including six catchment management agencies and six WMAs) that have the necessary capacity to manage our water resource sustainably and equitably, as well as to ensure sustainable and effective water and sanitation service delivery (Department of Water and Sanitation, 2023).

5.4.9 National Water Conservation and Water Demand Management Strategy (2004)

In 2004, the Department of Water Affairs and Forestry (DWAF) (2004) developed the National Water Conservation and Water Demand Management Strategy (NWC/WDMS) for the industry, mining and power generation sectors, water services and the agriculture sector. The NWC/WDMS is a crucial initiative aimed at promoting water use efficiency. It aligns with the NWA, emphasising the effective management of the country's water resources. This strategy plays a fundamental role in enhancing water services management, ensuring sustainability, efficiency and affordability for consumers.

The objectives of the NWC/WDMS are as follows:

1) To facilitate and ensure the role of water conservation or water demand management to achieve the sustainable, efficient and affordable management of water resources and water services.
2) To contribute to the protection of the environment, ecology and water resources.
3) To create a culture of water conservation or water demand management in all water management and water services institutions.
4) To create a culture of water conservation or water demand management for all consumers and users.
5) To support water management and water services institutions to implement water conservation or water demand management.
6) To promote the allocation of adequate capacity and resources by water institutions for water conservation or water demand management.
7) To enable water management and water services institutions to adopt integrated planning; and
8) To promote international cooperation and participate with other southern African countries, particularly basin-sharing countries, in developing joint water conservation or water demand management strategies.

The NWC/WDMS is combined with various other departmental strategies to culminate into the NWRS. While irrigated lands represent only 10% of the cultivated area, some 35% of all domestic foodstuffs and 85% of all agricultural exports are derived from irrigated lands (DWAF, 1999). The DWAF (1999) indicated that irrigation losses are often quite significant and it is estimated that no more than 60% of water abstracted from water resources is correctly placed in the root systems of plants. Approximately 35 % of irrigation system losses return to the river systems by overland flow and return seepage but this return water is normally nutrient enriched and polluted with herbicides, pesticides and other pollutants that affect the water quality of rivers and streams. Irrigation methods, irrigation scheduling, soil preparation, crop selection and evaporation all have a significant impact on the efficient usage of water. The application of water conservation and demand management (WC/DM) principles in the irrigation and farming sectors as presented in this strategy have a significant effect on the availability of water to other sectors and the protection of water resources and reuse

5.4.10 National Strategy for Water Reuse (2011)

The reuse of water in South Africa accounts for approximately 14% of total water use and return flows account for a large part of water available for use from some of the important river systems. The National Water Resources Strategy (First Edition) identifies water reuse as one of a number of important strategies to balance water availability with water requirements in future and the extent of water reuse in South Africa is very likely to increase substantially over time. There is an associated risk that water reuse is unplanned, unregulated and/or results in unintended or undesirable consequences. The reuse of water is widely practiced in the world, both in developed and emerging economies. Many countries have developed water reuse policies and associated laws and regulations. Water reuse internationally contributes in reconciling the gap between water availability and water needs in such countries as the United States of America, Spain, Australia, Israel and China (DWA, 2013). Within the above context, the National Strategy for Water reuse promotes a considered approach to the implementation of water reuse projects that are consistent with the NWRS and national water policy and legislation.

The National Strategy for Water Reuse in South Africa emphasises the importance of water reuse. With a growing population and recurring droughts, planning for increased freshwater demand becomes critical. Water reuse is one of the proposed strategies to address this challenge. The NWRS (First Edition) recognises water reuse as a crucial strategy to balance water availability and requirements in South Africa, likely leading to substantial increases in water reuse over time.

The strategy identifies the main source of water for reuse in municipal (urban) areas as wastewater from municipal treatment works. This typically comprises a mix of domestic sewage and other wastewater. Other sources of water for reuse include grey water (usually available at the household/water user level only) and industrial effluents. The main potential uses of treated wastewater from municipal wastewater treatment works are for the irrigation of public open spaces (parks etc.), sports fields (municipal, schools and clubs), golf courses and cooling (related to industry and power generation). The return flows from wastewater treatment works can also be important for urban water systems (rivers, lakes, dams and wetlands). Treated wastewater and/or grey water can also be used for firefighting, toilet flushing, cooling systems, street cleaning, dust control and a variety of applications that do not require potable water.

Of the total volume of municipal wastewater treated, it is estimated that only a small fraction is reused, most of it is for the irrigation of public open spaces, sports fields, golf courses and cooling systems (DWA, 2013). In the past, the urban/municipal reuse of treated wastewater was not actively promoted due to the cost of such systems and the potential public health risks. Some reuse of water, for example in the irrigation of recreational areas and golf courses may be in competition with other essential water uses.

The strategy identified three generic sources of 'used' water associated with different scales of water reuse (DWA, 2013). These are:

a) At a micro-level, the water that has been used by a household, a business, an institution or industrial facility, a power station, a farm or a mine. The key feature is that this used water is available at a specific and local geographic location. The quantity and quality of water available for reuse depends on how it has been used and if there is any local (on-site) treatment or not.

b) At a community or facility level, where wastewater has been collected from a group of users (typically within a natural drainage basin) and typically through a sewer network. In this case, the used water is available at the discharge point of the treatment facility at a quality that is dependent on both the characteristics of the inflow to the treatment facility as well as the treatment technology used and its effectiveness (both in terms of design and operational performance).

c) At a river system level, where used water (treated and untreated) has been discharged (or found its way) back into the river system. In this case, the used water is blended with the 'fresh' water in the river system. The quality of the river water depends on the quality and quantity of the return flows, the state of the receiving water body and its assimilative capacity and the ratio of fresh water flows to return flows (the dilution effect).

The strategy stresses that considerable potential exists to substantially expand the use of treated wastewater for irrigation purposes in the country. This brings many benefits. Irrigation is often labour intensive and expanding the area under irrigation may create jobs. Wastewater return flows are typically available close to urban areas and thus close to urban markets for agricultural produce, provided suitable land is available for irrigation. Treated wastewater can substitute for freshwater thus making more freshwater available for other uses.

5.4.11 Irrigation Strategy for South Africa

The Irrigation Strategy for South Africa set a target of an increase of more than 50% of irrigated land in South Africa over the next 10-20 years. This goal involves revitalising smallholder irrigation schemes across the country. The strategy emphasises collaboration with provincial departments of agriculture and the DWS to achieve its objectives. The strategy has a strong focus on rainwater harvesting as a solution to improve water security, acknowledging the numerous socio-economic benefits, particularly for smallholder farmers. The simplicity of rainwater harvesting construction is emphasised but also stated is the need to provide training to local users. Water management in South Africa needs to focus on women empowerment and developing locally relevant solutions for irrigation, which requires an emphasis on local knowledge from traditional small-scale farmers. The strategy stresses the importance of effective communication, co-ordination and cooperation between government, research institutions, private sector and farmers for establishing irrigation agriculture in South Africa. Irrigation information should be widely disseminated to build awareness of the beneficial impacts.

In order to address water scarcity and climate challenges, the country is adopting water-wise practices, efficient irrigation techniques and sustainable water management. These efforts are crucial for maximising water use and minimising environmental impact. By implementing these strategies, South Africa aims to enhance food security, support rural livelihoods and promote overall agricultural transformation.

For future scenarios, the DWS assumes that the amount of water allocated for agriculture will remain the same; all land reform projects and revitalisation of smallholder irrigation schemes will use the same amount of water as before. An increase in irrigation will be affected through water use efficiency and selected new development.

The Strategy recognises the gaps in irrigation-related knowledge and information, calling for new high-quality research conducted by South Africans to ensure local relevance. Also acknowledged is the challenge of inadequate financial support for implementing RWH in South Africa. However, the strategy does not provide any feasible mechanisms to source alternative funding beyond grants.

5.4.12 Strategic Plan 2020-2025, Agriculture, Land Reform and Rural Development

The Strategic Plan 2020-2025 of the DALRRD recognises agriculture as a crucial sector for South Africa's economy, with significant potential for growth and job creation (DALRRD, 2020). The plan aims to boost exports by emphasising the international market for local agricultural products. The implementation of spatial planning and land use management systems promotes social and economic inclusion. The goal is to ensure equal opportunity, access to government services and efficient land utilisation. The plan seeks to transform land ownership patterns, especially for previously disadvantaged groups. Allocating land to smallholder producers and providing comprehensive support packages are essential steps.

The plan aims to integrate rural areas into the country's economic activities. By overcoming poverty and unemployment, it ensures food security and basic services for the population. The plan aims at creating farmer production support units which improve farmers' activities and enhance their productivity. As all water users are required to implement electronic water measurement instruments to monitor their water usage, abstraction and storage rates so that these records could be submitted to the DWS weekly, the plan aims to assist agricultural users (irrigation farmers) so that they are able to reduce water usage, adapt to produce crops with higher returns and that they can introduce technologies regarding water-efficiency to monitor usage (DALRRD, 2020).

5.4.13 Agricultural Policy Action Plan, 2014-2019

The Agricultural Policy Action Plan (APAP) 2014-2019 was developed by the DAFF (DAFF, 2014) to address the sector's challenges and unlock its potential for job creation, food security and rural development. The APAP aligns with the country's broader economic strategies, including the New Growth Path (NGP), the NDP and the Industrial Policy Action Plan (IPAP). The APAP was designed to promote inclusive growth and transformation in the agriculture, forestry and fisheries sectors, improve food and nutrition security, stimulate job creation, especially in rural areas, drive sectoral competitiveness through value-chain development and support sustainable resource management (land, water and biodiversity). The APAP (2015-2019) represents a strategic, targeted approach to revitalising South Africa's agriculture, forestry and fisheries sectors. By focusing on high-impact value chains and transversal challenges and aligning with national development goals, the plan aims to drive inclusive growth, job creation and rural transformation (DAFF, 2014).

5.4.14 Water for Growth and Development Framework (2009)

The Water for Growth and Development (WfGD) Framework, which was launched on 2 March 2009, is a strategic initiative by the DWAF (DWAF, 2009). Its purpose is to guide actions and decisions that ensure water security in terms of both quantity and quality. The framework supports South Africa's economic growth targets, aligning with initiatives like the Accelerated Shared Growth in South Africa (AsgiSA). By optimising water use, it contributes to sustainable social development and poverty reduction. The WfGD Framework points to the relationship between water availability and the many forms of economic activity that depend on available water supply of specific levels of quality.

The Department's position is that the country's economic growth target cannot be achieved at the expense of the ecological sustainability of water resources or meeting people's human needs. The framework presents the response of the Department to the needs of the different economic sectors and this is best achieved when water supply and the impact of use are factored in during planning (DWAF, 2009). Rather than being an add-on or an afterthought, the Department sees the need for water to be mainstreamed and placed at the nucleus of all planning decisions both in the public and private sector. For water to support economic growth without compromising the primary needs or ecological sustainability requires adequate planning at a strategic level and in an integrated manner.

The WfGD framework identifies various areas for intervention, including: investing in technologies and practices that promote efficient water use across various sectors; implementing strategies to manage and reduce water demand, especially in areas facing shortages; investing in water infrastructure, including dams, pipelines and treatment plants to ensure reliable water supply; strengthening water resource management practices, including monitoring, allocation and protection of water sources; addressing the increasing impact of climate change on water resources and developing strategies to adapt and mitigate these impacts; and enhancing the capacity of water institutions to effectively manage water resources and implement the framework. The framework is a comprehensive approach to managing the country's water resources in a way that supports sustainable development, ensuring that water is available for both present and future needs. Regrading agricultural water, the framework supports the provision of incentives to encourage farmers to balance their risks of water supply against using more efficient irrigation systems.

5.4.15 Integrated Growth and Development Plan (2012)

The Integrated Growth and Development Plan (IGDP) of 2012 is a strategic framework developed primarily by DAFF. The main aim of the plan is to provide a long-term strategy for the growth and development of the agriculture, forestry and fisheries sectors in the country. The purpose of the plan is to guide sustainable socio-economic development within the sectors of agriculture, forestry and fisheries, aligning with national government priorities and policies (DAFF, 2012). It serves as a planning tool to coordinate efforts across government spheres and other stakeholders to enhance service delivery and economic growth. The IGDP is a comprehensive, multi-year strategic framework designed to drive sustainable development and economic growth in South Africa's agriculture, forestry, and fisheries sectors through integrated planning, stakeholder engagement and alignment with national policies (DAFF, 2012).

5.4.16 Second National Action Programme for South Africa to Combat Desertification, Land Degradation and the effects of Drought (2018-2030)

The development of South Africa's second National Action Programme (NAP) (2018-2030) was also aligned to the country's national priorities as 91% of the country falls within the category of drylands, making it susceptible to desertification, land degradation and drought, which are intricately linked to food and water insecurity and poverty (Department of Forestry, Fisheries and the Environment, 2018). The main objective of the programme is to ensure sustainable management of land, water and ecosystems so that by 2030, the country combats desertification, restore degraded land and soil, including land affected by desertification, drought and floods and strive to achieve a land degradation-neutral world (Department of Forestry, Fisheries and the Environment, 2018). The programme recognises that unsustainable human activities, including agricultural use of steep slopes and excessive irrigation can lead to salinisation of the soil and erosion.

5.4.17 Strategic Water Partners Network (2011)

The Strategic Water Partners Network (SWPN), which is hosted by the NEPAD Business Foundation (NBF), is a multi-stakeholder partnership (primarily between the DWS, the private sector and civil society) working cooperatively to close a 17% gap between water supply and demand that is anticipated to manifest by the year 2030 in South Africa (DWS, 2021). The underlying driver of the SWPN is the commitment by the partners to find solutions for South Africa's water challenges. They work collectively to identify, design and implement innovative and cost-effective solutions and programmes that address shared water challenges. The DWS, through the SWPN has implemented the WAS Release Module at several irrigation schemes. With the WAS, it is possible to release the correct amount of water from a source according to demand, thereby reducing wastage.

5.5 Guidelines related to AWM

Appendix H presents a summary of guidelines related to IDAWM practices while details of the IDAWM-related guidelines are presented in the following sections.

5.5.1 The South African Guidelines for the Permissible Reuse of Treated Sewage Effluents (1978)

In South Africa, the reuse of treated wastewater for irrigation has historically been limited to recreation facilities like sports fields and urban parklands. In rare cases, it Is also allowed for food-related activities such as fodder production. However, there are no formal guidelines specifically addressing wastewater reuse for irrigation. The DoH applies the South African Guidelines for the Permissible Reuse of Treated Sewage Effluents (1978) to regulate this practice (Steyn & Jagals, 2000). Interestingly, the guideline seems to focus more on the treatment method and configuration rather than the actual quality of the effluent. While more elaborate treatment facilities are generally considered favourably for food production and recreation, there are discrepancies in how different systems are evaluated. For instance, irrigation from a public stream with higher faecal coliform levels is permitted, even though the guideline may not provide the desired public health protection. As for greywater reuse for home gardens, the national legislation does not prohibit it, but there are no formal standards or guidelines in place at the moment.

Greywater is untreated household effluent from baths, showers, kitchen and hand wash basins and laundry (i.e., all non-toilet uses), More than half of indoor household water is normally used for these purposes and can potentially be intercepted by the householder for additional beneficial uses. Greywater use is practiced on an informal basis to supplement irrigation water, either in urban gardens in middle to upper income suburbs or in food gardens in lower income informal, peri urban and rural areas. It holds the potential to contribute significantly to food security in poor communities by providing a source of both irrigation water and nutrients for crop plants. While Rodda *et al.* (2011) reported there were no formal guidelines for the use of greywater in South Africa in 2011, Young *et al*. (2018) have produced guidelines for greywater use and management in South Africa as part of a project funded by WRC.

5.5.2 South African Water Quality Guidelines for Irrigation Water Use

South African Water Quality Guidelines serve as the primary source of information for determining the water quality requirements of different water uses and for the protection and maintenance of the health of aquatic ecosystems. The guidelines are used by the DWS as its primary source of information and decision-support to judge the fitness for use of water and for other water quality management purposes. They contain similar information to that which is available in the international literature. However, the information provided in these guidelines is more detailed and not only provides information on the ideal water quality for water uses, but in addition provides background information to help users of the guidelines make informed judgements about the fitness of water for use.

The South African Water Quality Guidelines (2nd edition) Volume 4: Agricultural Use: Irrigation is essentially a user needs specification of the quality of water required for different irrigation uses. It is intended to provide the information to make judgements on the fitness of water to be used for irrigation purposes, primarily for crop production. The guidelines are applicable to any water that is used for irrigation purposes, irrespective of its source (municipal supply, borehole, river, etc.) or whether or not it has been treated (DWAF, 1996) hence these guidelines are particularly important where unconventional water use for irrigation is practised.

The guidelines are used by the DWS as its primary source of information and decision-making to judge the fitness of water for use and for other water quality management purposes. The second edition of the guidelines was published in 1996 by the Department of Water Affairs and Forestry. It contains essential information related to water quality for agricultural irrigation. The guidelines consist of eight volumes in total with volume 4 covering Agricultural Use: Irrigation.

The term irrigation water as used in these guidelines refers to water which is used to supply the water requirements of crops and plants, which are not provided for by rain and refers to all uses water may be put to in this environment (DWAF, 1996). This includes water for

- the production of commercial crops;
- irrigation water application and distribution systems;
- home gardening;
- the production of commercial floricultural crops; and

- potted plants.

5.5.3 Guidelines for the Reuse of Treated Wastewater

Steyn and Jagals (2000) produced guidelines for treated wastewater (TWW) reuse in South Africa. Their guideline approach seems to favour the treatment method — and configuration that produces the effluent — as a benchmark for decision-making rather than the actual quality of such effluent. Reuse applications that involve more elaborate treatment facilities (primary, secondary and tertiary treatment processes within the configuration) would generally be favourably considered for purposes of food production and recreation-related applications. According to Steyn and Jagals (2000), the applications for the reuse of effluent from waste stabilisation pond systems (WSP) are generally discouraged - regardless of the effluent quality.

Steyn and Jagals (2000) developed their guidelines based on their study on WSP. The guidelines included the use of TWW for the irrigation of crops. Steyn and Jagals (2000) found the Guide (1978) confusing when crop and irrigation types are to be considered because it clearly does not provide for aquaculture nor does it make provision for newer agricultural practices such as hydroponics where certain edible crops are cultivated without the vegetable touching the water.

5.5.4 Guidelines for Sustainable Reuse of Effluent on Land – A Suggested Approach

Murphy (2000) developed guidelines for sustainable reuse of effluent on land in South Africa. The guidelines were developed on the basis that the effectiveness of land-application treatment of effluent depends on various factors, the major ones being soil media constituents, effluent contaminant characteristics, land use, vegetation type, effluent application rates and vulnerability of adjacent surface and ground water resources to contamination. The application of suitably treated effluent to land has the potential for low-cost crop-growth purposes, for effective effluent treatment using vegetation and soil and has the potential to conserve high-quality source waters, which would have been used for irrigation, for alternative use (Murphy, 2000).

Currently, the regulations exist which address pathogenic health risks associated with the use of sewage effluents on crops. However, further regulations and guidelines are needed in order to address site conditions, soil contamination limits and land application-rate restrictions and which address these together with other aspects such as water resource conservation in an integrated manner. These guidelines are designed to promote on-land effluent recycling for beneficial purposes which also take into account environmental precautionary and sustainability principles. The guidelines further present a proposed regulatory procedure, aligned in principle with one recommended by the World Health Organization (WHO), which is designed to augment existing regulations on applying effluents to land for beneficial purposes.

5.6 Overview of Water Management Institutions

The NWA provides the framework for water resource management. It outlines the different water management institutions as well as the specific functions of the different institutions. The institutional arrangements for water governance are presented in Figure 5.1.

5.6.1 Department of Water and Sanitation

The DWS has the overall responsibility for effective water management as the custodian of the indivisible national water resource. This responsibility is discharged through the DWS which is also responsible for overseeing the overall implementation of the Act (DWA, 2013). The Act also allows for the Catchment Management Agencies (CMAs) whose role is water management at a water management area/catchment level and is responsible for the progressive development of catchment management strategies. The Act also states that the CMAs will use the catchment management strategy consistently with the National Water Resource Strategy (NWRS), within its water management area. It is important to note that most of this responsibility is delegated by the Minister.

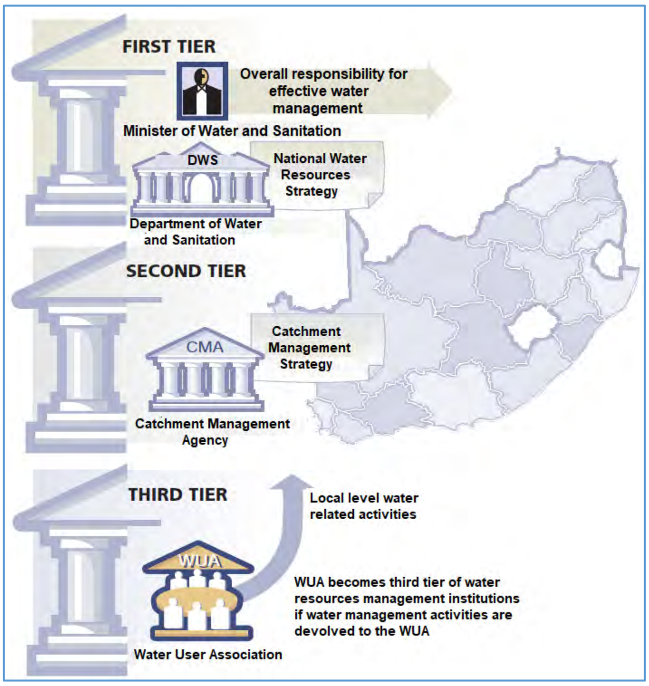


Figure 5.1: The water management institutions
(Adapted from: Department of Water Affairs, 2013)

The DWS is also responsible for administering all aspects of the National Water Act delegated to it by the Minister or Director-General. The various water resource management institutions are established and the responsibility and authority for water resource management is delegated or assigned to them. It increasingly focuses on national policy, a regulatory framework for water resource management and ensuring that other institutions are effectively fulfilling their roles and responsibilities.

5.6.2 Water management at local level

The third tier in this framework is considered to operate at a local level lower than the water management area (WMA). The concept of local water resource management is based on the internationally accepted principles of IWRM which requires the involvement of resource users in the implementation of water resources management. This proposition was also supported by the White Paper of 1997 which highlighted the role that Irrigation Boards (IBs) and WUAs play at this level (DWA, 2013). Accordingly, IBs and WUAs have continued to discharge functions related to this objective as well as those delegated to it by the Minister. Since the promulgation of the Act; these institutions have played crucial roles in managing water supply or distribution to various water users based on their water demands and licence schedule. This suggests that IBs and WUAs are critical institutions in the development and implementation of water demand management programs and initiatives at the local level especially in the agricultural sector.

5.7 Water governance systems

5.7.1 Introduction

Water governance refers to the political, social, economic and administrative systems that influence water's use and management. It includes the formulation, establishment and implementation of water policies, legislation and institutions, as well as the clarification of roles and responsibilities of government, civil society and the private sector in relation to water resources and services (Boran, 2018). The main components of water governance identified in the abstracts include core actors, law, policies and systems, budget support, information sharing and communication, mutual learning, external experts, village representatives, legislation, central government, policy committee, education course and facilitators (Blackstock *et al*., 2012).

Strengthening informal institutions and promoting the active participation of core actors such as farmers and villagers are recommended approaches to address water governance gaps in the agricultural sector (Blackstock *et al*., 2012). Water governance also involves legislative means, administrative mechanisms and governance principles to ensure the provision of assured quantity and quality of water resources to all potential users at an appropriate time (Blackstock *et al*., 2014). The government play an important role in water governance through planning and policy, regulation and support for local government and basin stakeholders (Brack *et al*., 2015).

5.7.2 Water governance systems in South Africa

The governance of water in South Africa is implemented under three spheres of government; namely, national, provincial and local. These spheres are constitutionally mandated to observe and apply the principle of cooperative governance and intergovernmental relations while developing and implementing policies and performing their functions (Simo, 2014). According to the South African Constitution 108 of 1996, each sphere of government has its distinctive character. However, the Constitution stresses that these spheres are interdependent and interrelated in their task of managing water resources (Adom & Simatele, 2021). The relationship of cooperative government binds all spheres of government together and underscores the principle of participative decision-making in water governance (Haigh *et al*., 2010).

The national and the local spheres are the significant role-players together with the citizens, who constitute an imperative component of governance, particularly at the local level (Simo, 2014). An integrated development plan is established to smooth cooperative governance across the three spheres of government. For the effective and efficient provision of water, the local governments' integrated development plans must be aligned to the Water Service Development at the National Department of Water and Sanitation (Fuo, 2013). The provincial governments play an important role in coordinating alignment between the integrated development plans and water services development plans. They manage water policies in relation to developmental planning and environmental management (Petzer *et al*., 2000).

The national water policies and legislations are transformational governance pieces that not only resolve the complications of the past, but also assist in building a better future (Karodia & Weston, 2002). This is explicitly stated in the resolution of the NWA of 1998, which is to ensure that the country's water resources are protected, used, developed, conserved, managed and controlled in ways that take into consideration factors such as, among other things, meeting the basic human needs of the present and future generations, promoting equitable access to water, redressing past discrimination, facilitating social and economic development and protecting aquatic elements and their associated ecosystems. In addition, the National Environmental Management Act (NEMA) 107 of 1998 and the WSA are linked to the sixth objective of the SDG Goal 6 (Clean Water and Sanitation), which is the cornerstone of social and economic development, as well as alleviating poverty and enhancing sustainable livelihoods.

In South Africa, there are two levels of strategic planning for water resources; namely, the National Water Resources Strategy (NWRS) and the more locally based Catchment Management Strategies (CMSs[9]. The NWA provides for the establishment of a variety of water management institutions. The aim of establishing these institutions is to delegate water resources management to more regional and localised levels, to involve stakeholders in water resources management and thereby give effect to integrated water resources management. The NWA outlines the different water management institutions as well as the specific functions of the different institutions. The Act defines a water management institution as:

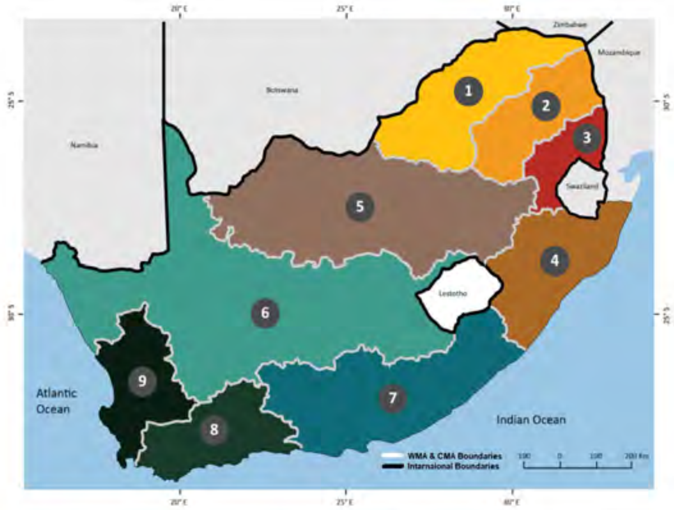
a) a catchment management agency;
b) a water user association;
c) a body responsible for international water management; or
d) any person who fulfils the functions of a water management institution in terms of the NWA.

5.7.3 Water Management Areas and Catchment Management Agencies

In the development of the NWRS (2004) 19 WMAs were defined for the country, in each of which, it was envisaged, a CMA would be established (Fig. 5.2). However, there were concerns raised during the gazetting of the original WMAs as to the capacity of the country to support 19 CMAs (DWA, 2013). Taking these matters into consideration, a decision was made to reduce the number of WMAs to nine, concomitantly requiring the establishment of nine CMAs (Fig. 5.3).

[9] https://www.dws.gov.za/IO/Docs/Starter%20Pack%20_Final_FULL%20(00000003).pdf

Figure 5.2: The previous and consolidated WMAs
(Source: Department of Water Affairs, 2013)



❶ Limpopo ❷ Olifants ❸ Inkomati-Usuthu ❹ Pongola-Mtamvuna ❺ Vaal ❻ Orange ❼ Mzimvubu-Tsitsikamma ❽ Breede-Gouritz ❾ Berg-Olifants

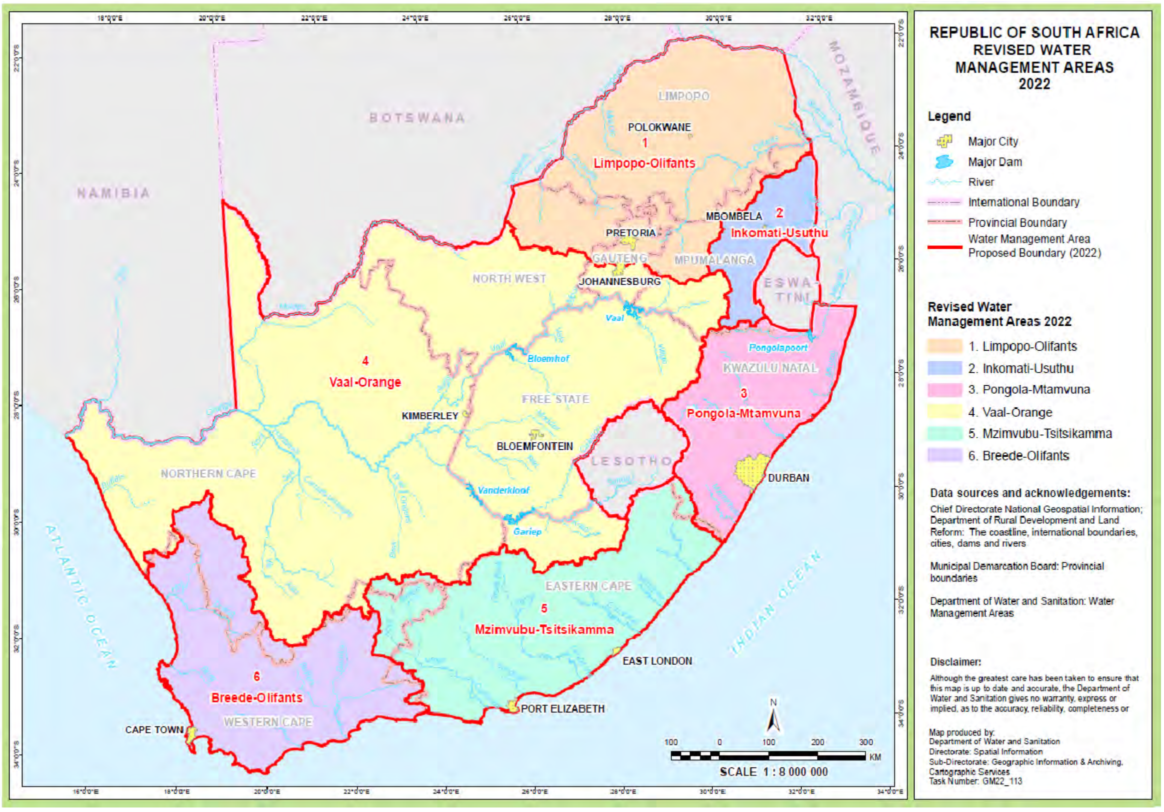
Figure 5.3: The nine WMAs and CMAs
(Source: DWS, Directorate: Catchment Management)

The DWS has reviewed the reconfiguration of the WMAs from nine (9) to six (6) (DWS, 2023). The intention is to establish six (6) Catchment Management Agencies (CMAs) nationally. The revised reconfiguration is presented in Figure 5.4.

The WMAs were established as management units in the national water resource strategy within which CMAs conduct the protection, use, development, conservation, management and control of water resources by involving local communities within the framework of the National Water Resource Strategy (2nd Edition 2013) established in terms of the Water Management Strategies. The map in Figure 5.3 depicts the boundaries of the nine WMAs and CMAs.

The CMAs are established to ensure that water resources are managed effectively at regional or catchment level where local community involvement is most effective (Toxopeüs, 2019). The CMAs are established progressively throughout the country, within the WMAs defined by the NWRS. Whilst certain water resource management functions may be assigned or delegated to these agencies, there are initial functions that all CMAs must perform upon establishment which include, amongst others:

- Playing a coordinating role regarding water-related activities and water management institutions;
- Developing and implementing a Catchment Management Strategy; and
- Encouraging public participation.



1: Limpopo-Olifants; 2: Inkomati-Usuthu; 3: Pongola-Mtamvuna;4: Vaal-Orange; 5: Mzimvubu-Tsitsikama; 6: Breede-Olifants

Figure 5.4: Water Management Areas within South Africa WMAs (Source: Department of Water and Sanitation, 2023)

A range of organisational models for these agencies are required to suit the differing needs of the various WMAs. Furthermore, the organisational structure depends largely on the functions that are assigned or delegated to it. The Governing Boards of the CMAs are accountable to the Minister for the Agencies' performance and are primarily responsible for setting the vision, mission and strategic direction. These Boards reflects the relevant sectoral, demographic and gender profiles, as well as possesses the appropriate expertise and experience. The Governing Boards are responsible for implementing the Catchment Management Strategies. They are also responsible for ensuring that the balance between socio-ecological protection and socioeconomic development is maintained in the WMAs. Thus, the Governing Boards ensure, via the staff of the CMAs, that stakeholders have their say with regard to resource protection and resource development and that the strategy reflects their needs and requirements.

5.7.4 Catchment Management Committees

The NWA provides specifically for the establishment of committees by the CMA "to perform any of its functions within a particular area or to advise it". It also provides for powers to be delegated to Committees. The established Catchment Management Committees (CMCs) provide an important means by which CMAs can broaden their management and technical capacity. These committees which are statutory committees have become known as 'catchment management committees' although in the National Water Act, they are simply referred to as 'committees' (DWS, 2013). A catchment management committee provides a mechanism for the CMA to increase its technical management capacity and/or broaden stakeholder representation. It further provides a mechanism for communication, cooperation and decision making between stakeholders and the CMA governing board.

5.7.5 Water User Associations

The WUA is a statutory body established by the Minister in terms of the NWA. WUAs are, in effect, cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit. WUAs provide the institutional structure necessary for individual water users to cooperate and pool their resources – allowing them to carry out water-related activities more effectively (Toxopeüs, 2019). The functions of a WUA depend largely on its constitution drafted in terms of the NWA. The broad role of a WUA is to enable people in a community to pool their resources (money, person-power and expertise) to carry out water-related activities more effectively. The establishment of a WUA must also assist in achieving the purposes of the Act.

Firstly, WUAs enable members to benefit from addressing local needs in terms of local priorities and resources. Secondly, they provide a mechanism through which a CMA (or the Minister) can devolve the implementation of aspects of the Catchment Management Strategy to the local level. WUAs normally operate at a localised level. However, there are exceptions, such as when the length of a river managed by a WUA is so long that it relates more to a regional than a local interest. A WUA may be concerned with a single purpose, such as controlling recreational activities on a river or providing water for emerging farmers. Alternatively, they may be multi-sectoral, dealing with a variety of water uses in their area of operation. They may also derive their functions through a process of delegation from the Minister or the CMA. The WUA is accountable, for exercising a delegated function, to whoever gave the specific delegation.

While the Act provides for the establishment of WUAs for any form of water use as described in the Act, there are two distinct types of WUAs that may be established; namely, a sectoral WUA and a multi-sectoral WUA. A sector based one acts in the interests and on behalf of a group of similar users (Fig. 5.5). For example, a group of emerging irrigation farmers could form a sector based WUA or a group with an interest in controlling recreational use and so on.

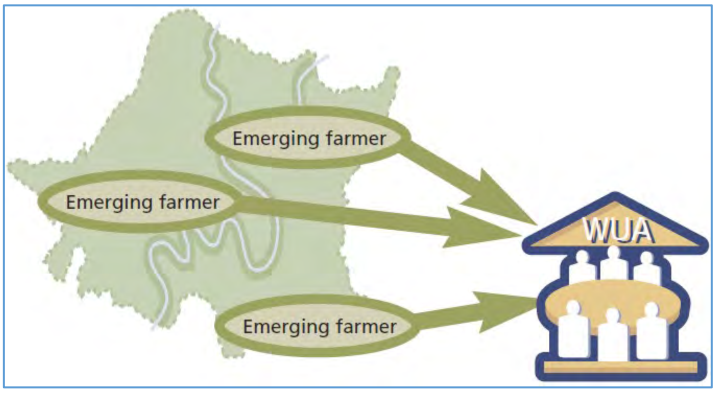


Figure 5.5: Sector based WUA
(Source: DWAF, undated)

A multi-sector based WUA acts in the interests and on behalf of a combination of different water users, such as conservation, forestry, mining and irrigation collectively (Fig. 5.6).

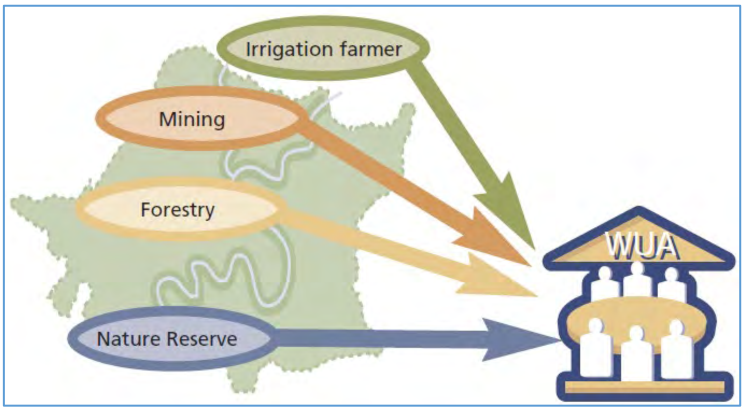


Figure 5.6: Multi-sector based WUA
(Source: DWAF, undated)

The NWA outlines all the matters that must be addressed in the constitution of a WUA. The Act (Schedule 5) also includes a model constitution that may be used as the basis for drafting a WUA constitution. In general, WUAs perform the following functions:

- Operational functions, related to the management of a service;
- Bulk raw water supply functions, related to the management of a bulk raw water supply system;
- Resource management functions, related to the management of the resource; and
- Representation functions, related to the representation of stakeholder needs at higher institutions of water management.

5.7.6 Recently developed water governance instruments

Since water governance systems were developed after the enactment of the National Water Act, more governance instruments have been developed. Recently developed water governance instruments are presented in Appendix I. One of the outstanding governance instruments is verification and validation of *existing lawful water uses* (ELUs) (Liebenberg, 2024). Since 1998, when South Africa's current NWA came into effect, registered ELUs have been allowed to continue as a transitional mechanism whereby water users may continue using water until such time as compulsory licensing is called for (Liebenberg, 2024).

Until such time as verification and validation of such ELUs is finalised, government will arguably not have the most important piece of the South African water governance puzzle. This is significant since without verification and validation of existing lawful water uses being completed, government cannot conclusively show that it knows which water uses are lawfully exercised, by whom and where (and whom to bill for it). Legislative and policy changes, which affect existing water use entitlements need to be procedurally and administratively fair. This includes government having to take all relevant considerations (including ELUs) into account in its legislative processes (Liebenberg, 2024).

5.7.7 Local level governance systems

Well-structured governance systems exist at the local level in irrigation schemes. The WUA is the high-level institution for the management of scheme operations. The hierarchical nature of the WUA cascades down from the river basin/catchment to the district, scheme/farm and sub-farm level (Fig. 5.7). The WUA is the main water governance institution of the irrigation scheme. At the farm-level authority of the WUA regulates and controls the construction of canal and lateral within the scheme whereas the sub-fam level authorities are responsible for canal maintenance. At the village level and below are field canals and ditches, which are maintained by the farmers who own or occupy leased land. They are responsible for farm water management under the direction of block committees.

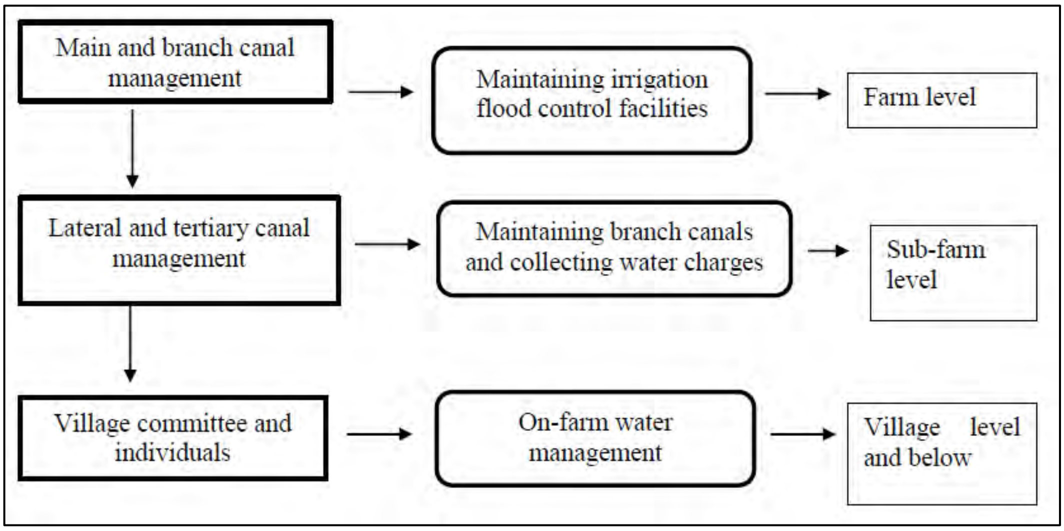


Figure 5.7: The hierarchal nature of the WUAs at scheme level
(Modified from Yang *et al*., 2003)

Another tier of water governance at local level is the traditional leadership. Traditional leaders are responsible for resolving conflicts among farmers which the scheme committees fail to settle. The rainfed and farmer-led irrigation systems are also governed at the local level by the traditional leadership governance systems. This, however, is mostly limited to land allocation and conflict management between farmers. Most small scale rainfed and farmer-led irrigation systems operate outside the governance structures that regulate water use. Nonetheless, the large scale rainfed and farmer-led irrigation systems comply with different governance systems particularly the water licence subscription through the DWS.

5.8 Agriculture governance systems

The South African Constitution states that the governance of agriculture functions falls within the competence of provinces, that governance needs to be guided by policy on a national level in which the distinction between the role of provincial and national agricultural administration and governance are clear (Department of Agriculture, 1995). Through its nine provincial departments of agriculture, the South African government has the mandate to implement agricultural policies using agricultural extension services (Khwidzhili & Worth, 2017). The objective of the white paper suggested that the DAFF has the obligation to establish a policy that promotes sustainable agriculture through inclusive consultation with the relevant stakeholders. Such a policy should integrate the five pillars of sustainable agriculture.

5.9 Degree of support of legislation, policies and strategies to the AWM systems

An analysis of how national legislation, policies and strategies in the IDAWM sectors support the AWM systems was conducted. The rating was conducted by stakeholders during a workshop in August 2024. In addition to the rating carried out by stakeholders during the workshop, the analysis also involved reviewing the sections and provisions of the legislation, policies and strategies in the water, agriculture, environment and health sectors and assessing the degree of support each provides to the AWM systems. The levels of degree of support considered in this analysis were strong, moderate, weak and none, based on the approach of the WHO (WHO, 2019). Table 5.1 presents the degree of support of national legislation, policies and strategies/plans for the AWM systems in the country. The colour coding used is specific to this study.

The Constitution, in Section 27: (1) (b) (Republic of South Africa, 1996), guarantees every person the right to access "sufficient water and food". The Constitution also has provisions for guaranteeing access to energy resources in the country. The NWA sets the basic human needs of water for drinking and food preparation and personal hygiene. The Act also contains provisions for water use for food production under irrigated agriculture hence it provides strong support for irrigated farming. General authorisations provided under the NWA were revised in 2004 to allow, amongst others, limited use of biodegradable industrial wastewater for irrigation. The Act has weak support for rainfed farming but strong support for irrigated farming and wastewater reuse for irrigation. The main objects of the WSA include providing for the right of access to basic water supply and sanitation necessary to secure an environment not harmful to human health or well-being and the promotion of effective water resource management and conservation (Republic of South Africa, 1997a). Although there is no mention of the use of water for agricultural purposes in all its provisions, the provision of water supplies in homes allows people to use domestic water supplies for irrigating backyard gardens in peri-urban agriculture which plays an important role in promoting food security.

Table 5.1: Degree of support of legislation, policies, plans and strategies for the four AWM systems

Act/Policy/Plan/Strategy	Rainfed farming	Farmer-led	Irrigation schemes	Wastewater reuse
The Constitution (No. 108 of 1996)				
National Water Act (No. 36 of 1998)				
Water Services Act (No. 108 of 1997)				
Water Research Act 34 of 1971				
Conservation of Agricultural Resources Act 43 of 1983				
Agricultural Research Act No.86 of 1990				
Provision of Land and Assistance Act 126 of 1993				
Restitution of Land Rights Acts 22 of 1994				
National Environmental Management Act 107 of 1998				

National Environmental Management: Waste Act 59 of 2008	Weak	Moderate	Moderate	Strong
National Health Act 61 of 2003	Weak	Moderate	Moderate	Strong
Climate Change Act 22 of 2024	Weak	Weak	Weak	Moderate
Land and Agricultural Development Bank Act 15 of 2002	Strong	Strong	Strong	Moderate
National Water Policy (1997)	Weak	Strong	Strong	Moderate
National Water Policy Review (2013)	Weak	Strong	Strong	Moderate
Policy on Agriculture in Sustainable Development	Weak	Strong	Strong	Weak
Conservation Agriculture Policy (2017)	Weak	Moderate	Moderate	None
National Policy on Food and Nutrition Security (2014)	Weak	Moderate	Moderate	Weak
National Environmental Health Policy (2013)	Weak	Moderate	Moderate	Strong
National Climate Change Response Policy: White Paper (2011)	Weak	Weak	Weak	Moderate
Environmental and Social Sustainability (ESS) Policy	Moderate	Moderate	Moderate	Strong
National Development Plan 2030	Strong	Strong	Strong	Strong
National Water and Sanitation Master Plan (2018)	Moderate	Strong	Strong	Strong
Agricultural Policy Action Plan 2014-2019	Weak	Strong	Strong	Weak
Agriculture and Agro-Processing Master Plan (2022)	Strong	Strong	Strong	Moderate
National Water Resources Strategy of 2004 (1) and 2013 (2) and 2023 (3)	Weak	Strong	Strong	Strong
Strategic Plan 2020–2025, Agriculture, Land Reform and Rural Development	Strong	Strong	Strong	Strong
National Water Conservation and Water Demand Management Strategy 2004	Strong	Strong	Strong	Strong
Irrigation Strategy for South Africa	Weak	Strong	Strong	Moderate
National Agricultural Research and Development Strategy (2008)	Moderate	Moderate	Moderate	Weak
Strategic Plan 2020–2025, Agriculture, Land Reform and Rural Development	Strong	Strong	Strong	Moderate
National Education and Training Strategy for Agriculture and Rural Development in South Africa (2005)	Weak	Weak	Weak	None
Integrated Growth and Development Plan (2012)	Weak	Moderate	Moderate	None
Strategic Plan for Smallholder Support (2011-2014/15)	Weak	Strong	Strong	None
National Water Security Framework for South Africa (2020)	Moderate	Strong	Strong	Weak
Water for Growth and Development Framework (2009)	Strong	Strong	Strong	Strong
National Water and Sanitation Master Plan Volume 1: Call for Action (2018)	Moderate	Strong	Strong	Strong
National Strategy for Water reuse (2011)	Weak	Moderate	Moderate	Strong

Colour code: (blue) Strong; (green) Moderate; (orange) Weak; (red) None

The Water Research Act, through establishment of the WRC, provides strong support for the AWM practices. The primary function of the WRC is to: promote coordination, cooperation and communication in the area of water research; to establish water research needs and priorities; stimulate and fund water research according to priority; promote effective transfer of information and technology; and enhance knowledge and capacity building in the water sector[10]. The WRC support research, innovation

[10] https://www.wrc.org.za/about-us/mandate/

development and uptake and capacity building in water which covers all the four AWM systems.

The objectives of the Conservation of Agricultural Resources Act are to provide for the conservation of the natural agricultural resources of the country by maintaining the production potential of land, combating and preventing erosion and weakening or destruction of the water sources, protection of vegetation and combating of weeds and invader plants. The Act provides strong support for conservation of soil and water under rainfed and irrigated farming systems.

The NWC/WDMS supports AWM practices by promoting equitable and efficient water use and by providing regulatory support and an incentive framework that would improve irrigation efficiency and increase productivity. The strategy aimed to promote optimal water use to allow for the release of water to be utilised by new entrants in the agriculture and other water use sectors. Just like the NWA, the national water policy promotes water use for food production under irrigated agriculture hence it provides strong support for irrigated farming.

The NWRS (DWA, 2013) supports irrigated agriculture through the promotion of water-efficient irrigation systems. It also promotes financial support and water allocation to improve water-based rural livelihoods and food security for all. In this strategy, water plays a central role in most of the national planning initiatives including agricultural development. The reliable supply of adequate quantities of water at the required quality is an essential input to economic growth and job creation.

The Agricultural Research Act establishes the Agricultural Research Council (ARC), a premier science institution that conducts research with partners, develops human capital and fosters innovation to support and develop the agricultural sector.[11] The Council conducts research and development in areas that include AWM practices such as rainwater harvesting, irrigation, wastewater reuse in agricultural, climate smart agriculture (CSA) and conservation agriculture (CA). The support of the Council to all the four AWM systems is strong.

The Provision of Land and Assistance Act provides financial assistance by way of an advance, subsidy, grant or otherwise to any person for the acquisition, maintenance, planning, development or improvement of property and for capacity building, skills development, training and empowerment, among other services. The Act provides moderate support for rainfed and farmer-led irrigation systems, while its support for irrigation schemes farming is weak. The Restitution of Land Rights Acts provides a framework for redress to people who had lost their land as a result of racially discriminatory practices such as forced removals, which include smallholder farmers who operate as rainfed farmers, farmer-led irrigation farmers or members of irrigation schemes. As such, the Act has strong support for rainfed and irrigation farming systems.

The EMF of the NEMA focuses on critical environmental conflict areas which include conservation, natural resources protection, land-use planning, waste management, river health and groundwater use and quality. The provisions of the Act guide

[11] https://www.arc.agric.za/Pages/Home.aspx

environmental sustainability of all the four AWM systems hence it has strong support for all the four AWM systems. On the other hand, NEMWA which provides measures for preventing pollution, ecological degradation and securing ecologically sustainable development, provides strong support for wastewater reuse for irrigation while its support for irrigated and rainfed systems is moderate and weak, respectively. Similarly, the National Health Act, which covers matters related to health services, such as norms and standards, health establishments, health workers, health information and health research, waste management, water quality monitoring and environmental pollution control, provides strong support for wastewater use for irrigation through wastewater reuse guidelines, but its support for irrigated and rainfed systems is moderate and weak, respectively. The provisions of the newly enacted Climate Change Act provide moderate support for wastewater use for irrigation, but its support for rainfed and irrigated farming systems is weak.

The Land and Agricultural Development Bank Act 15 of 2002 provides strong support for rainfed and irrigation farmers (both farmer-led and irrigation scheme farmers). Through the Land Bank, the Act brings specially designed financial services within the reach of farmers across the nation. These services enable rainfed and irrigation farmers to finance land, equipment, improve assets and obtain production credit. The analysis has shown that the levels of support that the sectoral policies and strategies provide to the AWM systems are similar to those provided by the corresponding pieces of legislation.

The overall analysis showed that there is overwhelming support by national laws, policies, plans and strategies for the four AWM systems in the country. The Constitution, WRA, ARA, the NEMA, NDP and the National Water Conservation and Water Demand Management Strategy provide strong support for the four AWM systems. The analysis also shows that the support by national laws, policies, plans and strategies is strongest for irrigated farming systems (for both farmer-led and irrigation scheme systems), followed by the use of wastewater for irrigation. The support for rainfed farming system is strong in some cases, but generally moderate to weak in most cases.

5.10 Discussions, conclusions and recommendations

5.10.1 Introduction

This chapter provides the discussions, conclusions and recommendations of the research. The section is structured into three parts. The first part presents discussions of the of the research findings. The research findings provide a scrutiny on how the information provided in this study answers the key research questions, which is to assess the roles of policy, legal, governance and institutional systems and arrangements in the implementation of the IDAWM practices in the country. The second part presents the main conclusions from the findings of the study. The third part considers recommendations in the context of the findings and the objectives of the research.

5.10.2 Discussions

As highlighted in Sections 4.2 and 4.3, South Africa has sound legislation and policies that guide water resource governance. The legislative framework consists of the Constitution of the Republic of South Africa Act 1996 (Act 108 of 1996), the National Water Act (NWA) 36 of 1998, the Water Services Act 108 of 1997, the Water Research

Act 34 of 1971, the Conservation of Agricultural Resources Act 43 of 1983, the Agricultural Research Act 86 of 1990, the Provision of Land and Assistance Act 126 of 1993, the Restitution of Land Rights Acts 22 of 1994, the National Environmental Management Act 107 of 1998, the National Health Act 61 of 2003, the Climate Change Act 22 of 2024 and the Land and Agricultural Development Bank Act 15 of 2002. The sectoral policies related to IDAWM systems policies include the White Paper on Agriculture 1995, the Policy on Agriculture in Sustainable Development – 8th Draft, the Rural Development Framework Policy, the Rural Economy Transformation Model One District One-Agri-Park/Every Municipality Policy, the Policy Framework for the RADP of the Department of Rural Development and Land Reform, the National Water Policy for South Africa - White Paper April of 1997, the National Environmental Health Policy of 2013, the National Climate Change Response Policy and the Environmental and Social Sustainability (ESS) Policy of the Land and Agricultural Development Bank.

The country has sectoral plans, strategies, frameworks, programmes, networks and guidelines which are related to IDAWM practices as presented in Sections 3.4 and 3.5. The plans, strategies, frameworks, programmes and networks which are related to the implementation of IDAWM practices in the country include the NDP 2030, the National Water and Sanitation Master Plan (2018), the AAMP, the National Water Resources Strategy of 2004 (1) and 2013 (2) and 2023 (3), the National Water Conservation and Water Demand Management Strategy (2004), the National Strategy for Water reuse (2011), the Irrigation Strategy for South Africa, the Strategic Plan 2020 – 2025, Agriculture, Land Reform and Rural Development, the WfGD Framework (2009), the Second National Action Programme for South Africa to Combat Desertification, Land Degradation and the effects of Drought (2018-2030), and the SWPN (2011).

The guidelines related to IDAWM practices include the South African Guidelines for the Permissible Reuse of Treated Sewage Effluents (1978), the South African Water Quality Guidelines for Irrigation Water Use, the Guidelines for the reuse of treated wastewater and the Guidelines for sustainable reuse of effluent on land – a suggested approach. The analysis of how these laws, policies and strategies support the AWM practices has shown that there is overwhelming support by national laws, policies, plans and strategies for the four AWM systems in the country. The Constitution, Water Research Act, Agricultural Research Act, National Environmental Management Act, National Development Plan and the National Water Conservation and Water Demand Management Strategy provide strong support for the four AWM systems. The analysis also shows that the support by national laws, policies, plans and strategies is strongest for irrigated farming systems (for both farmer-led and irrigation scheme systems), followed by use of wastewater for irrigation. The support for rainfed farming system is strong in some cases, but generally moderate to weak in most cases.

The study assessed the governance systems related to IDAWM practices. These were water and agriculture governance systems. The governance of water in South Africa is implemented under three spheres of government; namely, national, provincial and local. According to the NWA, the water management institutions are WMAs, CMAs, Catchment Management Committees and WUAs at local level. The governance of agriculture functions falls within the competence of provinces and governance needs to be guided by policy on a national level in which the distinction between the role of provincial and national agricultural administration and governance are clear.

At local level, WUAs provide the operational governance systems for farmer-led and irrigation scheme farming systems. Within each scheme there is a scheme committee which is the main water governance institution of the irrigation schemes. Traditional leaders, who constitute another important local institution are responsible for resolving conflicts among farmers which the scheme committee fails to settle. Informal water institutions organised by groups of farmers are other institutions that resolve issues the farmers face at the scheme. Both rainfed and farmer-led irrigation are governed by the traditional leadership governance systems.

Farmer's willingness to invest in their farming systems depend on their rights to the land, among other factors. When farmers have secured legal rights to their land, they are more likely to invest in long-term improvements, which leads to increased productivity and income. Land tenure security is crucial for smallholder farmers in farmer-led irrigation and irrigation scheme systems.

5.11 Conclusion

The main focus of the study was to assess the roles of policy, legal, governance and institutional systems and arrangements in the implementation of the IDAWM practices in the country. The need for IDAWM policies in South Africa is crucial for several reasons. The population in southern Africa is expected to reach 2.5 billion by 2050, necessitating increased food production (Wichelns, 2015). Rising temperatures and greenhouse gas emissions pose challenges to agriculture, making efficient water management essential. The importance of irrigation scheme development and modernisation cannot be overemphasised knowing that irrigation faces technical, management and financing issues and rehabilitating smallholder irrigation schemes can contribute to food output (Nhamo *et al*, 2024) hence to address these issues, the policy environment should promote flexible low-cost irrigation technologies, liberalising equipment imports and mapping water resources.

The study has shown that integrated policy and institutional interventions that promote inclusive and sustainable farmer-led irrigation, irrigation scheme development and sustainable wastewater use for irrigation are key to irrigation development in the country. The study has also shown that rainfed agriculture builds climate resilience and helps move farmers beyond subsistence farming towards sustainable livelihoods, development and economic growth. There is a significant opportunity to maximise the capture, storage and use of green water and unlock the potential of enhanced rainfed agriculture.

There are well-structured governance systems that provide an enabling environment for the implementation of AWM practices in the country. The governance systems exist at national, provincial, catchment, local and farm levels. Based on the informing document review, outcomes of stakeholder consultations, it can be concluded that the provisions of most of South Africa's IDAWM-related sectoral laws, policies, plans and programmes provide supportive and enabling environment for the implementation of IDAWM practices in the country. However, while acknowledging that a lot has been accomplished in terms of policy and institutional support for IDAWM practices, it was nevertheless widely acknowledged that there are areas where support for the four AWM systems need to be improved, particularly for rainfed farming and farmer-led irrigation systems.

5.12 Recommendations

The following recommendations are made based on the results of the study:

1) Improve policy implementation. While the provisions of most of the IDAWM-related policies and strategies indicate clear support for IDAWM practices, in some cases the actual support that the AWM systems receive is less than the pronounced support.
2) Provide comprehensive training of smallholder rainfed farmer in land and water management practices.
3) Provide comprehensive training of smallholder farmer-led irrigation in irrigation management (including irrigation scheduling), as well as in record-keeping skills so that they operate farming as a business.
4) Introduce land tenure systems which allow irrigation scheme farmers to have secured ownership of land.
5) Improve enforcement of regulations concerning wastewater which can reduce or prevent unsafe practices that threaten public health and environmental sustainability.
6) There is a need to strengthen governance systems, particularly at local levels, for effective implementation of AWM practices at scheme and farm levels.

CHAPTER 6

ASSESSMENT OF GAPS AND IDENTIFICATION OF OPPORTUNITIES FOR IMPROVING POLICY, GOVERNANCE AND INSTITUTIONAL DIMENSIONS

6.1 Introduction

The study assessed the policy, legal, governance and institutional systems related to agricultural water management under rainfed and irrigated farming systems. The study was conducted through interviews with farmers and focused group discussions with officials from national and provincial stakeholder institutions. This chapter presents the results of the interviews and the focused-group discussions as they relate to policy and institutional gaps and potentials of implementing IDAWM practices in the country.

6.2 Questionnaire results from Gauteng Province

Table 6.1 shows the socio-economic characteristics of the farmers in Gauteng Province. On average, a typical smallholder farmer in Gauteng is 47 years old, whereby the youngest and the oldest are 28 and 29 years old respectively.

Table 6.1: Socio-economic characteristics of the smallholder farmers in Gauteng Province

Variable	Mean	Std. Dev.	Min	Max
Age (years)	47.06	10.76	28	69
Household size (number)	5.17	3.89	1.0	28
Non-farm income (R/month)	19243.75	20522.32	0.0	65000
Farming experiences (years)	6.85	5.30	0.5	20

(Source: Survey data)

This implies that smallholder farming in Gauteng is predominantly practiced by middle-aged to older individuals, with relatively few young farmers entering the sector. The average household size among the surveyed group is 5 members, indicating that most households are moderately large. The range, from a minimum of 1 to a maximum of 12 members, reflects significant variability in family sizes, likely influenced by cultural, social or economic factors. The average nonfarm income is close to R20,000/month, suggesting that many households have moderate additional income sources outside farming.

However, the range from R0 to R65,000 indicates substantial disparities, with some households entirely reliant on farming while others earn significantly higher nonfarm incomes, highlighting diverse economic conditions. Farmers have a reasonable level of knowledge as seen by their average 7-year agricultural experience. The 0.25-20-year range indicates a mix of beginner farmers with little experience and seasoned farmers with decades of experience, demonstrating different degrees of practice and skills throughout the group.

Figure 6.1 shows the gender of the smallholder farmers who participated in the study. The results show that gender distribution among the group is relatively balanced, with 53% male and 47% female. This near-equal representation suggests that both men and women actively participate in the activities surveyed, indicating inclusive involvement in the sector.

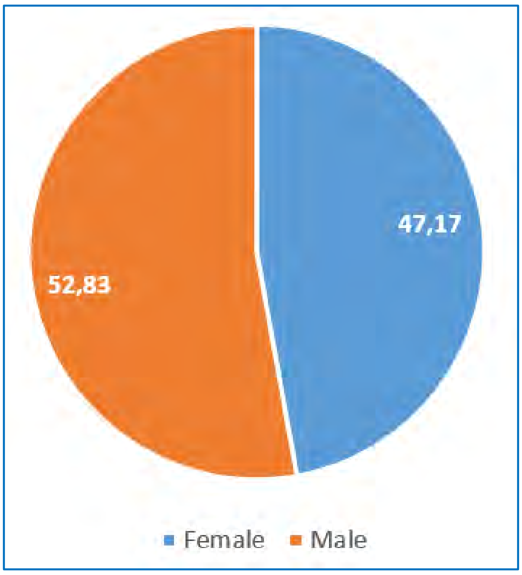


Figure 6.1: Gender of the smallholder farmers interviewed in Gauteng Province

Figure 6.2 shows the education level of the smallholder farmers in the study are. With 64.15% of farmers having a tertiary education, the farming population is clearly well-educated and probably exhibits the advanced skills and knowledge necessary to implement modern agricultural practices. Furthermore, just 3.77% of farmers lack formal education, indicating that education has a substantial impact on farmers' capacity to use and profit from advanced or innovative agricultural techniques, whereas 32.08% have secondary school, giving them a foundational understanding of farming principles.

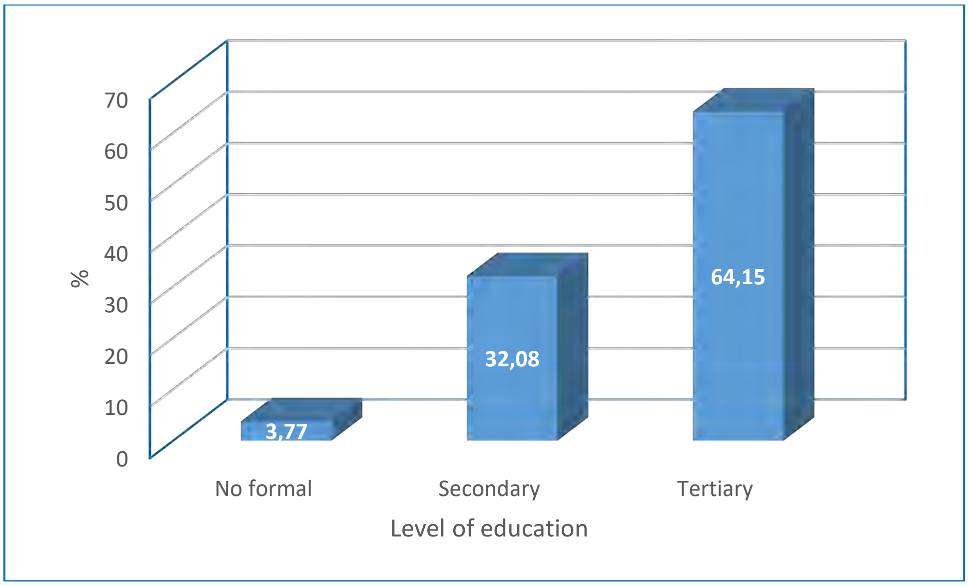


Figure 6.2: Education level of the respondents in Gauteng Province

Figure 6.3 shows the marital status of the respondents. According to the distribution of marital status among farmers, 46.15% are married, suggesting that a sizable percentage of farmers may rely on family support systems for their farming operations. In the meantime, 40.39% of people are unmarried, indicating that a sizable portion of people work as independent farmers. Furthermore, 5.77% are divorced and 7.69% are widowed, which may indicate different household dynamics that could affect how resources are allocated and decisions are made in farming operations.

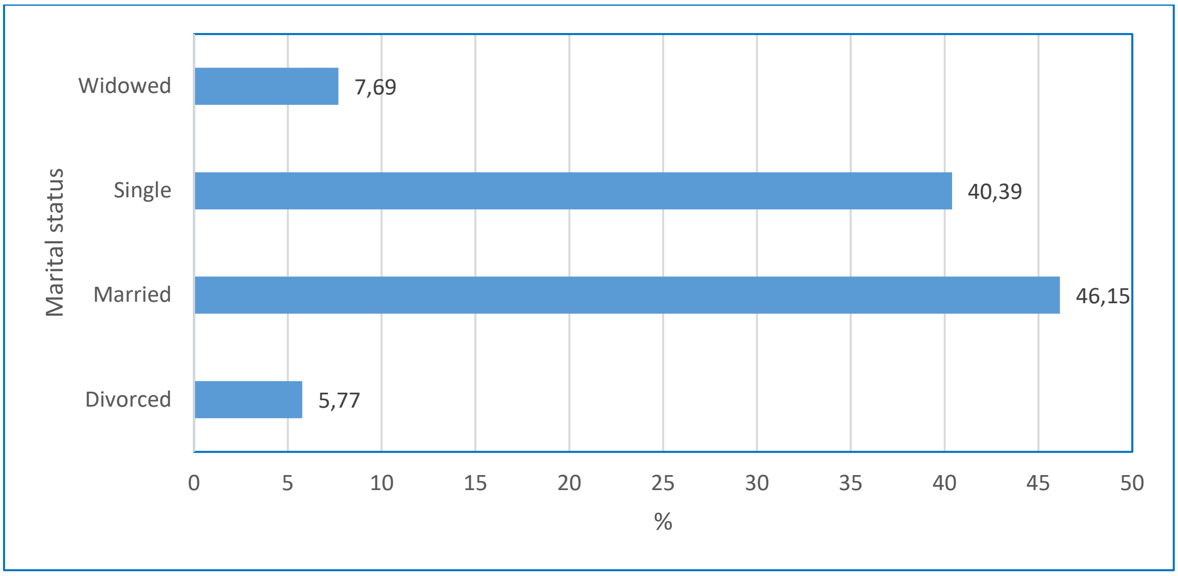


Figure 6.3: Marital status of the respondents in Gauteng Province

Table 6.2 shows the farm characteristics (average farm size, number of extension visits per month, percentage of produced sold to the markets and distance to the market) of the smallholder farmers. The results show significant variability in land sizes, with an average of 50 hectares, a minimum of 0.2 hectares and a maximum of 1 400 hectares, indicating a wide disparity between small and large landholders. Smallholder farmers with land under 1 hectare may struggle with limited resources and productivity, while large landowners can benefit from economies of scale and technological advancements.

Farmers receive a minimum of 0.25 and a maximum of 7 visitors per month, with an average of 1.29 visits. The comparatively low average implies that most farmers are not regularly using extension services, which could restrict their access to crucial agricultural insights, guidance and innovations. With a minimum of 10% and a maximum of 100%, the average percentage of produced goods sold is 72.86%. This suggests a somewhat market-oriented approach because it shows that, on average, a significant amount of the farmers' output is sold. The large range, from 10% to 100%, however, indicates notable variation in the amount of food that is sold.

Table 6.2: Farm characteristics of the respondents in Gauteng Province

Variable	Mean	Std. Dev.	Min	Max
Farm size (ha)	51.77	203.810	0.2	1365
Number of extension visits per month	1.293815	1.622611	0.0	7
% of produced sold	72.86207	26.64009	10.0	100
Distance to the market (km)	40.72414	31.14814	0.0	120

With a minimum of 0 km and a maximum of 120 km, the average distance to the market is 40.72 km. This implies that smallholder farmers are generally located a relatively long distant from markets, which may affect their capacity to sell goods effectively and profitably. While the maximum distance of 120 km suggests that some farmers face significant logistical challenges, such as high transportation costs, longer travel times and the risk of product spoilage, which can reduce market competitiveness, the minimum of 0 km suggests that some farmers may have markets very closeby, potentially making it easier for them to access buyers.

Figure 6.4 shows the land ownership of farmers in Gauteng Province. Most of the farmers (49%) own the land. With 49.02% of the land held privately, land tenure shows a varied distribution of land ownership among farmers, enabling more freedom in investment and land use. A significant percentage, 27.45% is under permission to occupy (PTO) agreements, which might restrict long-term investments and cause uncertainty. While rental property makes up 7.84% demonstrating that some farmers rely on leasing for access to land, which can be less secure, communal land makes up 1.96% reflecting low community ownership. About 13.73% is state land, which may provide access through government initiatives, but is also subject to usage restrictions. In order to increase agricultural output and investment prospects, policies that address land tenure security and provide equitable access to land are essential.

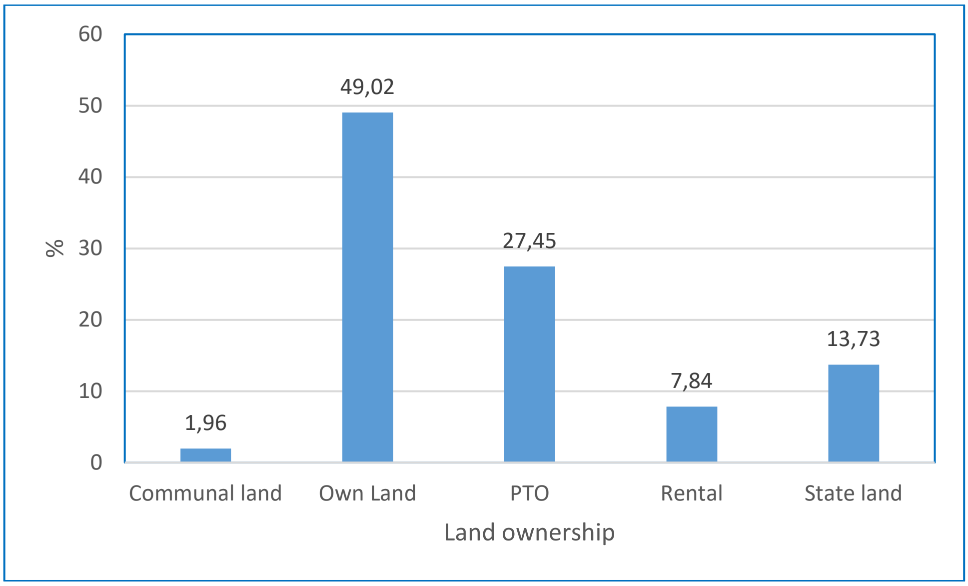


Figure 6.4: Land tenure systems among the respondents in Gauteng Province

Figure 6.5 shows the farmers’ organisation membership, agricultural extension access, credit access and market access. The results shows that most of the farmers are members of farmers’ organisation (those mentioned are African Farmers’ Association of South Africa (AFASA), National PLAS Farmers Association, Women in Agriculture and Rural Development Association (WARD), Youth in Agriculture and Rural Development (YARD) and the Rooiwal Farmers Support Union. The fact that 60% of farmers have access to extension services indicates that most farmers are getting help, counsel or direction regarding new developments in agriculture.

Extension services assist farmers in training, access to information and production skills. Access to credit is still a major challenge to smallholder farmers. Most of them

(84%) do not have access to credit. Some of the reasons mentioned are the lack of security (collateral). With 61% of farmers having access to markets, the majority are able to sell their produce, which is critical for their financial sustainability and growth. However, the 39% without market access may face difficulties in selling their goods, leading to lower incomes and limited opportunities for expansion. Expanding market access for the remaining farmers could significantly improve their livelihoods and contribute to overall agricultural development.

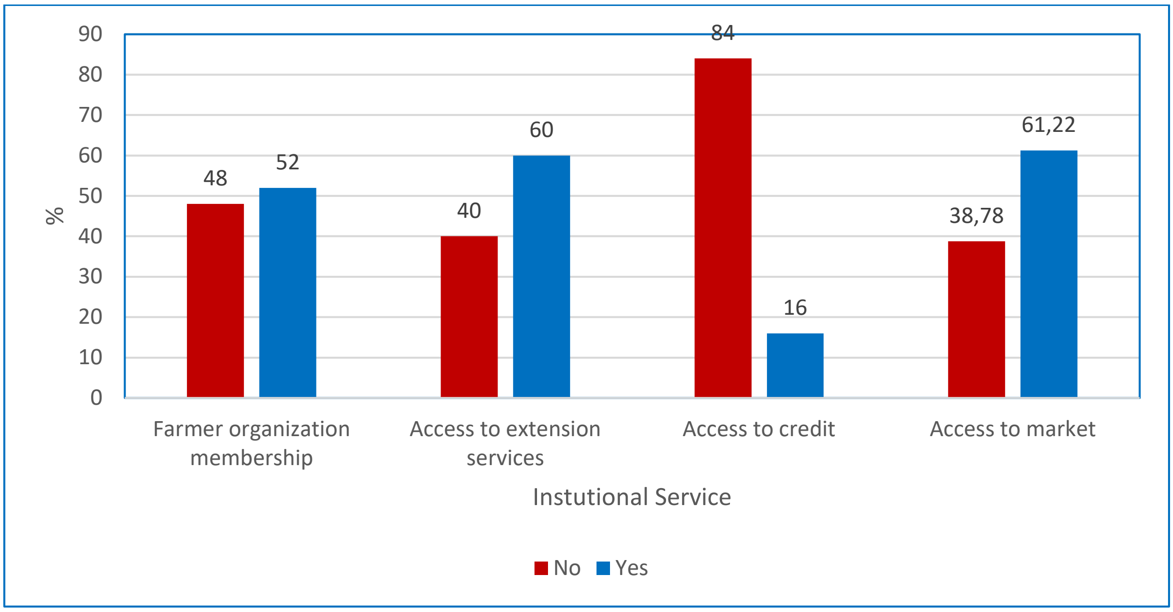


Figure 6.5: Institutional services accessed by respondents in Gauteng Province

Figure 6.6 shows the percentage of smallholder farmers knowledge and willingness to join Water User Associations (WUAs). About 87% of farmers are unaware of WUAs and this highlights a significant gap in knowledge about potential water management and irrigation support systems. However, 90% of smallholder farmers are willing to join WUAs and this indicates a strong interest in accessing organised, collective water management solutions, which could improve water usage efficiency, irrigation practices and overall farm productivity. Raising awareness and providing education about WUAs could enable more farmers to benefit from these associations, fostering better water management and agricultural production.

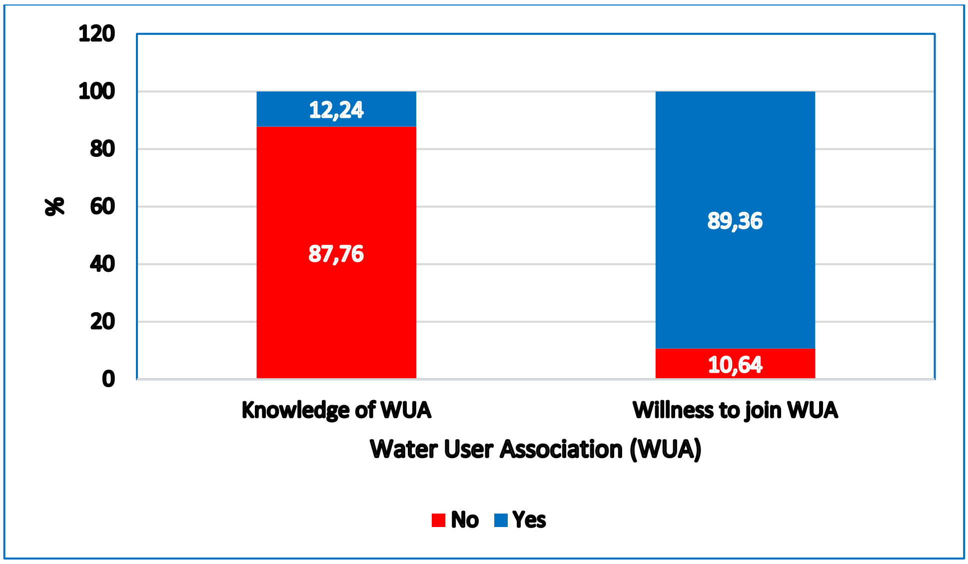


Figure 6.6: Membership to water user associations among respondents in Gauteng Province

6.3 Financial products accessed by respondents in Gauteng Province

Various financial entities confirmed the variety of funding available to all farmers who qualify, irrespective of the farming system they are engaged in. There are different types of loans to apply for. Appendix J show the types of loans farmers have access to.

Short term loans:
Short-term loans are designed for addressing immediate requirements for operational cash and agricultural inputs, especially for crop enterprises. To ensure consistency with the cyclical nature of farming activities, these loans are evaluated annually and have a maximum duration of five years. It is appropriate for farmers who depend on seasonal harvests because the payback is set up to align with the revenue from agricultural sales. However, farmers without assets may find their access restricted by the necessity of a first bond over immovable property or another approved security. In spite of this, the yearly renewal provides flexibility for continuous funding requirements.

Medium term loans:
More extensive agricultural initiatives, such as the planting of perennial crops, the upgrading of infrastructure and the acquisition of movable assets are supported by medium-term loans. These loans support improvements that improve agricultural resilience and productivity, with repayment terms of up to 15 years. Usually, a first bond on fixed property or other agreements are used to provide security. The repayment plans might be monthly, quarterly, biennial or annual and are quite flexible, depending on the business's cash flow cycles. Because of this, medium-term loans are a sensible choice for farmers who are involved in a variety of operations that need a sizable but controllable capital investment.

Asset finance:
The primary objective of the asset finance is to purchase specific moveable assets such as vehicles, tractors and farm equipment. Depending on the asset's type, this type of loan can be paid for up to 12 years. Title deeds, general notarial bonds or other

agreed-upon procedures are used to offer security. The repayment is synchronized with the cash flow cycles of the farm, just like medium-term loans. By enabling mechanisation and modernisation, asset finance enables farmers to increase productivity and efficiency. It is essential for expanding agricultural operations because of its emphasis on machinery that immediately improves operational capacities. This also includes irrigation systems.

Long term loan:
Large investments like buying land, paying off debt associated with buying property and installing machinery and equipment are the main uses for long-term loans. These loans, which have repayment durations of up to 25 years allow agricultural businesses to experience growth. Given the high capital nature of these loans, security is given in the form of a first bond over fixed property. Even for significant investments, affordability is guaranteed by the repayment schedule's synchronisation with cash-flow cycles. Long-term loans help farmers accomplish strategic objectives, including increasing farmland or switching to more advanced farming methods by providing longer durations.

Revolving credit:
Revolving credit facilities is meant to finance short term capital requirements, general and operational needs of the business such as cash crops. These facilities provide farmers with a great deal of flexibility by allowing them to use pre-approved credit levels as needed, with maturities of up to five years and yearly evaluations. Because repayments are based on the company's revenue streams, this facility is perfect for handling cash-flows. Though its brief lifespan requires strict financial control to prevent overuse or mismanagement, its flexibility makes it a useful tool for handling unforeseen needs.

Value chain finance
Value chain financing is a novel product that uses contracts for the production and sale of particular commodities to connect farmers and purchasers. These agreements offer a stable foundation for funding by defining quality, quantity, grade and pricing procedures. The loans are subject to annual review and are seasonal. In addition to other agreed-upon measures, security entails the cession of crop sale revenues, insurance and delivery contracts. By guaranteeing that both parties gain from steady revenue streams and dependable supply networks, this financing method improves the relationship between farmers and markets. It works especially well to promote integrated farming practices.

Financial entities offer a wide range of loan products so that farmers can find financing options that meet their unique requirements, whether they are long-term growth or short-term liquidity. Every loan type reduces risks for the bank and the farmer by matching the cash-flow dynamics of agricultural businesses.

6.4 Questionnaire results from Limpopo Province

During the discussion with the irrigation scheme farmers, they indicated that they face challenges such as poor marketing, badly damaged infield roads and the irrigation scheme having no fence. They also mentioned selling their produce to walk-ins, local shops, hawkers and on the road. They further indicated that some of their customers are local people from the village because it is expensive to transport the produce to the markets. Furthermore, the water supply in the irrigation scheme is poor for farmers found downstream and some in the midstream because some farmers take the water illegally and not during their time to irrigate.

The focused group discussions with the rainfed farmers revealed that most dryland farmers had one-hectare farms, the land was communal and some had PTO certificates for land ownership. Furthermore, most farmers in the Lwamondo area stated that because they are farming in a dryland area where the climatic conditions always vary, they use drought and heat-resistant crop varieties to obtain good production. They mostly planted maize for home consumption and income.

The results of gender, age, marital status, education level and off-farm income source are presented in Figure 6.7. The results revealed that male farmers were more dominant than females. This could be because females occupy other activities in the household than participating and taking the lead in agricultural production in the farms. In addition, most of the farmer-led irrigation farmers in the study are married, with fewer being single. Regarding the FLI farmers' age, most farmers were old with a majority of them being in the age group of 60 years and above, followed by the age group of 31-40 years. Furthermore, most farmers had tertiary education, with few having no formal education and this could be due to farmers seeing school as a learning opportunity to equip themselves with knowledge. Therefore, their level of education and their age level indicate that these farmers have higher chances of leading the farming process and are better equipped for decision-making. The study shows that most of the FLI farmers get their off-farm income from social grants, which are tied to those who are unemployed.

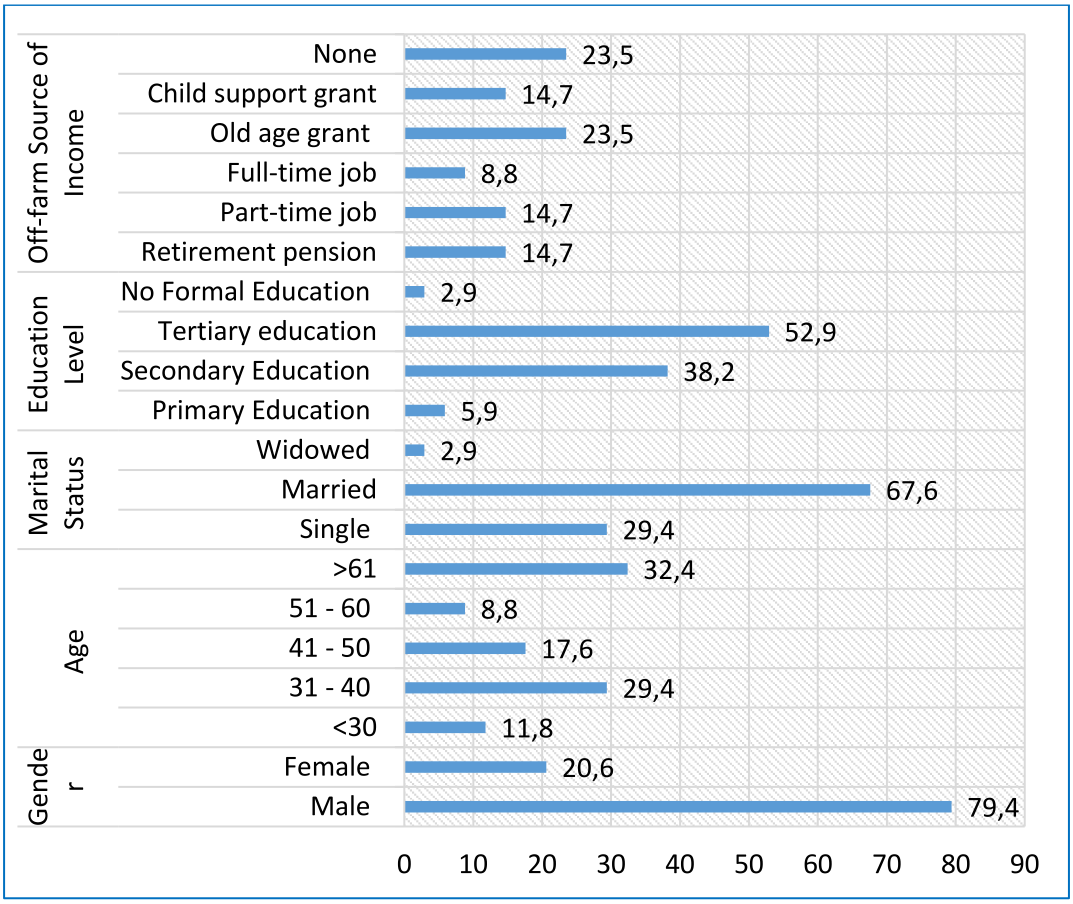


Figure 6.7: Demographic characteristics for the respondent farmer-led irrigation farmers in Limpopo Province.

The results from Limpopo Province show that access to water is a key factor driving the expansion of FLID. It is notable that a majority of FLID farmers use boreholes, followed by those who get the water from the river through diesel/petrol pumps and some use spring water (Figs 6.8 - 6.10). However, it is concerning that an overwhelming majority of the FLID farmers do not have water licences (Fig. 6.8). A water licence is one of the regulatory requirements for the commercial use of water. However, the FLID farmers' perception of water licensing is that they do not need a water license because they use groundwater and river water extracted from their own resource hence do not see the government support.

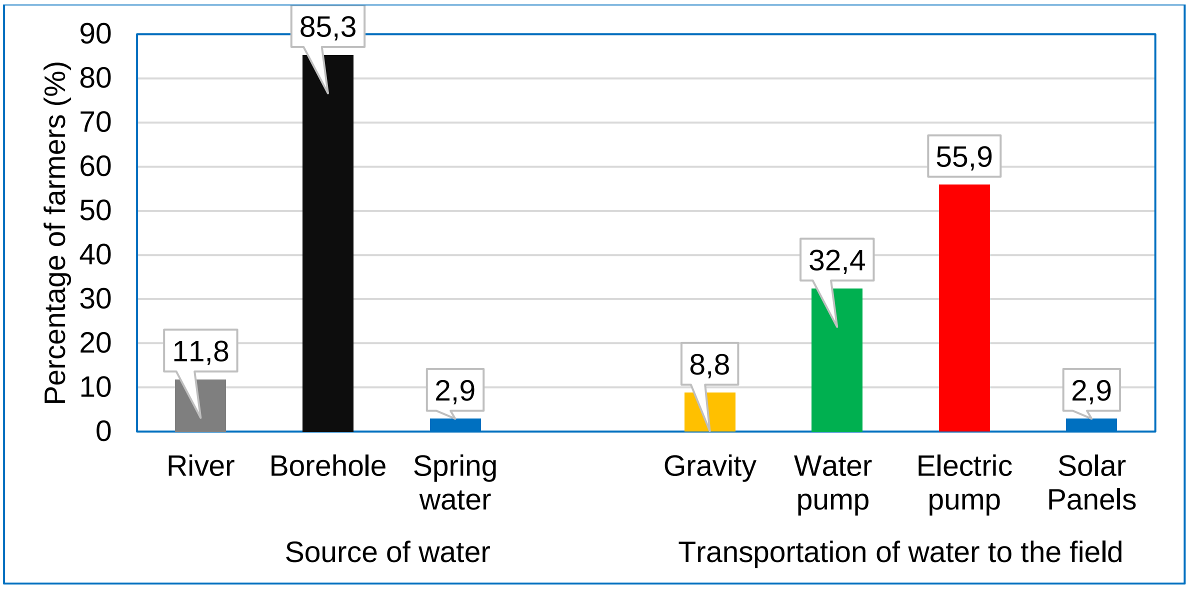


Figure 6.8: Sources of water for the FLI farmers and the type of power used to pump/transport the water to the field in Limpopo.

(a)

(b)

Figure 6.9: Water pumping systems (petrol (a) and diesel pump (b))

(a)

(b)

Figure 6.10: Water pumping systems (petrol (a) and diesel pump (b))

There is a varying degree of access to a variety of support services and institutions as shown in Fig 6.11. The survey data showed that 50% of the farmers received irrigation and water management training. Regarding access to loans or credit and financial assistance, 82.4% do not have access to loans/credit and 97.1% do not have access to financial assistance, which could be because they operate outside the government's scope. Although most of them acknowledged applying for the various funding opportunities from different government agencies, their applications were unsuccessful. This may partly be attributed to the absence of key regulatory requirements such as water use licence that a majority of the FLID farmers do not have.

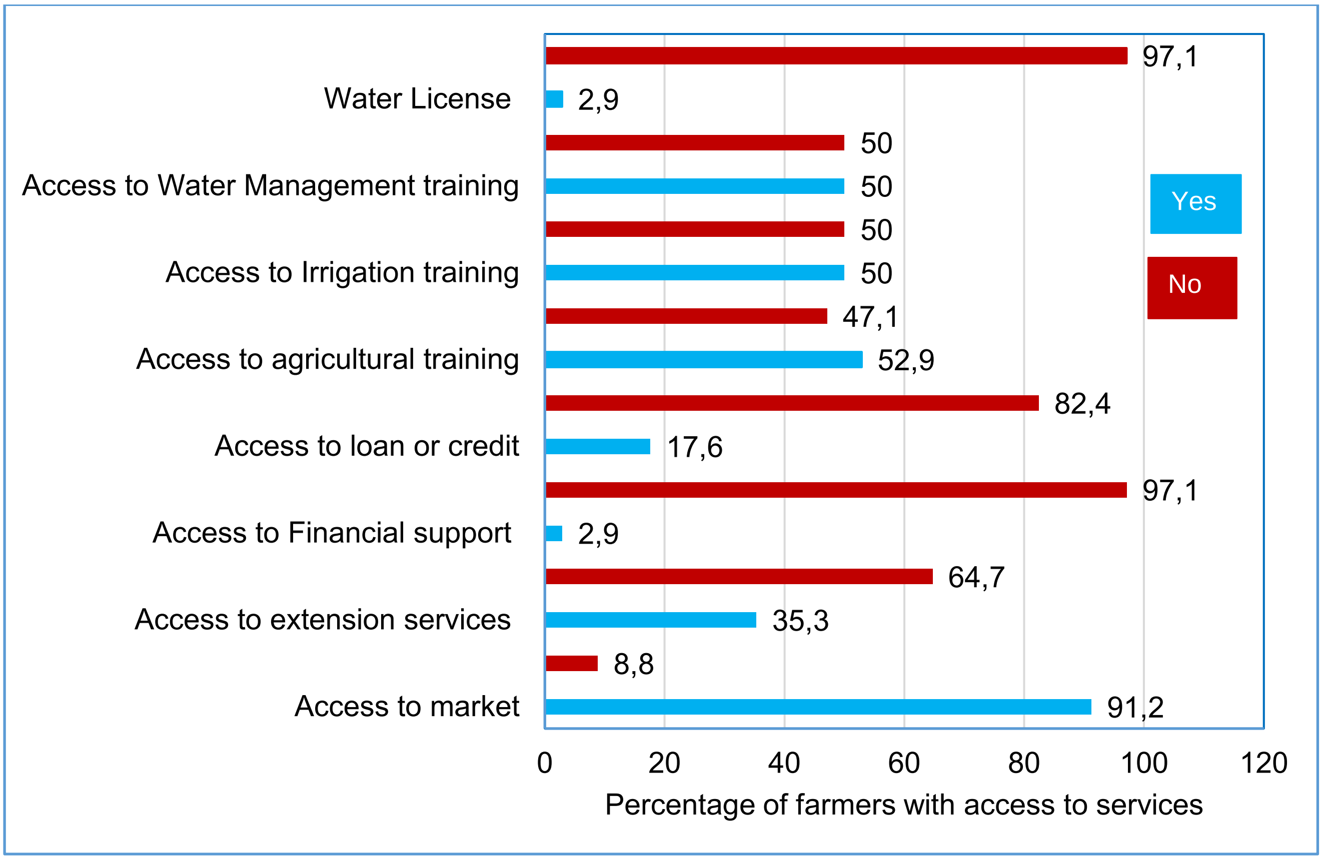


Figure 6.11: Access to market, extension services, financial support, loan/credit and training by respondents in Limpopo Province

The FLID farmers also indicated that they do not have access to extension services and they stated that it is because the LDARD has few extension officers hence those extension officers only visit a few FLID farmers and most irrigation schemes. The farmers who receive extension services complained about the poor services, such as poor training, poor technical advice and poor market knowledge. There is a need for continuous upskilling of the current agricultural extension officers to better equip them with the knowledge to support farmer-led initiatives.

There are a number of key policies and institutions that indirectly or directly support FLID in South Africa such as the National Water Act (NWA), 1998; National Development Plan (NDP), 2030; National Water Resources Strategy (NWRS); Agricultural Policy Action Plan (APAP), 2015; National Climate Change Response Policy (NCCRP); and Irrigation Strategy for South Africa (2015). All these policies aim to support small-scale farmers in gaining access to water rights and supporting farmers, resulting in sustainable water management. However, most of the farmers interviewed did not know about these existing policies for small-scale farmers. Furthermore, key institutions such as the ARC, WRC, the Department of Agriculture, Land Reform and Rural Development (DALRRD), NGOs and farmer Organisations **(**such as AgriSETA, Comprehensive Agricultural Support Programme (CASP)) play crucial roles in improving policies, provide funding, training and technical assistance to support FLID. In addition, banks such as the Land Bank offer financial assistance to small-scale farmers through loans. However, most farmers have limited knowledge of the existence of these opportunities for improving their farmer systems.

6.5 SWOT analysis for the AWM systems

This section presents the results of the strengths, weaknesses, opportunities and threats (SWOT) analysis which was conducted for rainfed farming, farmer-led irrigation system, irrigation scheme development and modernisation and wastewater use for irrigation in South Arica. The analysis was conducted for each of the four AWM pathways. The analysis was conducted during the workshop where diverse teams from different areas of the AWM systems discussed and agreed on the list of internal (strengths and weaknesses) and external (opportunities and threats) factors for each of the four AWM pathways. The results of the analysis for the rainfed farming, farmer-led irrigation system, irrigation scheme development and modernisation and wastewater use for irrigation are presented in Appendices H, I, J and K, respectively. The SWOT analysis indicates that supportive sectoral policies, strategies and plans provide important opportunities for implementing the four AWM systems in the country.

The main strengths of rainfed farming include lower capital requirements and deep indigenous knowledge that allows farmers to adapt practices effectively to local environmental conditions and enhancing sustainability and resilience. Inadequate training in modern agricultural practices leads to suboptimal farming outcomes and limited innovation, poor land and water management practices and land and financial constraints are some of the weaknesses of rainfed farming systems (Appendix K). The opportunities for this AWM system include government support in terms of enabling policies, strategies and plans and climate-smart innovations which are developed and promoted through research and development. Climate change and variation and the associated effects such as droughts and floods are some of the main threats to rainfed farming systems.

The main strength of farmer-led irrigation development is the independence in decision-making of farmers which allows them the ability to monitor their operations and make independent decisions, allowing for quick and adaptive responses to challenges (Appendix L). The main weaknesses of farmer-led irrigators include the lack of water usage data which complicates reporting to the DWS for water licensing, insufficient funding for irrigation systems and farmers lack the necessary skills for efficient irrigation scheduling, leading to inefficient water use. Government supportive sectoral laws, policies, strategies and plans provide the enabling environment while access to established market enhances profitability and provides a stable income stream for farmers using irrigation. These are some of the opportunities for farmer-led irrigation development. The main threats to farmer-led irrigation development include climate change and variability, limited extension support and unsustainable soil management practices.

Scheme irrigators operate within a well-defined governance system that supports scheme members and facilitates controlled water management and easy access to government support that provides financial resources, technical assistance and policy backing, which are crucial for the success of irrigation schemes (Appendix M). One of the weaknesses of irrigation schemes is weak scheme governance in the form of ineffective management and leadership within the scheme which leads to inefficiencies and hinders long-term sustainability. Non-adherence to rules is one of the weaknesses that some members do not follow the established rules, leading to conflicts in the scheme, which can disrupt operations and reduce overall effectiveness. One of the main opportunities for irrigation scheme development is that government has an on-going programme to rehabilitate and revitalise irrigation schemes in the country. The other opportunity is that co-operative organisations can improve resource sharing, management and collective bargaining power. The main threats to irrigation scheme development include cultural and institutional resistance to new practices or technologies that can slow down or block modernisation efforts, excessive government control which may limit flexibility and responsiveness to local needs and potentially stifling innovation and adaptability in the schemes.

The other threat is unresolved land tenure issues which can create uncertainty and limit investment in the scheme. Securing land rights for smallholder farmers within irrigation schemes is essential. When smallholders have autonomy over irrigation and planning, they can be better prepared to deal with rising temperatures, invasive pests and more frequent extreme weather events associated with the changing climate. Irrigation allows farmers to maintain crop growth during periods of low rainfall. Secured land ownership provides stability and encourage investment in agricultural activities. When farmers have legal rights to their land, they are more likely to invest in long-term improvements, leading to increased productivity and income. Land tenure security is crucial for smallholder farmers within farmer-led irrigation and irrigation scheme systems. It ensures their livelihoods, resilience and sustainable agricultural practices.

The strengths of wastewater use in irrigation include the fact that unconventional water sources, such as treated wastewater are often more readily available to farmers, providing a consistent supply for irrigation and that such water is consistently available for irrigation (Appendix N). The weaknesses of this system include the fact that obtaining market certification for crops irrigated with unconventional water can be challenging, potentially limiting market access and inadequate treatment of wastewater can lead to poor water quality, affecting crop health and safety. The other weakness is that certain irrigation systems, such as drip irrigation may be prone to blockages when using wastewater, requiring specific adaptations or maintenance. The main opportunities for wastewater use for irrigation include supportive legal framework can create an enabling environment for the safe and efficient use of unconventional water sources in agriculture and the existence of clear guidelines and standards for the use of wastewater in irrigation can ensure safe and effective practices, increasing adoption and trust and the demand for peri-urban agricultural production which offers great potential to expand peri-urban irrigation around cities, leveraging unconventional water sources to support local agriculture. The threats to wastewater use for irrigation include the fact that using poorly treated wastewater can pose health risks to both farmers and consumers, making it essential to ensure proper treatment and use practices, inadequate enforcement of regulations concerning wastewater use can lead to unsafe practices, threatening public health and environmental sustainability and negative consumer perception of crops irrigated with unconventional water sources, potentially affecting marketability.

6.6 Gaps in institutional and financial support for AWM practices

6.6.1 Unstainable water use and agricultural practices gaps

South Africa faces significant challenges in agricultural water management, exacerbated by the fact that it is a water-scarce country and the increasing impacts of climate change. Agriculture accounts for approximately 60-62% of South Africa's total water withdrawals, with commercial farming heavily reliant on irrigation due to limited arable land suitable for rainfed agriculture. However, inefficiencies result in water losses of up to 30-40%, particularly in smallholder irrigation schemes (Fanadzo & Ncube, 2018; Bonetti *et al*., 2022). In some cases, unsustainable irrigation practices have led to high water debt repayment times, especially for crops like potatoes, pulses, grapes, cotton, rice and wheat grown in arid regions. Vulnerable provinces include Limpopo, Free State, Northern Cape, Eastern Cape and Western Cape (Bonetti *et al.,* 2022). Projected decreases in rainfall and increased drought frequency are likely to intensify water scarcity. It is projected that by 2090, irrigation demand could rise by 6.5% to 32%, further straining water resources (Bonetti *et al*., 2022).

Most of the current agricultural water management practices rarely integrate sustainable intensification pathways (SIP) that address environmental integrity and agricultural productivity simultaneously. This piecemeal approach fails to leverage synergies between interventions targeting the same water resources (Haileslassi *et al*., 2022). Despite their prevalence, rainfed systems receive limited attention compared to irrigated agriculture. This oversight exacerbates yield gaps and environmental degradation (Haileslassi *et al*., 2022). There are limited methodological frameworks that connect sustainability assessments with tailored solutions for local contexts. This limits the ability to address heterogeneity in biophysical and social settings across South Africa (Haileslassi *et al*., 2022).

6.6.2 Institutional and financial support gaps

An analysis of the gaps and opportunities for institutional and financial support for AWM practices was conducted during a stakeholder workshop. The rating of such support was conducted by stakeholders during the workshop mentioned in Section 3.3. The levels of degree of support considered in this analysis were strong, moderate, weak and none based on the approach of the World Health Organisation (WHO)

(WHO, 2019). The level of support for rainfed farming and farmer-led irrigation development were determined based on two farming systems, smallholder and commercial famers. Table 6.3 presents the degree of institutional and financial support for the AWM systems in the country. The colour coding used is specific to this study.

Table 6.3: Status of institutional and financial support for the four AWM systems

AWM system		Institutional support	Financial support
Rainfed farming system	Smallholder farmers		
	Commercial farmers		
Farmer-led irrigation development	Smallholder farmers		
	Commercial farmers		
Irrigation scheme development and modernization			
Wastewater use for irrigation			
Colour code:	Strong · Moderate · Weak · None		

The analysis showed that smallholder rainfed farmers and farmer-led irrigation farmers receive moderate institutional and financial support. Smallholder farmers under rainfed and farmer-led irrigation systems receive limited extension services. Access to finance is critical for the growth of the agriculture sector (IISD, 2015). However, it was observed that the rainfed and farmer-led irrigation farmers usually operate in rural areas environment where transaction costs are higher than under commercial farming environment due to a more dispersed population with weak infrastructure. The other risk factors inherent in these AWM systems which often inhibit financial institutions from lending farmers are high production risks linked to natural hazards (such as droughts, floods and pests) and farmers´ weak ability to provide collateral (either because the farmer lacks title to land to offer as a loan guarantee or the value of the land may be too low).

One of the main factors which limit financial support for these AWM systems is limited availability of innovative financial instruments and services that are suited for smallholder rainfed and farmer-led irrigation development farmers. Also, although financial services may be available, they may not be suitable for all types of agricultural activities under these systems, which may have diverse needs with respect to timing for disbursements, amounts and risks, among others (IISD, 2015).

Many smallholder irrigation schemes (SIS) suffer from poor construction quality, incomplete infrastructure (e.g., canals) and inadequate intake valves all which render systems ineffective or unsustainable (Fanadzo & Ncube, 2018; McCarthy, 2022). Farmers and extension staff often lack adequate training in irrigation water management. This gap undermines the sustainability and productivity of SIS (Fanadzo and Ncube, 2018). Uncertain land ownership limits farmers' ability to invest in long-term improvements for irrigation schemes (Fanadzo & Ncube, 2018). Insufficient government funding for smallholder farmers further hampers efforts to revitalize SIS and improve water-use efficiency (Fanadzo & Ncube, 2018).

Commercial farmers under rainfed and farmer-led irrigation systems operate at the level that attracts investment. Most commercial farmers have access and have ability to utilise innovations hence the farmers receive strong institutional and financial support. Strong WUAs provide strong institutional support for irrigation scheme development system. There is also strong government support for irrigation schemes in the country. However, financial support is moderate as there are some limitations to access financial services by scheme farmers. There is strong institutional support for wastewater use for irrigation through legislation and government interventions. Financial support for wastewater use for irrigation is weak, with issues such as lack of proper maintenance and malfunctioning of wastewater treatment plants.

6.6.3 Policy gaps in implementation of IDAWM practices

The country has national and sectoral pieces of legislation, policies and strategies related to IDAWM practices as presented in Chapter 5 above. IDAWM provides a unique opportunity to address low agricultural productivity, climate change emergency, land degradation and loss of biodiversity while contributing to national, provincial and local development aspirations, targets and commitments. The four pathways of AWM constitute unique approaches of managing water in agricultural systems which should be promoted and supported by national policies and institutional systems. Most of the legislations and policies including strategies have not been achieved in driving different pathways. The results of the study indicate that despite vigorous efforts, AWM has not been sufficiently mainstreamed or supported through some of the existing policy frameworks in the country. Since IDAWM systems contain elements of agriculture, forestry, land, water and environment, they tend to fall into the cracks between sectoral policies. In some cases, IDAWM systems are not well integrated into planning and financing under the key ministries.

Government efforts focus more on repairing infrastructure ("hard components") while neglecting "soft components" like capacity building and institutional support. This imbalance contributes to the failure of SIS (Fanadzo & Ncube, 2018). Poor oversight during construction and rehabilitation of irrigation systems leads to design flaws and premature failures. Transferring supervision responsibilities among various authorities has not resolved these issues (McCarthy, 2022). Top-down approaches dominate irrigation scheme development, often disregarding farmers' objectives or preferences. Bottom-up initiatives have proven more successful, but are underutilised (McCarthy, 2022).

The other policy gaps arise from the fact that fragmentation and ineffective coordination among government institutions and stakeholders dealing with the different elements of IDAWM (private sector, non-governmental organisations (NGOs), research and academic institutions), leads to inefficiencies in financial resource use, as well as duplication or poor attention to needed efforts. The results also show that there is a critical need and opportunity to address the gaps in technical advisory and implementation capacities and the financial mechanisms to scale IDAWM. Technical advisory services remain underfunded, under-capacitated and not well facilitated to support smallholder farmers under the various IDAWM systems. The government advisory system (extension) must be strengthened as it offers one of the key enabling factors for the effective implementation of AWM practices.

IDAWM value chain opportunities exist but require incentives, investment and favourable policy conditions to ensure their implementation, particularly in that, in some cases, the benefits of good AWM practices may take a number of years to be realised. Land tenure policies have great impact on the success and failure of IDAWM practices. Unsecured or ambiguous land tenure create long-term uncertainty for farmers, restricting the success of AWM initiatives. Secured land tenure system enable farmers to invest in and adopt AWM systems. Land tenure reforms need to take into consideration the tenure rights of vulnerable groups, including women. With clear rights over land, women and men farmers are strongly incentivised to invest in IDAWM practices to their benefit and to the benefit of the national economy.

Despite the general drive to provide financial support to famers in the country, the funding policies in many cases do not favour smallholder farmers who are unable to provide the required securities for some of the financial products. Incentives and investment in implementing viable AWM practices are needed, including an enabling policy environment. Greater support for developing IDAWM practices should include removing policy obstacles, providing or directing investment, enhancing credit access and providing market information, particularly for smallholder farmers.

The results show that some levels of success have been achieved in terms of policy formulation for supporting the implementation of IDAWM practices in the country. However, there is a lack of comprehensive coordination and synergy that cut across the broad objectives of these policies in meeting environmental, social and economic targets and aspirations (Adom & Simatele, 2021). The other gap is that the implementation of the policies and programmes is sometimes stalled by structural, systemic and institutional factors, coupled with new challenges arising from climatic variabilities.

6.6.4 Human capacity gaps

The results of the study show that limited skills in good farming practices, poor land and water management practices, lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation farming systems. The potentials for farmer-led irrigation development include supportive laws, policies, strategies and plans that provide the enabling environment and access to established markets that enhances profitability and provides a stable income stream for farmers using irrigation. The impact of climate change and variation, limited extension, institutional and financial support are some of the threats to these AWM systems.

6.7 Opportunities for AWM practices in South Africa

South Africa faces significant challenges in agricultural water management due to it being a water-scarce country. However, there are several opportunities to improve water efficiency and sustainability in the agricultural sector. These opportunities span technological, policy, infrastructure interventions and funding. The country’s rainfed agricultural systems face significant challenges due to water scarcity, climate variability and increasing pressure on natural resources. However, several opportunities exist to enhance water management and improve productivity under these conditions.

6.7.1 *Opportunities for improving rainfed systems in South Africa*

Rainfed agriculture relies on "green water," which is infiltrated rainfall stored in the soil and accessible to plant roots. Enhancing the capture, storage and efficient use of green water can significantly boost productivity at a low cost (Abrams, 2018). Techniques such as soil moisture conservation, mulching and improved tillage practices can optimise green water use (Strauss *et al*., 2021). Collecting and storing rainwater for infiltration into the root zone is a critical strategy for increasing yields in rainfed systems. This includes building small-scale reservoirs or using contour bunds to retain water (Rafta, 2023). Conservation agriculture principles, which are based on minimal soil disturbance, permanent soil cover and crop rotation offer another opportunity as they can improve water-use efficiency and resilience to climate variability. These practices are particularly suited to South Africa's semi-arid conditions (Strauss *et al*., 2021).

Good governance systems offer great opportunities for improving rainfed agriculture. Strengthening governance structures for rainwater management, decentralising decision-making and involving farmers in technology development can create sustainable systems. Providing credit access, crop insurance and safety nets can eliminate barriers to investment in rainfed agriculture (Rafta, 2023). Rainfed agriculture produces the vast majority of Africa's food — about 95% — yet receives only 5% of public agricultural water investment as illustrated in Figure 6.12 and 6.13 (Abrams, 2018). In South Africa and across the continent, smallholder farmers who depend on rainfed systems are central to food production and rural livelihoods. Increased investment can directly boost yields, improve food security and reduce poverty by making farming more productive and reliable.[12][13]

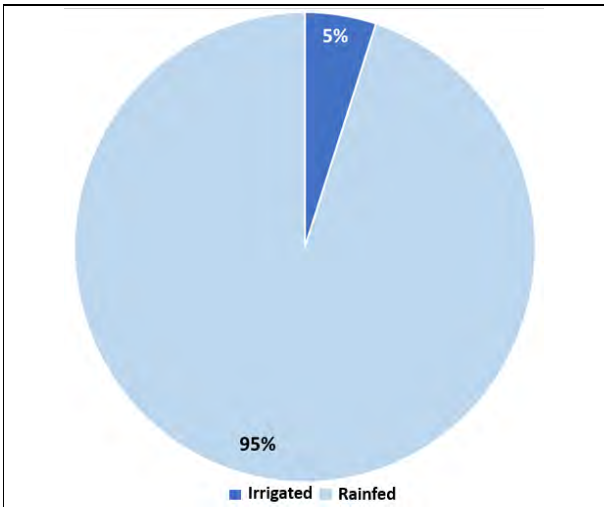


Figure 6.12: Food production by rainfed and irrigated agriculture in Africa (Source: Abrams, 2018)

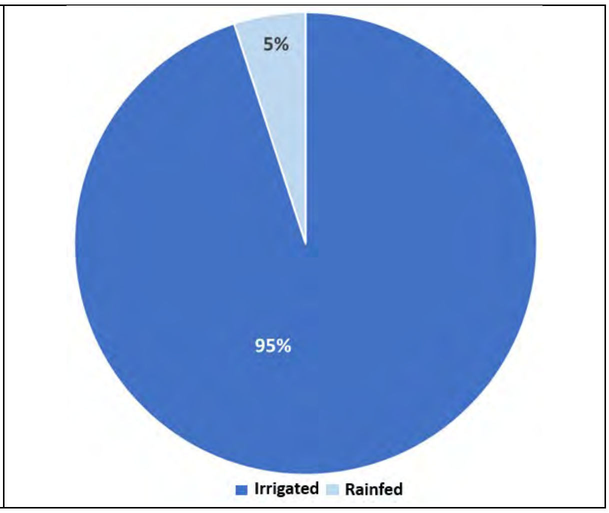


Figure 6.13: Public money spent on agricultural water in Africa (Source: Abrams, 2018)

Rainfed farming is highly vulnerable to climate variability and change, with smallholder farmers especially affected by erratic rainfall and dry spells. Investment in better rainwater management, such as water harvesting infrastructure and soil moisture

[12] https://siwi.org/latest/whats-next-for-rainfed-agriculture/
[13] https://dialogue.fanrpan.org/wp-content/uploads/2023/03/Transforming-Investments-in-African-Rainfed-Agriculture.pdf

conservation can increase resilience to droughts and extreme weather, helping communities adapt to a changing climate.[14] Investments that focus on soil and water management helps to reduce soil erosion, improve groundwater recharge, increase carbon sequestration and support biodiversity. These environmental benefits are essential for the long-term viability of agriculture and the health of ecosystems. Adopting climate-resilient cropping systems and integrating soil and water management practices can mitigate the impacts of climate change on rainfed agriculture (Strauss *et al*., 2021; Rafta, 2023). Another important opportunity lies in the building of farmers' capacity through extension services and research on locally adapted technologies which is crucial for accelerating the adoption of improved practices (Rafta, 2023).

It requires significant resources to achieve impactful improvement in rainfed agriculture and more investment is urgently needed (Abrams, 2018). Public sector financing could include a range of different fiscal mechanisms and activities such as subsidies, farmer support and extensions services, micro-credit for inputs, market access roads and small-scale infrastructure such as small dams and rainwater harvesting systems. New innovative finance could increase opportunities for green funds to reclaim degraded lands through conservation agriculture or off-set financing to invest in green water and micro infrastructure accessing to increase climate resilience.

There is significant untapped potential for rainfed crop production in South Africa and with the right investment and government support, rainfed agriculture can be transformed from subsistence-level activity to a driver of commercial agricultural development, benefiting both local communities and the national economy hence investing in rainfed farming systems in South Africa is essential for improving food security, building climate resilience, protecting the environment, creating jobs and making efficient use of scarce water resources. Without such investment, the country risks continued low productivity, vulnerability to climate shocks and missed opportunities for sustainable rural development. The study has shown that by focusing on green water management, conservation agriculture, improved governance and targeted investments, South Africa can unlock the potential of its rainfed agricultural systems. These strategies offer sustainable pathways to enhance productivity, build resilience against climate change and support rural livelihoods.

6.7.2 Opportunities for improving FLID systems in South Africa

FLID offers significant potential to enhance agricultural productivity, rural livelihoods and food security in South Africa. However, several challenges must be addressed to unlock these opportunities effectively. As the study has shown, smallholder rainfed farmers often lack the necessary skills in irrigated crop management and water-use efficiency hence training programs focused on farm and scheme management are critical for improving irrigation practices under this pathway. Another opportunity lies in improved agricultural extension services which can provide farmers with guidance on irrigation water management, agronomic practices and crop diversification.

Uncertainty around land tenure discourages investment in irrigation infrastructure and farming practices. Policies that ensure secure land tenure for rural farmers can promote long-term investments and sustainable irrigation development (Fanadzo &

[14] https://www.nepad.org/blog/improving-food-security-africa-through-water-harvesting-technologies

Ncube, 2018). Many FLID farmers are located in remote areas with poor road infrastructure, limiting access to markets. Investments in transportation networks can help farmers sell their produce more efficiently (Fanadzo & Ncube, 2018). Encouraging partnerships with agribusinesses and processors can strengthen market linkages, reduce post-harvest losses and stabilise prices for farm products.

High upfront costs of technologies like solar water pumps hinder adoption by smallholder farmers. Introducing pay-as-you-go financing models can make these technologies more accessible (World Bank, 2023). Promoting low-cost, farmer-friendly irrigation systems tailored to local conditions can enhance productivity while conserving water resources (Harmon, 2023). Supporting farmers as drivers of irrigation investments fosters autonomy and adaptability. Overly technocratic or top-down approaches risk undermining the entrepreneurial spirit of farmer-led irrigation (Harmon, 2023).

Efficient irrigation systems are essential to mitigate the impacts of climate change on water availability and agricultural productivity. Promoting alternative cropping systems suited to local climates can enhance resilience and sustainability for smallholder farmers (Fanadzo & Ncube, 2018). Increased financial support from government and private entities can help smallholder FLID farmers invest in irrigation infrastructure and inputs. The opportunity also lies in facilitating access to microfinance institutions which can empower farmers to self-finance their irrigation ventures. It is concluded that by addressing the areas of capacity building, policy reforms, market connectivity, technology access, farmer autonomy, climate resilience and financial support, South Africa can significantly improve farmer-led irrigation development.

6.7.3 Opportunities for improving irrigation scheme development and modernisation in South Africa

The country faces significant challenges in its irrigation sector, which consumes 62% of the country's water resources, with losses of up to 30-40%. However, there are numerous opportunities to improve irrigation scheme development and modernisation, particularly for smallholder farmers. Below are key areas of focus: One of the opportunities for improving irrigation scheme development is promoting low-cost, water-saving technologies such as efficient pumps and modular irrigation designs can significantly reduce water wastage (de Lange, 1999; Reinders, 2011). Adoption of advanced irrigation techniques (e.g., micro-irrigation) can optimise water delivery and improve beneficial water-use components (Reinders, 2011). Implementing water measurement systems and risk management plans can help track water distribution and usage effectively.

It has been observed from the study findings that the lack of skilled farmers and extension staff is one of the major barriers in irrigation schemes. Training programs focused on irrigation water management has the potential of empowering smallholder farmers to operate schemes efficiently (Fanadzo & Ncube, 2018; Reinders, 2011). Increased interaction between farmers and technical advisors is essential for selecting appropriate technologies and improving operational knowledge. Balancing infrastructure repair with capacity-building initiatives is crucial for sustainable irrigation development (Fanadzo & Ncube, 2018; Reinders, 2011).

Addressing land tenure insecurity can enhance farmers' commitment to irrigation schemes and improve scheme performance. Greater financial support and policy alignment can position smallholder agriculture as a driver of economic growth. The potential of irrigation schemes can also be unlocked by tailoring irrigation schemes to the unique needs of communities through participative planning which can ensure better outcomes. Collaboration with manufacturers to produce affordable, robust equipment tailored to small-scale needs could address gaps in technology availability for irrigation famers (de Lange, 1999). With these opportunities, the country can modernise its irrigation schemes, improve agricultural productivity, reduce poverty and adapt to climate challenges effectively.

6.7.4 Opportunities for unconventional water use for irrigation in South Africa

Wastewater reuse for irrigation offers promising opportunities for addressing these issues. Over 60% of wastewater treatment works in South Africa are classified as "poor to critical" (Swartz *et al*., 2022; Wikipedia, 2015). One of the potentials of using wastewater for irrigation lies in investing in modern technologies, such as enzyme biotechnology, which can improve wastewater plant performance and compliance with water quality standards. Combining traditional treatment methods with natural-based infrastructure (e.g., artificial wetlands) can reduce nutrient pollution while providing ecological and tourism benefits (Pallaske *et al*., 2022). Treated wastewater contains essential nutrients like nitrogen, phosphorus and potassium, which can reduce fertiliser costs and improve soil health (Hoogendijk *et al*., 2023). Ensuring microbial safety through advanced treatment processes can make treated wastewater more viable for irrigation without compromising crop safety (Kgopa *et al*., 2021).

High salt loads in treated wastewater can degrade soil properties over time. Implementing measures to mitigate salinity and toxic substance accumulation is critical for sustainable irrigation practices (Hoogendijk *et al*., 2023). Establishing clear regulations for wastewater reuse in agriculture is essential. Current frameworks lack enforcement mechanisms to ensure safe reuse practices (Abdallah & Mourad, 2021). Encouraging public-private partnerships (PPPs) to fund infrastructure upgrades can accelerate adoption of wastewater reuse technologies (Wikipedia, 2015). Small-scale farmers often lack access to treated water due to cost barriers. Decentralised treatment systems or subsidies could increase accessibility and adoption among rural communities (Swartz *et al*., 2022). Conducting field studies under South African conditions is necessary to understand long-term impacts of treated wastewater on crops and soil health (Hoogendijk *et al*., 2023). Regular monitoring of microbial quality and nutrient levels will ensure safe and effective use of wastewater for irrigation and enhance the effective reuse of treated wastewater for irrigation in the country (Kgopa *et al*., 2021).

6.7.5 Opportunities in funding for AWM

Agriculture, being the backbone sector of the country's economy, requires robust financial support to ensure sustainable growth and development. Agriculture finance plays a pivotal role in facilitating the smooth functioning of the agricultural sector. One of the key factors that determine success of IDAWM practices is the access to sources of finance at the right time which is a cornerstone for building better living conditions for rainfed and irrigation farmers by ensuring profitability of their operations.[15] Finance

[15] https://www.agristudoc.com/agriculture-finance-importance-source-types/#:~:text=Importance%20of%20Agriculture%20Finance%3A%201%201.%20Enhancing%20Agricultural,Agriculture%20Practices%3A%20...%205%205.%20Market%20Access%3A%20

is required for the purchase of different types of agricultural implements and high-quality seeds, for making marketing arrangements, for storage and processing, among others.

Agri-finance provides farmers with the necessary capital to invest in modern technologies, high-quality seeds, fertilisers and other inputs. This, in turn, boosts agricultural productivity and ensures a steady supply of food to meet the growing demands of the growing population. Agri-finance contributes significantly to rural development by fostering economic growth in agricultural communities. It creates employment opportunities, improves infrastructure and enhances the overall quality of life in rural areas. Financial support encourages farmers to adopt sustainable agricultural practices. This includes investing in organic farming methods, conservation of water resources and promoting environmentally friendly approaches, ensuring long-term viability and ecological balance.

The significance of agriculture finance lies in its ability to address the specific needs and challenges faced by farmers and stakeholders in the agricultural sector. It catalyses economic development and poverty alleviation, playing a crucial role in achieving sustainable agricultural growth. Access to finance is an essential factor of the agriculture value chain which enables farmers to purchase essential inputs and infrastructure (e.g., machinery and land) necessary for the production process, grading, processing, packaging and distribution of their produce (Mtombeni *et al.,* 2019). Finance is also required where there are specific regulatory requirements (such as licencing and certification) which a participant must adhere to and these may differ from commodity to commodity. With this in mind, it is clear that any farming enterprise that wishes to enter and participate in the agricultural sector needs access to finance to compete effectively. The significance of agri-finance stretches far beyond simply providing loans to farmers. It plays a crucial role in ensuring food security, driving economic development and empowering rural communities. The following are some of the key contributions of agri-financing[16]:

(a) Increased productivity:

By enabling farmers to invest in better seeds, fertilizers, equipment and technologies, agriculture finance helps them boost their yields and improve overall production. This directly contributes to a more stable food supply for local communities and beyond.

(b) Improved market access:

Financial resources allow farmers to connect with wider markets, diversify their crop choices and respond to changing demand. This enhances market efficiency and ensure that food reaches where it is needed most.

(c) Building resilience:

By providing access to weather insurance and risk management tools, agriculture finance helps farmers mitigate the impact of natural disasters and unpredictable weather patterns. This protects food production and prevents food insecurity in vulnerable regions.

(d) Rural job creation:

[16] Ibid

A thriving agricultural sector supported by robust finance creates additional jobs in related industries like processing, transport and retail. This stimulates local economies and improves livelihoods in rural areas.

(e) Increasing trade and revenue:

Enhanced agricultural productivity and market access leads to increased trade and export opportunities. This generates revenue for rural communities and contributes to national economic growth.

(f) Infrastructure development:

The need for efficient agricultural production often drives infrastructure development in rural areas, such as improved roads, irrigation systems and storage facilities. This not only boosts agriculture, but also enhances the overall quality of life in rural communities.

(g) Financial inclusion:

Access to financial services like loans, savings accounts and insurance empower farmers to make informed decisions and manage their finances effectively. This fosters financial independence and increases their bargaining power in the agricultural value chain.

(h) Reduced poverty and inequality:

By improving agricultural productivity and income potential, agriculture finance contributes to poverty reduction in rural areas. This also help bridge the inequality gap between rural and urban populations.

(i) Improved education and healthcare:

A stronger agricultural sector leads to increased tax revenue and investment in rural communities. This can facilitate improvements in education, healthcare and other essential services, leading to a better quality of life for rural families.

6.7.6 Funding sources in agriculture in South Africa

There are government and private sector institutions that offer funding to the agriculture sector in the country. In doing so, these funds support the implementation of IDAWM practices in the country. The Land and Agricultural Development Bank of South Africa (Land Bank) is an agricultural development financial institution and it offers various financial products to the agricultural sector which include (Western Cape Department of Agriculture, 2022):

- The long-term mortgage loan which is designed to finance capital expenditure related to agriculture; this is for the purchase and improvement of fixed agricultural property.
- Medium-term loans which are designed for medium-term agricultural finance requirements.
- Instalment loan finance (assets finance) which is designed for farmers that require financing for the purchase of tractors, vehicles, agricultural equipment not covered under medium-term loans and any agriculturally justifiable moveable assets.
- Short-term loans which are tailored to meet important financing needs faced by commercial and emerging farmers during the vital agricultural production cycle and revolving credit facility for the finance of short-term capital requirements and other general or operational needs of the business offered to agri-

processing businesses, wine, poultry, feedlots, piggery, wine, cash crops and mixed farming (livestock and crop).

- Value chain finance which is a loan that offers production finance to farmers against a written agreement between the buyer and the seller for the production of and sale of specific quantity, quality, specific price which allows the value of the contract to be determined over the loan term.

The beneficiaries of Land Bank funding include emerging farmers, established farmers, co-operatives and agricultural related businesses (Western Cape Department of Agriculture, 2022). Agriculture is one of the priority sectors which Standard Bank supports in the country. The focus areas that the Standard Bank Group supports include strengthening the agriculture value chain and providing climate smart agriculture financing solutions (Standard Bank Group, 2023). Table 6.4 provides the products that Standard Bank offers to rainfed farmers in support of their farming operations.

Table 6.4: Financial products Standard Bank offers to rainfed farmers in the country

Finance	Repayment term	Detail	Security
Production credit	< 1 year	Overdraft facility	Bond over the property
		Agricultural production loan	Comprehensive crop insurance or hail insurance. Session of crop income
Term loan	10-15years	Land and fixed improvements	Bond over the property
Asset	3-7 years dependent on asset	Farming equipment like: tractor and implements	Secured by the asset

(Source: Standard Bank)

Over and above the support to rainfed farmers, Standard Bank also provides specific support for irrigation development subject to lawful water use under a valid water licence. The products for such support are presented in Table 6.5.

Table 6.5: Financial products that Standard Bank offers to farmer-led irrigation famers in the country

Finance	Repayment term	Equipment	Security
Term loan	3-10 years	Motherliness, reservoirs and irrigation equipment: In field drip-, micro- and sprinkler systems. Also, meters, filters, pumps and irrigation management software	Bond over the property
Asset	3-7 years	In field centre pivot irrigation systems including variable drives, meters, filters, pumps and irrigation management software	Secured by the asset

(Source: Standard Bank)

Regarding irrigation schemes, Standard Bank provides financial support for upgrading/modernisation of private irrigation schemes against future income (levies) based on the effective management of the irrigation scheme in the past and future. The support is based on the condition that all participants on the scheme provide guarantees limited to the proportion of their water use. Another financial institution that also provides funding to the agricultural sector is Nedbank. Nedbank provides sustainable funding solutions to unlock growth opportunities and help farmers meet the challenges in the agriculture sector, whether the business is in horticulture, field crops, livestock or a secondary agri-related business.[17]

Nedbank's sustainable agriculture funding solutions aim to address the challenges that farmers face due to climate change (Nedbank Group, 2023). These challenges include reduced rainfall and increased temperatures, which make it difficult for farmers to produce food sustainably. The sustainable agriculture solutions help farmers to improve their farming practices, such as water conservation and storage, improved soil health, advanced irrigation techniques and shade-netting to minimise evaporation (Nedbank Group, 2023). The solutions are offered either directly or via financing cooperatives.

The bank's short-term, medium-term and long-term funding solutions are presented in Table 6.6.

[17] https://business.nedbank.co.za/commercial-banking/industry/agriculture/borrow.html

Table 6.6: Agricultural funding solutions provided by Nedbank

Time frame	Financial products
Short-term	• Current accounts with seasonal overdraft facilities or a short-term loan. • Agriculture production loans to finance production inputs such as fertiliser, seed and diesel. • Debtor and trade finance to help maintain a constant cash-flow. • Structured finance solutions, including export credit finance.
Medium -term	• Shade-netting finance for field and tree crop farmers to help them improve the yield of underperforming orchards and protect them from natural hazards. • An instalment sale agreement to help you buy moveable assets. • Medium-term loans to help you grow your business by buying livestock or establishing new orchards. • Global commodity finance.
Long-term	• Agri-Nedbank – a long-term loan with a repayment term of up to 15 years to help your business buy additional property or to improve existing assets. • Renewable energy and efficiencies – to mitigate the impacts of load shedding and rising energy costs. • Sustainable agriculture transformation – to ensure that the future of agriculture remains stable through the provision of advice, technical assistance and differentiated finance solutions for transformation changes.

(Source: https://business.nedbank.co.za/commercial-banking/industry/agriculture/borrow.html)

Absa Bank considers that climate change, environmental vulnerabilities, social disparities and corporate governance issues present significant challenges to growth in the country (Absa, 2023a). These factors critically affect agriculture, water, health and energy. In order to reduce social disparities, Absa bank supports black agricultural financing. The bank's strategy is to expand financial support for the developing agribusiness sector, particularly black-owned businesses. Their approach is to leverage strategic partnerships, both internal and external and create synergies that enhance our impact on the target market (Absa, 2023b).

Absa's structured Trade and Commodity Finance offering is the largest for agricultural commodities and a market leader in terms of the size and breadth of their solutions.[18] The Bank also connects key sector players through the value chain and facilitates Black Economic Empowerment on a sustainable basis as part of their offering. As the largest agricultural funder in South Africa, Absa has solid experience in this market.[19] The Department of Agriculture, Forestry and Fisheries (DAFF), in its draft National Policy on Comprehensive Producer Development Support, published for public comment on 30 May 2018, indicated that it would be the overall national policy for the agriculture, forestry and fisheries sector in South Africa that would regulate and guide

[18] Agriculture | Sector Expertise | Absa CIB
[19] Ibid

interventions to various categories of producers by the government, such as accessing finance, land ownership, access to water resources, access to markets and compliance with market standards (DAFF, 2018). The policy document differentiates between four categories of farmers; namely, household producer (subsistence farmer), smallholder producer/farmer, medium scale producer/farmer and large-scale commercial producer/farmer.

Figure 6.14 provides a schematic representation of BFAP's proposed framework that links different farmer categories and farming systems coexisting in South Africa to diverse value chains and markets (BFAP, 2024). The farmer categories are (loosely) paired against their target markets and examples of specific support services required for these farmers to thrive are identified. Successful transformation will result in an increased number of smallholder farmers able to produce for local markets and ensure regional food security and where possible and viable, link into formal or tailor-made value chains for domestic and global markets.

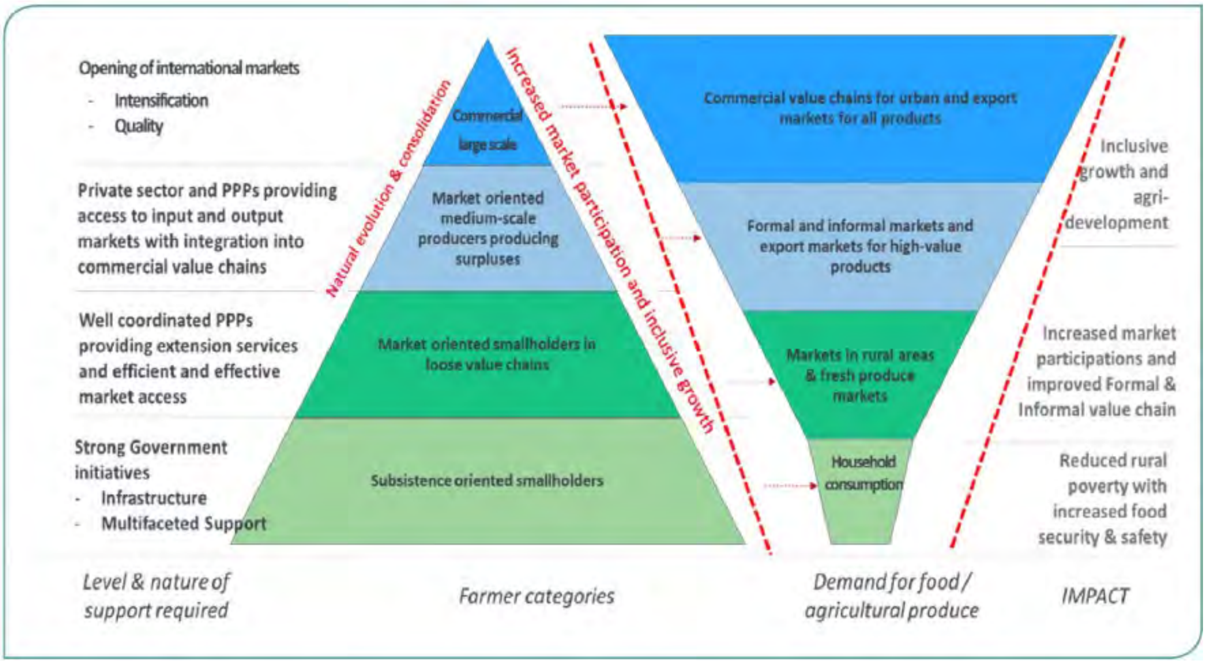


Figure 6.14: Potential framework linking producer support to dedicated value chains (Source: BFAP, 2024)

BFAP (2024) observed that South Africa's largely urbanised population and economically important international trade balance will still largely depend on large scale commercial farming operations. Access to finance is not easy for emerging farmers. Stakeholders, including the Land Bank have raised the same concern regarding the ability to obtain finance for emerging farmers in order to ensure their entry and participation in the South African agricultural sector (Mtombeni *et al*., 2019). Mtombeni *et al*. (2019) reported that the competition authorities have over the years tried to address issues of access to finance for new entrants and smaller players by establishing several developmental funds as part of conditions attached to mergers and abuse of dominance cases and penalties imposed on firms involved in cartels.

These development funds include the Agro-Processing Competitiveness Fund (APCF), the Massmart Supplier Development Fund (MSDF), the Coca-Cola Supplier

Development Fund and the ABInBev Fund. Although there has been some positive impact of the developmental funds introduced by the competition authorities in addressing market entry and concentration levels, it is evident that these interventions and remedies alone will not address the issue of persisting high concentration in this sector (Mtombeni *et al*., 2019).

There is a need for more effective policy support for the emerging sector (represented by smallholder and subsistence farmers) in Figure 6.12 so that they can be improved. This is in line with the views of BFAP (2024) who argue that transformation of the commercial farming sector and the establishment and support of increased numbers of emerging commercial farmers is key for the continued existence of the agricultural sector.

As reported by BFAP (2024), critical maintenance in irrigation scheme infrastructure has fallen behind, with water losses estimated at approximately 30% of supply. While on-farm water use efficiency has improved with the rising prevalence of netting, increase in investment, expansion and maintenance of infrastructure in existing irrigation schemes is critical for new entrants to enter the sector successfully.

6.8 Discussions, conclusions and recommendations

6.8.1 Introduction

This chapter provides the discussions, conclusions and recommendations of the research. The section is structured into three parts. The first part presents discussions of the of the research findings. The research findings provide a scrutiny on how the information provided in this study answers the key research questions, which is to assess the policy and institutional gaps and opportunities for implementing IDAWM systems in the country. The second part presents the main conclusions from the findings of the study. The third part considers recommendations in the context of the findings and the objectives of the research.

6.8.2 Discussions

The study shows the impact of land ownership on the ability of the farmer towards the investment in agricultural irrigation and equipment purchase. The 27.45% of land that is under PTO agreements was perceived as the land that might restrict long-term investments and cause uncertainty. The use of rental properties by some of the farmers demonstrate that some of the farmers do not have land, which could result in low investment due to low security. The least own land is the communal land which makes up 1.96%, reflecting low community ownership. Furthermore, the less proportion of the land belong to the state at 13.73% which the farmers could invest in less due to some of the restriction. Mdoda and Gidi (2023) reported that farmers invest more on the land they own than on the rented land, meaning that the farmers can make an effort on the provision of irrigation system if he owns the land.

On the other hand, the results of the interviews with the farmers show that the FLID farmers have various opportunities, such as having access to make their own decisions in their farms, choosing irrigation technologies based on their finances and taking the initiative in everything they require on the farm. One of the challenges they mentioned is that they do not keep records of their produce or what they sell, affecting their financial situation. Furthermore, they mentioned that the lack of funding from the government is a barrier to the expansion of FLID farmers.

However, while there are opportunities offered by the policy and instructional systems, there are gaps which limit how the farmers benefit from these opportunities. The study has shown that most farmers have limited knowledge of the institutional and policy opportunities of such financial products. The study done by Harmon *et al*. (2023) indicated that although FLID is made through the initiative from the farmers themselves, it does not guarantee sustainability especially when there is lack of knowledge and support. The provision of funds and support increase the productivity and sustaining of jobs as proven by the support provided during the COVID-19 pandemic (Popoola & Yusuf, 2021).

A key barrier to financial support for FLID may be due to the lack of water licences due to the high correlation between these two factors. The lack of water licenses could be due to farmer apathy towards paying this levy or perhaps the difficulty or the lack of knowledge of the applications procedure for the water licences. However, there is hope based on the high levels of education of a majority of the FLID farmers that they can readily understand the application process and importance of the water licence once properly sensitised on the issue.

Nonetheless this needs significant improvement in the access to extension services offered to the FLI farmers. The high percentage of access to the market by the FLI farmers is a key driver for the farmers to comply with regulatory directives that would unlock the numerous funding opportunities that would help in modernising their operation thus optimising and improving their outputs and consequently their earnings.

The results of the SWOT analysis conducted for each of the four AWM pathways showed that limited skills in good farming practice, poor land and water management practices, the lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation systems. The potentials for farmer-led irrigation development include supportive laws, policies, strategies and plans that provide the enabling environment and access to established markets that enhances profitability and provides a stable income stream for farmers using irrigation. The impacts of climate change and variation, limited extension, institutional and financial support are some of the threats to these AWM systems.

The study by Mokgomo *et al*. (2022) reported that access to state support and controlled water management are two of the main strengths of irrigation scheme development. Most of the irrigation schemes suffer from weak scheme governance, which is one of the weaknesses of this AWM system. These findings are similar to those reported by McCathy *et al*. (2023) who indicated that the irrigation schemes in Sub-Saharan African countries fail from the start due to poor construction and the lack of funds to sustain them.

The opportunities of irrigation scheme development and modernisation are that scheme irrigators operate within a well-defined governance system that supports scheme members and facilitates controlled water management and easy access to government support that provides financial resources, technical assistance and policy backing, which are crucial for the success of irrigation schemes. Cultural and institutional resistance to new practices or technologies, excessive government control which may limit flexibility and responsiveness to local needs and unresolved land tenure issues which can create uncertainty and limit investment in the scheme are some of the main threats to irrigation scheme development.

The availability of wastewater supplies is one of the strengths of wastewater use for irrigation. One of the weaknesses of wastewater use for irrigation is that wastewater cannot be used in certain irrigation systems, such as drip irrigation due to the risk of blockages hence it requires specific adaptations or maintenance. The potential for wastewater use for irrigation include the growing demand for peri-urban agricultural production. The potential health risks associated with wastewater use, poor wastewater quality monitoring and negative consumer perception of crops irrigated with wastewater are some of the threats to wastewater use for irrigation.

6.8.3 Conclusion

In terms of financial support for IDAWM practices, the analysis has shown that some financial institutions have clear mandate and objectives to serve both commercial and emerging farmers by bringing specially designed financial services within the reach of farmers across the nation. However, it has emerged from the study that there is still more to be done to ensure that smallholder rainfed and irrigation farmers fully benefit from this important financial support. This is important since the services that the Land Bank provides enable farmers to finance land, equipment, improve assets and obtain production credit.

6.8.4 Recommendations

The following recommendations are made based on the results of the study:

1) There is need for a clear policy of providing emerging and all smallholder farmers with simple and clear information about the existence of various support products, whether technical or financial.
2) There is need for providing extension services to rainfed and farmer-led irrigation at a regular basis.
3) Water licensing policy needs to be clearly explained to the farmers so that government can have accurate national database of irrigation farmers which is very crucial for national planning.
4) There is need policy revision to ensure that smallholder farmers have improved access to markets for their produce.
5) Land tenure policy needs to be reviewed to ensure that smallholder have more secured tenure of the land they farm than it is in some of the cases.
6) Most of the irrigation farmers face the challenge of high prices of electricity, petrol, and diesel, while they do not have any source of income. There is need for a policy of making these inputs affordable to emerging and all smallholder farmers.
7) The results of the study further show that limited skills in good farming practice, poor land and water management practices, lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation farming systems. There is need for policy revision to address these challenges smallholder farmers face.

CHAPTER 7

GENERAL CONCLUSIONS AND RECOMMENDATIONS

In 2020, the AU endorsed the IDAWM framework as a blueprint for advancing AWM in Africa along four distinct development pathways: 1) Improved water control and watershed management in rainfed farming 2) Farmer-led irrigation development (FLID) 3) Irrigation scheme development and modernisation and 4) Unconventional water use for irrigation. The study set out to conduct context-specific literature search (i.e. desktop study) to expand the knowledge base on AWM and establish the current level of AWM practices in the study area. The main focus of the study was to identify opportunities and priorities for using agricultural water as an entry point for improving the country's agri-food systems while sustaining the natural resource base. The activities of the study included identifying, mapping and assessing IDAWM practices in South Africa. It also included an analysis of how policy, governance and institutional systems affect the implementation of AWM practices in South Africa. In assessing the potential of implementing the IDAWM framework, the study assessed gaps and identified opportunities for improving policy, governance and institutional dimensions in the country. The study examined how the identified opportunities and priorities can provide guidance to the national stakeholders on constraints, potential investments and approaches to expand effective AWM practices and provide the national context and priorities for implementing the IDAWM framework in the country.

7.1 Conclusions

The findings of the literature review show that there are effective AWM practices that are important for improving agricultural production especially in water scarce countries and that large proportion of farming land is under rainfed farming systems, FLID systems, small-scale irrigation schemes and wastewater reuse have great roles in improving agricultural production. The review also showed that good policies and governance and institutional systems create an enabling environment for improving AWM practices. The literature review findings highlighted the need to understand the existing AWM practices and how existing policies and governance systems affect the use and management of agricultural water resources for sustainable agricultural development.

The results of the study show that based on the four AWM pathways, there are promising investment opportunities in the country. The study shows that a pre-requisite for success in IDAWM practices is to ensure that policies and institutions that support sustainable, equitable implementation are in place and effective and are accompanied by realistic long-term plans. The study showed that rainfed farming system is a high-priority area for investment with potentially large benefits as it involves the majority of small-scale farmers in the country. This is why it is important that the country develops specific policies and implement long-term investment programmes to work with local communities to restore degraded landscapes and move to sustainable resource management.

Rainfed agriculture produces the vast majority of Africa's food — about 95% — yet receives only 5% of public agricultural water investment. In South Africa, smallholder farmers who depend on rainfed systems are central to food production and rural livelihoods. There is significant untapped potential for rainfed crop production in South

Africa and with the right investment and government support, rainfed agriculture can be transformed from subsistence-level activity to a driver of commercial agricultural development, benefiting both local communities and the national economy. The study has shown that, by focusing on green water management, conservation agriculture, improved governance and targeted investments, South Africa can unlock the potential of its rainfed agricultural systems.

The results of the study show that the FLI farmers have various opportunities, such as the ability to make their own decisions in their farms, choosing irrigation technologies based on their finances and taking the initiative in everything they require on the farm. However, the lack of proper records is a serious challenge that affects their financial situation. Furthermore, they mentioned that the lack of funding from the government is a barrier to the expansion of FLI farmers and modernisation of their farming techniques since they have to rely solely on their meagre own resources. However, while there are opportunities offered by the policy and instructional systems, there are gaps that limit access to these opportunities by the FLI farmers. The study has shown that most farmers have limited knowledge of the institutional and policy support system, such as financial products and training opportunities.

Easy access to state support and controlled water management are two of the main strengths of irrigation scheme development. Most of the irrigation schemes suffer from weak scheme governance, which is one of the weaknesses of this AWM system. The opportunities of irrigation scheme development and modernization are that scheme irrigators operate within a well-defined governance system that supports scheme members and facilitates controlled water management and easy access to government support that provides financial resources, technical assistance and policy backing, which are crucial for the success of irrigation schemes. Cultural and institutional resistance to new practices or technologies, excessive government control which may limit flexibility and responsiveness to local needs and unresolved land tenure issues which can create uncertainty and limit investment in the scheme are some of the main threats to irrigation scheme development.

The availability of wastewater supplies is one of the strengths of wastewater use for irrigation. One of the weaknesses of wastewater use for irrigation is that wastewater cannot be used in certain irrigation systems, such as drip irrigation due to the risk of blockages hence it requires specific adaptations or maintenance. The use of wastewater for irrigation has significant implications for both the environment and the agricultural sector in South Africa. One of the most notable benefits is the potential for expanding irrigated agricultural land, particularly in water-scarce regions where access to freshwater is limited. By utilising treated wastewater, farmers can reduce their reliance on freshwater resources, thereby alleviating pressure on these dwindling supplies.

Wastewater also contains valuable nutrients, such as nitrogen and phosphorus, which can act as natural fertilisers and improve soil fertility. This can lead to reduced reliance on synthetic fertilisers, which are often costly and can have negative environmental impacts. Furthermore, the use of wastewater for irrigation can contribute to mitigating the impacts of climate change on agriculture. By providing a reliable source of water, wastewater irrigation can help farmers adapt to changing rainfall patterns and reduce their vulnerability to droughts and water shortages. The implementation of wastewater irrigation in South Africa is governed by a comprehensive policy and regulatory framework, primarily based on the National Water Act. This legislation provides the foundation for water resource management, including the regulation of water use, water quality and wastewater discharge. The National Water Act also outlines guidelines for water reuse, specifying the conditions under which treated wastewater can be used for various purposes, including irrigation.

The study has shown that the South African government has implemented several initiatives aimed at promoting sustainable water management, including the development of national water resource strategies and the provision of funding for water infrastructure projects. Institutional support for wastewater irrigation projects is also available through various government agencies and research institutions, which provide technical assistance, training and monitoring services. Collaborative approaches between government, agriculture and the technology sectors are essential for fostering innovation and ensuring the effective implementation of wastewater irrigation projects. The future of wastewater use for irrigation in South Africa is promising, with several opportunities for further development and innovation. Technological advancements in water treatment are expected to play a key role in improving the quality and affordability of treated wastewater, making it more accessible for irrigation purposes. Integrated water resource management strategies, which consider the interconnections between different water sources and uses are also essential for ensuring the sustainable and equitable allocation of water resources.

In terms of financial support for IDAWM practices in the country, the analysis has shown that some financial institutions have clear mandate and objectives to serve both commercial and emerging farmers by bringing specially designed financial services within the reach of farmers across the nation. However, it has emerged that there is still more to be done to ensure that smallholder rainfed and irrigation farmers fully benefit from this important financial support.

The study has shown that, among other things, the effective implementation of IDAWM practices requires:

- enabling environment provided by good policy, governance and institutional systems;
- appropriate technologies and innovations;
- investment (public and private);
- stakeholder engagement to secure social commitment, ownership and acceptability; and
- capacity building of the stakeholders.

7.2 Recommendations

It has been observed from the study results that the successful implementation of IDAWM practices requires effective capacity building, financial resources and investment in AWM practices, supportive infrastructure, research and development in AWM, as well as policy reform.

Capacity building: There is an urgent need for more investment in capacity strengthening at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers' knowledge and skills. At the knowledge generation level, there is need to strengthening research capacities through investing in human resources and reforming research institutions to make them more attractive places to work and more effective. At the knowledge utilisation level, there is need to build the capacity of small-scale farmers so that they are able to adopt the developed AWM technologies for effective and sustainable use and management of agricultural water resources. It is important to invest in extension services in order to improve the skills of extension workers in irrigation water management.

The results of the study show that limited skills in good farming practice, poor land and water management practices, the lack of record-keeping of farming operations including water use data are some of the weaknesses of smallholder rainfed and farmer-led irrigation farming systems hence there is need for providing comprehensive training of smallholder farmer-led irrigation farmers in irrigation management (including irrigation scheduling), as well as in record-keeping skills so that they can operate farming as a business.

The importance of building and strengthening scheme governance systems to promote effective AWM practices on irrigation schemes was also supported by the study of two irrigation schemes, one in the Eastern Cape and the other in KwaZulu-Natal by Mnkeni *et al.* (2010), which revealed that most of the problems in small-scale schemes were institutional and related to governance of the schemes. The study revealed that both schemes had very weak organisational and institutional arrangements.

As for unconventional water use for irrigation, capacity building and skills development are crucial for supporting the growth of the wastewater irrigation sector. Training programs for water treatment plant operators, agricultural extension officers and farmers can help ensure that they have the knowledge and skills necessary to implement and manage wastewater irrigation systems effectively. Ultimately, a holistic and sustainable approach to water reuse in agriculture is essential for addressing water scarcity, promoting food security and protecting the environment in South Africa.

There is need for more investment in capacity building at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers' knowledge and skills. There is a need to strengthen research capacities through investing in human resources and reforming research institutions to make them more attractive places to work and more effective. At the knowledge utilisation level, there is need to build the capacity of small-scale farmers so that they are able to adopt the developed AWM technologies for effective and sustainable use and management of agricultural water resources. It is important to invest in extension services in order to improve the skills of extension workers in irrigation water management.

Financial resources and investment in AWM practices: Enhancing access to financial resources has consistently been identified as a major strategy to rapidly increase the use of AWM practices (DWFI, 2018). Small-scale farmers, whether operating under rainfed systems or farmer-led farming systems find it difficult to afford the money required to purchase essential AWM technologies such as pumps and small local agro-businesses also struggle to obtain operating capital to stock equipment and spare parts or to develop and implement new services to AWM operators such as irrigators hence what is needed are investments in local institutions, such as farmers' organisations and small-scale credit schemes, which are particularly important in this context, as the study shows that many farm households cannot afford the initial costs required for small-scale AWM technologies such as water harvesting.

Public investments in infrastructure such as roads are crucial so that farm produce can be transported easily to markets. Furthermore, private investors must be attracted to investments in rainfed agriculture. Investments are also needed in capacity building as the lack of knowledge on farms and among extension service personnel regarding AWM practices such as water harvesting and conservation agriculture can limit yields in rainfed areas (Rockström *et al*., 2009), engendering development initiatives are needed as women play a major role in agriculture, particularly in rainfed areas. Innovative public-private financial instruments aimed at supporting the entire AWM value chain should be scaled-up in collaboration with local banks, cooperatives and farmers' organisations.

Supportive infrastructure: The study has shown that one of the major constraints to AWM is the inadequacy of supportive infrastructure: transport (roads, railways), electricity, communications and storage and processing facilities for agricultural products. It is, therefore, recommended that in remote areas with land and water resources that can be exploited, there should be an increase in the pace of both public and private infrastructure investments in supportive infrastructure to make AWM investments attractive in the longer run. It is also recommended that, for achieving rapid impacts, target irrigation investments to areas that already have other basic infrastructure be speeded up.

Agricultural research and development: The level of investments in agricultural research and development needs to be boosted, particularly in agricultural water management, including irrigation. It is recommended that the government and the private sector raise the level of funding of applied agricultural and especially water management research and also implement reforms to create the institutional support system that will encourage innovation.

Policy reform: Finally, but perhaps most critical of all, is policy reform. The attractiveness of investing in AWM technologies and services is to a large extent a function of policies related to imports, currency exchange rates, competitiveness of input and output markets and trade policies. Numerous studies have identified these policy areas as major impediments to investments – and major opportunities to encourage investments (e.g., Jayne *et al.,* 2010; Giordano and de Fraiture, 2014; Fanzo, 2017). There is need for new water management policies and investments in human capacities, research, institutional development and specific technologies. There is a need to improve enforcement of regulations concerning wastewater, which can reduce or prevent unsafe practices that threaten public health and environmental sustainability.

REFERENCES

Abah, J., Mashebe, P., and Denuga, D. (2015). Prospect of integrating African indigenous knowledge systems into the teaching of sciences in Africa. *American Journal of Educational Research*, 3(6), 668-673.

Abdallah, C.K. and Mourad, K.A. (2021). Assessing the quality of water used for vegetable irrigation in Tamale Metropolis, Ghana. Scientific Reports, *Nature Portfolio*, https://doi.org/10.1038/s41598-021-84617-8

Abrams, L. (2018). Unlocking the potential of enhanced rainfed agriculture. Report no. 39. Stockholm International Water Institute (SIWI), Stockholm.

Absa (2023a). Absa Group Limited Integrated Report. Absa Group Limited, Johannesburg, South Africa.

Absa (2023b). Absa Group Limited broad-based black economic empowerment Report. Absa Group Limited, Johannesburg, South Africa.

Adem, A. A., Yibeltal, M., Mhiret, D. A., Tilahun, S. A., Zimale, F. A., Worqlul, A. W. and Teferi, E. T. (2023). Identification of suitable land for supplemental surface irrigation in semi-arid areas of North-western Ethiopia. *Remote Sensing Applications: Society and Environment*, 29(1):1-15.

Adom, R.K. and Simatele, M.D. (2021). Analysis of public policies and programmes towards water security in post-apartheid South Africa. *Water Policy,* 23: 503–520.

African Union (2015). Agenda 2063 - The Africa We Want. Framework Document, African Union Commission, Addis Ababa, Ethiopia

African Union (2020). Framework for Irrigation Development and Agricultural Water Management in Africa. African Union Commission, Addis Ababa, Ethiopia.

Aghaloo, K., and Chiu, Y. R. (2020). Identifying optimal sites for a rainwater-harvesting agricultural scheme in Iran using the best-worst method and fuzzy logic in a GIS-based decision support system. *Water*, 12(7):1-24.

AGRA (2018). What is farmer-led irrigation? Unlocking innovation for livelihood, food, and water security. Retrieved February 27, 2019, from www.agra.org/what-is-farmer-led-irrigation-unlocking-innovation-for-livelihood-food-and-watersecurity/.

Amoah, I. D., Reddy, P., Seidu, R., and Stenström, T. A. (2018). Removal of helminth eggs by centralized and decentralized wastewater treatment plants in South Africa and Lesotho: health implications for direct and indirect exposure to the effluents. *Environmental Science and Pollution Research*, 25, 12883-12895.

Anderson, J.J., Koatla, TAB., Meyer, E., Thubela, T., Gulwa, U. and Botha, J.J. (2021). Upscaling of rainwater harvesting and conservation to croplands and rangelands for food and renewable fuel (biogas) production. WRC Report No. TT 850/21.

Backeberg, G.R. (1997). Water institutions, markets and decentralised resource management: prospects for innovative policy reforms in irrigated agriculture. *Agrekon*, 36(4):350-384.

Badisa, K.T. (2011). Socio-economic factors determining in-field RWH technology adoption for cropland productivity in Lambani village: A case study of Thulamela Local Municipality of the Vhembe District in Limpopo Province. MSc dissertation, Mankweng, University of Limpopo.

Bahri, Akissa; Drechsel, Pay; Brissaud, F. (2008). Water reuse in Africa: challenges and opportunities. Paper presented at the First African Water Week, Accelerating Water Security for Socio-Economic Development of Africa, Tunis, Tunisia, 26-28 March 2008. 16p.

Baiyegunhi, L. J. S. (2015). Determinants of rainwater harvesting technology (RWHT) adoption for home gardening in Msinga, KwaZulu-Natal, South Africa. *Water SA*, 41(1):33-39.

Barron, J., Kemp-Benedict, E., Morris. J., de Bruin, A., Wang, G. and Fencl, A. (2015). Mapping the potential success of agricultural water management interventions for small-scales: where are the best opportunities? Water Resources and Rural Development, 32p. (Online first). doi: http://dx.doi.org/10.1016/j.wrr.2015.06.001

Barron, J., Noel, S. and Mikhail, M. (2009). Review of Agricultural Water Management Intervention Impacts at the Watershed Scale: A Synthesis Using the Sustainable Livelihoods Framework. Project Report, Stockholm Environment Institute, Kräftriket, Stockholm, Sweden.

Beyer, M., Wallner, M., Bahlmann, L., Thiemig, V., Dietrich, J. and Billib, M. (2016). Rainfall characteristics and their implications for rain-fed agriculture: a case study in the Upper Zambezi River Basin. *Hydrological Sciences Journal*, 61(2): 321-343.

BFAP (2024). BFAP Baseline: Agricultural Outlook 2024-2033. Bureau for Food and Agricultural Policy (BFAP). https://baseline.bfap.co.za. Accessed on 13 November 2024.

Binswanger-Mkhize, H.P., Byerlee, D., McCalla, A., Morris, M. and Staatz, J. (2011). The growing opportunities for African agricultural development. ASTI-FARA Conference Working Paper 16. https://www.asti.cgiar.org/pdf/conference/Theme1/Binswanger.pdf

Bjornlund, V., Bjornlund, H. and van Rooyen, A.F. (2020a). Exploring the factors causing the poor performance of most irrigation schemes in post-independence sub-Saharan Africa. *International Journal of Water Resources Development*, 36:sup1, S54-S101, DOI: 10.1080/07900627.2020.1808448.

Bjornlund, V., Bjornlund, H. and van Rooyen, A.F. (2020b). Why agricultural production in Sub-Saharan Africa remains low compared to the rest of the world: A historical perspective. *International Journal of Water Resources Development*, 1–34. https://doi.org/10.1080/07900627.2020. 1739512.

Blackstock, K.L., Waylen, K.A., Dunglinson, J., and Marshall, K.M. (2012). Linking process to outcomes — internal and external criteria for a stakeholder involvement in river basin management planning. *Ecological Economics*, 77: 113-122.

Blackstock, K.L., Waylen, K.A., Marshall, K.M., and Dunglinson, J. (2014). Hybridity of representation: insights from river basin management planning in Scotland. *Environment and Planning C: Government and Policy*, 32(3): 549-566.

Bonetti, S., Sutanudjaja, E.H., Mabhaudhi, T., Slotow, R. and Dalin, C. (2022). Climate change impacts on water sustainability of South African crop production. *Environmental Research Letters*. 17 (2022) 084017.

Bonthuys, J. (2021). South Africa's agricultural water scenarios: The future we choose? In: Agriculture and Water, *The Water Wheel,* May/June 2021, pp 12-16.

Boran, M. (2018). Water Governance and Its Effectiveness. *Transactions on Engineering and Management*, Vol 4(1): 28-35.

Boshoff, B.C. (2010). Conceptualizing Sustainability: The Case of Johannesburg and Water. Environmental Design and Planning, Virginia Polytechnique Institute, Virginia.

Bosma, L. (2015). 'You've got to pump it up': Analysis of the appropriation and utilization of petrol pumps for small scale horticulture in West-Uyoma, Kenya. MSc thesis, Wageningen University, The Netherlands.

Botlhoko, G.J. (2012). Factors associated with the revitalisation of small-scale irrigation schemes among farmers in the North West Province, South Africa. MSc dissertation, Mafikeng, North-West University.

Brack, W., Altenburger, R., Schüürmann, G., Krauss, M., Herráez, D. L., van Gils, J., and Schriks, M. (2015). The SOLUTIONS project: challenges and responses for present and future emerging pollutants in land and water resources management. *Science of the Total Environment*, 503, 22-31.

Busari, I. T., Senzanje, A., Odindo, A. O., and Buckley, C. A. (2019). The impact of irrigation water management techniques on the performance of rice using treated wastewater reuse in Durban, South Africa. *Water Supply*, 19(6), 1604-1611.

Cai, X., Magidi, J., Nhamo, L. and van Koppen, B. (2017). Mapping irrigated areas in the Limpopo Province, South Africa. Colombo, Sri Lanka. *International Water Management Institute (IWMI*). 37p. (IWMI Working Paper 172). [doi: 10.5337/2017.205].

Chikozho, C., Managa, R. and Dabata, T. (2020). Ensuring access to water for food production by emerging farmers in South Africa: What are the missing ingredients? *Water SA*, 46(2): 225-233.

Chipfupa, U. and Wale, E. (2019). Smallholder willingness to pay and preferences in the way irrigation water should be managed: A choice experiment application in KwaZulu-Natal, South Africa. *Water SA*, 45(3): 383-392.

Chipfupa, U. and Wale, E. (2020). Linking earned income, psychological capital and social grant dependency: empirical evidence from rural KwaZulu-Natal (South Africa) and implications for policy. *Journal of Economic Structures*, 9(1): 22.

Chitakira, M. and Ngcobo, N. Z. (2021). Uptake of Climate Smart Agriculture in Peri-Urban Areas of South Africa's Economic Hub Requires Up-Scaling. *Frontiers in Sustainable Food Systems*, 5(1):1-13.

Chitima, M. and Rutten, G. (2015). Scaling up results in agricultural water management: Scaling up note. International Fund for Agricultural Development, Rome, Italy.

Cousins, B. (2013). Smallholder irrigation schemes, agrarian reform and 'accumulation from above and from below' in *South Africa. Journal of Agrarian Change,* 13 (1): pp 116-139.

DAFF. (2011). Strategic Plan for Smallholder Support 2011-2014/15. Department of Agriculture, Forestry and Fisheries, Pretoria.

DAFF. (2012). Integrated Growth and Development Plan 2012. Department of Agriculture, Forestry and Fisheries, Pretoria.

DAFF. (2013). National Policy on Food and Nutrition Security (2014). Department of Agriculture, Forestry and Fisheries, Pretoria.

DAFF. (2014). Agricultural Policy Action Plan (APAP) 2015–2019. Department of Agriculture, Forestry and Fisheries, Pretoria.

DAFF. (2015). National irrigation strategy for South Africa. Pretoria: Department of Agriculture, Forestry and Fisheries (DAFF). Pretoria.

DAFF. (2017). Draft Conservation Agriculture Policy 2017. Department of Agriculture, Forestry and Fisheries, Pretoria.

DALRRD. (2024). *Agriculture and Agro-Processing Master Plan*. Department of Agriculture, Land Reform and Rural Development, Pretoria.

de Bont, C. and Veldwisch, G.J. (2020). State Engagement with Farmer-led Irrigation Development: Symbolic Irrigation Modernisation and Disturbed Development Trajectories in Tanzania, *The Journal of Development Studies*, 56:12, 2154-2168, DOI: 10.1080/00220388.2020.1746278

de Bont, C., Liebrand, J., Veldwisch, G.J. and Woodhouse, P. (2019). Modernisation and African farmer-led irrigation development: Ideology, policies and practices. *Water Alternatives,* 12(1): 107-128.

de Fraiture, C., Kouali, G.N., Sally, H. and Kabre, P. (2014). Pirates or pioneers? Unplanned irrigation around small reservoirs in Burkina Faso. *Agricultural Water Management,* 131: 212–20.

de Lange, M. (1999). Promotion of low-cost and water saving technologies for small-scale irrigation. *ICID Journal*, Vol 48 No. 1: 61-70.

DEA (Department of Environmental Affairs). (2013). Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Agriculture and Forestry Sectors in South Africa. Pretoria, South Africa.

Denison, J.A.N. (2018). An investigation into the performance of smallholder irrigation schemes in Limpopo Province, South Africa: Success factors, typologies and implications for development. PhD thesis, Grahamstown, Rhodes University, South Africa.

Department of Agriculture, Land Reform and Rural Development. (2022). Agriculture and Agro-Processing Master Plan. Department of Agriculture, Land Reform and Rural Development, Republic of South Africa, Pretoria.

Department of Agriculture, Land Reform and Rural Development. (2020). Strategic Plan 2020 – 2025 Agriculture, Land Reform and Rural Development. Department of Agriculture, Land Reform and Rural Development, Republic of South Africa, Pretoria.

Department of Agriculture. (1995). White paper on agriculture. Printed and published by Department of Agriculture, Pretoria: RSA. ISBN 0-621-16111.

Department of Agriculture. (2005). National Education and Training Strategy for Agriculture and Rural Development in South Africa (AET Strategy). Directorate Education and Training, Department of Agriculture, Pretoria.

Department of Agriculture. (2008). National Agricultural Research and Development Strategy 2008. Department of Agriculture, Pretoria

Department of Forestry, Fisheries and the Environment. (2018). The second National Action Programme for South Africa to combat desertification, land degradation and the effects of drought (2018-2030). Pretoria, South Africa. pp 1-35.

Department of Health. (2013). National Environmental Health Policy. Government Gazette No. 37112, Office of the President, Cape Town.

Department of Rural Development and Land Reform. (2011). Policy Framework for the Recapitalization and Development Programme of the Department of Rural Development and Land Reform: Final Version. Department of Rural Development and Land Reform, Pretoria.

Department of Water Affairs and Forestry. (1996). South African Water Quality Guidelines (second edition). Volume 4: Agricultural Use: Irrigation. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. (1997). White paper on a National Water Policy for South Africa. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. (1999). Water Conservation and Demand Management National Strategy Framework – Draft. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. (2004). National Water Conservation and Water Demand Management Strategy. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. (2009). Water for Growth and Development Framework. Version 7. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry. (Undated). Water Management Institutions: Overview. Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs. (2013) National Water Resource Strategy. 2nd Edition, Department of Water Affairs, Republic of South Africa, Pretoria.

Department of Water and Sanitation (DWS). (2013). National Water Policy Review (NWPR) 2013. Water Policy Positions. Department of Water and Sanitation, Pretoria, South Africa.

Department of Water and Sanitation (DWS). (2014). The National State of Water Resources; Quarterly report for July to September 2014.

Department of Water and Sanitation (DWS). (2018). National Water and Sanitation Master Plan: Volume 2: Plan to Action, Version 4.2.

Department of Water and Sanitation (DWS). (2021). Strategic Water Partners Network. Celebrating a decade of success in conserving water – Towards South Africa’s water security. Department of Water and Sanitation, Republic of South Africa, Pretoria.

Department of Water and Sanitation (DWS). (2023) National Water Resource Strategy Third Edition (NWRS-3). Department of Water and Sanitation, Republic of South Africa, Pretoria.

Department of Water and Sanitation (DWS). (2024). National State of Water Report 2023. Integrated Water Resource Studies Report Number WII/IWRS/NSoW 2023 Pretoria, South Africa.

Devendra, C. (2016). Rainfed agriculture: its importance and potential in global food security. *Agriculture Science Journal*, 2(2):4-17.

Dirwai, T.L., Senzanje, A. and Mudhara, M. (2019). Water governance impacts on water adequacy in smallholder irrigation schemes in KwaZulu-Natal province, South Africa. *Water Policy*, 21(1), pp.127-146.

Drechsel, P., Graefe, S., and Fink, M. (2007). Rural-urban food, nutrient and virtual water flows in selected West African cities. Colombo, Sri Lanka: International Water Management Institute. IWMI Research Report 115, 35 pp. www.iwmi.org.

Drechsel, P., Graefe, S., Sonou, M. and Cofie, O. (2006). Informal irrigation in urban West Africa: An Overview. IWMI, Colombo. Research Report 102. www.iwmi.org.

Dube, S.V. (2023). Institutional arrangements and support systems for independent small-scale irrigators in the Msinga Local Municipality, South Africa. *South African Journal of Agricultural Extension*, 51(1), pp.66-81.

Dumani, A., Mbangcolo, M.M., Mpambani, B., Mpengesi, X. and Titimani, M. (2023). Impact of a Multi-Stakeholder Approach on Rural Livelihood and Socioeconomic Status of the Farming Community at Zanyokwe Irrigation Scheme, Amahlathi Local Municipality, Eastern Cape. *South African Journal of Agricultural Extension*, 51(1): 1-12.

DWA. (2013) National Water Resource Strategy. 2nd Edition, Department of Water Affairs, Republic of South Africa, Pretoria.

DWAF. (2021). Water for Growth and Development in South Africa: Version 6. The Department of Water Affairs and Forestry (DWAF), Pretoria.

DWFI. (Daugherty Water for Food Global Institute). (2018). Pathways to Increasing Farmer-led Investments in Sustainable Agricultural Water Management in sub-Saharan Africa. Working paper. Robert B. Daugherty Water for Food Global Institute at the University of Nebraska (DWFI). Available online at http://waterforfood.nebraska.edu/resources-3/.

Ennis, A. (2010) Indicators of Content: the role of word clouds in the creation of summaries. A masters Dissertation, Department of information Science, Loughborough University, UK. 72 pp.

Fanadzo, M. (2012). Revitalisation of small-scale irrigation schemes for poverty alleviation and household food security in South Africa: A review. *African Journal of Agricultural Research,* Vol. 7(13): 1956-1969.

Fanadzo, M. and Ncube, B. (2018). Challenges and opportunities for revitalising smallholder irrigation schemes in South Africa. *Water SA*, 44(3): 436-447.

Fanadzo, M., Chiduza, C. and Mnkeni, P.N.S. (2010). Overview of smallholder irrigation schemes in South Africa: Relationship between farmer crop management practices and performance. *African Journal of Agricultural Research*, 5(25), pp.3514-3523.

Fanadzo, M., Ncube, B. (2018). Challenges and opportunities for revitalising smallholder irrigation schemes in South Africa. *Water SA*, 44(3): 436-447.

Fanzo, J. (2017). From big to small: The significance of small-scale farms in the global food system. Lancet Planet Health 1: e15-e16. http://www.thelancet.com/journals/lanplh/issue/vol1no1/PIIS2542-5196(17)X0002-8.

FAO. (2001). Small-scale Irrigation Technology: Prospects for Sub-Saharan Africa. IPTRID Secretariat Food and Agriculture Organization of the United Nations Paper Number 3 – March2001. Rome, Italy.

FAO. (2006). Policy Highlights: Irrigation and Water Management. Agricultural Policy Support Service, Policy Assistance Division, Rome, Italy.

FAO. (2018). What is conservation agriculture? https://www.fao.org/conservation-agriculture/overview/what-is-conservation-agriculture/en [accessed 23 September 2023.

FAO. (2022). The future of food and agriculture – Drivers and triggers for transformation. The Future of Food and Agriculture 3. Rome, FAO. https://doi.org/10.4060/cc0959en.

Faurès, J.M. and Santini, G. (eds). (2008). Water and the Rural Poor Interventions for improving livelihoods in sub-Saharan Africa. FAO.

Feike, T. and Hanseler, M. (2017). Multiple Policy Instruments for Sustainable Water Management in Crop Production - A Modeling Study for the Chinese Aksu-Tarim Region. *Ecological Economics*, 35: 42-54. https://doi.org/10.1016/j.ecolecon.2016.12.012.

Firoozzare, A., Saghaian, S., Bahraseman, S. E. and Dehghani Dashtabi, M. (2023). Identifying the Best Strategies for Improving and Developing Sustainable Rain-Fed Agriculture: An Integrated SWOT-BWM-WASPAS Approach. *Agriculture*, 13(6):1-16.

Fox, P., Rockström, J, and Barron, J. (2005). Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. *Agricultural Systems*, 83:231–250.

Fuo, O. N. (2013). A critical investigation of the relevance and potential of IDPs as a local governance instrument for pursuing social justice in South Africa. *Potchefstroom Electronic Law Journal/Potchefstroomse Elektroniese Regsblad,* 2013(16): 225–230.

Giordano, M. and de Fraiture, C. (2014). Small private irrigation: Enhancing benefits and managing trade-offs. *Agricultural Water Management,* 131: 175-182. https://doi.org/10.1016/j.agwat.2013.07.003.

Gordon, L. J., Finlayson, C. M., and Falkenmark, M. (2010). Managing water in agriculture for food production and other ecosystem services. *Agricultural Water Management*, 97(4): 512–519. https://doi.org/10.1016/j.agwat.2009.03.017.

Gottron, T. (2009,) Document word clouds: visualising web documents as tag clouds to aid users in relevance decisions. ECDL'09: Proceedings of the 13th European Conference on Research and advanced Technology for Digital Libraries, September 2009 Pages 94-105, http://portal.acm.org/citation.cfm?id=1812814.

Green Drop. (2023). Green Drop 2023 report - Water Services. from https://ws.dws.gov.za/iris/releases/Report_DPW_Rev02_29Mar22_MN%20web.pdf

Haarhoff, S.J., Kotzé, T.N. and Swanepoel, P.A. (2020). A prospectus for sustainability of rainfed maize production systems in South Africa. *Crop Science*, 60(1): 14-28. https://doi.org/10.1002/csc2.20103

Haigh, E.H., Fox, H.E. and Davies-Coleman, H.D. (2010). Framework for local government to implement integrated water resource management linked to water service delivery. *Water SA,* 36(4): 477-478.

Haileslassie, A., Mekuria, W., Uhlenbrook, S., Ludi, E. and Schmitter, P. (2022). Gap analysis and methodological framework to assess and develop water centric sustainable agricultural intensification pathways in Sub-Saharan Africa. *Frontiers in Water*, 4: 747610, d10.3389/frw.2022.747610oi

Hardy, M., Dziba, L., Kilian, W., Tolmay, J. (2011). Rainfed Farming Systems in South Africa. *In:* Tow, P., Cooper, I., Partridge, I., Birch, C. (eds) Rainfed Farming Systems. Chapter 16, pp 395-449, Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9132-2_16

Harmon, G. (2023). Farmer-led irrigation development in sub-Saharan Africa: A policy paradox? The Water Dissensus, Water Alternatives Forum. On-line Discussions and Debates around Water. https://www.water-alternatives.org/index.php/blog/flid.

Harmon, G.; Jepson, W.; Lefore, N. (2023). Farmer-Led Irrigation Development in Sub-Saharan Africa. Wiley Interdisciplinary *Reviews Water* 2023,10, e1631.

Hartley, F., Gabriel, S., Cullis, J. and Arndt, C. (2021). Climate uncertainty and agricultural vulnerability in South Africa. Southern Africa – Towards Inclusive Economic Development (SA-TIED) Working Paper 162# February 2021.

Hessari, B. and Oweis, T. (2021). Conjunctive use of green and blue water resources in agriculture: Methodology and application for supplemental irrigation. *Irrigation and Drainage*, 70(5):1193-1208.

Hoogendijk, K., Myburgh, P. A., Howell, C. L., & Hoffman, J. E. (2023). Irrigation of Agricultural Crops with Municipal Wastewater-A Review. *South African Journal of Enology and Viticulture*, *44*(1), 31-54.

Hoogendijk, K., Myburgh, P.A., Howell, C.L. and Hoffman, J.E. (2023). Irrigation of Agricultural Crops with Municipal Wastewater - A Review. *South African Journal of Enology and Viticulture*, 44 (1).

Howell, C., and Myburgh, P. (2018). Management of winery wastewater by re-using it for crop irrigation-A review. *South African Journal of Enology and Viticulture*, 39(1), 116-131.

IISD. (2015). Financing for Agriculture: How to boost opportunities in developing countries. Investment in Agriculture: Policy Brief No. 3. International Institute for Sustainable Development. Winnipeg, Manitoba, Canada.

IWMI (International Water Management Institute). (2006). Recycling Realities: Managing health risks to make wastewater an asset. Water Policy Briefing 17; IWMI and GWP, Colombo, Sri Lanka, www.iwmi.org.

IWMI (International Water Management Institute). (2007). Water for Food, Water for Life: A comprehensive Assessment of Water Management in Agriculture. London: Earthscan; and Colombo, Sri Lanka: IWMI. Available at: http://www.iwmi.cgiar.org/assessment/Publications/books.htm.

Jagals, P. and Steyn, M. (2002). A Review of the Applicability of the South African Guide for the Permissible Utilisation and Disposal of Treated Sewage Effluent in

Agriculture and Aquaculture. Report to the Water Research Commission, WRC Report No 1039/1/02, ISBN No: 1-86845-945-4.

Jayne, T.S., Mather, D. and Mghenyi, E. (2010). Principal challenges confronting small-scale agriculture in Sub-Saharan Africa. *World Development,* 38 (10): 1384–1398. DOI: 10.1016/j.worlddev.2010.06.002.

Jones, P.G., Thornton, P.K. (2009). Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. *Environmental Science & Policy,* 12: 427–437. doi: 10.1016/j.envsci.2008.08.006.

Kader, M. A., Singha, A., Begum, M. A., Jewel, A., Khan, F. H. and Khan, N. I. (2019). Mulching as water-saving technique in dryland agriculture. *Bulletin of the National Research Centre*, 43(1):1-6.

Kahinda, J. M. M., Rockström, J., Taigbenu, A. E. and Dimes, J. (2007). Rainwater harvesting to enhance water productivity of rainfed agriculture in the semi-arid Zimbabwe. *Physics and Chemistry of the Earth*, Parts A/B/C, 32(15-18):1068-1073.

Kalebaila, N., Ncube, E. J., Swartz, C. D., Marais, S., and Lubbe, J. (Undated). Strengthening the implementation of water reuse in South Africa. Working paper, Water Research Commission, South Africa.

Karodia, A.M. and Khan, S. (2015). South Africa enters a water crisis: Management, agriculture, public health considerations and government ineptitude are some of the causes for this grave dilemma. *Asian Journal of Agricultural Extension, Economics and Sociology*, 7(4):1-18.

Karodia, H. and Weston, D.R. (2002). South Africa's new Water Policy and Law. Department of Water Affairs and Forestry, Pretoria.

Kativhu, S., Mwale, M.M. and Zuwarimwe, J. (2020). Agricultural resilience under increasing water security threats: Insights for smallholder farming in Limpopo Province, South Africa. *Water Practice and Technology*, 15(4): 849-862.

Kgopa, P.M., Mashela, P.W. and Manyevere, A. (2021). Microbial Quality of Treated Wastewater and Borehole Water Used for Irrigation in a Semi-Arid Area. *International Journal of Environmental Research and Public Health* 2021, 18, 8861. https://doi.org/10.3390/ijerph18168861

Khalid, S., Shahid, M., Natasha, Bibi, I., Sarwar, T., Shah, A. H. and Niazi, N. K. (2018). A review of environmental contamination and health risk assessment of wastewater use for crop irrigation with a focus on low and high-income countries. *International Journal of Environmental Research and Public Health*, 15(5), 895.

Khwidzhili, R.H. and Worth, S.H. (2017). Evaluation of policies promoting sustainable agriculture in South Africa. *South African Journal of Agriculctural Extension*, Vol. 45, No. 2: 73 – 85.

Kim, H., Yoon, S. Cho, E., and Kim, J. (2015*). A Study on Policy Directions for the Water-Food-Energy Nexus (I). Project Report 2015-13-02.* Network of Institutions for Sustainable Development, Korea Environment Institute, Sejong, Republic of Korea.

Kimani, M. W., Gitau, A. N. and Ndunge, D. (2015). Rainwater harvesting technologies in Makueni county, Kenya. *International Journal of Engineering and Science*, 5(2): 39-49.

Lamptey, S. (2022). Agronomic practices in soil water management for sustainable crop production under rain fed agriculture of Drylands in Sub-Sahara Africa. *African Journal of Agricultural Research*, 18(1): 18-26.

Land Bank. (undated). Environmental and Social Sustainability (ESS) Policy. Land and Agricultural Development Bank of South Africa, Centurion.

Lankford, B. (2009). Viewpoint – The right irrigation? Policy directions for agricultural water management in Sub‐Saharan Africa. *Water Alternatives, 2(3): 476‐480.*

Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H., Salgot, M. and Brissaud, F. (2001). Role of water reuse for enhancing integrated water management in Europe and Mediterranean countries*. Water Science and Technology,* 43(10): 25-33.

Lefore, N., Giordano, M., Ringler, C., & Barron, J. (2019). Viewpoint – Sustainable and equitable growth in farmer-led irrigation in Sub-Saharan Africa: What will it take? *Water Alternatives*, 12, 156–168.

Letsoalo, S.S. and van Averbeke, W. (2006). Infrastructural maintenance on small-scale canal irrigation schemes in the north of South Africa. Proceedings. International Symposium on Water and Land Management for Sustainable Irrigated Agriculture. 4-8 April 2006, Cukurova University, Adana, Turkey.

Liebenberg, T. (2024). Taking stock of water governance in South Africa during the sixth administration. AgriSA, 31 May 2024.

Lund, J. R. (2015). Integrating social and physical sciences in water management. *Water Resources Research*, 51: 5905–5918. https://doi.org/10.1002/2015WR017125

Mabuza, M. and Ndoro, J.T. (2023). Borich's Needs Model Analysis of Smallholder Farmers' Competence in Irrigation Water Management: Case Study of Nkomazi Local Municipality, Mpumalanga Province in South Africa. *Sustainability*, 15, 4935. https://doi.org/10.3390/su15064935

Madigele, P.K. (2018). South Africa's water regulatory and policy framework: new institutional economic review. Sustain. *Water Resource Management*, (2018) 4:129–141. https://doi.org/10.1007/s40899-017-0167-7.

Magesa, B. A., Mohan, G., Matsuda, H., Melts, I., Kefi, M., and Fukushi, K. (2023). Understanding the farmers' choices and adoption of adaptation strategies, and plans to climate change impact in Africa: A systematic review. *Climate Services*, 30(1):1-16.

Makaya, E., Rohse, M., Day, R. and Vogeld, C. (2020). Water governance challenges in rural South Africa: Exploring institutional coordination in drought management. *Water Policy*, 22(4):519-540.

Mandal, S., Vema, V. K., Kurian, C. and Sudheer, K. P. (2020). Improving the crop productivity in rainfed areas with water harvesting structures and deficit irrigation strategies. *Journal of Hydrology*, 586(1):1-14.

Mangisoni, J.H., Chigowo, M. and Samson Katengeza, S. (2019). Determinants of adoption of rainwater-harvesting technologies in a rain shadow area of southern Malawi. *African Journal of Agricultural and Resource Economics*, 14(2):106-119.

Materechera, F. and Scholes, M.C. (2022). Understanding the Drivers of Production in South African Farming Systems: A Case Study of the Vhembe District, Limpopo South Africa. *Frontiers in Sustainable Food Systems,* 6:722344. doi: 10.3389/fsufs.2022.722344

McCarthy, N. (2022). Designed to fail: Many irrigation schemes in sub-Saharan Africa are neither fit nor fit for purpose. Water Alternative Forum, Water policies Water and agriculture Water Economics, Tuesday, 15 November 2022.

McCosh, J., Dedekind, L., Ntombela, Z., Khuzwayo, M., Letty, B., Shezi, Z., Bambalele, N., Gasa, N., Everson, T., Everson, C., Dlamini, N., Sosibo, N. and Maling A, M. (2017). Upscaling of rainwater harvesting and conservation on communal crop and rangeland through integrated crop and livestock production for increased water use productivity. Water Research Commission, Pretoria, South Africa Report No.712/16.

Mdoda, L. and Gidi, L.S. (2023). Impact of land ownership in enhancing agricultural productivity in rural areas of Eastern Cape Province. *South African Journal of Agricultural Extension*. Vol. 51 No. 2, 2023: 1-23.

Meinzen-Dick, R. (2014). Property rights and sustainable irrigation: A developing country perspective. *Agricultural Water Management*, 145: 23–31. https://doi.org/10.1016/j.agwat.2014.03.017.

Meissner, R., Funke, N., Nienaber, N. and Ntombela, C. (2013). The status quo of research on South Africa’s water resource management institutions. *Water SA,* 39(5):721–732.

Mendoza-Espinosa, L., Burgess, J., Daesslé, L., and Villada-Canela, M. (2019). Reclaimed water for the irrigation of vineyards: Mexico and South Africa as case studies. *Sustainable Cities and Society*, 51, 101769.

Merrey, D., Regassa Namara, and De Lange Marna. (2006). Agricultural Water Management Technologies for Small Scale Farmers in Southern Africa: An Inventory and Assessment of Experiences, Good Practices and Costs. Final Report Produced by the International Water Management Institute (IWMI) Southern Africa Regional Office Pretoria, South Africa For Office of Foreign Disaster Assistance, Southern Africa Regional Office, United States Agency for International Development Order No. 674-O-05-05227-00 (USAID/OFDA/SARO) and Investment Centre of the Food and Agriculture Organization of the United Nations Letter of Agreement No. PR 32953.

Mkuhlani, S., Crespo, O., Rusere, F., Zhou, L. and Francis, J. (2020). Classification of small-scale farmers for improved rainfall variability management in South Africa. *Agroecology and Sustainable Food Systems*, 44(1): 7-29.

Mkuna, E., and Wale, E. (2023). Smallholder farmers' choice of irrigation systems: Empirical evidence from Kwazulu-Natal, South Africa and its implications. *Scientific African*, 20, e01688.

Mogogana, B.P., Olorunfemi, O.D., Oladele, O.I. (2018). Knowledge and adoption of water use efficiency techniques among women irrigators: Evidence from South Africa. *Journal of Agriculture and Environment for International Development*, 112(2) :271-295.

Mogomotsi, P. K. (2017). South Africa's regulatory and policy framework: A new institutional economic review. Okavango Research Institute, University of Botswana, Maun.

Mokgomo, M.N., Chagwiza, C. and Tshilowa, P.F. (2022). The impact of government agricultural development support on agricultural income, production and food security of beneficiary small-scale farmers in South Africa. *Agriculture* 2022, 12, 1760.

Mokgope, K., Pollard, S. and Butterworth, J. (2001) Water resources and water supply for rural communities in the Sand River Catchment, South Africa. In: 27th WEDC Conference: People and systems for water, sanitation and health. Lusaka.

Mokonyama, S. Schalkwyk, M. and Rajagopaul, R. (2017). Guidelines and good practices for water treatment residues handling, disposal and reuse in South Africa. WRC Report No. TT 738/17.

Mortimore, M.J. (2010). Adapting to drought in the Sahel: lessons for climate change. *WIREs Climate Change,* 1: 134–143.

Mothetha, M.L. (2016). Evaluation of the impacts of municipal wastewater treatment on the receiving environment: a case study of the Olifantsvlei wastewater treatment plant in the Gauteng Province, South Africa. MSc dissertation, Pretoria, University of South Africa.

Moyo, N.A.G., Rapatsa M.M., & Mbokane E.M., (2020). Evaluation of Heavy Metal and Microbiological Contamination and Assessment of the suitability of the sand river water for irrigation in Limpopo Province. WRC Report No.TT 835/20. ISBN: 978-0-6392-0211-2

Mpandeli, S. (2014). Managing climate risks using seasonal climate forecast information in Vhembe District in Limpopo Province, South Africa. *Journal of Sustainable Development,* 7, 68. doi: 10.5539/jsd.v7n5p68

Mtombeni, S., Bove, D., and Thibane, T. (2019). An analysis of finance as a barrier to entry and expansion for emerging farmers. Paper presentation at Biennial Conference of the Economic Society of South Africa, Johannesburg, South Africa.

Mtyelwa, C., Yusuf, S. F. G. and Popoola, O. O. (2022). Adoption of in-field rainwater harvesting: Insights from smallholder farmers in Raymond Mhlaba Local Municipality, Eastern Cape Province, South Africa. *South African Journal of Agricultural Extension*, 50(2):81-100.

Mudhara, M and Senzanje, A, (2020). assessment of policies and strategies for the governance of smallholder irrigation farming in Kwazulu-Natal Province, South Africa. WRC Report No. 2556/1/20 ISBN 978-0-6392-0161-0. Available from: https://www.wrc.org.za/wp-content/uploads/mdocs/2556 final.pdf

Mudzielwana, R.V.A., Mafongoya, P. and Mudhara, M. (2022). An Analysis of Livelihood-Diversification Strategies among Farmworker Households: A Case Study of the Tshiombo Irrigation Scheme, Vhembe District, South Africa. *Agriculture (Switzerland)*, 12(11), art. no. 1866.

Murphy, K.O. (2000). Guidelines for sustainable reuse of effluent on land – a suggested approach. Presented at WISA 2000 Biennial Conference Sun City, South Africa, 28 May – 1 June 2000, CSIR, Stellenbosch, South Africa.

Murugani, V.G. and Thamaga-Chitja, J.M. (2018). Livelihood assets and institutions for smallholder irrigation farmer market access in Limpopo, South Africa. *International Journal of Water Resources Development*, 34(2): 259-277.

Muturi, J., Oggema, S., van Veldhuizen, L., Mehari, A. and Veldwisch, G.J. (2019). Accelerating Farmer-led Irrigation Development: Theory and practice of the Smart Water for Agriculture in Kenya project. SWA Kenya, SNV Netherlands Development Organisation, Nairobi.

Mwadzingeni, L., Mugandani, R. and Mafongoya, P. (2020). Localized institutional actors and smallholder irrigation scheme performance in Limpopo province of South Africa. *Agriculture*, 10, 418.

Mwendera, E. J. (2003). Overcoming constraints to the implementation of water demand management in Southern Africa. Faculty of Agriculture, University of Swaziland, Luyengo.

Myeni, L., Moeletsi, M., Thavhana, M., Randela, M., and Mokoena, L. (2019). Barriers affecting sustainable agricultural productivity of smallholder farmers in the eastern Free State of South Africa. *Sustainability*, 11(11), 3003.

Namara, R. E., Hanjra, M. A., Castillo, G. E., Ravnborg, H. M., Smith, L. and van Koppen, B. (2010). Agricultural water management and poverty linkages. *Agricultural Water Management,* 97(4):520-527.

Namara, R., Awulachew, S. B. and Douglas, M. (2006). Review of agricultural water management technologies and practices. Conference Papers h039623, International Water Management Institute.

Natasha, Shahid, M., Khalid, S., Murtaza, B., Anwar, H., Shah, A. H., ... and Niazi, N. K. (2020). A critical analysis of wastewater use in agriculture and associated health risks in Pakistan. *Environmental Geochemistry and Health*, 1-20.

National Department of Agriculture. (Undated). Policy on agriculture in sustainable development. A discussion document. 8th draft. Pretoria, South Africa.

Ndhleve, S., Nakin, M. D. V. and Longo-Mbenza, B. (2017). Impacts of supplemental irrigation as a climate change adaptation strategy for maize production: a case of the Eastern Cape Province of South Africa. *Water SA*, 43(2), 222-228.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O. (2021). Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane KwaZulu-Natal. *Land Use Policy*, 109, art. no. 105611.

Nedbank Group. (2023). Annual Integrated Report. Report for the year ended 31 December 2023. Johannesburg, South Africa

NEPAD. (2013). Agriculture Food Security and Nutrition. 2013 New Partnership for Africa's Development (NEPAD Agency) Report. Midrand, South Africa.

Nepfumbada M.P. (2020). National Water Security Framework for South Africa. 1st Edition. Led by Commissioners P.E. Molokwane and T.T.C. Dlamini, of the Water Task Team, National Planning Commission. Pretoria, South Africa.

Nesamvuni, E., Mpandeli, S., Tshikolomo, K. and Kgowedi, C. (2016). The enabling geophysical agricultural environment for agriculture in Gauteng Province, South Africa. *Journal of Human Ecology*, 54(1):59-69.

Nhamo, L., Mpandeli, S. Liphadzi, S.; Dirwai, T.L., Mugiyo, H., Senzanje, A., Lankford, B.A. and Mabhaudhi, T. (2024). Why Do Farmers Not Irrigate All the Areas Equipped for Irrigation? Lessons from Southern Africa. *Agriculture*, 14, 1218. https://doi.org/10.3390/agriculture14081218.

Nhamo, L., Rwizi, L., Mpandeli, S., Botai, J., Magidi, J., Tazvinga, H., Sobratee, N., Liphadzi, S., Naidoo, D., Modi, A.T., Slotow, R. & Mabhaudhi, T. (2021). Urban nexus and transformative pathways towards a resilient Gauteng City-Region, South Africa. *Cities,* 116(1): 1-11.

Niekerk, A., Jarmain, C., Goudriaan, R., Muller, S., Ferreira, F., Münch, Z., and Gibson, L. (2018). An earth observation approach towards mapping irrigated areas and quantifying water use by irrigated crops in South Africa. Report No. TT 745/17. *Water Research Commission, Gezina, South Africa*.

Norström, A. (2007). Planning for drinking water and sanitation in peri-urban areas. Swedish Water House Report 21. SIWI, 2007. 15 p.

Nzima, B., Adegoke, A., Ofon, U., Al-Dahmoshi, H., Saki, M., Ndubuisi-Nnaji, U., and Ogundeji, A.A. (2022). Adaptation to climate change and impact on smallholder farmers' food security in South Africa. *Agriculture*, 12(5):1-16.

Odiyo, J.O. and Makungo, R. (2012). Water quality problems and management in rural areas of Limpopo Province, South Africa. In: Brebbia, C.A. (ed.). Water Pollution XI. Southampton: WIT Press: 135-146.

OECD. (2011). Water Governance in OECD Countries: A Multi-level Approach. OECD Studies on Water. https://doi.org/10.1787/9789264119284-en

Olabanji, M. F., Ndarana, T., Davis, N., and Archer, E. (2020). Climate change impact on water availability in the olifants catchment (South Africa) with potential adaptation strategies. Physics and Chemistry of the Earth, Parts A/B/C, 120, 102939.

Orne-Gliemann, M. (2008). Water users' associations from the users' perspective: Local water management at Thabina Irrigation Scheme, Limpopo, South Africa. *Journal for Transdisciplinary Research in South Africa*, 4(1): 1-29.

Pallaske, G., Bassi, A., Bechauf, R., Casier, L., Gouett, M. and Uzsoki, D. (2022). Sustainable Asset Valuation of Wastewater Treatment Infrastructure in South Africa. NBI Report, Nature-Based Infrastructure, Global Resource Centre.

Perret, S.R. (2002). Water policies and smallholding irrigation schemes in South Africa: A history and new institutional challenges. *Water Policy*, 4(3):283-300.

Petzer, E., Oranje, M. and van Huyssteen, E. (2000). A Policy Paper on Integrated Development Planning. Department of Provincial and Local Government, Cape Town.

Phakathi, S., Sinyolo, S., Marire, J. and Fraser, G. (2021). Farmer-led institutional innovations in managing smallholder irrigation schemes in KwaZulu-Natal and Eastern Cape Provinces, South Africa. *Agricultural Water Management*, 248, pp.106780.

Phali, L., Mudhara, M., Ferrer, S. and Makombe, G. (2022) Evaluation of water-user performance in smallholder irrigation schemes in KwaZulu-Natal Province, South Africa: A stochastic meta-frontier analysis*. Frontiers in Sustainable Food Systems* 6:1022410. doi: 10.3389/fsufs.2022.1022410.

Piemontese, L., Castelli, G., Fetzer, I., Barron, J., Liniger, H., Harari, N., Bresci, E. and Jaramillo, F. (2020). Estimating the global potential of water harvesting from successful case studies. *Global Environmental Change*, 63(1):1-13.

Popoola, O.O. and Yusuf, S.F.G. (2021). South African government palliative funds for agriculture amid Covid-19: Challenges of implementation and suggestions for improvements. *South African Journal of Agricultural Extension,* 49(3), 2021: 16-30.

Qin, W., Wang, D., Guo, X., Yang, T. and Oenema, O. (2015). Productivity and sustainability of rainfed wheat-soybean system in the North China Plain: results from a long-term experiment and crop modelling. *Scientific Reports*, 5(1):17514.

Rafta, A. (2023). Soil and water management in Rainfed Agriculture. Global Symposium on Soils and Water, Soil and Water: A source of life, Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils (ITPS).

Raghavendra, K. J., and Suresh, A. (2018). Risk management in rainfed agriculture: an analysis of strategies and adaptations followed by farmers in Madhya Pradesh. *Indian Journal of Agricultural Sciences,* 88 (6): 895–901.

Rao, C.S., Lal, R., Prasad, J.V., Gopinath, K.A., Singh, R., Jakkula, V.S., Sahrawat, K.L., Venkateswarlu, B., Sikka, A.K. and Virmani, S.M. (2015). Potential and challenges of rainfed farming in India. *Advances in Agronomy*, 133 (1):113-181.

Reinder, F.B. (2011). Irrigation methods for efficient water application: 40 years of South African research excellence. *Water SA* Vol. 37 No. 5 WRC 40-Year Celebration Special Edition 2011.

Republic of South Africa. (1971). Water Research Act 1971 (Act 34 of 1971). Government Gazette No. 3105, Office of the President, Cape Town.

Republic of South Africa. (1983). Conservation of Agricultural Resources Act (No 43 of 1983). Government Gazette No. 883, Office of the President, Cape Town.

Republic of South Africa. (1990). Agricultural Research Act, 1990 (No. 86 of 1990). Government Gazette No. 1461, Office of the President, Cape Town.

Republic of South Africa. (1993). Provision of Land and Assistance Act 1993 (Act 126 of 1993). Government Gazette No. 14992, Office of the President, Cape Town.

Republic of South Africa. (1994). Restitution of Land Rights Act 22 of 1994. Government Gazette No. 16106, Office of the President, Cape Town.

Republic of South Africa. (1996). The Constitution (No 108 of 1996). Government Gazette, 26 of 1998, Office of the President, Cape Town.

Republic of South Africa. (1997a). Water Services Act. (No. 108 of 1997). Government Gazette No. 1662, Office of the President, Cape Town.

Republic of South Africa. (1997b). White Paper on a National Water Policy for South Africa. Department of Water Affairs and Forestry, Pretoria.

Republic of South Africa. (1998a). National Water Act. (No. 36 of 1998). Government Gazette No. 19182, Office of the President, Cape Town.

Republic of South Africa. (1998b). National Environmental Management Act 1998 (Act 107 of 1998). Government Gazette No. 19519, Office of the President, Cape Town.

Republic of South Africa. (2002). Land and Agricultural Development Bank Act 2002 (Act 15 of 2002). Government Gazette No. 3506, Office of the President, Cape Town.

Republic of South Africa. (2003). National Health Act 2003 (Act 61 of 2003). Government Gazette No. 26595, Office of the President, Cape Town.

Republic of South Africa. (2008). National Environmental Management: Waste Act 2008 (Act 59 of 2008). Government Gazette No. 32000, Office of the President, Cape Town.

Republic of South Africa. (2011). White Paper on the National Climate Change Response. Government Gazette No. 334695, Notice No. 757 of 19 October 2011. Pretoria: Government Printer.

Republic of South Africa. (2013). National Development Plan 2030: Our future–make it work. National Planning Commission, The Presidency, Pretoria.

Republic of South Africa. (2020). National Policy Development Framework 2020. Government Printer, Pretoria.
Republic of South Africa. (2020). National Policy Development Framework 2020. Government Printer, Pretoria.

Republic of South Africa. (2024). Climate Change Act 2024 (No. 22 of 2024). Government Gazette No. 50966, Office of the President, Cape Town.

Riha, S.J. and McIntyre, B.D. (1999). Water management with hedge-row agroforestry systems. In LE Buck et al. (ed) Agroforestry in sustainable agricultural systems. CRC Press, Boca Raton FL, p 47-65.

Rockström, J., Karlberg, L., Wani, S.P., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J. and Qiang, Z. (2010). Managing water in rainfed agriculture—The need for a paradigm shift. *Agricultural Water Management,* 97 (2010) 543-550.

Rockström, J., Kaumbutho, P., Mwalley, J., Nzabi, A.W., Temesgen, M., Mawenya, L., Barron, J., Damgaard-Larsen, S. (2009). Conservation farming strategies in East and Southern Africa: a regional synthesis of crop and water productivity from on-farm action research. *Soil and Tillage Research* 103: 23-32.

Rodda, N., Carden, K. and Armitage, N. (2010). Sustainable Use of Greywater in Small-Scale Agriculture and Gardens in South Africa. Technical Report submitted to Water Research Commission, WRC Report No 1639/1/10.

Rodda, N., Carden, K. and Armitage, N. (2010). Sustainable Use of Greywater in Small-Scale Agriculture and Gardens in South Africa. Technical Report submitted to Water Research Commission, WRC Report No 1639/1/10.

Rodda, N., Carden, K., Armitage, N. and du Plessis, H.M. (2011). Development of guidance for sustainable irrigation use of greywater in gardens and small-scale agriculture in South Africa. *Water SA,* 37(5): 727-737

SADC. (2003). Regional Indicative Strategic Development Plan. Gaborone, Botswana: Southern African Development Community (SADC) http://www.sadc.int/files/5713/5292/8372/Regional_Indicative_Strategic_Development_Plan.pdf.

SAFI. (2018). Farmer-led irrigation development and investment strategies for food security, growth and employment in Africa. Studying African Farmer-led Irrigation (SAFI), The University of Manchester, Manchester, UK.

Saikanth, D. R. K., Das, H., Kumar, V. and Pancholi, R. (2023). Application and Impacts of Mulch Installation Techniques on Indian Horticulture: An In-depth Review. *International journal of Plant and Soil Science*, 35(18):2135-2147.

Saldías, C., Speelman, S., van Huylenbroeck, G. and Vink, N. (2016). Understanding farmers' preferences for wastewater reuse frameworks in agricultural irrigation: lessons from a choice experiment in the Western Cape, South Africa. *Water SA*, Vol.

42 No. 1: 26-37. Available on website http://www.wrc.org.za (Accessed on 10/06/2022).

Schreiner, B. (2013). Viewpoint – why has the South African national water act (NWA) been so difficult to implement? *Water Alternatives,* 6(2), 239–245.

Serote, B., Mokgehle, S., Du Plooy, C., Mpandeli, S., Nhamo, L. and Senyolo, G. (2021). Factors influencing the adoption of climate-smart irrigation technologies for sustainable crop productivity by small-scale farmers in arid areas of South Africa. *Agriculture*, 11(5):1-17.

Shange, N.S.Q. (2015). Socio-economic factors influencing the adoption of in-field rainwater harvesting technology for enhancing household food security by smallholder farmers in the Nkonkobe Municipality, Eastern Cape Province. Masters' dissertation, Alice, University of Fort Hare.

Shikwambana, S., Malaza, N. and Shale, K. (2021). Impacts of rainfall and temperature changes on small-scale agriculture in the Limpopo Province, South Africa. *Water*, 13(20):1-16.

Sikosana, M. L., Sikhwivhilu, K., Moutloali, R., and Madyira, D. M. (2019). Municipal wastewater treatment technologies: A review. *Procedia Manufacturing*, 35, 1018-1024.

Simo, T.S. (2014). Cooperative Governance in South Africa: A Case Study of Intergovernmental Relations in Provision of Housing. University of KwaZulu-Natal, Durban.

Sokile, C.S., Mwaruvanda, W. and van Koppen, B. (2005). Integrated water resource management in Tanzania: Interface between formal and informal institutions. International workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa', 26 – 28 January 2005, Johannesburg, South Africa

Soyapi, C.B. (2017). Water Security and the Right to Water in Southern Africa: An Overview. *PER / PELJ,* 2017(20) - DOI http://dx.doi.org/10.17159/1727-3781/2017/v20n0a1650.

Standard Bank Group. (2023). Annual Integrated Report. Report for the year ended 31 December 2023. Johannesburg, South Africa

StatsSA. (2017). Household Access to Services Stabilised. Department of Statistics, Pretoria.

Stein, R. (2005). Water law in a democratic South Africa: a country case study examining the introduction of a public rights system. *Texas Law Review,* 83(7):2169–2196.

Stevens, J. and van Koppen, B. (2015). Trends and Outlook: Agricultural Water Management in Southern Africa: Country Report South Africa. Regional Strategic Analysis and Knowledge System (ReSAKSS) Report, International Water Management Institute, Pretoria.

Steyn, M. and Jagals, P. (2000). Guidelines for the reuse of treated wastewater: Public health protection or denial of essential resources? Paper presented at WISA 2000 Biennial Conference, Sun City, South Africa, 28 May – 1 June 2000, Centre for Health and Environment Research and Development, Technikon Free State, Bloemfontein, South Africa.

Strauss, J.A., Swanepoel, P.A. Laker, M.C. and Smith, H.J. (2021). Conservation Agriculture in rainfed annual crop production in South Africa. *South African Journal of Plant and Soil*, 38(3): 217–230.

Suresh, A., Raju, S. S., Chauhan, S., and Chaudhary, K. R. (2014). Rainfed agriculture in India: An analysis of performance and implications. *Indian Journal of Agricultural Sciences*, 84(11): 1415-1422.

Swartz, C.D., Menge, J.G., du Plessis, J.A. and Wolfaardt, G.M. (2022). A water reclamation and reuse guide for South African municipal engineers. WRC Report No. TT 882/22.

Tesfuhuney, W.A., Walker, S and Fourie, A. (2020). Uptake of knowledge, technology and practices for improving water productivity in rain-fed cropping systems in the Eastern Free State province. Water Research Commission, Pretoria, South Africa Report No.2821/1/20.

Todorovic, M., Lamaddalena, N., Jovanovic, N. and Pereira, L.S. (2015). Agricultural water management: Priorities and challenges. *Agricultural Water Management,* 147: 1–3.

Toxopeüs, M. (2019). The Institutional Structure of water resources management. Helen Suzman Foundation, Westcliff, Johannesburg.

UN-Water (2020). UN-Water Analytical Brief on Unconventional Water Resources. Geneva, Switzerland.

van Antwerpen, R., Laker, M.C., Beukes, D.J. Botha, J.J. Collett, A. and du Plessis, M. (2021). Conservation Agriculture farming systems in rainfed annual crop production in South Africa. *South African Journal of Plant and Soil,* 38(3): 202–216.

van Averbeke, W., Denison, J. and Mnkeni, P.N.S. (2011) Smallholder irrigation schemes in South Africa: A review of knowledge generated by the Water Research Commission. *Water SA,* Vol. 37 No. 5: 797-808.

van Koppen, B. and Schreiner, B. (2019). A hybrid approach to statutory water law to support smallholder farmer-led irrigation development (FLID) in Sub-Saharan Africa. Water Alternatives 12(1): 146-15. Available from bschreiner@win-s.org.

van Niekerk, A.M. and Schneider, B. (2013). Implementation plan for direct and indirect water re-use for domestic purposes–Sector Discussion Document. WRC Report No. KV, 320, p.13.

Vaughan, S. (2007). Good governance and water management: Background note for OAS national focal point meeting. Guatemala, 11-12 August 2007. The OAS Department of Sustainable Development, Washington D.C., USA.

Vaughan, S. (2007). Good governance and water management: Background note for OAS national focal point meeting. Guatemala, 11-12 August 2007. The OAS Department of Sustainable Development, Washington D.C., USA.

Velasco-Muñoz, J. F., Aznar-Sánchez, J. A., Batlles-delaFuente, A., and Fidelibus, M. D. (2019). Rainwater harvesting for agricultural irrigation: An analysis of global research. *Water*, 11(7), 1320.

Veldwisch, G. J., Venot, J.-P., Woodhouse, P., Komakech, H. C., and Brockington, D. (2019). Re-introducing politics in African farmer-led irrigation development: Introduction to a special issue. *Water Alternatives*, 12, 1-12.

Venot, J.-P., Bowers, S., Brockington, D., Komakech, H., Ryan, C., Veldwisch, G.-J. and Woodhouse, P. (2021). Below the radar: Data, narratives and the politics of irrigation in Sub-Saharan Africa. *Water Alternatives* 14(2): 546-572.

Vink, N., Saldias, C., Speelman, S., and Van Huylenbroeck, G. (2016). Understanding farmers' preferences for wastewater reuse frameworks in agricultural irrigation: lessons from a choice experiment in the Western Cape, South Africa.

Wani, S.P., Rockström, J. and Oweis, T. (2009). *Rain-fed agriculture: Unlocking the potential. Comprehensive assessment of water management in agriculture*. Series 7. USA: CABI International. p. 310

Ward, C., Torquebiau, R. and Xie, H. (2016). Improved Agricultural Water Management for Africa's Drylands. International Bank for Reconstruction and Development/The World Bank, Washington, DC.

Western Cape Department of Agriculture. (2022). Sources of Finance for Agricultural Businesses. Agricultural Economics Programme, Production Economics Division, Western Cape Government, Cape Town.

Whittingham, K. L., Earle, A. G., Leyva-de la Hiz, D. I., and Argiolas, A. (2023). The impact of the United Nations SUSTAINABLE DEVELOPMENT GOALS on corporate sustainability reporting. *BRQ Business Research Quarterly*, 26(1), 45-61.

WHO (World Health Organization) (2019). National systems to support drinking-water, sanitation and hygiene: global status report 2019. UN-Water global analysis and assessment of sanitation and drinking-water (GLAAS) 2019 report. World Health Organization; Geneva, Licence: CC BY-NC-SA 3.0 IGO.

WHO (World Health Organization) and UNICEF (United Nations Children's Fund). (2006). Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade. WHO/UNICEF, Geneva and New York, 41 p.

WHO (World Health Organization). (2006). Guidelines for the Safe Use of Wastewater, Excreta and Grey Water. Volume 2. Wastewater Use in Agriculture. Geneva.

Wichelns, D. (2015). Achieving water and food security in 2050: Outlook, policies, and investments. *Agriculture* 2015, 5, 188–220.

Wiggins, S. and Lankford, B. (2019). Farmer-led irrigation in sub-Saharan Africa: Building on farmer initiatives. ODI (Overseas Development Institute).

Wiggins, S. and Lankford, B. (2019). Farmer-led irrigation in sub-Saharan Africa: synthesis of current understandings. Synthesis Report, The DFID-ESRC Growth Research Programme (DEGRP), UK.

Wikipedia (2015). Water supply and sanitation in South Africa. https://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_South_Africa#Wastewater_treatment. Accessed on10/01/2025

Woodhouse, P., Jan Veldwisch, G.J.A., Venot, J., Brockington, D., Komakech, H. and Manjichi, A. (2017). African farmer-led irrigation development: re-framing agricultural policy and investment? *The Journal of Peasant Studies*, 44:1, 213-233, DOI: 10.1080/03066150.2016.1219719.

World Bank (2023). Farmer-led Irrigation Development for Water and Food Security. Water in Agriculture Global Solutions Group Fiscal Year 2023, World Bank Group.

World Bank. (2006). Reengaging in Agricultural Water Management: Challenges and Options. Directions in Development Series. The World Bank, Washington DC. http://siteresources.worldbank.org/INTARD/Resources/DID_AWM.pdf.

World Bank. (2018). Innovation, entrepreneurship, positive change. Join the farmer-led irrigation revolution. Retrieved September 23, 2023, from www.worldbank.org/en/news/feature/2018/09/05/innovation-entrepreneurship-positive-changejoin-the-farmer-led-irrigation-revolution.

World Bank. (2022). Water in Agriculture. Towards Resilient Agriculture. World Bank Group Water Global Practice. https://www.worldbank.org/en/topic/water-in-agriculture.

World Bank. (2023). Farmer-led Irrigation Development: Implementation Across Africa, and Vision Beyond. Water in Agriculture Global Solutions Group Fiscal Year 2023.

Yang, H, Zhang, X & Zehnder, AJ. (2003). Water scarcity, pricing mechanism and institutional reform in northern China irrigated agriculture. *Agricultural Water Management,* 61 (2): 143-161.

Young, C., Barnes, J. and Winter, K. (2018). Carden, K., Fisher-Jeffes, L., Guidelines for greywater use and management in South Africa. WRC Report No. TT 746/17.

Zhu, T., Ringler, C. and Rosegrant, M.W. (2019). Viewing Agricultural Water Management Through a Systems Analysis Lens. *Water Resources Research,* 55(3): 1778-1791**. DOI:** https://doi.org/10.1029/2017WR021007.

Ziye, L.I.U. and Junying, J.I.N. (2016). Review on rainfed agriculture and rainwater harvesting techniques. *Advances in Biological Sciences Research*, 3(1):329-331.

APPENDICES

Appendix A: Data collection tool

PART 1: GENERAL QUESTIONNAIRE

SMALLHOLDER FARMER QUESTIONNAIRE

The purpose of this questionnaire is to “evaluate pathways to sustainable agricultural water management: Case studies of smallholder communities in rural and peri-urban areas of the Limpopo and Gauteng Provinces”. The information of each participant will be kept private. Please make sure that you only answer questions that are associated with the pathway that you are currently farming under. Use an "X" next to the code to answer the questions where appropriate. Should you feel uncomfortable answering any question, please leave the item blank and answer the next question.

INTERVIEWER DECLARATION:

I, ...

Declare that I will ask this questionnaire as it will be laid out. I declare that all responses recorded will be the true responses of the respondent and that I have thoroughly checked the questionnaire.

Signature :..

Date :..

District :..

Municipality :..

SECTION A: DEMOGRAPHICS OF PARTICIPANTS

1. Gender

Male	Female

2. Age (in years) ....
3. Race

Black	White	Coloured	Indian

4. Marital status of respondent

Single	Married	Widowed	Divorced	Separated

5. Do you have a disability?

Yes	No

6. Please indicate your highest education level

Primary school	High school	Tertiary	No formal education

7. Number of household members..
8. Who is the household head?

Father	Mother	Sister	Brother	Grandmother

9. Besides farming, do you engage in any other income-generating activities?

Yes	No

10. If yes, please indicate which of the following is your major source of income? **Please select one option**

Major source of income	**Tick**
Retirement pension	
Part-time job	
Full-time job	
Old age pension	
Child support grant	
Disability grant	
None	

11. How much is your household's total non-farm monthly income? R...........................

SECTION B: FARM CHARACTERISTICS

1. How long have you been farming?...................................Years
2. How did you obtain the land that you are currently farming on? (**Please select one option**)

Means of ownership	**Tick**
Bought (Title deed)	
Leased	
Inherited	
Allocated by the local authority	
Renting or sharecropping	
Other (please specify)	

3. What is the total size of your farm in hectares?..........................Ha
4. How many hectares of land did you use for planting your crops in the last 12 months?
............Ha
5. Please indicate the crops you planted in the past summer (rainy season) starting with the most important ones, the area you planted, the output you produced and how much it cost you (**Complete the table below**).

Crop name	Area planted (ha)	Quantity harvested *(specify units e.g., kg)*	Quantity sold *(specify units e.g., kg)*	Price per unit	Inputs used	Quantity purchased (and used)	Cost per unit

Key

Crops	**Inputs used**
1Maize 6 Cabbage	1Fertilizers 6 Seeds
2Tomatoes 7 Beans	2Herbicides 7 Pesticides
3Potatoes 8 Onions	3Labour 8 Tillage
4Sugarcane 9. Butternut	4Transport 9 Packaging
5Spinach 10 Other (specify):	5Marketing 10 Other (specify):

6. Please indicate the crops you planted in the past winter (dry season) starting with the most important ones, the area you planted, the output you produced and how much it costs youth (**Complete the table below**).

Crop name	Area planted (ha)	Quantity harvested *(specify units e.g., kg)*	Quantity sold *(specify units e.g., kg)*	Price per unit	Inputs used	Quantity purchased (and used)	Cost per unit

Key

Crops	**Inputs used**
1.Maize 6 Cabbage 2.Tomatoes 7 Beans 3.Potatoes 8 Onions 4.Sugarcane 9. Butternut 5.Spinach 10 Other (specify):	1.Fertilizers 6.Seeds 2.Herbicides 7.Pesticides 3.Labour 8 Tillage 4.Transport 9 Packaging 5.Marketing 10 Other (specify):

7. How much do you make annually from your produce? R....................................
....
8. What are the main sources of the labour for your farming activity?

Family labour	Permanent labour	Casual labour

9. Fill in the table based on the information on your main source of labour.

Type of labour	**Number of workers**	**Salary per week/month (Rands)**
Family labour		
Permanent labour		
Casual labour		

10. How does farming contribute to your overall income and livelihood?..............
....
....
....
....

SECTION C: SUPPORT SERVICES

C1. EXTENSION SERVICES

1. Did you have any contact with extension officer in the past 12 months?

Yes	No

2. Have you used extension services for agricultural water management?

Yes	No

3. If yes, where do the extension services primarily come from? **Please select all that apply:**

Sources of information	**Tick**
Government agricultural department or agency	
Non-governmental organization (NGO)	
Agricultural cooperative or association	
Local community-based organization	
Private sector entities (e.g., companies, consultants)	
Other (please specify):	

4. How often do you have contact extension officers?

Regularly (at least once a month)	Occasionally (a few times a year)	Rarely (once a year or less)

5. What types of extension services have you received for agricultural water management? **Please select all that apply:**

Type of extension services	**Tick**
Training workshops	
Demonstration farms or field visits	
Technical advice or consultations	
Information materials (brochures, leaflets, etc.)	
Farmer-to-farmer knowledge sharing	
Other (please specify):	

6. Do you find the information and advice provided by extension service providers for managing water in your farming practices useful?

Yes	No

7. Have you encountered any challenges or limitations in accessing extension services for agricultural water management?

Yes	No

8. If yes, please indicate the challenges or limitations you have faced. **Please select all that apply:**

Challenges	**Tick**
Lack of information about available services	
Limited availability of extension service providers	
Distance and transportation issues to reach the service providers	
Language or communication barriers	
Lack of awareness about the importance of agricultural water management	
Other (please specify):	

C2: WATER USER ASSOCIATION

1. Do you know about water user association (WUA)?

Yes	No

2. If the response is yes, are you a member of a water user association?

Yes	No

3. If the response in question2 is no, would you be interested in joining a WUA?

Yes	No

4. If yes, what is the name of your WUA?..
....

5. How long has your WUA been in operation?..................Years
6. What is the main water source managed by your WUA? **Please select all that apply**:

Water Source	**Tick**
Rainwater	
Groundwater (wells, boreholes)	
Surface water (rivers, lakes, reservoirs)	
Municipal or piped water supply	
Other (please specify):	

7. How many members are currently part of your WUA?..
8. What is the process for becoming a member of the WUA? **Please select all that apply:**

Process	**Tick**
Application form and registration	
Membership fee payment	
Approval by the WUA board or committee	
Training or orientation session	
Other (please specify):	

9. How often are general meetings held by the WUA?

Monthly	Quarterly	Annually	Other (please specify):

10. How is water allocation managed within your WUA? **Please select all that apply:**

Water allocation	**Tick**
Fixed allocation for each member	
Rotation system	
Priority-based allocation	
Other (please specify):	

11. What methods or tools does your WUA use to measure water usage? **Please select all that apply:**

Methods	**Tick**
Flow meters	
Water meters	
Manual measurement (e.g., measuring cups, buckets)	
Estimation based on irrigated area	
Other (please specify):	

12. Does your WUA collect fees or contributions from its members?

Yes	No

13. How much is the membership fee? R....................
14. How are the collected fees or contributions used by the WUA? **Please select all that apply:**

Use of membership fee/ contributions	**Tick**
Operation and maintenance of infrastructure	
Water resource monitoring and management	
Administrative expenses	
Capacity building and training programs	
Other (please specify):	

15. What are the potential advantages of using WUA to manage irrigation water demand? **Please select all that apply:**

Advantages	**Tick**
Local knowledge of water resources and irrigation needs	
Improved water use efficiency	
Resolving of conflicts among farmers over water allocation,	
Accountability and transparency in water allocation and management by establishing clear rules and procedures for water allocation	
Access to financing and support	

16. What are the main challenges faced by your WUA? **Please select all that apply:**

Challenges	**Tick**
Water scarcity or inadequate supply	
Conflicts or disputes among members	
Insufficient financial resources	
Limited technical expertise or knowledge	
Other (please specify):	

17. What are the future plans or goals of your WUA? **Please select all that apply:**

Future plans/goals	**Tick**
Expansion of water infrastructure	
Improving water conservation and efficiency practices	
Strengthening governance and member participation	
Enhancing collaboration with other stakeholders	
Other (please specify):	

C3: FINANCIAL SUPPORT

1. Are you aware of any financial support programs or initiatives available specifically for agricultural water management?

Yes	No

2. Have you received any financial support for agricultural water management?

Yes	No

3. If yes, please indicate the source(s) of financial support you have received. **Please select all that apply:**

Financial support	Tick
Government grants	
Non-governmental organizations (NGOs)	
Agricultural cooperatives or associations	
Microfinance institutions	
Private sector entities (e.g., companies, sponsors)	
Other (please specify):	

4. What was the purpose of the financial support? **Please select all that apply:**

Purpose of financial support	Tick
Investment in irrigation infrastructure such as pumps, pipes, and sprinklers	
Installation of irrigation systems such as drip irrigation or micro-irrigation	
Purchase of water storage tanks or reservoirs	
Maintenance and repair of irrigation equipment	
To cover costs associated with energy or fuel for operating irrigation systems	
Construction of rainwater harvesting structures such as ponds or tanks.	
Water management tools such as soil moisture sensors or rain gauges.	
Purchase seeds or seedlings of drought-tolerant or rain-fed adapted crops.	
Implementation of wastewater treatment systems for safe reuse in irrigation.	
Purchase and installation of filtration or purification equipment for treating wastewater	
Monitoring and testing tools for assessing water quality.	
Safe handling and application equipment for wastewater irrigation.	
Other (please specify):	

5. Have you accessed credit or loans specifically for agricultural water management purposes?

Yes	No

6. If yes, please indicate the source(s) of credit or loans you have accessed. **Please select all that apply:**

Sources of credit /loan	Tick
Relative or friend	
Savings club (stokvel)	
Banks or financial institutions	
Microfinance institutions	
Agricultural cooperatives or associations	
Government-supported credit programs	
Other (please specify):	

7. Were you able to pay back the loan/credit in time?

Yes	No

8. Have you faced any challenges or limitations in accessing credit for agricultural water management? **Please select all that apply:**

Challenges	Tick

Limited availability of credit options	
High interest rates or collateral requirements	
Complex application or eligibility requirements	
Lack of information about available credit options	
Other (please specify):	

9. In your opinion, what additional financial support mechanisms or programs would be beneficial for smallholder farmers in agricultural water management?

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

C4: TRAINING AND CAPACITY BUILDING

1. Have you received any training related to agricultural water management?

Yes	No

2. If yes, please specify the type(s) of training you have received.

Training areas	**Yes/No**
Conservation agriculture techniques such as minimum tillage, mulching and cover cropping	
Rainwater harvesting techniques	
Crop selection and rotation	
Soil management techniques (tensiometer, wetting front detectors and chameleon sensor card)	
Irrigation scheduling	
Water quality monitoring	
Infrastructure management	
Conflict resolution	
Irrigation system design and operation	
Water use efficiency	
Water rights and governance	
Other (please specify):	

3. Where did you receive the training or capacity building programs from? **Please select all that apply:**

Training institution	**Tick**
Government agricultural department or agency	
Non-governmental organization (NGO)	
Agricultural cooperatives or associations	
Research or academic institutions	
Private sector entities (e.g., companies, consultants)	
Other (please specify):	

4. Do you feel that the training or capacity building programs has adequately equipped you with the necessary knowledge and skills in agricultural water management?

Yes	No

5. If no, please specify the areas or topics where you feel additional training or capacity building is needed.

Training areas	**Yes/No**
Conservation agriculture techniques such as minimum tillage, mulching and cover cropping	
Rainwater harvesting techniques	
Crop selection and rotation	
Soil management techniques (tensiometer, wetting front detectors and chameleon sensor card)	
Irrigation scheduling	
Water quality monitoring	
Infrastructure management	
Conflict resolution	
Irrigation system design and operation	
Water use efficiency	
Water rights and governance	
Other (please specify):	

6. Have you faced any challenges or limitations in accessing training or capacity building programs for agricultural water management? **Please select all that apply:**

Challenges	**Tick**
Limited availability of training programs	
Distance and transportation issues to training locations	
Language or communication barriers	
Lack of awareness about available training programs	
Other (please specify):	

7. In your opinion, what can be done to improve the accessibility and quality of training and capacity building programs for agricultural water management? ....

SECTION D: WATER SOURCES FOR AGRICULTURAL PRODUCTION

1. What is your method of agricultural production? **You can select more than one option:**

Main source of water for irrigation	**Tick**	
Rainfall		**Go to section E**
Irrigation		**Go to section F**
Wastewater		**Go to section G**

SECTION E: PATHWAY 1 (RAIN-FED FARMING)

1. How do you water your crops on your rain-fed farm? **Please select one option that describes your main method**:

Depend only on natural irrigation (rainfall only)	Only harvest rainwater for irrigation	Using both natural irrigation and harvested rainwater for irrigation

2. If you practice rainwater harvesting, how do you collect rainwater on your farm?

....

....

....

3. How do you store the collected rainwater? **Please select all applicable options:**

Storage method	**Tick**
Containers or tanks.	
Underground storage.	
Ponds or reservoirs.	
Other (please specify	

4. Which crops do you produce under rain-fed farming? Please list the crops according to their importance?

....

....

....

5. Do you only plant crops during the rainy season, or do you plant crops during other times as well? **Please select one option:**

Only plant crops during the rainy season	Plant crops throughout the year

6. Have you observed any changes in the timing of the rainy season in recent years?

Yes	No

7. If yes, how would you describe the changes in the timing of the rainy season? **Please select all applicable options:**

Changes in the timing of the rainy season	**Tick**

Rainy season starts later than usual.	
Rainy season starts earlier than usual.	
Rainfall patterns are inconsistent or unpredictable.	
No noticeable changes in the timing of the rainy season.	

8. Have you noticed any changes in the duration of the rainy season?

Yes	No

9. If yes, how would you describe the changes in the duration of the rainy season? **Please select all applicable options:**

Changes in the duration of the rainy season	**Tick**
Shortened rainy season.	
Extended rainy season.	
Inconsistent duration from year to year.	
No noticeable changes in the duration of the rainy season.	

10. Besides changes observed in the timing and duration of the rainy season, which other changes in weather patterns have you observed? **Please select all applicable options:**

Other changes in weather patterns	**Tick**
Warmer temperatures than before	
More frequent periods of drought	
Heavy rainfall resulting in floods	
Other (please specify):	

11. How have these changes in the rainy season affected your rainwater harvesting practices and overall farming activities? **Please select all applicable options:**

Impacts of changes in the rainy season on rainwater harvesting practices	**Tick**
Reduced availability of rainwater for harvesting.	
Increased difficulty in collecting rainwater.	
Shortened duration of rainwater availability.	
Increased evaporation of stored rainwater.	
Inadequate storage capacity for harvested rainwater.	
Increased competition for limited water resources.	
Other (please specify):	

12. Besides irrigation, do you use the harvested rainwater for other purposes?

Yes	No

13. If yes, please select the other purposes for which you use the harvested rainwater. **Please select all applicable options:**

Other uses for rainwater harvesting	**Tick**
Drinking water for household use.	
Livestock watering.	
Cooking and food preparation.	

Cleaning and sanitation.	
Other (please specify):	

14. Do you collect and utilize floodwater for irrigation purposes?

Yes	No

15. If yes, please describe the methods or techniques you use to collect and utilize floodwater for irrigation. ....

16. Have you faced any challenges or limitations in rainwater harvesting or utilizing floodwater for irrigation?

Yes	No

17. If yes, please select the challenges or limitations you have faced. **Please select all applicable options:**

Challenges	**Tick**
Insufficient water storage capacity for irrigating crops.	
Difficulties in capturing and storing rainwater effectively.	
Inadequate knowledge on proper irrigation techniques using harvested rainwater.	
Limited availability of suitable irrigation infrastructure or equipment.	
Financial constraints in implementing rainwater harvesting systems for irrigation.	
Lack of access to necessary tools or equipment for rainwater irrigation.	
Inefficient utilization of collected rainwater for irrigation purposes.	
Other (please specify):	

SECTION F: PATHWAY 2&3 (IRRIGATION)

1. Are you using your own irrigation system or public irrigation scheme?

Own irrigation/farmer led	Public irrigation scheme

2. What is the source of water for your irrigation?

Dam	River (answer 3)	Borehole	Municipal water	Other (specify)

3. What is the location of your farm?

Upstream
Midstream
Downstream

4. How does the water from the source reach your field? (you can tick more than 1)

Gravity	Water Pump (diesel)	Electric Pump	Open canal flow	Watering cans/containers	Others(specify) …………….

5. What is the distance between the sources of water to your crops? .... Km

6. Which irrigation system are you using? **Please select all applicable options:**

Irrigation system	**Tick**
Sprinkler	
Drip	
Micro	
Furrow	
Flood	
Bucket/ watering can	
Centre pivot	
Combination of different irrigation systems	
Other (please specify):	

7. What are the advantages of using the irrigation system selected in question 5? **Please select all applicable options:**

Advantages	**Tick**
Increased crop yields	
Improved crop quality	
Reduced risk of crop failure	
Extended growing season	
Increased flexibility in crop management:	
Improved water use efficiency	
Other (please specify):	

8. What are the main challenges associated with using the selected irrigation system in question 5? **Please select all applicable options:**

Challenges	**Tick**
Leakage or loss of water	
Clogging or blockage issues	
High energy or fuel costs for operation	
High cost of infrastructure installation or repairs	
Difficulty in maintaining or repairing irrigation system	
Inadequate water flow or pressure for irrigation	
Other (please specify):	

9. Who funded the selected irrigation system? **Please select all applicable options:**

Funder	**Tick**
Government	

NGO	
Local municipality	
Own funds	
Other (please specify):	

10. How much did it cost to install the irrigation system? R......................................

ONLY FOR PUBLIC IRRIGATION SCHEME

11. What is the name of the irrigation scheme?

....

12. In which year was the scheme formed?..
............Years
13. Who initiated the formation of the scheme?

Farmers	Non-profit organization (NGO)	Government	Other specify

14. Is the scheme registered with any authority?

Yes	No

15. If the response is yes, which authority are you registered with?

Companies and Intellectual Property Registration office (CIPRO) under department of trade and industry	Government department (Specify, e.g., Department of agriculture	Other (please specify)

16. If the response to question 4 is no, what is the main reason?

Not interested	Lack of information about where to register	Registration too cumbersome/ complicated	Too costly	Other (please specify)

17. How far away is your household from the scheme? ....
Km
18. What is the position of your plot(s) from the main water supply or canal?

Head	Middle	Tail

19. What is the current status of the scheme? **Please select all applicable options:**

Irrigation scheme status	**Tick**
Fully functional and providing water for irrigation	
Under construction or being developed	

Requires repairs or maintenance to operate effectively	
Limited water availability or irregular supply	
Not yet implemented or started	
No longer in use or abandoned	
Fully functional and providing water for irrigation	
Other (please specify):	

20. Is water distribution fair?

Yes	No

21. If the response is no, what are the major management challenges related to water distribution in the irrigation scheme? **Please select all applicable options:**

Management challenges	**Tick**
Poor coordination by water committee	
Lack of punishment against illegal water users	
Rotations are not strictly implemented	
Water theft	
We have no problem	
Other (please specify):	

22. Do you face any conflicts with other farmers in relation to water sharing within your block?

Yes	No

23. If the response is yes, what were the major causes of the conflicts? **Please select all applicable options:**

Major causes	**Tick**
Unequal access to water	
Inadequate water management	
Lack of trust	
Difference in farming practices	
Lack of effective water governance	
Other (please specify):	

24. What measures were taken to resolve the conflict? **Please select all applicable options:**

Possible solutions	**Tick**
Establishing clear rules and regulations	
Developing a water management plan	
Encouraging dialogue and collaboration	
Investing in water infrastructure	
Encouraging crop diversification	
Seeking assistance from water management expects	
Other (please specify):	

25. Are the following water management bylaws implemented in the irrigation schemes?

Water management bylaws	Yes/No
Guidelines for water allocation	
Requirements for water measurement	
Water conservation requirements (reducing water loss from irrigation systems, mulching or using drought-resistant crops	
Enforcement mechanisms (fines or penalties)	
Monitoring and reporting requirement	
Other (please specify):	

26. Has the government involvement of any of the following authorities in water management improved water access in the scheme?

Government management	Yes/No
Involvement of local Department of Agriculture officials in water management (local managers and extension officers	
Involvement of government canal rangers in water allocation	
Involvement of Department of Water Affairs personnel local/community management	
Involvement of block committees	
Involvement of ordinary non-committee members	
Involvement of traditional authorities	
Involvement of the Water Users Association (WUAs)	
Other (please specify):	

what role does the government play?

- farm implements
- inputs
- training

SECTION G: PATHWAY 4 (WASTEWATER RECOVERY/REUSE)

1. How long have you been practicing wastewater irrigation on the farm?
   ....Years
2. What are the main reasons why you are using wastewater for irrigation purposes?
   Please select all applicable options:

Reason	Tick
There are no other available sources of irrigation water	
Wastewater is readily available near the farm	
Reduced reliance on freshwater resources	
Cost-effective alternative to using freshwater sources	
Wastewater is readily cheap	
Ensures high yields of the cultivated crops	
Improves the structure of agricultural soils	
Is a strategic source of nutrients for crop production	
Environmental benefits	
Other (please specify)	

3. From where does the water originate? **Please select all applicable options**:

Types of wastewater	**Tick**
Domestic wastewater (Washing dishes, clothes and bathing)	
Municipal wastewater	
Industrial wastewater	
Agro-processing wastewater	
Other (specify)	

4. What are the sources of the wastewater mentioned in Question 3?

5. Do you store the wastewater before using it for irrigations?

Yes (If yes go to Question 6)
No

6. How do you store wastewater before using it for irrigation? **Please select one option:**

Underground storage tanks	Above-ground storage tanks	Reservoir	Other (please specify):

7. Do you require permission to use the wastewater?

Yes	No

8. What kind of wastewater do you use?

Treated	Untreated

9. If treated, who pays for the treatment and how much is it?

……

……

10. How is the wastewater treated? **Please select all applicable options:**

Wastewater treatment	**Tick**
No treatment: Wastewater is used as it is without any additional steps.	
Filtering: Remove solid particles from the wastewater before use.	

Settling: Allow the wastewater to sit and let the solids settle at the bottom before using it for irrigation.	
Natural purification: Use natural methods, such as plants or soil, to clean the wastewater before using it for irrigation.	
Chemical treatment: Add specific chemicals to the wastewater to remove contaminants before using it for irrigation.	
Sunlight disinfection: Expose the wastewater to sunlight for a certain period to kill harmful bacteria before using it for irrigation.	
Other (please specify):	

11. Do you notice any changes in the quality of this water after treatment?

Yes	No

12. If yes, indicate the noticed changes? **Please select all applicable options:**

Changes	**Tick**
Odour	
Colour	
Froth	

13. Do you monitor the quality of the wastewater by testing?

    Yes (If yes, specify the type of tests)
    No

14. Is your wastewater use regulated by DWS?

    Yes
    No

15. Is your wastewater compliant?

    Yes
    No

16. Which crops do you cultivate under wastewater irrigation? Please list them according to their importance. ....
    ....
    ....
    ....

17. From your point of view, what are the challenges of wastewater irrigation? **Please select all applicable options:**

Disadvantages	**Tick**
Health risks	
Lack of awareness of risks of using wastewater and training	
Limited access to water treatment technology	
Social stigma associated with using wastewater for irrigation	
Legal and regulatory barriers	
Wastewater Treatment Costs	

Soil contamination/pollution	
Groundwater contamination/pollution	
None	
Other (specify)	

18. Are you aware of the health risks associated with wastewater use for irrigation?

Yes	No

19. If the response is yes, which ones do you know? **Please select all applicable options:**

Health risks	**Tick**
Diarrhoea	
Typhoid fever	
Cholera	
Chemical exposure	
Skin and eye irritation	
Respiratory problems	
Long-term health effects such as cancer, reproductive problems, and immune system damage	

20. Have you been exposed to any of the illnesses indicated above?

Yes	No

21. If the response is yes, name the one that had a major impact on your health?

....

....

22. Did you receive medical attention after exposure?

Yes	No

23. If the response to question is no, what is the main reason you did not seek medical attention?

....

....

....

24. Based on your experience, which stage in wastewater irrigation requires primary attention in order to minimize health and environmental hazards?

Pre-farm wastewater management	On-farm wastewater application	Post-harvest crop handling

25. During on-farm wastewater handling, have you adopted any risk-reduction measures to minimize the risk of infections in your household?

Yes	No

26. If the response is yes, which of the following guidelines related to the use of wastewater for irrigation have you adapted? **Please select all applicable options:**

Wastewater use guidelines	**Tick**
Educate workers about the risks associated with using wastewater for irrigation and ensure that they follow all necessary safety protocols	
Practice good hygiene by washing their hands and equipment thoroughly after handling wastewater	
Comply with regulations	
Monitor soil and water quality	
Avoid splashing or spraying wastewater during irrigation	
Avoid consuming crops immediately after harvesting	
Application of the appropriate amount of wastewater in irrigation	
Imposing a minimum period of no irrigation immediately prior to harvest	
Use appropriate protective clothing such as gloves and boots, to prevent direct contact with wastewater	
Regular anti-helminthic treatment	
Treatment of wastewater irrigated soils against pathogens	
Other (specify)	

27. How do you dispose of the wastewater after irrigation? **Please select all applicable options:**

Method of disposal	**Tick**
Surface runoff: allow the wastewater to flow into nearby streams, rivers, or other water bodies	
Subsurface drainage such as tile drains or perforated pipe	
Evaporation ponds	
Reuse	

28. Have you received any training on safe use of wastewater for irrigation?

Yes	No

29. If yes, who provided the training? **Please select all applicable options:**

Trainer	**Tick**
Government representatives (Extension officers)	
Private consultants	
Non-Governmental Organization (NGO)	
Other (specify)	

30. Based on your option did you receive enough knowledge and skills on wastewater use for irrigation purposes?

Yes	No

31. If you answered no to the previous question regarding needing training, please indicate the specific type of training you require

Training areas	**Yes/No**

Health and safety	
Appropriate selection of irrigation techniques to ensure efficient use of water and minimize soil erosion and contamination	
Timing of irrigation to reduce the risk of foodborne illness	
Soil testing to ensure that it is suitable for irrigating with wastewater	
Crop selection to learn which crops are best suited for irrigation with wastewater and which crops are not	
Learn basic wastewater treatment techniques to ensure that the wastewater is safe for irrigation	
Keep accurate records of their wastewater irrigation practices, including application rates, irrigation schedules, and crop yields	
Compliance with regulations related to the use of wastewater for irrigation.	

SECTION H: WATER ACCESS AND AVAILABILTY

1. How many times per week do you have access to water on your farm?

Daily	1-2 times per week	3-4 times per week	Other (please specify):

2. Is water available throughout the year?

Yes	No

3. If the answer is yes, what are the challenges you face in accessing water for irrigation? **Please select all that apply:**

Challenges	**Tick**
Limited access to water sources	
Irregular water supply	
Uneven distribution of rainfall	
Financial difficulties for investing in irrigation infrastructure (e.g., pumps, pipes)	
Water quality issues	
Lack of knowledge or technical skills for water management	
Other (please specify):	

4. Have you implemented any of the following agricultural water management techniques to address the challenges of water availability on your farm? **Please select all that apply:**

Agricultural water management	**Tick**
Rainwater harvesting	
Installing water-efficient irrigation systems (e.g., drip irrigation)	
Soil moisture monitoring	
Water conservation techniques (e.g., mulching)	
Adopting drought-tolerant crop varieties	
Crop rotation	
Intercropping	

Other (please specify):

5. How did the adoption of agricultural water management improve your livelihood options? **Please select all that apply:**

Benefits	**Tick**
Increase crop yields and productivity	
Diversify income through alternative agricultural practices	
Enable cultivation of high-value crops	
Improve water availability and efficiency	
Reduced water costs	
Create opportunities for off-farm activities	
Other (please specify):	

SECTION I: WATER COSTS

1. Are you currently paying for water usage on your farm?

Yes	No

2. If yes, how do you pay for water?

Fixed monthly fee	Based on the amount of water used (metered)

3. How much do you pay monthly per hectare for water? R...................................
4. If you are charged a fixed monthly fee for water usage, how do you check if you are using too much water for irrigation? **Please select all that apply:**

Monitoring strategies	**Tick**
Field visits and inspections (Agricultural extension officers, water management officials, or other experts)	
Installation of water meters	
Estimated based on crop water requirements	
Water monitoring (installing water meters on irrigation systems or manual water measurement)	
Farmer training and education	
Peer-to-peer learning	
Other (please specify):	

5. Do you face any challenges or difficulties in managing the costs of water on your farm?

Yes	No

6. If yes, please describe the challenges or difficulties you face in managing water costs.

Challenges	**Tick**
High cost of water	
Difficulty in budgeting for water expenses	
Inequitable water pricing	

Lack of transparency in billing	
Other (please specify):	

SECTION J: CLIMATE CHANGE AND FARMING PRACTICES

1. Do you think changes in the weather patterns and occurrence of natural disasters (floods/droughts) is a result of climate change?

Yes	No

2. If the response to the question is yes, what is your understanding of climate change? **Please select all that apply:**

Definition of climate change	**Tick**
A natural process that has always happened	
A term used to describe changes in the weather	
Taking actions to protect crops from extreme weather	
Finding ways to save water during dry periods	
Adjusting farming practices to match changing weather patterns	
Other (please specify):	

3. If you use irrigation for your farming activities, how has climate change affected your irrigation practices? **Please select all that apply:**

Effects of climate change	**Tick**
Changes in water availability for irrigation	
Changes in rainfall patterns	
Increased competition for water resources	
Higher temperatures	
Other (please specify):	

4. If you use wastewater for your farming activities, how has climate change affected your irrigation practices? **Please select all that apply:**

Effects of climate change	**Tick**
Decreased access to wastewater	
Reduced water quality for irrigation	
Changes in wastewater flow rates	
Other (please specify):	

5. Do you have access to weather information or forecasts for your farming area?

Yes	No

6. If yes, please specify the sources of weather information you rely on. **Please select all that apply:**

Source of weather information	**Tick**
Local weather stations	
Cell phone (Weather apps or websites)	

Radio or television stations	
Farmer Organizations and Cooperatives	
Extension officers	
Other (please specify):	

7. Are you currently implementing any adaptation measures to address the impacts of climate change?

Yes	No

8. If yes, indicate the adaptation measures you have implemented. **Please select all that apply:**

Adaptation measures	**Tick**
Crop rotation	
Intercropping	
Planting drought-tolerant crop varieties	
Implementing water-saving irrigation techniques (e.g., drip irrigation)	
Constructing water storage facilities (e.g., rainwater harvesting)	
Development of alternative water sources	
Adopting agroforestry practices to enhance soil fertility and moisture retention	
Other (please specify):	

9. If no, please select the adaptation measures you are interested in implementing. **Please select all that apply**:

Adaptation measures	**Tick**
Crop rotation	
Intercropping	
Planting drought-tolerant crop varieties	
Implementing water-saving irrigation techniques (e.g., drip irrigation)	
Constructing water storage facilities (e.g., rainwater harvesting)	
Adopting agroforestry practices to enhance soil fertility and moisture retention	
Other (please specify):	

7. What are the main challenges you faced in implementing adaptation measures? **Please select all that apply:**

Challenges	**Tick**
Lack of access to financial resources	
Limited knowledge or information on effective adaptation practices	
Inadequate technical support and guidance	
Limited availability of suitable inputs or technologies	
Other (please specify):	

8. Have you received any information or support on climate change adaptation?

Yes	No

9. If yes, please specify the sources of information or support you have received. **Please select all that apply:**

Source of support	**Tick**
Government extension services	
Non-governmental organizations (NGOs)	
Farmer cooperatives or associations	
Other (please specify):	

10. If no, are you interested in receiving information or support on climate change adaptation?

Yes	No

SECTION K: MARKETING

1. Do you produce for the market?

Yes	No

2. If you don't produce for market, what is the main reason? **Please select all that apply:**

Reason	**Tick**
Not enough water is received for surplus production	
Not enough land for surplus production	
Not enough market demand	
Others (please specify)	

3. If yes**,** where do you sell your farm products? **Please select all that apply:**

Marketing channel	**Tick**
Farm gate	
In pension points	
Road side	
Shops around my area	
Supermarkets	
Hawkers	
Farmers' markets	
Cooperative or collective marketing	
Selling to middlemen or brokers	
Other (please specify):	

4. How do you transport the farm produce to the market? **Please select all that apply:**

Transport	**Tick**
Own transport	
Hired vehicle(group)	
Public transport	
Buyer's transport	
By foot	

Other (please specify):

5. What is the distance from your farm to the nearest market? .... Km
6. How much do you pay to transport your farm produce to the market? R........
7. Do you receive any market information?

Yes	No

8. If the response is yes, what type of market information do you usually receive? **Please select all that apply:**

Market information	**Tick**
Price information	
Buyer's information	
Market place information	
Other (please specify):	

9. Who are the main sources of the market information? **Please select all that apply:**

Main sources	**Tick**
Extension officers	
Contact with traders/buyers	
Farmers association	
Personal knowledge of the market	
Fellow farmers	
Community meetings	
Project meetings	
Radio	
Television	
Other (please specify):	

10. When do you receive the marketing information?

Before planting	Before harvesting	After harvesting

11. Is the information reliable?

Yes	No

12. What are the challenges that you face in marketing your produce? **Please select all that apply:**

Marketing problems	**Tick**
High transportation costs	
Lack marketing standards	
Limited marketing options	
Lack of capital	
Low market prices	
Low demand of agricultural produce	

High postharvest losses	
Lack of information about available markets	
Poor storage facilities	
Others (please specify):	

13. Suggest ways in which the problems mentioned above can be addressed **Please select all that apply:**

Possible solutions	**Tick**
Funding	
Construction of irrigation infrastructure and water sources	
Provision of training	
Bringing market close to the farmers	
Other (specify)	

SECTION L: FOOD SECURITY

1. How would you describe the availability of food for your household throughout the year? **Please select all that apply:**

Availability of food	**Tick**
Always available in required quantities	
Limited availability, with occasional shortages	
Insufficient at certain times, leading to food insecurity	
Varied throughout the year, with periods of sufficiency and scarcity	

2. Have you experienced any periods of food shortage or limited access to nutritious food?

Yes	No

3. If yes, indicate when?

During the dry season	During the rainy season	During times of financial challenges

4. How can better water management help improve food security for you and your family?

Increase crop production and yield	Enable cultivation of diverse and nutritious crops	Improve water availability for crops

Thank you for your participation

PART 2: KEY INFORMANT INTERVIEWS SCHEDULES

A. STAKEHOLDER QUESTIONNAIRE

The purpose of this questionnaire is to “evaluate pathways to sustainable agricultural water management: Case studies of smallholder communities in rural and peri-urban areas of the Limpopo and Gauteng Provinces.” The information of each participant will be kept private. Please make sure that you only answer questions that are associated with the pathway that you are currently farming under. Use an "X" next to the code to answer the questions where appropriate. Should you feel uncomfortable answering any question, please leave the item blank and answer the next question.

INTERVIEWER DECLARATION:	
I, ...	
Declare that I will ask this questionnaire as it will be laid out. I declare that all responses recorded will be the true responses of the respondent and that I have thoroughly checked the questionnaire.	
Signature	:..
Date	:..
Organization Name	:..
Stakeholder role in the organization	:..

1. How familiar are you with the water policies and regulations that affect smallholder farmers in this area?

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

2. How familiar are you with the Irrigation Development and Agricultural Water Management (IDAWM) framework and its objectives?

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

3. What is your role in implementing these water policies and regulations for smallholder farmers?

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

4. How effective do you think your organization has been in implementing these policies and regulations for smallholder farmers?

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

5. What are the biggest challenges you face in implementing these policies and regulations for smallholder farmers?

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

6. How do you involve smallholder farmers in the decision-making process related to water policies and regulations?

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

7. In your opinion, what is the most important thing that smallholder farmers need in order to successfully comply with water policies and regulations?

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

8. How do you monitor and enforce compliance with water policies and regulations among smallholder farmers?

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

9. What kind of support do you provide to smallholder farmers who are struggling to comply with water policies and regulations?

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

10. Are there any areas where you feel that the current water policies and regulations are inadequate or could be improved? If so, please explain.

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

11. In your opinion, what role do smallholder farmers play in shaping water policies and regulations?

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

B. SWOT ANALYSIS FOR IDAWM IN SOUTH AFRICA

1. INTRODUCTION

Stakeholder engagements to be conducted in order to identify the strengths, weakness, opportunities and threats (SWOT) for each of the pathways in the country. A SWOT analysis to be conducted in order to set out a series of conclusions which they seek to respond to different strategies for the four development pathways of: (1) improved water control and watershed management in rainfed farming; (2) farmer-led irrigation development; (3) irrigation scheme development and modernization; and (4) unconventional water use for irrigation.

Strengths and weakness are internal factors considered in the country, while opportunities and threats are posed by external factors. The internal factors, strengths and weakness, give certain advantages or disadvantages of the agricultural water management in the country. On the other hand, the external analysis examines the opportunities and threats that exist independently of the study area.

1.1 SWOT Matrix for rainfed farming

In your opinion:

- What are the strengths for implementing rainfed farming in the country?

- What are the weaknesses for implementing rainfed farming in the country?
- What are the opportunities for implementing rainfed farming in the country?
- What are the threats to implementing rainfed farming in the country?

	Positive/Helpful to achieving the goal	Negative/Harmful to achieving the goal
INTERNAL Origin facts/ factors of the system	**Strengths** Things that are good now, and should be maintained, built on them and used as leverage	**Weaknesses** Things that are bad now, and should be remedied, changed or stopped.
EXTERNAL Origin facts/ factors of the environment in which the system operates	**Opportunities** Things that are good for the future, and should be prioritized, captured, exploited, built on, and optimized	**Threats** Things that are bad for the future, put in plans to manage them or counter them

1.2 SWOT Matrix for farmer-led irrigation development

In your opinion:

- What are the strengths for implementing farmer-led irrigation development in the country?
- What are the weaknesses for implementing farmer-led irrigation development in the country?
- What are the opportunities for implementing farmer-led irrigation development in the country?
- What are the threats to implementing farmer-led irrigation development in the country?

	Positive/Helpful to achieving the goal	Negative/Harmful to achieving the goal
INTERNAL Origin	**Strengths**	**Weaknesses**

facts/ factors of the system	Things that are good now, and should be maintained, built on them and used as leverage	Things that are bad now, and should be remedied, changed or stopped.
EXTERNAL Origin facts/ factors of the environment in which the system operates	**Opportunities** Things that are good for the future, and should be prioritized, captured, exploited, built on, and optimized	**Threats** Things that are bad for the future, put in plans to manage them or counter them

1.3 SWOT Matrix for irrigation scheme development and modernization

In your opinion:

- What are the strengths for implementing irrigation scheme development & modernization in the country?
- What are the weaknesses for implementing irrigation scheme development & modernization in the country?
- What are the opportunities for implementing irrigation scheme development & modernization in the country?
- What are the threats to implementing irrigation scheme development & modernization in the country?

	Positive/Helpful to achieving the goal	**Negative/Harmful to achieving the goal**
INTERNAL Origin facts/ factors of the system	**Strengths** Things that are good now, and should be maintained, built on them and used as leverage	**Weaknesses** Things that are bad now, and should be remedied, changed or stopped.

EXTERNAL Origin facts/ factors of the environment in which the system operates	**Opportunities** Things that are good for the future, and should be prioritized, captured, exploited, built on, and optimized	**Threats** Things that are bad for the future, put in plans to manage them or counter them

1.4 SWOT Matrix for unconventional water use for irrigation

In your opinion:

- What are the strengths for implementing unconventional water use for irrigation in the country?
- What are the weaknesses for implementing unconventional water use for irrigation in the country?
- What are the opportunities for implementing unconventional water use for irrigation in the country?
- What are the threats to implementing unconventional water use for irrigation in the country?

	Positive/Helpful to achieving the goal	**Negative/Harmful to achieving the goal**
INTERNAL Origin facts/ factors of the system	**Strengths** Things that are good now, and should be maintained, built on them and used as leverage	**Weaknesses** Things that are bad now, and should be remedied, changed or stopped.

EXTERNAL Origin facts/ factors of the environment in which the system operates	**Opportunities** Things that are good for the future, and should be prioritized, captured, exploited, built on, and optimized	**Threats** Things that are bad for the future, put in plans to manage them or counter them

C. ENABLING ENVIRONMENT

Degree of support of legislation, policies, and strategies for the four development pathways

Act/Policy/Strategy	Pathway 1*	Pathway 2	Pathway 3	Pathway 4
The Constitution (No. 108 of 1996)				
National Water Act (No. 36 of 1998)				
Water Services Act (No. 108 of 1997)				
The National Water Policy (1997)				
National Water Policy Review (2013)				
National Water Resources Strategy (2013)				
National Water Conservation and Demand Management Strategy 2004				
Conservation of Agricultural Resources Act (No. 43 of 1983)				
Agricultural Research Act, 1990 (No. 86 of 1990)				
Policy on Agriculture in Sustainable Development				
Strategic Plan 2020 – 2025, Agriculture, Land Reform and Rural Development				
Agriculture and Agro-Processing Master Plan 2022				
Land Reform: Provision of Land and Assistance Act, 1993 (Act No. 126 of 1993)				
Key: Strong	Moderate	Weak	None	

* Pathway 1 = Improved water control and watershed management in rainfed farming; Pathway 2 = Farmer-led irrigation development; Pathway 3 =Irrigation scheme development and modernization; and Pathway 4 = Unconventional water use for irrigation.

D. INSTITUTIONAL AND FINANCIAL SUPPORT

What is the status of institutional support for:

(a) Rainfed farming?

(b) Farmer-led irrigation development?

(c) Irrigation scheme development and modernization?

(d) Unconventional water use for irrigation?

What is the status of financing for?

(a) Rainfed farming?

(b) Farmer-led irrigation development?

(c) Irrigation scheme development and modernization?

(d) Unconventional water use for irrigation?

E. OPPORTUNITIES AND CHALLENGES

What are the key opportunities of implementing successful and sustainable:

(a) Rainfed farming in the country?

(b) Farmer-led irrigation development in the country?

(c) Irrigation scheme development and modernization in the country?

(d) Unconventional water use for irrigation in the country?

What are the key challenges of implementing successful and sustainable:

(a) Rainfed farming in the country?

(b) Farmer-led irrigation development in the country?

(c) Irrigation scheme development and modernization in the country?

(d) Unconventional water use for irrigation in the country?

Thank you for your participation

Appendix B: Small-scale irrigation schemes in Thulamela District, Limpopo Province

Name of the irrigation scheme	Area	Hectares	Number of beneficiaries	Operation	Source of water	Challenges
1. Tshiombo irrigation scheme (There are seven blocks)	• Mutshenzheni • Mbahela • Maraxwe • Mianzwi • Tshiombo • Matombotswa • Matangari	1100	930	Operational	The water flow from the river to the field through the canal	• The main canal is broken and the earth dams that supply water to the irrigation schemes are silted • Poor marketing • The infields roads are badly damaged. • The Irrigation schemes have no fence
2. Malavuwe	Malavuwe	26	24	Operational	They pump water from the river to the field using the pump engine	• The pump engines not working.
3. Murara	Murara	37	29	Operational	They use water from the river through a canal	• The main canal is broken and the earth dams that supply water to the irrigation schemes are silted
4. Dopeni	Dopeni	180	132	Operational	They use water from the river through a canal	• The irrigation scheme has no fence and the fence is dilapidated. • The main canal is broken and the earth dams that supply water to the irrigation schemes are silted

Name of the irrigation scheme	Area	Hectares	Number of beneficiaries	Operation	Source of water	Challenges
5. Dzindi	Dzindi	137	105	Operational	They use water from the river through a canal	• The Irrigation scheme have no fence and the fence is dilapidated. • There is also an encroachment of residential area in the schemes due to poor water supply.
6. Khumbe	Khumbe	147	127	Operational	They use water from the river through a canal	• The main canal is broken and the earth dams that supply water to the irrigation schemes are silted
7. Palmary Vile	Muledane	92	68	Operational	They use water from the river through a canal	• The main canal is broken and the earth dams that supply water to the irrigation schemes are silted
8. Tshikonelo	Tshikonelo (Under Collins Chabane Municipality)	83	58	Under revitalization	They pump water from the river using an engine	• The scheme is still under revitalization
9. Tswinga	Tswinga	17	7	Not operational	They were using a pump to get water from the river	• There is poor supply of water/ no water for irrigation due to the pump engines not working.
10. Mbahe	Mbahe	10	10	Not operational	They were using floppy irrigation systems	• The floppy irrigation systems need some repairing

Name of the irrigation scheme	Area	Hectares	Number of beneficiaries	Operation	Source of water	Challenges
11. Tshidzini	Tshidzini	5.7	25	Not operational	They were using a pump to get water from the river	• Installation of pump

Appendix C: Guidelines for reuse in agriculture and aquaculture in South Africa

Category	Reuse conditions	Exposed groups	Irrigation technique	Intestinal nematodes[b] (arithmetic mean no of eggs per litre[c])	Faecal coliforms (geometric mean no per 100 mL[d])	Wastewater treatment expected to achieve required microbiological quality
A	**Unrestricted irrigation** A1 Vegetable and salad crops eaten uncooked, sports fields, public parks	Workers, consumers, public	Any	⩽ 0.1[1]	⩽ 1,000	Well-designed series of waste stabilization ponds (WSPs), sequential batch-fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g., conventional secondary treatment supplemented by either

						polishing ponds or filtration and disinfection)
	A2 fruit trees	Workers, consumers	Not spray / sprinkler	⩽ 1	Not applicable	Retention in 2-3 WSP in series or WSTR depending on number of eggs in raw wastewater or equivalent treatment (e.g., conventional secondary treatment supplemented, if necessary, by either polishing ponds or filtration)
B	**Restricted irrigation** Cereal crops, industrial crops, fodder crops, pasture and trees	B1 Workers (no children <15 years), nearby communities	(a) Spray / sprinkler	⩽ 1	⩽ 1,000	Retention in WSP series inc. one maturation pond or in sequential WSTR or equivalent treatment (e.g., conventional secondary treatment supplemented by either polishing ponds or filtration)
		B2 as B1	(b) Other	⩽ 1	Not applicable	As for category A2
		B3 Workers including children	Any	⩽ 0.1[e]	⩽ 1,000	As for category A1
C	**Localised irrigation** of crops in Category B if exposure of workers and the public does not occur	None	Trickle, drip or bubbler	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation.

[a] In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.

[b] Ascaris and Trichuris species and hookworms.

[c] During the irrigation season (if the wastewater is treated in WSP or WSTR which have been designed to achieve these egg numbers, then routine effluent quality monitoring is not required).

[d] During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly).

[e] Irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground.

[f] ≤1 egg per litre if (i) conditions are hot and dry and spray irrigation is used, or (ii) if wastewater treatment is supplemented with anti-helminthic chemotherapy campaigns in areas of wastewater re-use.
(Source: Blumenthal et al., 1999)

Appendix D: Reuse types in the South African Guide compared to similar guides

South African Guide (1978) *Irrigation of*	**WHO Health Guidelines (1989)** *Reuse conditions*	**US-EPA/USAID Guidelines (1992)** *Reuse type*	**Recommended revised microbiological guidelines (1999)** *Reuse conditions*	**Examples for an international guideline (2001)** *Application*
• Vegetables and crops that are eaten raw by humans. • Lawns at swimming pools, children's play parks and crèche's • Sports fields where limited contact is made with the field, e.g., golf-, cricket-, hockey-, soccer fields, et cetera. • School grounds and public parks	**Category A type use** • Irrigation of crops likely to be eaten uncooked • Sports fields, public parks	**Agricultural Reuse** • Any food crop, food crops not commercially processed, including crops eaten raw **Urban Reuse** • All types of landscape irrigation (e.g., golf courses, parks, cemeteries).	**Category A type use** **Unrestricted irrigation** • A1 Vegetable and salad crops eaten uncooked, sports fields, public parks • A2 Fruit trees	**Food crops** • Foods eaten raw including salad vegetables and root crops, RW contacts edible portion • Foods cooked, processed, before eating • Orchards - No RW contact on edible portion. **Urban and residential** • Sporting fields, golf courses, parklands, open space, landscaping, fire protection
• Crops for human use not eaten raw (i.e., fruits, vegetables and sugar cane) • Cultivation of cut-flowers • Fruit trees and vineyards for cultivation of fruit which is eaten raw by humans	**Category B type use** • Irrigation of cereal crops • Industrial crops • Fodder crops • Pastures and trees	**Agricultural Reuse** • Food crops commercially processed • Surface irrigation of Orchards and Vineyards	**Category B type use** **Restricted irrigation** • Cereal crops, industrial crops, fodder crops, pasture and trees	**Non-food crops** • Silviculture, turf farms • Fodder, fibre and seed crops **Pasture animals and fodder** • Stock water • Pasture and fodder for dairy cattle and pigs

• Pasture for livestock • Pasture for dairy animals • Crops not for grazing but as dry feed • Crops cultivated only for use as seeds				• Pasture and fodder for beef cattle, sheep • Dairy wash down water
• Parks - only for embellishment of flower gardens, traffic islands et cetera viz. not recreational areas • Tree plantations • Nursery - Cut-flowers excluded • Any park or sports fields only during development as well as before opening the allowing activities.	**Category C type use** • Localised irrigation of crops in Category B if exposure to workers and the public does not occur		**Category C type use** • Localised irrigation of crops in Category B if exposure of workers and the public does not occur	**Urban and residential** • Residential gardens, car washing, pavement washing, toilet flushing • Sporting fields, golf courses, parklands, open space, landscaping, fire protection
• Mines and industries: ore dressing, dust control, et cetera • Dust control on roads				**Commercial and industrial** • Open systems, minimal aerosols • Road making, soil compaction concrete mixing, dust suppression

(Source: Jagals and Steyn, 2002)

Appendix E: Summary of pieces of IDAWM-related legislation

Name of Act/Legislation	Sector	Relation to IDAWM
Constitution of the Republic of South Africa Act 1996 (Act 108 of 1996)	All Sectors	The supreme law of the SA embraces human rights principles and sets forth the right of access to water as part of a list of social and economic rights. These include the right to a healthy environment, housing, health care, food, security, education, and culture. The state must take legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights".
The National Water Act (NWA) 36 of 1998	Water	The NWA recognises that water in South Africa is scarce and unevenly distributed and belongs to all; and that the government is responsible for water resources and their use. This should be sustained in a sustainable way by means of, inter alia, an integrated water catchment management of all water resources, and where appropriate, the delegation of management functions to a regional or catchment level, to enable everyone to participate. The NWA requires the development of Water Management Plans by irrigation schemes, which involve the analysis of current water use, the setting of targets for improved water efficiency and planning of realistic means to reach targets.
Water Service Act (WSA) of 1997 (Act 108 of 1997)	Water	The WSA provide the fundamental governing framework for water services institutions, which are primarily municipalities, giving effect to the Bill of Rights by providing for access to essential water supply and sanitation services necessary to secure sufficient water and an environment not harmful to human health or well-being.
Conservation of Agricultural Resources Act (CARA) 43 of 1983	Agriculture	The Act aims to promote the conservation of the soil, water sources, and vegetation, and the combating of weeds and invader plants. The Act provides for control over the utilization of the natural agricultural resources of the country.
Agricultural Research Act No.86 of 1990	Agriculture	The Act aims at improving the country's agricultural sector through research and development. The fields of research include AWM areas such as rainwater harvesting, irrigation, wastewater reuse in agricultural, climate smart agriculture (CSA), and conservation agriculture (CA)
Land Reform: Provision of Land and Assistance Act (Act No. 126 of 1993 as	Agriculture	The Act provides, in Section 10, the government with the power to utilize money from Parliament to support small-scale farmers through advance, subsidy, grant, maintenance, planning, development or improvement of property and

Name of Act/Legislation	Sector	Relation to IDAWM
amended in 2008)		capacity building, skills development, training and empowerment.
Restitution of Land Rights Acts, 1994 (Act No. 22 of 1994 as amended)	Agriculture	The Act aims to provide restitution for land rights to individuals or communities who were dispossessed of such rights after 19 June 1913 due to past racially discriminatory laws or practices. In this way, farmers may have secured tenure of land for AWM development.
National Environmental Act (NEMA) (Act 107 of 1998)	Environment	The Act provides the framework for enforcing Section 24 of the Constitution, which guarantees everyone the right to an environment that is not harmful to their health or well-being. The environmental management framework (EMF) of the Act focusses on critical environmental conflict areas which include conservation, natural resources protection, land-use planning, waste management, river health, and groundwater use and quality.
National Environmental Management: Waste Act (NEMWA) (Act No 59 of 2008)	Environment	The NEMWA provides measures for preventing pollution, ecological degradation, and securing ecologically sustainable development. The act covers institutional arrangements, national norms and standards, specific waste management measures, licensing and control of waste management activities, remediation of contaminated land, a national waste information system, compliance, and enforcement.
National Health Act 61 of 2003	Health	The law also covers matters related to health services, such as norms and standards, health establishments, health workers, health information, and health research, waste management, water quality monitoring, and environmental pollution control. Some of the norms and standards guide the use of wastewater in irrigation
Climate Change Act 22 of 2024	Environment	Provisions of the Act are based on the principle that include measure to secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development. Both rainfed and irrigated agriculture systems are affected by climate change and hence these principles apply to all the IDAWM practices.
Land and Agricultural Development Bank Act 15 of 2002	Agriculture	The Land and Agricultural Development Bank Act 15 of 2002 establishes the Land and Agricultural Development Bank whose sole objective is to serve South African commercial and emerging agriculture by bringing specially designed financial services within the reach of farmers across the nation. These services enable farmers to finance land, equipment,

Name of Act/Legislation	Sector	Relation to IDAWM
		improve assets and obtain production credit[20]. The bank supports rainfed and irrigation farmers (farmer-led and irrigation scheme farmers). Although the bank does not have explicit provisions for supporting wastewater use for irrigation, it is expected that smallholders who use wastewater for irrigating their field may obtain financial support from the bank

[20] Our Business (landbank.co.za)

Appendix F: Summary of IDAWM-related policies

Name of Instrument	Sector	Relation to IDAWM
The White Paper on Agriculture of 1995	Agriculture	The White Paper acknowledges that water in South Africa is a limited resource and is, naturally, essential to both urban and rural areas leading to conflict among users. In the past water tariffs were heavily subsidised by the Government but now, as detailed in the White Paper, the Government ensures that the benefits and real cost of natural resources are reflected in the pricing of resources so as to discourage inefficient use of water.
Policy on Agriculture in Sustainable Development – 8th Draft	Agriculture	Sustainable use of water in agriculture should be accompanied by better husbandry of soils, fertilizers, improved plant varieties, etc. The policy promotes increasing the efficiency of water use in agriculture and improving irrigation system performance in a sustainable manner as a key goal for agricultural development.
Rural Development Framework Policy	Rural Development	The policy introduced the River Valley Catalytic Programme (RVCP) which offers a framework for integrating water planning and management with environmental, social and economic development along the river banks (watershed development). The AWM-related components of the RVCP include soils and land management, water management, crop management, and afforestation
Rural Economy Transformation Model One District One-Agri-Park/Every Municipality Policy	Agriculture	The policy led to the establishment of Agri-Parks which operate like modern irrigation schemes that demonstrate how available high value agricultural land and other important production resources will be most beneficially utilized.
Policy Framework for the Recapitalization and Development Programme (RADP) of the Department of Rural Development and Land Reform (DRDLR)	Rural Development	The RADP policy aims to support emerging farmers (small-scale rainfed and farmer-led irrigation farmers) by providing specialised agricultural financing in the form of financial guarantees to those financial institutions that the farmers are indebted to.
National Water Policy for South Africa - White Paper April 1997	Water	Under water resource management activities, the Paper identifies the following activities: water use authorization; water resource protection; water utilization and conservation; water pricing; water resource development; public safety and disaster prevention; monitoring, assessment and auditing; and international cooperation.
National Environmental Health Policy 2013	Environment	The policy defines Environmental Health Services as the assessment, monitoring, correction, control and prevention of environmental factors that can

		adversely affect human health. This includes, but not limited to, anticipation and identification of environmental health hazards and risks associated with rainfed and irrigated farming systems, and the use of wastewater for irrigation.
National Climate Change Response Policy: White Paper 2011	Environment	The policy considers agriculture as the largest consumer of water (through irrigation) and that it is vulnerable to changes in water availability, increased water pollution and soil erosion from more intense rainfall events and increased evapotranspiration. Under-resourced, small-scale and subsistence farmers are particularly vulnerable to the impacts of climate change. The policy supports research and development system which prioritise technologies for climate change adaptation within rural areas, including low water-use irrigation systems, improved roll-out of rainwater harvesting strategies, and drought resistant seed varieties
Environmental and Social Sustainability (ESS) Policy	Agriculture	The Environmental and Social Sustainability (ESS) Policy of the Land and Agricultural Development Bank of South Africa outlines the bank's commitment to responsible practices. The policy aims to promote land stewardship, protect the environment, and support communities impacted by the bank's activities. The policy commitments of the Bank include promoting land stewardship through the efficient use of resources, prevention and pollution reduction and enhancement of biodiversity protection, which supports sustainable use of wastewater for irrigation

Appendix G: Summary of IDAWM-related plans, strategies, programmes, and networks

Name of Instrument	**Type of Instrument**	**Sector**	**Relation to IDAWM**
National Development Plan 2030	Plan	All	Under the agricultural sector, the NDP actions include substantial investment in irrigation infrastructure, including water storage, distribution and reticulation throughout the country where the natural resource base allows, as well as in water-saving technology.
National Water and Sanitation Master Plan 2018	Plan	Water	The key planned actions of the NW&SMP include to reduce the water demands and water losses at all major irrigation and agricultural schemes by 2030

Name of Instrument	Type of Instrument	Sector	Relation to IDAWM
Agriculture and Agro-Processing Master Plan	Plan	Agriculture	The plan aims at ensuring food security, expanded production (under rainfed and irrigated agriculture), and employment creation, enabling market expansion, improving market access, and facilitating trade, and developing localized food, import replacement, and expanded agro-processing.
National Water Resources Strategy of 2004 (1) and 2013 (2)	Strategy	Water	The main objective of the strategy is to provide a framework for the protection, use, development, conservation, management, and control of water resources for the whole country. The NWRS supports a national water harvesting programme (rainwater and fog harvesting whereby the collected water is primarily intended for irrigation of food gardens to improve food sufficiency and for other productive water uses.
National Water Conservation and Water Demand Management Strategy (2004)	Strategy	Water	The NWC/WDMS is a crucial initiative aimed at promoting water use efficiency. It supports application of water WC/DM principles in the irrigation and farming sectors which have a significant effect on the availability of water to other sectors and the protection of water resources.
National Strategy for Water reuse (2011)	Strategy	Water	The strategy stresses that considerable potential exists to substantially expand the use of treated wastewater for irrigation purposes in the country. This will bring many benefits. Irrigation is often labour intensive and expanding the area under irrigation may create jobs. Wastewater return flows are typically available close to urban areas and thus close to urban markets for agricultural produce, provided suitable land is available for irrigation.
Irrigation Strategy for South Africa	Strategy	Agriculture	The Irrigation Strategy for South Africa set a target of an increase of more than 50% of irrigated land in South Africa over the next 10 to 20 years. In order to address water scarcity and climate challenges, the strategy supports adopting water-wise

Name of Instrument	Type of Instrument	Sector	Relation to IDAWM
			practices, efficient irrigation techniques, and sustainable water management.
Water for Growth and Development Framework (2009)	Framework	Water	The purpose of the framework is to guide actions and decisions that ensure water security in terms of both quantity and quality. The framework supports provision of incentives to encourage farmers to balance their risks of water supply against using more efficient irrigation systems
Strategic Plan 2020–2025 of the Department of Agriculture, Land Reform, and Rural Development	Strategy	Agriculture	As all water users are required to implement electronic water measurement instruments to monitor their water usage, abstraction and storage rates so that these records could be submitted to the DWS weekly, the plan aims to assist agricultural users (irrigation farmers) so that they are able to reduce water usage, adapt to produce crops with higher returns and that they can introduced technologies regarding water-efficiency to monitor usage
Second National Action Programme for South Africa to Combat Desertification, Land Degradation and the effects of Drought (2018-2030)	Programme	Environment	The programme recognizes that unsustainable human activities, including agricultural use of steep slopes and excessive irrigation, can lead to salinization of the soil and erosion
Strategic Water Partners Network 2011	Network	Water	The DWS, through the SWPN has implemented the WAS Release Module at several irrigation schemes. With the WAS, it is possible to release the correct amount of water from a source according to demand, thereby reducing wastage

Appendix H: Summary of IDAWM-related guidelines

Name of Instrument	Sector	Relation to IDAWM
The South African Guidelines for the	Health	The guidelines support the reuse of treated wastewater as well as greywater for

Permissible Reuse of Treated Sewage Effluents (1978)		irrigation. The guidelines stress that reuse of greywater holds the potential to contribute significantly to food security in poor communities by providing a source of both irrigation water and nutrients for crop plants.
South African Water Quality Guidelines for Irrigation Water Use	Water	The guidelines are intended to provide the information to make judgements on the fitness of water to be used for irrigation purposes, primarily for crop production. The guidelines are applicable to any water that is used for irrigation purposes, irrespective of its source (municipal supply, borehole, river, etc.) or whether or not it has been treated.
Guidelines for the reuse of treated wastewater	Environment	The guidelines were developed based on the reuse of effluent from waste stabilisation pond systems (WSP). The guidelines include use of treated wastewater for irrigation of crops.
Guidelines for sustainable reuse of effluent on land – a suggested approach	Environment	These guidelines are designed to promote on-land effluent recycling for beneficial purposes which also take into account environmental precautionary and sustainability principles.

Appendix I: Recently developed water governance instruments

Year	Governance instrument	Details
2019	National Water and Sanitation Master Plan (NWSMP) presented for implementation	The plan contained a comprehensive collection of actions required in relation to water infrastructure development, institutional reform and capital and financial investment, with specific timelines by which specified actions needed to be performed
2021	Draft regulations on hydraulic fracturing (fracking) published	The Regulations identify prohibited activities and prohibited geographic areas for the use of hydraulic fracturing technology, which include the use of potable water for hydraulic fracturing activities and the use of municipal water treatment facilities for the disposal of wastes from hydraulic fracturing operations
	Draft regulations for the use of water for fracking and underground gasification	The purpose of these Regulations is to protect water resources in order to avoid and minimise detrimental and cumulative impacts on the water resource caused by the exploration and production of natural hydrocarbons onshore.
2022	Blue Drop Report on water quality released	The Blue Drop report is a comprehensive assessment of the state of all drinking water

Year	Governance instrument	Details
		systems (including water treatment works) in the country
	Green Drop Report on water quality released	The Green Drop report is a comprehensive assessment of the state of all waste water treatment systems in South Africa, including municipal, Department of Public Works and private waste water treatment systems
	Draft national pricing strategy for raw water use charges	This pricing strategy provides the framework for the pricing of the use of water from South Africa's water resources, i.e., the use of raw (untreated) water from the water resource and/or supplied from government waterworks and the discharge of water into a water resource or onto land. The strategy seeks to facilitate reform in the sector as well to provide transparency and predictability to water users on how water will be priced. It is intended to support the achievement of the goal, as articulated in the National Water Resources Strategy, that water is efficiently and effectively managed for equitable and sustainable growth and development.
	Draft national water infrastructure agency bill	The Bill seeks to provide for the incorporation and establishment of the South African National Water Resources Infrastructure Agency Limited as a state-owned company and major public entity owned and controlled by the State to administer, fund, finance, provide, operate, maintain and provide advisory services in respect of national water resources infrastructure in accordance with sections 10, 11, 24, 27(1)(b) and 27(2) of the Constitution and national policy.
2023	Notice to update water registration information	The notice requested that the following water users should send an application for amendment of the registration of water use information: those that take water from a water resource (Section 21(a) of the NWA, 1998); those storing water (section 21(b) of NWA, 1998); and those engaged in a stream flow reduction activity contemplated in section 36 (Section 21(d) of the NWA, 1998).
	Notice to register certain wastewater uses	Registration Guide for the registration of Waste Discharge Water Use information under the NWA, (Act 36 of 1998)
	Amendments of the general authorisation in respect of impeding or diverting water and altering of watercourses	The Revised General Authorisation under the National Water Act addresses water use activities related to impeding or diverting water flow in a watercourse (section 21(c)) and altering the bed, banks, course, or characteristics of a watercourse (section 21(i)) of the NWA (Act 36 of 1998)

Year	Governance instrument	Details
	Revision of the regulations regarding the procedural requirements for water use licence applications and amendments	The DWS revised the regulations related to water use license applications to achieve the following key objectives: table Allocation: The reforms focus on ensuring a fair distribution of water use rights among different users. :edural Requirements: The amendments address procedural aspects related to new water use license applications. This includes reviewing timeframes and fees associated with the application process. uced Turnaround Times: The regulations aim to process license applications within 90 days instead of the previous 300 days. tional Aspects: The revised regulations also cover areas previously omitted, such as public participation and financial security for post-license rehabilitation. These changes are crucial for managing South Africa’s limited water resources effectively and ensuring equitable access for all users.
	Notice of intention to transform irrigation boards to WUAs	The notice invites irrigation boards to prepare proposals for their transformation into WUAs. This move aligns with section 91 of the National Water Act, 1998.
	Draft national climate change response strategy for the water and sanitation sector published	The objectives of the strategy include improved collaborative governance, increase investment in climate resilient infrastructure, manage knowledge and information, sustainable manage water resources and sanitation, reduce the carbon footprint of the water and sanitation sector.
	Draft national water amendment bill and water services amendment bill	The National Water Amendment Bill proposes sweeping changes to water governance in South Africa. Concurrence: The bill ensures concurrence between the Minister, the Minister responsible for mineral resources, and the Minister responsible for environmental affairs when amending provisions related to prospecting, exploration, mining, or production activities
2024	Water and sanitation services policy on privately owned land introduced	The Water and Sanitation Services Policy on Privately Owned Land was approved by Cabinet in November 2023 and gazetted in February 2024. This policy aims to address the provision of water services to residents living on privately owned land in South Africa. Many people living on privately owned land lack access to basic water and sanitation services. The policy outlines the government’s intentions regarding water and sanitation services provision for residents on

Year	Governance instrument	Details
		privately-owned land. It establishes a framework for enhancing services in areas where traditional municipal

(Source: Liebenberg, 2024)

Appendix J: Types of loans meant for farmers from formal financial institutions

Loan type	Purpose	Loan term	Security required	Repayment terms
Short term loan	Used to finance agricultural inputs and working capital for crop enterprises	Maximum 5 years (reviewed annually). Loan renewed at the end of the term.	First bond over fixed property or through additional security arranged in agreement with the bank.	Repayable in full annually or when proceeds of the crops are received.
Medium term loans	Used to finance needs such as: Establishment of perennial crops, Structural and general, Infrastructure improvements, Purchase of movable assets, Purchase of livestock.	Term up to 15 years	First bond over fixed property or through additional security arranged in agreement with the bank.	Linked to cash flow cycles of the business: Monthly/quarterly/ biannually/annually.
Asset finance	Used to finance assets such as vehicles, tractors, agricultural equipments (assets not covered under medium term loan) and other movable assets used in agriculture.	Term depends on the purpose of the loan. Up to 12 years.	Titleholder, general notarial bonds over the assets or through additional security arranged in agreement with the bank.	Linked to cash flow cycles of the business: Monthly/quarterly/ biannually/annually
Long term loans	Used to finance: Land, Repayment of debt incurred when purchasing land, Purchase and installation of machinery and equipments.	Depends on the purpose of the loan. Term up to 25 years	First bond over fixed property	Linked to cash flow cycles of the business: Monthly/quarterly/ biannually/annually
Revolving credit facility	Used to finance short term capital requirement, general and operational needs of the business such as cash crops.	Up to 5 years (reviewed annually.		Repayable in line with the income streams and structured based on cash flow cycles of the business. It is managed through pre-approved limits by the bank.

Value chain finance	It allows the financial entity to provide the production finance to a farmer against a written agreement between the farmer and the buyer for cultivation and sale of specific quality, quantity, grade, and variety of a commodity based on a specific price setting mechanism that allows the value of the contract to be determined over the loan term. Both the buyer and the farmer should meet the eligibility conditions set by the credit process.	Season term, renewable annually upon review with the client or at the end of production.		Cession of proceeds from the sale of crops financed. Cession of comprehensive insurance and cession of off-taker agreement or delivery contract as a specified price. Other additional security arranged in agreement with the financial entity.

Appendix K: SWOT analysis for rainfed farming system

	POSITIVE	NEGATIVE
INTERNAL	**STRENGHTS** • Lower capital requirements (Rainfed farming requires low financial investment compared to irrigated systems, making it accessible to farmers). • Deep indigenous knowledge (Smallholder farmers bring valuable indigenous knowledge, allowing them to adapt practices effectively to local environmental conditions and enhancing sustainability and resilience) • Effective management by commercial farmers (Commercial farmers often have better management practices, enhancing productivity and resilience in rain-fed farming systems).	**WEAKNESSES** • Limited market access (Poor market linkages reduce income opportunities and hinder investment in farming improvements). • Aging farmer population (Elderly farmers face manpower shortages and risk losing traditional knowledge without younger involvement). • Small land sizes (Limited land size restricts scalability, reducing overall productivity and profitability) • Resource and financial constraints (Farmers face significant financial challenges, including limited subsidies, lack of inputs, and overall resource constraints, hindering their ability to sustain operations. • Poor land and water management practices (Some farmers, particularly those with less experience, lack proper management skills, reducing efficiency and sustainability). • Lack of training (Inadequate training in modern agricultural practices leads to suboptimal farming outcomes and limited innovation).
EXTERNAL	**OPPORTUNITIES** • Supportive sectoral laws, policies, strategies and plans • Rising demand for food security (Growing food security concerns make rain-fed farming crucial for providing local, sustainable food sources).	**THREATS** • Continued land degradation (Without intervention, ongoing land degradation could lead to long-term declines in productivity). • Erratic Rainfall Due to Climate Change (Unpredictable rainfall threatens yields, necessitating

	• Research and development potential (There is significant scope for R&D in drought-resistant crops and soil management, improving system viability). • Reduced operational costs (Lower energy and input costs make farming operations more cost-effective and increase the viability of rain-fed farming). • Climate-smart agriculture innovations (Integrating conservation agriculture (CA) practices, including the use of indigenous and adaptable crops, can improve sustainability and resilience against climate variability) • Indigenous and adaptable crops (Cultivation of indigenous crops that are well adapted to local climates can enhance productivity and food security).	adaptive strategies like diversified cropping). • Water scarcity (Being in a water-scarce country poses a significant challenge, as limited water availability directly impacts crop yields and farming viability). • Climate change (Climate change increases unpredictability in weather patterns, leading to challenges in maintaining consistent crop production. It also exacerbates extreme weather events, such as floods, which can damage crops and infrastructure, disrupting farming activities and reducing overall productivity. • Floods (Extreme weather events, such as floods, can damage crops and infrastructure, disrupting farming activities and reducing overall productivity).

Appendix L: SWOT analysis for farmer-led irrigation development

	POSITIVE	NEGATIVE
INTERNAL	**STRENGHTS** • Adaptation to new technologies **(**Farmers are able to adopt and integrate new irrigation systems, technologies, and cultivars, provided they have the financial capacity to do so). • Independence in decision-making (Farmers have the ability to monitor their operations and make independent decisions, allowing for quick and adaptive responses to challenges). • Access to new technologies with conditions (New scientific and technological systems are available, though access	**WEAKNESSES** • Lack of water usage data (There is a lack of accurate statistics on water usage by farmer-led irrigation farmers, complicating reporting to the Department of Water and Sanitation). • Insufficient funding for irrigation systems (farmers struggle with limited funding, making it difficult to install or maintain effective irrigation systems). • Inadequate skills in irrigation scheduling (Many farmers lack the necessary skills for efficient irrigation scheduling, leading to inefficient water use).

	depends on the farmer's financial capacity). • Personal drive (Initiatives are driven by the farmers themselves, leading to strong commitment and adaptability). • Positive yield (Farmer-led irrigation often results in improved crop yields, boosting food security and income).	• Poor record-keeping (Lack of record-keeping hampers effective farm management and planning, reducing overall efficiency). • Lack of government support (Limited or no support from government hinders the expansion and sustainability of irrigation projects. • Farmers often work in isolation with limited external support. • Sustainability of irrigation depend on the farmer's potential and skills.
EXTERNAL	**OPPORTUNITIES** • Supportive sectoral laws, policies, strategies and plans. • Potential for water licensing (As independent farmers, there is an opportunity to obtain water licenses from the Department of Water and Sanitation, enhancing water security). • Interest from younger generation (Growing interest from younger farmers offers potential for innovation and long-term sustainability in irrigation practices). • Established market linkages (Access to established markets enhances profitability and provides a stable income stream for farmers using irrigation).	**THREATS** • Lack of proper soil management practices (Poor soil management practices can lead to soil degradation, reducing the long-term viability of farming operations). • Lack of government/extension support (Insufficient government or extension support limits access to training, resources, and assistance, hindering farm development). • Impact of climate change (Climate change poses a significant threat, leading to unpredictable weather patterns, water scarcity, and increased vulnerability of crops). • Unlawful operations (Many farmer-led irrigation farmers operate without proper registration as water users, risking legal issues and potential shutdowns).

Appendix M: SWOT analysis for irrigation scheme development and modernisation

	POSITIVE	**NEGATIVE**
INTERNAL	**STRENGHTS** • Operating within a well-defined governance system that supports scheme members which facilitates easy access to state support (Government support provides financial	**WEAKNESSES** • Weak scheme governance (Ineffective management and leadership within the schemes lead to inefficiencies and hinder long-term sustainability).

	resources, technical assistance, and policy backing, crucial for the success of irrigation schemes. • Controlled water management (Water resources are effectively controlled, managed, and allocated within the scheme, ensuring efficient use and distribution). • Bulk crop production reduces costs (Producing a large volume of a single crop reduces transport costs, enhancing cost efficiency in the scheme).	• Lack of transformation (Slow adaptation to new practices or organizational changes limits the potential for growth and modernization). • Poor technical support (Inadequate technical assistance hampers the effective operation and maintenance of irrigation systems, reducing their effectiveness). • Inefficient use of irrigation technology (Failure to fully utilize available irrigation technology results in suboptimal water use and reduced productivity). • Limited individual independence (Scheme members have limited ability to act independently, as decisions are controlled at the scheme level, which can limit flexibility and responsiveness). • Non-adherence to rules leads to conflicts (Some members do not follow the established rules, leading to conflicts within the scheme, which can disrupt operations and reduce overall effectiveness).
EXTERNAL	**OPPORTUNITIES** • Supportive sectoral laws, policies, strategies and plans. • Modernization and technology adoption (Upgrading irrigation schemes and adopting new technologies can boost food production, improve infrastructure, and enhance resource management, contributing to food security). • Co-operative organization (Encouraging cooperative structures among farmers can improve resource sharing, management, and collective bargaining power). • Rehabilitation and revitalization (There are opportunities for	**THREATS** • Resistant to change (Cultural and institutional resistance to new practices or technologies can slow down or block modernization efforts). • Government control (Excessive government control may limit flexibility and responsiveness to local needs, potentially stifling innovation and adaptability within the schemes). • Land tenure system issues (Unresolved land tenure issues can create uncertainty and limit investment in the scheme). • Land encroachment by communities (Encroachment by communities building houses on scheme land

	rehabilitating and revitalizing the irrigation scheme, which can improve infrastructure and efficiency). • Support from government (Government offers support to address water management and conservation challenges, providing guidance and resources). • Access to more funding (Increased access to funding can support modernization efforts and enhance the overall performance of the irrigation scheme).	poses a threat to the integrity and operation of the irrigation system).

Appendix N: SWOT analysis for unconventional water use for irrigation

	POSITIVE	**NEGATIVE**
INTERNAL	**STRENGHTS** • Readily available water resources (Unconventional water sources, such as treated wastewater, are often more readily available to farmers, providing a consistent supply for irrigation). • Consistent water availability (Water is consistently available for irrigation, although its usefulness depends on the volume and quality of the water source).	**WEAKNESSES** • Challenges with market certification (Obtaining market certification for crops irrigated with unconventional water can be challenging, potentially limiting market access). • Poor wastewater quality (Inadequate treatment of wastewater can lead to poor water quality, affecting crop health and safety). • Variable water quality (The quality of water can be inconsistent, potentially affecting crop health and soil quality. • Competition for water resources (There may be competition for water resources, especially in areas where water is scarce or where multiple users depend on the same source). • System adaptability issues (Certain irrigation systems, such as drip irrigation, may be prone to blockages when using

		wastewater, requiring specific adaptations or maintenance).
EXTERNAL	**OPPORTUNITIES** • Supportive sectoral policies, strategies and plans. • Legislative support (A supportive legal framework can create an enabling environment for the safe and efficient use of unconventional water sources in agriculture). • Capacity for increased wastewater use (Expanding the use of treated wastewater can enhance water availability for irrigation, especially in water-scarce regions such as South Africa). • Peri-urban agriculture (Per-urban areas provide opportunities for unconventional water use in irrigation, promoting sustainable agriculture within city environments. Hence there is potential to expand peri-urban irrigation around cities, leveraging unconventional water sources to support local agriculture). • Existence of clear guidelines and standards (Established clear guidelines for the use of wastewater in irrigation can ensure safe and effective practices, increasing adoption and trust).	**THREATS** • Potential health risks (Using poorly treated wastewater can pose health risks to both farmers and consumers, making it essential to ensure proper treatment and use practices). • Lack of enforcement (Inadequate enforcement of regulations concerning wastewater use can lead to unsafe practices, threatening public health and environmental sustainability). • Poor wastewater monitoring (Insufficient monitoring of wastewater quality can result in the use of contaminated water, posing risks to crop safety and soil health). • Water loss during dry seasons (Water sources may diminish during dry seasons, leading to reduced availability for irrigation). • Groundwater contamination (There is a risk of surface water polluting underground water sources, which can have long-term environmental and health impacts). • Negative consumer perception (consumers may have a negative perception of crops irrigated with unconventional water sources, potentially affecting marketability).

Appendix O: Capacity development and knowledge dissemination

(A) Introduction

The project resulted in the development and enhancement of institutional and human capacities. The human capacities related to formal training of students and enhancing capacities of communities in implementing IDAWM practices. Knowledge dissemination was done through presentation at symposium.

(B) Capacity development

i. Students

The project recruited three full-time students, one M.Sc. student and two PhD. Students (Appendix P), who conducted their research projects on the IDAWM project. The study details of the three students are presented in Table A.1.

Table A.1: Students working on the project

Student	Level and area of study	Area of study related to the project
Ms Serote B.	PhD in Agricultural Economics and Extension	**Work Packages 3 - 5:** Evaluating pathways to sustainable agricultural water management: Case studies of smallholder communities in rural and peri-urban areas of the Limpopo and Gauteng Provinces
Mr Nemakonde, N.D.	PhD in Environmental Health	**Work Package 3 - 5:** Development of the Environmental health framework for farmers using wastewater for irrigation in South Africa.
Mr Mamogobo N.M.	MSc in Soil Sciences	**Work package 3:** Assessment of farmer-led irrigation development (FLID) in South Africa: A case study of Vhembe District

ii. Communities

Communities which participated in the study came from Thulamela and Makhado local Municipality in Limpopo Province. The other communities who participated in the study came for peri-urban areas of Stinkwater; Mashemong; Lephengville; Kanana; Marokolong; Majaneng; Suurman; Unit 7; Themba; Eersterust (F4); Soshanguve; Rooiwal; Unit D; and Ramotse in the Gauteng Province. Communities gained knowledge on the concept of IDAWM framework and practices (some of which they were already implementing but without realising that they fit with the IDAWM framework).

iii. Participating institutions

The capacity of the partner institutions was enhanced through the implementation of the project. The partner institutions were CLOVITA Consulting Services, Faculty of Sciences, Tshwane University of Technology, and Department of Agricultural and Rural Engineering, University of Venda. The participating institutions shared knowledge on research methodologies and data analysis techniques. The research team also learned a lot about various practices related to AWM in the study areas.

(C) Knowledge dissemination

Another major capacity building activity during this period was the acceptance of Mr Natalian Mamogobo to attend the South African Institute of Agricultural Engineers (SAIAE) and Pan African Society for Agricultural Engineering (PASAE) International Symposium 2024 which was held from 23 to 25 October 2024 at the Houw Hoek Hotel, in Grabouw of the Western Cape Province (Appendix Q).

The presentation of Mr Mamogobo was titled, *'Characterization of Farmer-Led Irrigation Development (FLID) And the Associated Agricultural Water Management Practices in Vhembe*' (Appendix R). The report of his attendance to the symposium is presented in Appendix S.

(D) Conclusions

The project has helped to build capacities of students in terms of conducting research and disseminating research findings to various audiences. The capacity of participating communities and the research partner institutions were enhanced through the implementation of the project. The partner institutions benefited from sharing research methodologies and data analysis techniques, as well as dissemination of the research findings. The research teams also benefited from the vast experience of indigenous knowledge systems on AWM practices by the participating communities. Participating communities benefited from the new knowledge on the various pathways of the IDAWM framework in which they are involved.

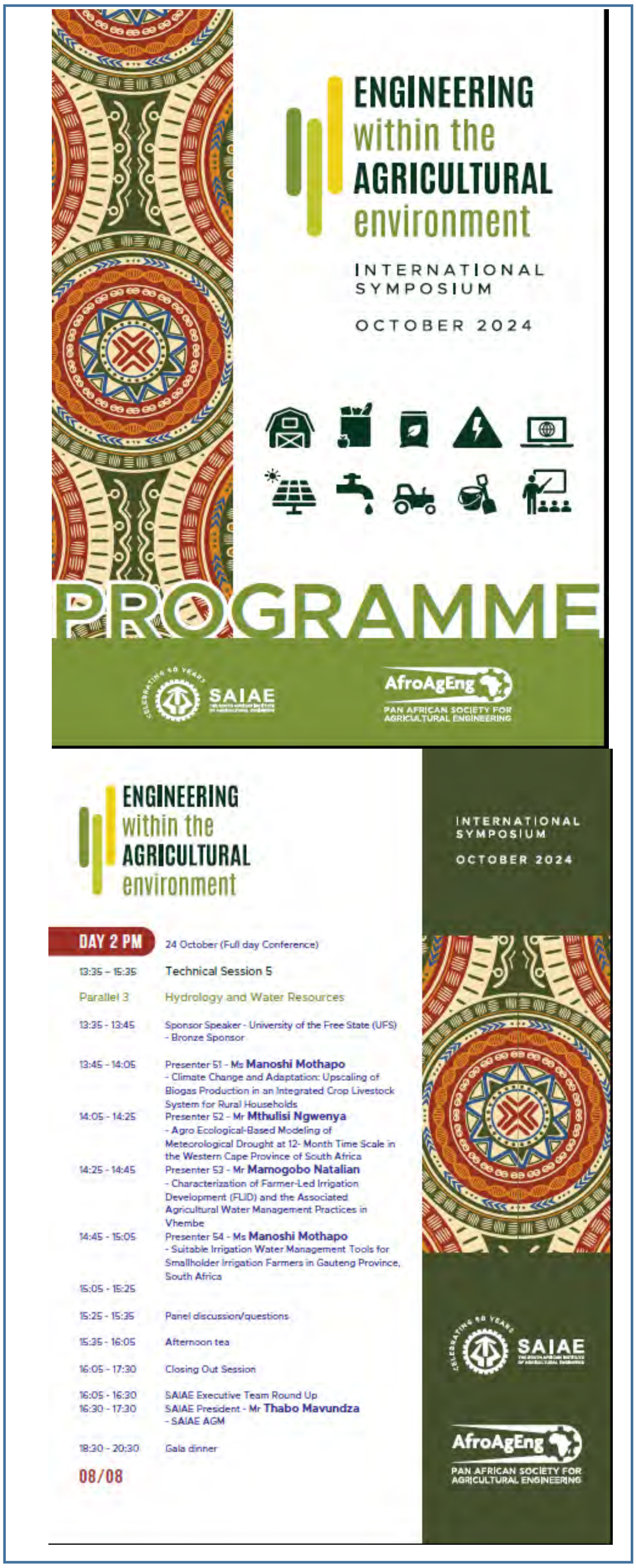
Appendix P: Capacity building – post-graduate students involved in the project

Student Name	Gender	Race	Degree	Title of study	Supervisors	Progress
Serote B.	Female	African (Black)	PhD in Agricultural Economics and Extension	Evaluating pathways to sustainable agricultural water management: Case studies of smallholder communities in rural and peri-urban areas of the Limpopo and Gauteng Provinces	Prof. G. Senyolo, Prof. L. Mudau and Dr. E.J. Mwendera	• After thorough evaluation and careful consideration of the study objectives in light of the existing literature, the student has decided to compile a traditional literature review rather than a systematic literature review. This approach allows for the inclusion of a broader range of studies and types of literature, which might not strictly meet the inclusion criteria typical of a systematic review. The final draft of this traditional review is nearing completion. • Currently, the student is actively engaged in the data collection phase of the research project.
Nemakonde, N.D.	Male	African (Black)	PhD in Environmental Health	Development of the Environmental health framework for farmers using wastewater for irrigation in South Africa.	Prof. L. Mudau, Prof. G. Senyolo and Dr. E.J. Mwendera	• Research proposal has been sent to Departmental Committee for Post Graduate Studies and it is in the process of being approved. • Draft literature review has been finalised
Mamogobo N.M.	Male	African (Black)	MSc in Soil Sciences	Assessment of farmer-led irrigation development (FLID) in South Africa: A case	Prof. J.J.O. Odhiambo, Dr. F. Onyando and Dr. E.J. Mwendera	• The student's research is connected to pathway 3: farmer-ed irrigation development of the project. • The student presented the research proposal to the Department of Plant and Soil Sciences on the 29th of February. He then

Student Name	Gender	Race	Degree	Title of study	Supervisors	Progress
				study of Vhembe District		incorporated the feedback provided and applied for project registration and ethical clearance. • The research proposal has been approved by the Faculty of Science, Engineering, and Agriculture (FSEA), the Faculty of Higher Degrees Committee (FHDC), and the Animal, Environment and Biosafety Research Ethics Committee (AEBREC). This approval grants the student the authorization and assurance to proceed with his research and complete his studies. • Throughout the year, the student attended a series of online workshops organized by the Greenmatter Fellowship in partnership with the Water Research Commission (WRC). Furthermore, in July 2024, the student collected research data through structured questionnaires across farmers in Thulamela and Makhado municipalities for Farmer-led irrigation farmers. • The student took part in writing this year's project deliverables and attended the project's workshop in Pretoria regarding policy and governance framework and other meetings regarding the project. • The student attended the South African Institute of Agricultural Engineers (SAIAE) and 6th Pan African Society for Agricultural Engineering (PASAE) International

Student Name	Gender	Race	Degree	Title of study	Supervisors	Progress
						Symposium Held from 23 to the 25th of October 2024 at the Houw Hoek Hotel in Grabouw of the Western Cape Province (Cape Town). Furthermore, the student presented his work on the topic titled; "Characterization of Farmer-Led Irrigation Development (FLID) and the associated Agricultural Water Management (AWM) practices in Vhembe" under the session of Hydrology and Water Resources on the 24th at the SAIAE symposium. • The student is currently working on the experimental plan for objective two and beefing up the literature review.

Appendix Q: Part of the programme for the SAIAE International symposium October 2024



ENGINEERING within the AGRICULTURAL environment

INTERNATIONAL SYMPOSIUM

OCTOBER 2024

PROGRAMME

SAIAE

AfroAgEng

PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

ENGINEERING within the AGRICULTURAL environment

INTERNATIONAL SYMPOSIUM

OCTOBER 2024

DAY 2 PM	24 October (Full day Conference)
13:35 – 15:35	Technical Session 5
Parallel 3	Hydrology and Water Resources
13:35 - 13:45	Sponsor Speaker - University of the Free State (UFS) - Bronze Sponsor
13:45 - 14:05	Presenter 51 - Ms **Manoshi Mothapo** - Climate Change and Adaptation: Upscaling of Biogas Production in an Integrated Crop Livestock System for Rural Households
14:05 - 14:25	Presenter 52 - Mr **Mthulisi Ngwenya** - Agro Ecological-Based Modeling of Meteorological Drought at 12- Month Time Scale in the Western Cape Province of South Africa
14:25 - 14:45	Presenter 53 - Mr **Mamogobo Natalian** - Characterization of Farmer-Led Irrigation Development (FLID) and the Associated Agricultural Water Management Practices in Vhembe
14:45 - 15:05	Presenter 54 - Ms **Manoshi Mothapo** - Suitable Irrigation Water Management Tools for Smallholder Irrigation Farmers in Gauteng Province, South Africa
15:05 - 15:25	
15:25 - 15:35	Panel discussion/questions
15:35 - 16:05	Afternoon tea
16:05 - 17:30	Closing Out Session
16:05 - 16:30	SAIAE Executive Team Round Up
16:30 - 17:30	SAIAE President - Mr **Thabo Mavundza** - SAIAE AGM
18:30 - 20:30	Gala dinner

08/08

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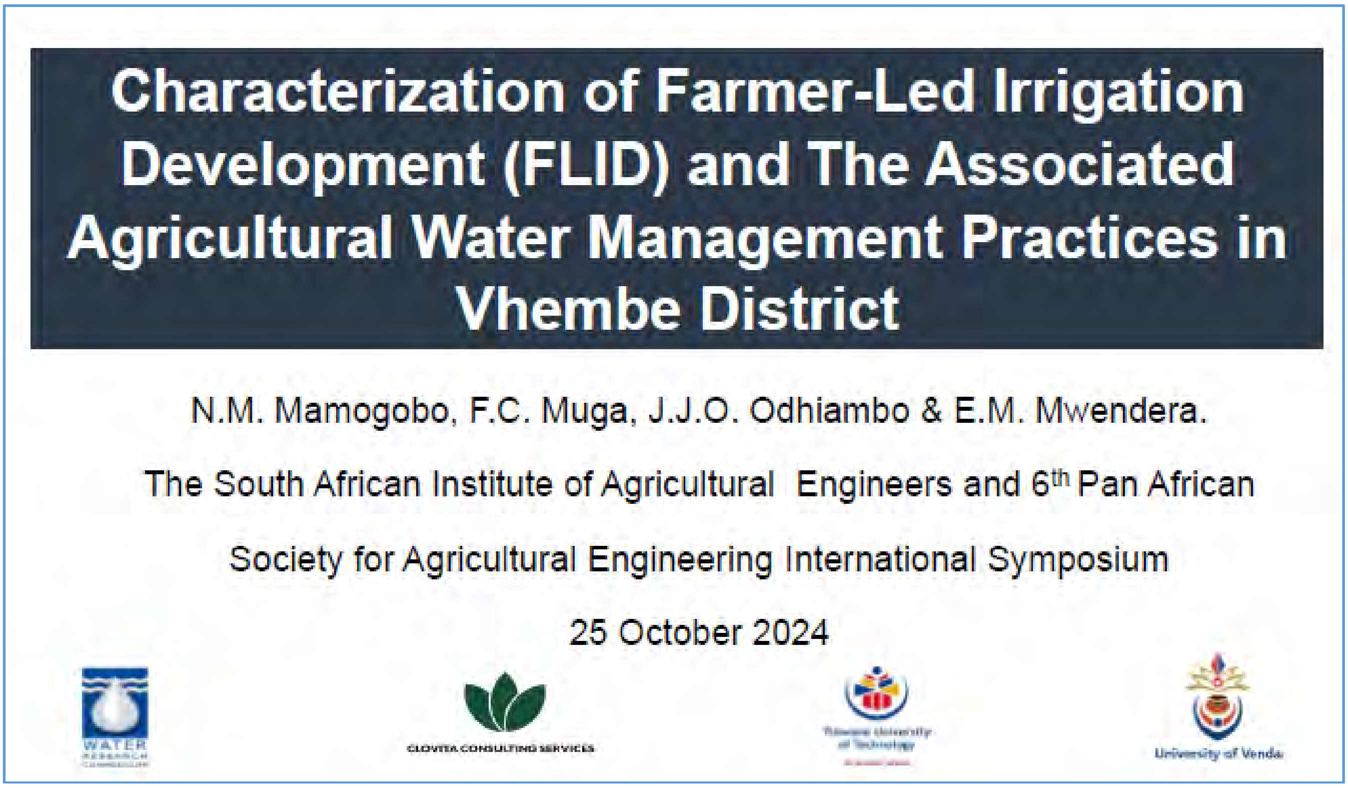
Appendix R: Presentation made at SAIAE International symposium October 2024



Appendix S: SAIAE Symposium report by Natalian M. Mamogobo

University of Venda
Creating Future Leaders

Faculty of Science, Engineering and Agriculture
Department of Agricultural and Rural Engineering

Report on The South African Institute of Agricultural Engineers (SAIAE) and 6th Pan African Society for Agricultural Engineering (PASAE) International Symposium Held at from 23 to 25 October 2024 at the Houw Hoek Hotel, in Grabouw of the Western Cape Province.

Prepared by
Mamogobo NM